Transportation Energy Intensity Trends: 1972–1992

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Trends in energy use and energy intensity in transportation are analyzed by growth in transportation activity, changes in energy intensity, and changes in modal structure. Trends in the fuel economy of light-duty vehicles are also analyzed. Reductions in the energy intensity of transport have held back the growth of energy use but with widely varied success across modes. Analysis of trends in the fuel economy of new passenger cars and light trucks from 1975 to 1993 shows that changes in the vehicle sales mix have had a relatively minor impact and that decreased vehicle weight has boosted fuel economy by 0.85 km/L (2 mpg). Increased performance has erased almost all of that gain, though, so the increase for new vehicles is due almost entirely to improved fuel economy technology.

The U.S. transportation sector, which remains 97 percent dependent on petroleum, used a record high 24.05 EJ of energy in 1993 (*1,2*). [One quadrillion Btus (quad) is equal to somewhat more than 1 exajoule (1 EJ = 10^{18} joules) and represents about 172 million barrels, or 0.5 million barrels per day, of crude oil.] This paper examines 20 years of energy use in the transportation sector and analyzes it into components associated with the growth of transportation activities, changes in energy use per unit of activity, and changes in the modal structure of transportation activities. Where data permit, the effects of trends in vehicle occupancy rates or load factors are also measured. The objective is to better understand when and how changes in transportation energy use came about as a guide to where energy use and energy efficiency are headed. The Divisia decomposition method, a simple yet elegant means of breaking a time trend into components, is used (*3,4*). Greene and Fan present a more detailed explanation of the Divisia analysis and documentation of the precise equations and data used (*5*).

This analysis differs from previous decompositions of transportation energy trends (*4,6*) in the period covered (1972–1992) and in that consistent activity measures are used as much as possible. Whereas passenger kilometers are used herein to measure activity for all passenger modes and ton kilometers for nearly all freight modes, Ross (*4*) used vehicle kilometers for automobiles and light trucks and measured heavy-truck activity in dollars of gross national product. One approach is not wrong and the other right, but they will give different answers. Available data suggest that important trends in highway vehicle load factors have greatly influenced energy intensity.

Data are deficient in several areas. Estimates of ton kilometers transported are poorly known for all types of trucks, especially single-unit trucks. Ton kilometers transported by pipelines are not reported on an annual basis. Estimated energy intensities for domestic waterborne transportation fluctuate widely for reasons that are not well understood, and ton kilometers and energy use in international shipping are poorly known. Consistent estimates of passenger vehicle occupancy rates are available only from infrequent surveys; intervening years must be interpolated. The reader is urged to keep these serious data limitations in mind when interpreting the results of this analysis. Broad trends are likely to be meaningful, but results involving suspect data, such as truck ton kilometers and sometimes year-to-year changes, must be interpreted with caution.

In contrast, excellent detailed data exist on the fuel economy and related characteristics of light-duty vehicles (*7*). Because of this and the fact that light-duty vehicles account for 57 percent of transportation energy use (*8*), trends in light-duty vehicle fuel economy are the subject of more detailed analysis.

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ANALYSIS OF ENERGY USE TRENDS BY DIVISIA DECOMPOSITION

Divisia decomposition is a simple but elegant mathematical method for precisely analyzing any time trend that can be expressed as a product of several factors (*3*). In general, energy use (E) per unit of time (t) can be expressed as energy use per unit of activity (A) times the level of activity.

$$E_t = \left(\frac{E}{A}\right)_t \cdot A_t = e_t \cdot A_t \tag{1}$$

Here e measures energy intensiveness (energy use per dollar, passenger kilometers, ton kilometers, etc.). If the activity measured by A can be subdivided into meaningful categories such as modes of transport, Equation 1 can be written as a sum of energy uses,

$$E_t = \sum_{i=1}^{n} \left(\frac{E_{it}}{A_{it}}\right)\left(\frac{A_{it}}{A_t}\right) A_t \tag{2}$$

or

$$e_t = \frac{E_t}{A_t} = \sum_{i=1}^{n} e_{it} s_{it} \tag{3}$$

where e is energy intensity and s is the share of activity by mode. The Divisia method decomposes $e = E/A$ into changes in efficiency within subcategories and changes in the mix of activity among categories over time. By the product rule of differential calculus,

$$\frac{de_t}{dt} = \sum_{i=1}^{n}\left(\frac{de_{it}}{dt} s_i + \frac{ds_{it}}{dt} e_{it}\right) \tag{4}$$

According to the definition of the derivative

$$\lim_{\Delta t \to o} \frac{\Delta e_t}{\Delta t} = \frac{de_t}{dt} \tag{5}$$

it follows that

$$\Delta e_t = \sum_{i=1}^{n} \left[(e_t - e_{t-1})_i \frac{(s_t + s_{t-1})_i}{2} + (s_t - s_{t-1})_i \frac{(e_t + e_{t-1})_i}{2} \right] \tag{6}$$

In Equation 6, the change in energy use from year $t - 1$ to t is decomposed into two parts: change in energy intensiveness, and change in activity shares. For example, an improvement in passenger kilometer per joule (Btu) for air and highway travel would show up in the first component as a decrease in energy intensiveness. A shift in travel from less energy intensive highway travel to air travel would show up as an increase in the second component.

