Chapter 5

The Transportation Sector

Photo credit: Bressler Editorial Cartoons, New York, Artist: Packer

A World War II poster encouraging carpooling. Today, urban commuters average 1.2 passengers per vehicle to and from work.

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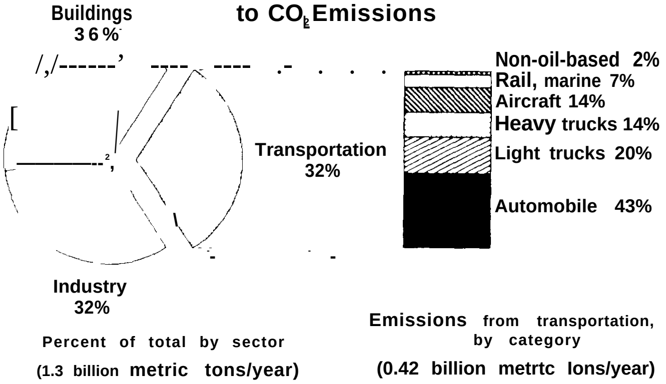
INTRODUCTION

This chapter examines the relationship between activity in the transportation sector and global warming. It looks at both the technology and the economics of passenger travel and freight within the United States and, to a lesser extent, the rest of the world. In 1987, transport contributed about one-third of the U.S. total carbon dioxide (CO_2) emissions (figure 5-1). Worldwide, transportation is responsible for about 20 to 25 percent of total CO_2 emissions from fossil fuels (27, 73).

Assuming current trends and regulations, we estimate that U.S. transportation-related CO_2 emissions will grow by about 25 percent by 2010. The Energy information Administration (69) forecasts growth of between 16 and 32 percent, depending on oil prices. in the developing world, transportation fuel consumption could nearly triple over the next 20 to 30 years (27), These forecasts imply that the transport sector will continue to be a major source of CO_2 emissions throughout and well beyond this study timeframe.

A number of measures could be initiated to reduce CO_2 emissions from transport, but OTA's analysis reveals that it will be very difficult to reduce U.S. emissions much below 1987 levels through changes in technology alone. Reducing emissions below 1987 levels by 2015 would require, in addition, some behavioral compromise such as the acceptance of smaller cars, carpooling or increased use of mass transit, or lower growth in the expected increase in demand for highway or air travel.

Figure 5-l—Contribution of the Transportation Sector to CO_2 Emissions



SOURCE Off Ice of Technology Assessment, 1991.

The difficulty of holding emissions low will be compounded even further past the 25-year time horizon of this assessment if population and demand for travel per person continue to grow, The gains possible over the next few decades can be easily lost. Lunger term progress will depend on either lowering the need for travel (e.g., through innovations in urban design or telecommunications) or drastically cutting emissions per mile through use of lower emitting fuels (e. g., methanol derived from sustainably harvested wood).

To be most effective, any program to promote more efficient modes of transport and discourage less efficient ones should incorporate both ' 'regulatory push" and "market pull" mechanisms. One obvious tool is government standards, particularly for passenger car and light-truck fuel economy. Fuel economy standards appear to have been an effective instrument for raising efficiency levels over the past decade, though some believe that much of the improvement was due to higher fuel prices. Another obvious tool is fuel taxes. Though effective, taxes are more severely felt by low income segments of the population. Other financially oriented policies, such as **rebates** on high efficiency vehicles, do not have the same near-term potential as fuel taxes alone. Nevertheless, they could bean important element in a diversified strategy to reduce CO_2.

To help ensure success, a reduction program could incorporate an extensive group of policies, some of which may be worth implementing because they will lay the groundwork for future progress; because, when taken as a package, they can achieve larger gains; or even for their symbolic value. Support of R&D in new technologies (e.g., novel engine and transmission designs and lightweight materials) may result in longer term gains. A package of strategies to encourage people to change travel patterns (i.e., parking controls, vanpools or cat-pools, expanded mass transit, and increased ''telecommuting' can achieve large gains. Stepped up support for innovation in the above activities could have significant impacts on the U.S. ability to control its CO_2 emissions.

CURRENT TRANSPORT EMISSIONS AND ACTIVITIES

Source of Emissions

About 80 percent of transport's contribution to global warming comes from the carbon dioxide released by burning fuel. The remaining 20 percent comes from chlorofluorocarbons (CFCs) used in vehicle fabrication and for transport air-conditioning (see box 5-A).[1]

The United States is the single largest emitter of transport CO_2 emissions, with Western Europe and Eastern Europe following at some distance. The developing world presently adds about 20 percent of the CO_2 from this sector (see table 5-l).