The year-to-year components of energy intensity changes can be added over time to produce estimates of the cumulative effects, which can be multiplied by the current activity level to obtain cumulative components in terms of energy use. Adding these to actual energy use in the current year produces an estimate of what energy use would have been for that year's activity level, at the base year energy efficiency and base year modal structure. That is called the trended energy use. The trended energy use equals the level of activity in a given year multiplied by the energy intensity of the base year. The difference between the trended energy use and the actual energy use is the net effect of changes in the efficiency and structural components.

Transportation activity is divided into (*a*) passenger, (*b*) freight, and (*c*) other. Six passenger modes are defined: three highway vehicle types (light-duty vehicles, larger single-unit trucks, combination trucks), commercial and general aviation, and passenger rail. Freight includes highway freight (divided between larger single-unit and combination trucks), domestic waterborne freight, rail, and pipeline. Air freight has not been included. Military transportation and international waterborne freight energy use make up a separate category.

Six Divisia analyses were carried out: (*a*) all transportation modes, (*b*) passenger modes, (*c*) air passenger, (*d*) highway passenger, (*e*) all freight, and (*f*) rail freight.

Combined passenger and freight activity is measured in dollars. Although reasonable estimates of freight revenues are available, most passenger travel is produced by households, so comparable revenue estimates are not available. The authors have substituted estimates of dollar costs of personal vehicle travel, based on vehicle operating costs per kilometer. The values of modal activities are computed using dollars per unit of modal activity in 1987 as an index year and multiplying that value by modal activity in each year. Productivity effects (changes in physical output per dollar) are zero by construction. For the separate analyses of freight and passenger modes, ton kilometers and passenger kilometers, respectively, are used as activity measures.

TRANSPORTATION SECTOR EFFICIENCY

Transportation would have used 4 EJ (3.8 quads) more energy in 1992, had passenger and freight movements taken place at 1972 energy intensities per dollar and relative modal activity levels (Figure 1). Shifts in activity to more energy intensive modes erased 1.16 EJ (1.1 quad) of a potential 5.17-EJ (4.9-quad) savings due to reduced energy intensities. Figure 2, which illustrates these trends, should be interpreted as follows. Cumulative component changes are shown as "stacked" bars in the lower portion of the graph, with effects tending to reduce energy use shown as negative values. The difference between the energy use trend line and the actual energy use line is the net effect, or sum, of the components. Note that in a given year an energy use component could increase due to an increase in activity with no change in energy intensity in that year.

The fact that trended and actual energy use move together from 1975 to 1979 implies that transportation energy intensity was essentially constant. The decline in energy use in 1973–1974 was

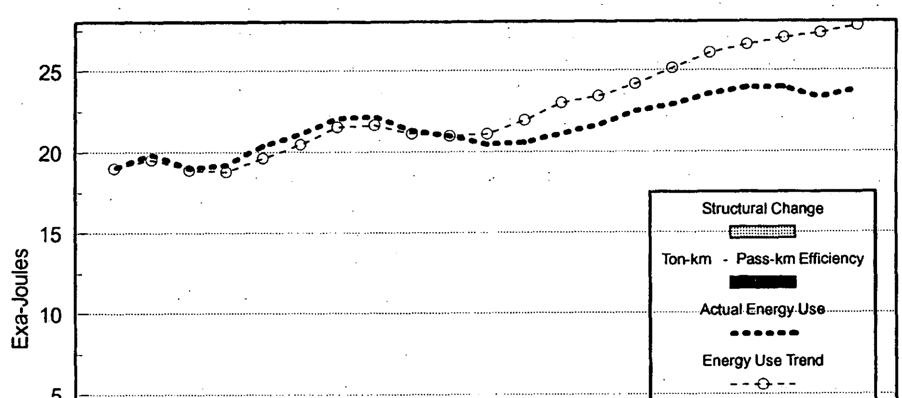

FIGURE 1 Transportation energy use.

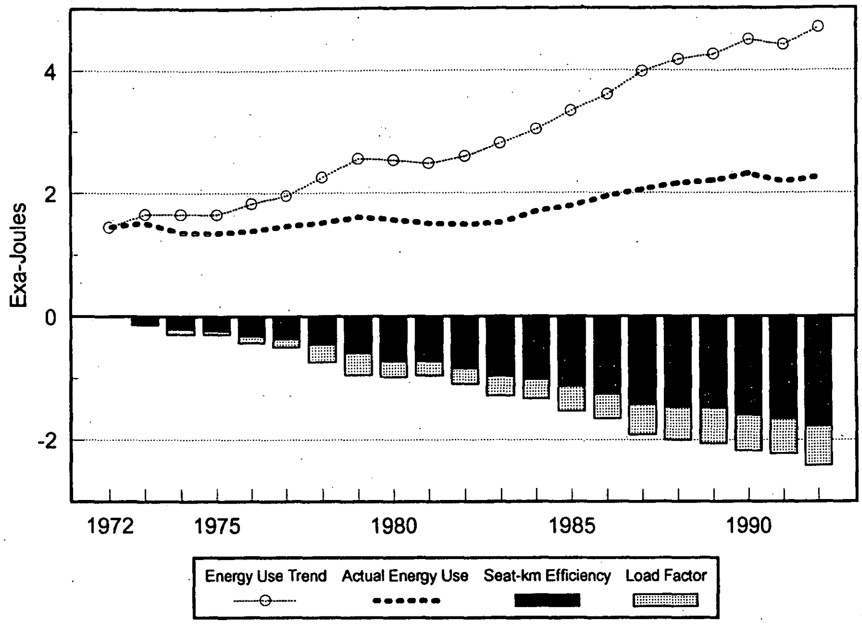

FIGURE 2 Air passenger energy use.

therefore due to decreased transportation activity. Starting in 1978, energy efficiency began improving, a trend that continued through 1992. Throughout, gradual modal shifts tended to increase energy use with a cumulative effect of 1.06 EJ through 1990.