Trends in Passenger Travel

Total vehicular travel per person ranges from an average of several thousand miles per year in the industrial countries to several hundred miles per year in the developing world. Table 5-2 shows trends in passenger travel for six countries and the primary means of transportation--private car, buses, rail water, air. Values for the poorest countries are biased downward because they omit walking, cycling, and animal transport (37).

Total travel, car ownership, and travel by car have all increased steadily throughout the world over the past two decades, gradually in the industrial countries and rapidly in the developing countries. Currently, car ownership ranges from one car per 1.8 people in the United States (in 1987) to one car per 1,075 in the People's Republic of China (see table 5-3). In many of the developing countries, travel and car ownership have been growing faster than income (49). Recent political changes and hoped for economic progress in Eastern Europe and the U.S.S.R. could lead to especially large increases in transport-related emissions in these countries (see box 5-B).

In the United States, travel per person (all modes) increased from 10,400 miles in 1970 to 13,300 in 1985, an average annual increase of 1.7 percent(11, 40). About 90 percent of travel was by car and light trucks, 9 percent by air, and 2 percent by bus and rail. Figure 5-2 illustrates the increase in annual auto travel per driving-age adult from 1960 to the present.

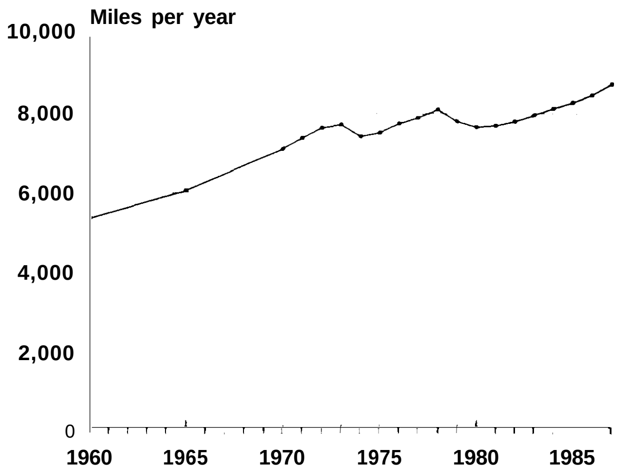
Table 5-l—Carbon Emissions From Transportation

	Transport CO*	Share of world	Transport share of region's fossil CO_2
U.S.A.	413	36%	30%
Canada and Western Europe	266	23	31
Japan, Australia and New Zealand	90	8	30
U.S.S.R. and E. Europe	171	15	12
S. and E. Asia	50	4	19
China	19	2	4
Africa	40	4	26
Latin America	83	7	36
Middle East	21	2	14
World total	1,153		22%

*Transport share of world's fossil-fuel CO_2 emissions.

SOURCES: U.S. Environmental Protection Agency, *Policy Options for Stabilizing Global Climate,* draft report (Washington, DC: 1989), app. B; and ICF Inc., background tables to EPA stabilization report, personal communication to OTA, 1989.

Figure 5-2—Vehicle Travel per Year per Driving-Age Adult



SOURCES: Motor Vehicle Manufacturers Association, *Facts and Figures '89* (Detroit, MI: 1990). U.S. Department of Commerce, *The Statistical Abstract of the United States* (Washington, DC: 1989).

These trends reflect changing economics, demographics, and settlement patterns. As the large post-war "baby boom" generation and unprecedented numbers of women moved into the workforce, employment increased much faster than the total population—it grew even in metropolitan

[1]As detailed in box 5-A, U.S. CFC emissions total about 53,000 metric tons of CFC-12 and 15,000 metric tons of CFC-11 annually. U.S. CO_2 emissions from transportation amount to about 420 million metric tons of carbon per year. One ton of CFC-12 has a global warming potential equal to about 2,000 tons of carbon (28). The corresponding figure for CFC-1 1 is about 950.

Box 5-A-Chlorofluorocarbons in the Transportation Sector

Chlorofluorocarbons (CFCs) are used in transport as working fluids for air-conditioning, and in smaller quantities in foam seats, padding, and insulation. Because of their destructive effect on the stratospheric ozone layer, they have been restricted by an international agreement, the recently ratified Montreal Protocol (see box 2-C in ch. 2). These compounds are also major contributors to global warming.