These trends differ from those reported by the U.S. Department of Energy (DOE) (*6*) for 1972–1986 and from Ross's (*4*) calculations for 1972–1985. By 1986 the DOE study reports a savings of 4.22 EJ due to efficiency improvements, primarily due to light-duty vehicles and commercial aircraft. Ross's findings are similar, annual average growth rates in passenger and ton kilometers of traffic of 3.6 percent and 1.7 percent, but an overall growth rate of energy use of only 1 percent due to a 2.4 percent annual decrease in energy intensity for passenger travel and a 1.1 percent/annual decrease for freight. The authors' analysis finds no net energy savings until after 1980 and no net savings for the freight modes, collectively. Previous studies found earlier and larger energy savings because they measured energy intensities for highway vehicles per vehicle kilometer; the authors, however, use passenger and ton kilometers. Apparent declines in vehicle occupancy rates and in truck load factors result in smaller reductions in energy intensities.

PASSENGER TRAVEL ENERGY EFFICIENCY TRENDS

Had there been no changes in vehicle efficiencies, vehicle occupancies, and the modal shares of passenger travel, 20.47 EJ (19.4 quads) would have been required for the more than 6.44 trillion passenger kilometers (4 trillion passenger-mi) traveled in 1992, 23 percent more than was actually used. Energy intensity increased through 1977. By 1978 this trend reversed and efficiency improvements added continuously to energy savings through 1992. Structural shifts and vehicle occupancy rates gradually and continuously pushed up energy use. Because load factors on commercial aircraft improved, the increase in energy use due to structural change must be attributable to shifts to more energy intensive types of highway vehicles and the decline in highway vehicle occupancy rates (Table 1). Air travel's share of passenger kilometers increased from 5.6 percent in 1972 to 12.3 percent in 1992. The increasing popularity of light trucks boosted their share of passenger kilometers from 11.6 percent in 1972 to 20.4 percent by 1992. Declines in the shares of rail and bus had a minor impact.

Commercial air travel has achieved dramatic gains in energy efficiency. Air travel would have used more than twice as much energy in 1992 had there been no reductions in energy use per passenger kilometer (Figure 2). Three-fourths of the gain can be attributed to more seat kilometers per liter, the remainder to an increase in the average number of passenger kilometers per seat kilometer. Aircraft load factor improvements through 1989 contributed 0.53 EJ (0.5 quad) to air travel energy savings. (This analysis does not include the effects of circuity because the data necessary to evaluate it were not available.)

The 5.63 trillion passenger kilometers traveled by highway in 1992 would have required 6.96 EJ more energy had vehicle fuel economy remained at 1972 levels (Figure 3). Vehicle kilometer energy efficiency decreased until 1973 and then began continuous improvement, reflecting the gradual process of turnover of the vehicle stock. As will be seen, the fuel economy of new light-duty vehicles has not improved appreciably since 1982. Since the average life expectancy of a light-duty vehicle is about 12 years (*8*), it is not surprising that fleet efficiency improvements are slowing to a halt. The estimated average kilometers per liter (km/L) of highway vehicle travel decreased in 1992 for the first time in almost 20 years and decreased again in 1993. The increase in cumulative savings in 1992 was produced by the growth in vehicle travel, which outweighed the decline in efficiency per vehicle kilometer.

Energy savings due to fuel economy improvements since 1972 were halved by falling vehicle occupancy rates. Fewer passengers per vehicle kilometer added 3.7 EJ to total energy use, while vehicle type shifts added 1.5 EJ. The effect of the increasing light-truck

TABLE 1 Vehicle Occupancy Rates and Load Factors (*5*)

	1972	1975	1977	1980	1983	1985	1990	1991[1]
Passenger (passenger-km/vehicle-km)								
Passenger Car[1]	2.07	1.95	1.86	1.81	1.76	1.72	1.62	1.59
Light Truck[1]	2.02	1.89	1.81	1.76	1.71	1.71	1.72	1.72
Air[2]	65.2	77.3	85.2	91.6	101.0	101.4	100.0	101.6
Bus[3]	18.3	18.5	18.6	18.7	18.2	18.6	17.1	17.6
Rail[4]	26.7	25.3	26.9	28.6	25.6	24.5	23.4	23.0
Freight (ton-km/vehicle-km)[5]								
Combination Trucks[6]	10.4	8.8	9.1	7.3	7.4	7.0	6.9	7.4
Rail[7]	23.2	24.8	26.0	28.5	30.8	31.9	35.8	37.0

Data are from Greene and Fan (*3*), tables B.4 and B.5 and accompanying documentation.

[1] Represents passenger-km per vehicle-km according to the Nationwide Personal Transportation Surveys for 1969, 1977, 1983, and 1990. Intervening years are linearly interpolated.

[2] Statistics are for domestic and international operations of U.S. certificated route air carriers.

[3] Includes school bus, intercity and transit bus operations. School bus statistics are largely based on assumed load factors.