Three CFCs are used in transport: CFC-12,CFC-11, and CFC-113, all controlled under the Montreal Protocol. CFC-12 is the working fluid in auto air conditioners, and is also used for blowing rigid foam insulation. CFC-11 is used in vehicle manufacture for blowing flexible foam seat cushions and interior padding, and for blowing rigid foam insulation in refrigerated trucks and rail cars. CFC-113 is a solvent used for cleaning electronic components in vehicle manufacture. Table 5A-1 shows estimated 1985 CFC use in American transport. The largest component, CFC-12 in mobile air-conditioning, represents about 20 percent of total U.S. CFC use.

All three of the CFCs currently used in transport will have to be cut back under the terms of the Montreal Protocol. For each of them, there are new techniques or substitute materials under development to reduce emissions. Just as the CFCs differ in their ozone depletion potential, they also differ in their relative greenhouse effect. Chapter 2 discusses both the ozone depletion and greenhouse potential for the three CFCs used in *transport* and some possible substitutes,

Although emissions of CFCs are much smaller than emissions of CO_2, the greenhouse potential per ton of CFC-12 is roughly 2,000 times greater than that of CO_2(measured in tons of carbon) (28), so the CFC contribution to human-induced warming is significant. CFC emissions from all sources (not just transportation) are estimated to account for about one-quarter of the current effect from all greenhouse gases (28).

The United States dominates the world mobile air-conditioning market, and mobile air-conditioning dominates U.S. CFC use in transport. In the 1986 model year, 80 percent of new U.S. domestic cars and light trucks, and 50 percent of imports, were air-conditioned. About 65 percent of the total U.S. vehicle fleet was air-conditioned in 1985 (45). In contrast, only 20 percent of new vehicles-sold in the rest of the world are air-conditioned (24); because air-conditioning is growing, the fraction in the fleet would be lower still.

Of the 115 million pounds of CFC-12 produced for U.S. mobile air-conditioning in 1985,35 percent went to charging new systems, 25 percent to recharging after leaks, 35 percent to recharging after service venting, and 7 percent to recharging after accidents.

New compounds are being developed to replace CFC-12 in air-conditioning systems. HCFC-134a is a promising replacement candidate because it resembles CFC-12 closely enough to be used in existing systems. It will require development of new lubricants, though, because it is not soluble in present mineral oil lubricants, and still requires several years of toxicity testing. Other possible substitutes include HCFC-22, mixtures, and hydrocarbons, but these presently require substantial system redesign and retooling. DuPont has recently announced a promising new blend requiring minimal retooling (2).

For blowing flexible foams, several alternative blowing agents are available. Carbon dioxide and methylene chloride are both used at present (58), and a new water-blown process is under development (38a). For cleaning electronic components, methyl chloroform can replace CFC-113 in many but not all applications. Nearly complete capture and recycling of CFC-113 will be possible, though (38a).

In summary, CFCs are a significant contribution to total transport greenhouse emissions, especially through leaks from mobile air-conditioning systems. Control of CFCs in transport will likely continue to be driven by concern over ozone depletion. Greenhouse considerations, though, should preclude a strategy based on replacing present CFCs with new ones that are less damaging to stratospheric ozone but just as active as greenhouse gases.

Table 5A-1—1985 U.S. Transport CFC Use, Millions of Pounds

	CFC-11	CFC-12	CFC-113
Air-conditioning		113.1	
Foam seats and padding	24a		
Rigid foam insulation	7.8	2.5	
Solvents			b

[a]Use of CFC-11 for flexible foams is about 33 million pounds, which includes furniture, bedding, packaging, and carpet underlay as well as vehicles. Unestimated 24 million pounds is the transport share, based on roughly 2 pounds for each of the 12.2 million light vehicles *manufactured* in the United States in the 1986 model year (38a).
%otalCFC-113 use for solvents was 164 million pounds. Transport share not available,

SOURCE: T.G. Statt, "The Use of CFCs in Refrigeration, Insulation, and Mobile AC in the U.S.," paper prepared for the *EPA Conference on Substitutes ancAlternatives to CFCs and Ha/ens,* Washington, DC, Jan. 13-15, 198S.

Table 5-2—Trends in Passenger Travel for Six Selected Countries

				Mode shares (percent)				
				Road				
		Passenger miles per person	People per car	(private)	(public)	Rail	Water	Air
Brazil	197CI	752	34	28	66	5	0	2
	198CI	2,270	15	33	62	3	0	2
China	197C'	76	27,700	—	23	70	7	0.2
	1980	145	—	—	32	61	6	1.8
India	1 970'	263	902	7	52	41		0.5
	1980	487	718	7	52	41		0.9
Japan	1970	2,700	12.0	51	12	34	1	2
	1980	3,366	4.9	57	11	26	1	5
United Kingdom	1971	4,817	—	79	12	9		0.4
	1981	5,643	3.6	85	8	7		0.6
U.S.S.R.	1970	1,624	147	6	38	43	1	12
	1980	2,976	32	19	41	27	1	13