[4] Includes transit, commuter and intercity. Vehicle-km are defined as railroad car-km.

[5] Original data source uses short ton unit. Here, short ton has been converted into metric ton.

[6] Represents **intercity** truck ton-km divided by **all** combination truck-km and is therefore likely to be biased downward in all years.

[7] Intercity ton-km divided by car-km for class I freight railroads.

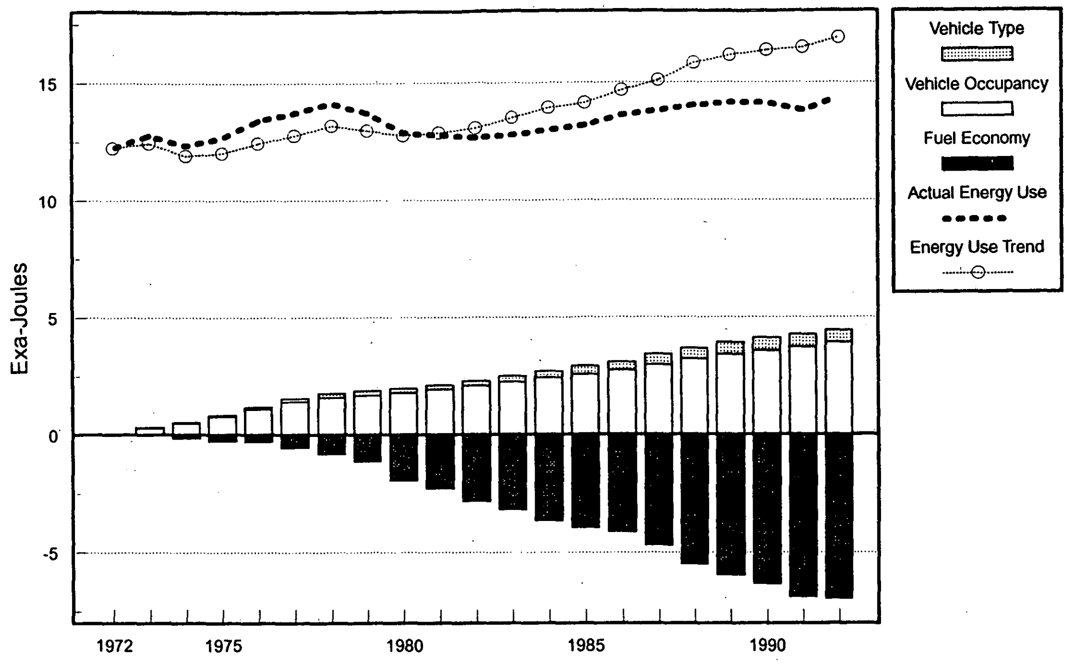

FIGURE 3 Highway passenger energy use.

market share on efficiency is small but evident at the very beginning of the period and persists despite the fuel price shocks of 1973–1974 and 1979–1980.

FREIGHT

The freight sector looks different, although the reader is cautioned that the quality of data on freight activities is poor and could be misleading. However, the available data suggest that had ton kilometer energy efficiencies and the distribution of traffic by mode remained at their 1972 levels, freight transport in the United States in 1992 would have required 0.1 EJ more energy than was actually used (Figure 4). The modal shares of ton kilometers in 1992 were very close to those in 1972. Rail carried an estimated 28 percent of ton kilometers in 1972 and 29 percent in 1991. Combination trucks increased their share from 17 to 20 percent. Changes in the energy intensity of ton kilometer movements tended to increase energy use slightly. Rail freight joules per ton kilometer, however, declined from 510,268 in 1972 to just over 288,380 in 1992. The energy intensiveness of domestic waterborne commerce shows a more erratic but still overall downward trend.

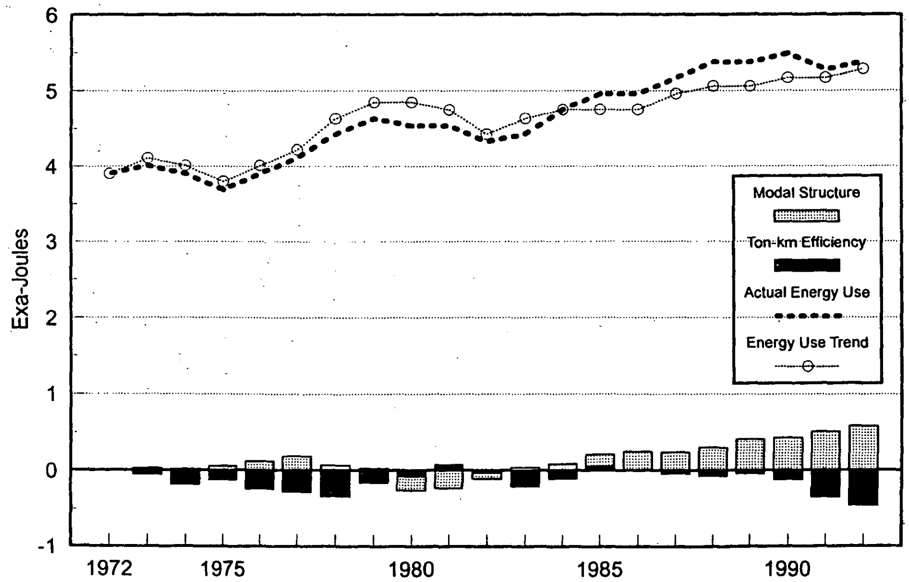

FIGURE 4 Freight energy use.

The factor most responsible for the apparent decline in freight energy efficiency is fewer tons per truck. The data are rough estimates and could be subject to substantial error, but what little other evidence there is tends to corroborate decreasing heavy-truck load factors. The Census of Transportation Truck Inventory and Use Survey (TIUS) indicates that the average load carried by combination trucks declined from 16 tons (17.7 short tons) in 1982 to 14.42 tons (15.9 short tons) in 1987 (these estimates are about twice those shown in Table 1, which are certainly biased downward). The TIUS data also suggest a decline in tons carried per heavy single-unit truck. Factors such as the changing composition and delivery requirements of freight and greater movements with part loads or empty backhauls appear to have more than offset the potential for larger trucks to increase truck load factors. Because trucks account for the majority of freight energy use, these apparent changes in truck ton kilometer efficiencies offset changes in the other modes.

In contrast, rail freight movements show enormous efficiency gains that are primarily due to increased carloads. If the 1992 rail ton kilometers had been moved at 1972 energy intensities, 75 percent more energy would have been required (Figure 5). Nearly all (85 percent) of the 0.35-EJ (0.33-quad) savings was achieved by increasing railroad carload factors from 22 tons per car in 1972 to 36 tons in 1992. More than any other mode, the rail mode has reduced energy intensity by improving the efficiency of its operations (perhaps aided by the changing composition of its freight). There must certainly have been technological efficiency improvements to vehicles, however; otherwise energy use per carload would have increased as carloadings increased.

LIGHT-DUTY-VEHICLE FUEL ECONOMY

The fuel economy of new passenger cars and light trucks improved dramatically in the decade following the oil price shock of 1973–1974. Those gains were not reversed by the price collapse in 1986 that returned motor fuel prices near to pre-1973 levels. Both passenger-car and light-truck kilometer per liter remained just above the levels required by federal automotive fuel economy standards despite falling gasoline prices and waning interest in kilometer per liter on the part of car buyers. Trends in the sizes and types of vehicles purchased had little to do with the fuel economy trends. Over the past two decades, light-truck sales boomed while demand for passenger cars became sluggish. Sales by market segment have waxed and waned in complex patterns. In the 1980s vehicle performance increased dramatically. Vehicle weight reductions made in the 1970s were reversed completely for light trucks and only partially for passenger cars. In this section, the Divisia method is used to analyze the effects of sales mix, and constant elasticity methods are used to analyze the impacts of weight and performance. All of the data used are from the Environmental Protection Agency's (EPA's) data base of light-duty vehicle fuel economy (*7*).

The key to past increases in the fuel economy of light-duty vehicles has been the improvement in km/L of all types of vehicles—large and small, car and truck. Analysis of the effects of performance and weight on fuel economy using a constant elasticity method revealed the importance of technological gains. If neither weight nor horsepower-to-weight ratios had changed since 1975, the average fuel economy of light-duty vehicles would be the same as it is today, 10.63 km/L (25 mpg). In other words, vehicle technology has been improved to the extent that a vehicle of the same size performance and weight getting 6.38 km/L (15 mpg) in 1975 would get 10.63 km/L (25 mpg) using today's technology.

Changes in Vehicle Sales Mix

From 6.50 km/L (15.3 mpg) in 1975, the fuel economy of new light-duty vehicles increased to a peak of 11 km/L (25.9 mpg) in 1987 and stands at 10.63 km/L (25.0 mpg) today (Figure 6). Essentially all (97 percent) of the 60 percent fuel economy gain had been achieved by 1982. Neither passenger-car nor light-truck fuel economy has changed significantly for more than a decade.

Since 1975 light-truck sales have nearly doubled because of the increased popularity of minivans and sport utility vehicles; passenger car sales have fluctuated near 10 million units annually. As a result, the market share of light trucks increased from 19.4 to 34.2 per-

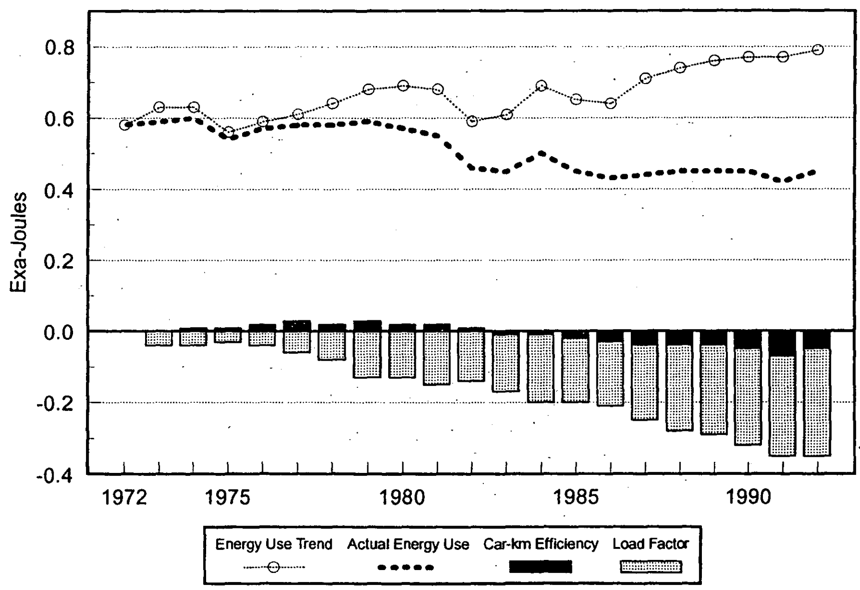

FIGURE 5 Rail freight energy use.