NOTES: 1. The division of road transport into private and public for Japan, Brazil, China, and India is estimated based on other studies.[a]

2. Walking and cycling, large modes in China and India, are excluded.

[a]For Japan, a 1968 Tokyo study on trip split has been used for 1965 and 1970 (81 percent private, 19 percent public; Moavenzadeh and Geltner, table 4-14), and aggregated mode splits for Japan, Australia and New Zealand in 1979 used for 1980 (84 percent private; Ang, table 6.6). For Brazil, a 1867 Sao Paolo trip survey has been used for 1965 and 1970 (30 percent private; Moavenzadeh and Geltner, table 4-14), and a 1977 trip survey of all metropolitan areas for 1980 (Poole, table 3.2). For China, because of extremely low auto ownership, all road travel has been called public. For India, a crude estimate was derived from registration data presented in Dunkerley et al. It was assumed that annual miles per bus were triple the value for autos, and that buses averaged 30 occupants versus 2 for automobiles. These assumptions yielded estimates of 89 percent private in 1965, 88 percent in 1970 and 1980.

SOURCES: B.W. Ang, "Modelling World Energy Demand for Transport," Discussion Paper EDP 28 (Cambridge: Cambridge University, Energy Research Group, Aug. 25, 1983); J. Dunkerley et al., "Energy and Transport: The Indian Experience," *Pacific and Asian Journal of Energy, 1987; G.* Leach, L. Jarass, G. Obermair, and L. Ho ffmann, *Energy and Growth: A Comparison of 13 Industrial and Developing Countries* (London: Butterworth Scientific, 1986); F. Moavenzadeh and D. Geltner, "Transportation, Energy, and Economic Development: A Dilemma in the Developing World," *Energy Research, Volume 5* (Amsterdam: Elsevier, 1984); Motor Vehicle Manufacturer's Association, *Facts* and *Figures* (Detroit, MI: various years); A. Poole, "Energy and Transport in Brazil," report to U.S. Agency for International Development (Washington, DC: Resources for the Future, January 1983) ;A. Tretyakovaand B. Kostinsky, *USSR: Motor Fuel Use and Conservation in Transportation and Agriculture, 1970 to 1984,* Center for International Research, U.S. Bureau of the Census, CIR Staff Paper No. 32 (Washington, DC: December 1987); J. Yenny and L.V. Uy, "Transport in China," World Bank Staff Working Paper No. 723 (Washington DC: 1985).

areas that lost population between 1960 and 1980. The accompanying increase in work travel accounts for much of the growth in per-capita car ownership and travel. Also during this period, low-density suburbs grew more rapidly than central cities. Although data are ambiguous on whether or not average trip length has increased, it seems plausible that it increased through the 1960s, and has leveled off or declined since the 1970s.[2]

The large increase in air travel since 1960 can be attributed both to rising personal incomes and to the declining real cost of air travel brought about by technological advance and, in the 1980s, deregulation. Events of the last few years suggest, though, that industry consolidation may bring higher real prices, moderating current growth trends.

In 1985, passenger travel accounted for two-thirds of the energy consumed in U.S. transport. The other major energy user was freight, which consumed roughly one-quarter of the total transport energy. (11).

Trends in Freight

Freight has been growing worldwide at roughly the same rate as gross domestic product (GDP) in OECD countries and faster than GDP elsewhere (32, 44,60, 77). Freight intensity (ton-miles of freight per dollar of GDP) varies greatly among countries, generally as a function of country size, population density, and economic structure. Intensity increases as an economy moves from agriculture into primary industry, then declines slowly as an economy shifts toward secondary manufacturing and services. U.S. freight statistics have followed this trend.

In 1987, U.S. freight activity amounted to about 11,000 ton-miles per person. About 37 percent was by rail, 25 percent by road, 22 percent by pipeline, 16 percent by water and less than 1 percent by air. These shares have been roughly constant since the

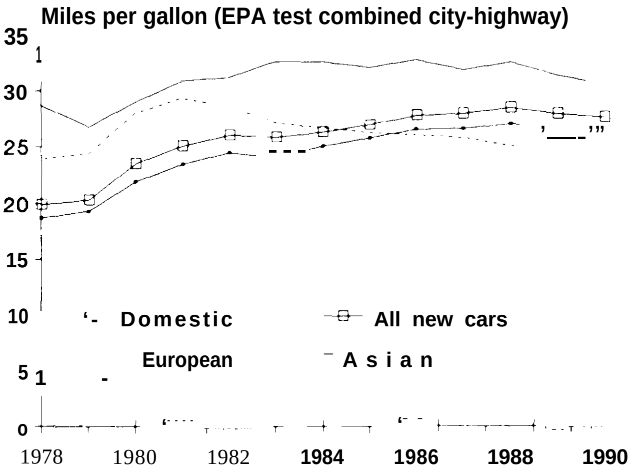
'See discussions in table 3.26 of ref. 43 and refs. 30 and 34.