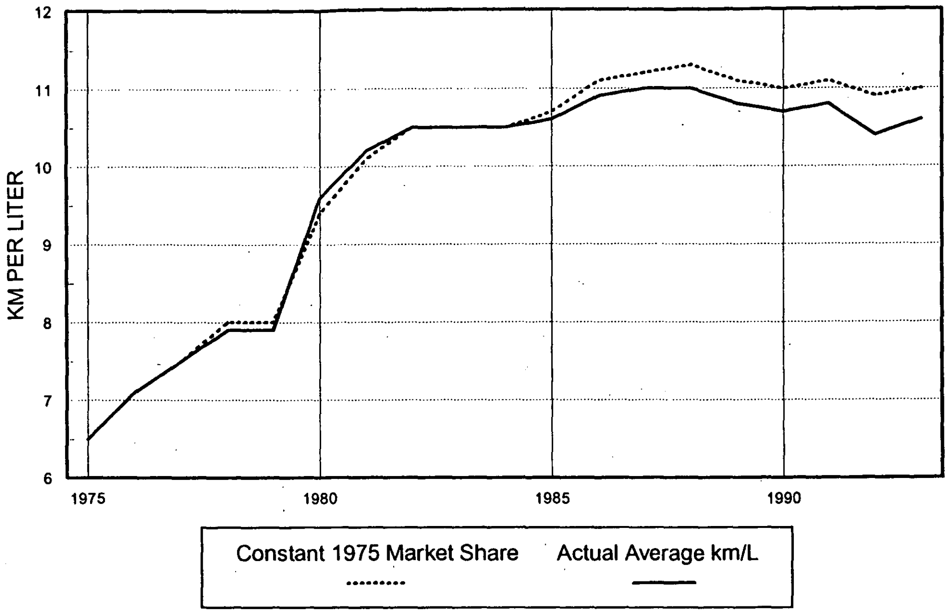

FIGURE 6 New light-duty-vehicle fuel economy.

cent. Because light-truck km/L averages only about 75 percent of passenger-car km/L, the market shift to light trucks might have been expected to seriously depress overall fuel economy. The Divisia analysis reveals that the shift to light trucks brought overall light-duty-vehicle km/L down by less than 0.425 km/L (1 mpg) (4 percent). There are two reasons for this. First, both passenger-car and light-truck km/L increased significantly over the period. Second, because average fuel economy is a weighted harmonic rather than a simple arithmetic mean, changes in market shares have less impact than intuition suggests.

Another misconception is that fuel economy increased because consumers decided to buy smaller cars. The sales mix among classes of car size based on interior volume is nearly the same today as in 1975 and, as a result, has been a minor factor in fuel economy trends. The weight and exterior dimensions of passenger cars have decreased, but the room available for driver and passengers has not.

Shifts in sales among vehicle classes have had little impact on fuel economy. The increased share of light trucks tended to reduce light-duty-vehicle fuel economy. Yet, within the car and light-truck markets, the sales shifts had the opposite effect. For passenger cars, sales shifts boosted km/L by a fraction out of a 5.1-km/L gain. For light trucks, sales shifts had a much larger beneficial impact, about 0.85 out of 12.98 km/L (2 out of 7 mpg). Thus, although the shift to light trucks tended to decrease the fuel economy of the light-duty fleet, the shift within the light-truck segment tended to increase it (Figure 7). Consumers moved away from passenger cars to light trucks, but the light trucks that they favored are basically passenger vehicles: minivans and small sport utility trucks. The net result of

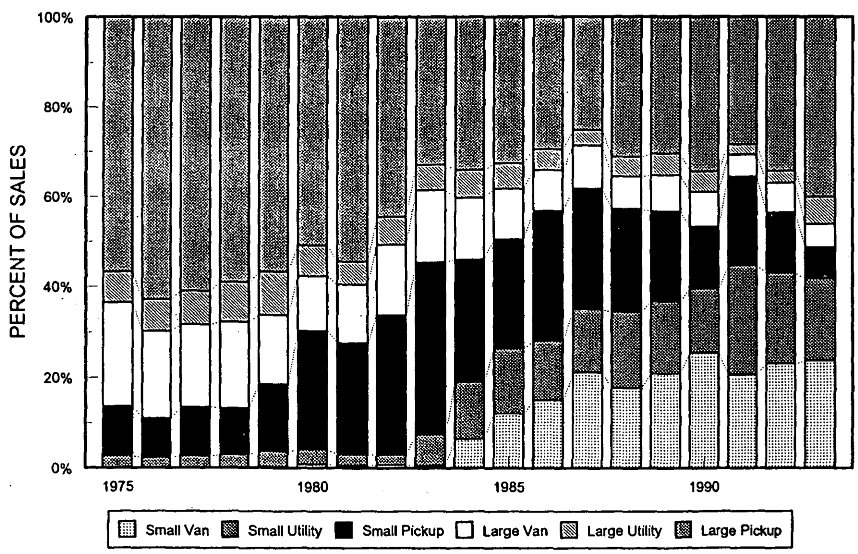

FIGURE 7 Light-truck market shares.

sales shifts among classes of cars and trucks and between cars and trucks has been to slightly increase the fuel economy of light-duty vehicles.

Changes in Performance and Weight, 1975–1993

Since 1975 passenger cars have become lighter and more powerful. The average passenger car is 363 kg (800 lb) lighter today than it was in 1975 (Figure 8). Light-truck weight fell initially but, like most dieters, light trucks have regained all of the weight that they lost during the 1980s. Measured in terms of the ratio of power to weight, performance is up 30 percent for passenger cars and 15 percent for light trucks (Figure 8). Zero–96 km/hr (0–60 mph) acceleration times are correspondingly down, 20 percent for cars and more than 10 percent for light trucks since 1975. These trends have important implications for fuel economy since, holding technology constant, weight (or mass) is the most important determinant of vehicle energy use and power is second (*9*). In the late 1970s, fuel economy gains were aided by stripping 454 kg (1,000 lb) from passenger cars and about 136 kg (300 lb) from light trucks. In the latter half of the 1980s and early 1990s, km/L gains were maintained in the face of rising weights and performance levels.

To analyze the effects of weight and power on km/L, a constant elasticity method is used. The km/L at 1975 weight and performance ($kmpl_y$) in any year, y, is computed from the actual fuel economy ($KMPL_y$) by the following formula:

$$\text{kmpl}_y = \text{KMPL}_y\left(\frac{W_y}{W_0}\right)^{\alpha}\left(\frac{P_y}{P_0}\right)^{\beta} \qquad (7)$$

where W is weight and P performance in years y and 0, and α and β are the constant elasticity parameters. The elasticity values used are $\alpha = -0.66$ (*10*, p.112) and $\beta = -0.34$. [DeCicco and Ross (*11*) cite an elasticity of 0.44 with respect to 0–96 km/hr (0–60 mph) acceleration time. On the basis of work by Murrell et al. (*7*), an elasticity of acceleration time, with respect to the ratio of horsepower to weight, is estimated at -0.77. This implies an elasticity of KMPL with respect to P of -0.34.] In a previous analysis of fuel economy changes during 1979–1990, Energy and Environmental Analysis, Inc. (*12*) used weight and performance elasticities of $\alpha = -0.66$ and $\beta = -0.29$.

If the weight of light-duty vehicles had not been decreased, all else constant, passenger cars would be getting about 10.2 km/L (24 mpg) instead of 11.9 km/L (28 mpg) (Figure 9). Performance increases, on the other hand, have cost cars about 1.1 km/L (2.5 mpg). At 1975 performance levels, the 1993 new car fleet would have averaged 13 km/L (30.6 mpg) instead of 11.9 km/L (28.0 mpg). Had there been no changes in performance or weight, the 1815-kg (4,000-lb) "gas guzzlers" of 1975 vintage, using today's fuel economy technology, would still get 11.22 km/L (26.4 mpg) as compared with 6.72 km/L (15.8 mpg) in 1975. The curve labeled "Constant 1975 Weight and *P*" in Figure 9 represents the progress of fuel economy technology. For passenger cars, this curve trends upward at an almost constant rate of 0.255 km/L/year (0.6 mpg/year) and has continued its climb despite the leveling off of actual new car km/L.

Weight has had a negligible effect on light-truck km/L, but increased horsepower has reduced light-truck fuel economy by 0.425 km/L (1 mpg). Technological improvements do not show the same steady rate of advance as for passenger cars. The curve suggests that fuel economy technology has been applied in a very different manner in the light-truck market.

Overall, weight reduction has raised light-duty-vehicle km/L by about 0.85 km/L (2 mpg), and performance increases have reduced light-duty-vehicle km/L by about 0.85 km/L (2 mpg). Had neither changed since 1975, the combined average km/L of passenger cars and light trucks would be only 0.128 km/L (0.3 mpg) lower than the actual 1993 value.

CONCLUSIONS

At 1972 energy intensities and modal shares, the passenger and freight movements accomplished in 1992 would have required 4.2 EJ (17 percent) more energy. Trends in energy intensity vary greatly across transport modes. Commercial air travel halved energy use

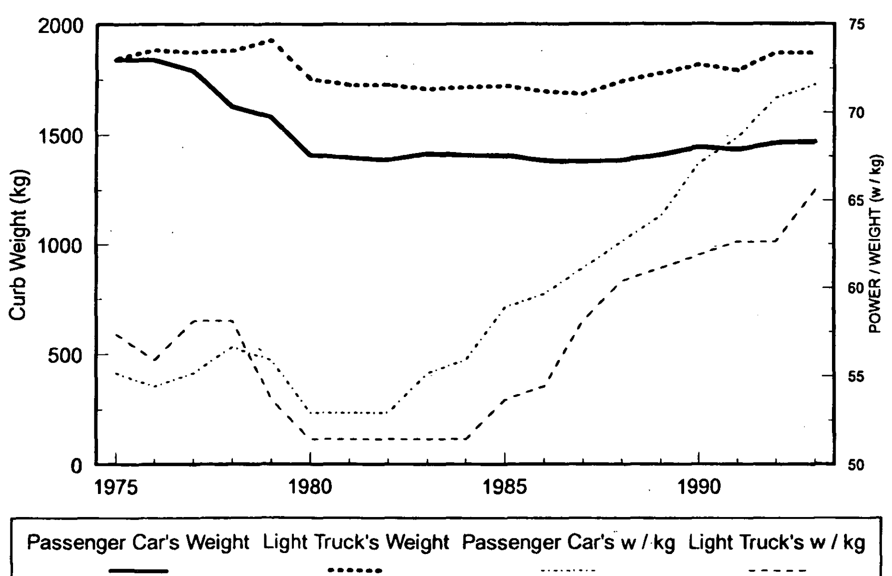

FIGURE 8 Passenger-car and light-truck weight and performance.

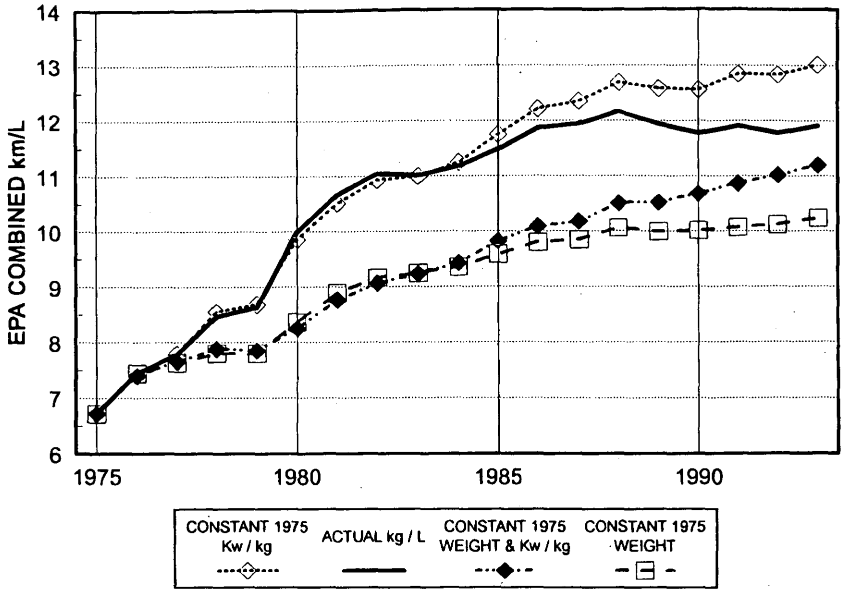

FIGURE 9 Effects of weight and horsepower on passenger-car fuel economy.

per passenger kilometer. The on-road fuel economy of light-duty vehicles improved 50 percent, from about 5.48 km/L (12.9 mpg) in 1972 to 8.245 km/L (19.4 mpg) in 1992, but the average number of passengers per vehicle dropped 25 percent, from 2.1 to 1.6, erasing half of the potential energy savings. In contrast, average energy use per ton kilometer of freight has remained essentially constant. Rail energy use per ton kilometer decreased by more than 40 percent, largely because of increased load factors. Heavy-truck load factors, in contrast, appear to have declined significantly. The increased energy intensity of truck freight and trucking's greater share of intercity ton kilometers appear to have offset rail's energy intensity reductions, resulting in nearly a constant energy intensity for freight movements over the past 20 years. For the transport sector as a whole, modal structure has been relatively unimportant compared with efficiency improvements within modes.

There is no single explanation for the varied energy intensity trends of different modes. The oil price shocks of 1973–1974 and 1979–1980 played an important role in focusing attention on energy efficiency and providing an economic incentive to reduce energy intensity by all modes, but this does not explain why modal responses have been so different. Furthermore, from a high of \$283/M^3 (\$45/barrel) (1987 dollars) in 1981, crude oil prices fell to \$176/M^3 (\$28/barrel) in 1985 and then crashed to \$94.36/M^3 (\$15/barrel) in 1986. For nearly a decade, energy prices have not signaled to the market that efficiency improvements are needed. There have also been no new regulatory initiatives to boost energy efficiency, and the fuel economy standards in place have been held nearly constant since 1985.

The analysis of light-duty-vehicle fuel economy trends from 1975 to 1993 has shown clearly that technology, rather than trends in vehicle sales, has been the force behind past fuel economy increases. The growing market share of lower-km/L light trucks has been accompanied by a transformation of the average light truck, making it more like a passenger car. The net result has been no impact on overall light-duty-vehicle km/L. Increases in vehicle performance have largely offset decreases in passenger-car weight, once again with little or no net impact on km/L. It appears that improved technology, driven in large part by federal fuel economy standards (*13*), is responsible for nearly all of the rise in km/L.

According to FHWA, the in-use fuel economy of passenger cars and light trucks declined in 1992 for the first time in 20 years and decreased again in 1993. Though contrary to nearly all past predictions, in hindsight this is no surprise since the fuel economy of new light-duty vehicles is no higher today than it was 12 years ago. Fuel economy gains from the replacement of older vehicles with low fuel economy with newer, more efficient ones have been largely played out. The countereffects of increasing urbanization and traffic congestion now appear to be causing in-use fuel economy to decline.

Today, energy use in transportation is on the rise at a rate just slightly lower than the growth of the economy. Energy efficiency, though up slightly in some areas, is down in others, and the overall rate of improvement appears to be slowing. If energy prices remain at current levels and no other significant actions are taken, there is little reason to expect anything else.

ACKNOWLEDGMENTS

The authors thank the U.S. Department of Energy for support; Chris Hanson, Stacy Davis, and Jennifer Young for assistance; and the reviewers for helpful suggestions. This paper is dedicated to Michael Greene.

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Publication of this paper sponsored by Committee on Transportation Energy.