Table 5-3--World Auto Registrations, 1987

Continent/country	Cars (thousands)	Population per car
North & Central America		
Canada	11,500	2.2
Honduras	30,000	170
Mexico	5,402	16
U.S.A.	137,323	1.8
Total	156,776	2.6
South America		
Argentina	4,060	8
Brazil	9,527	16
Colombia	579	55
Peru	390	56
Total	17,165	17
Asia		
China	995	1,075
India	1,471	566
Indonesia	974	193
Japan	29,478	4.2
Pakistan	272	404
Total	43,782	65
Oceania		
Total	8,666	2.4
Africa		
Egypt	417	131
Nigeria	774	149
South Africa Republic	3,078	12
Total	7,860	80
Europe		
France	21,950	2.5
Germany, East	3,462	4.8
Germany, West	28,304	2.1
Italy	22,800	2.5
Turkey	1,193	46
U.S.S.R.	13,000	22
United Kingdom	20,096	2.8
Total	159,958	5.2
World total		
1987	394,209	13

SOURCE: Motor Vehicle Manufacturer's Association, *Facts and Figures '89* (Detroit, MI 1990).

Figure 5-3-Trends in New Passenger Car Fuel Economy, 1978-90



SOURCE: R.M. Heavenrich and J.D. Murrell, "Light-Duty Automotive Technology and Fuel Economy Trends Through 1988," U.S. Environmental Protection Agency, Office of Mobile Sources, EPA/AA/CTAB-88-07 (Ann Arbor, MI: June 1988).

mid-1970s, while over a longer period freight has shifted gradually from rail to truck and pipeline. Continued movement of producers to suburbs, often far from rail spurs, and increased use of sophisticated inventory management (e.g., just-in-time delivery systems) is likely to provide a continuing advantage to trucking or novel combinations of road, rail, and other modes.[3] Worldwide, continuing industrialization in the developing countries will likely offset reductions in U.S. freight intensity. For example, between 1960 and 1980, the freight intensity of Korea increased by more than 40 percent, that of Brazil by over 25 percent (77).

Trends in Efficiency

The energy efficiency of transport has increased both in the United States and worldwide. The largest gains have been in American light vehicles (see figure 5-3). New-vehicle average fuel economy almost doubled (from 13 to 24 miles per gallon (mpg)) between 1973 and 1985 through the combined effects of technical progress, oil price shocks, and regulation (29). During the same period, new-car efficiencies in the United Kingdom increased from 21 to 31 mpg; in Japan, from 23 to 30 mpg; and in West Germany, from 23 to 31 mpg. Almost no efficiency gains have been made in new vehicles since 1985, however (11, 25).

In freight, the broad trend worldwide *is* towards energy-intensive modes, but with substantial efficiency improvements within each mode. For example, in the United States, truck freight efficiency improved by 20 percent between 1970 and 1985 (66). Less dramatic but nevertheless substantial efficiency gains have been made in other modes worldwide.

[3] An uncertain factor in future freight demand and structure, at least in the OECD, is recycling. As total material demands become smaller, a larger fraction can be met by recycled materials. This fact changes the basic path of material travel through the economy from a once-through trip to a circular one. The overall effect on total freight requirements could be an increase or decrease. (For more on recycling, see ch. 6.)

Box 5-B-Transportation Energy Use in Eastern Europe and the U.S.S.R.

Eastern Europe--The transportation sector currently accounts for about 13 percent of energy demand in Eastern Europe. Railroads account for 30 to 55 percent of total passenger miles, depending on the country, and for a greater share of freight transport (31). While railroads are expected to remain important, passenger and freight transport are expected to increasingly shift to private cars and large trucks, especially as per-capita car ownership increases. Air travel also is expected to increase rapidly.

Kolar and Chandler (31) projected that if only minimal improvements occur in automobile fuel economy, primary energy demand in the sector will more than double by 2025. In contrast, significant increases in vehicle fuel **economy (e.g.,** from the current East European average for passenger cars of 27 miles per gallon to 47 miles per gallon) and conversion of the truck fleet from predominantly gasoline-powered to predominantly diesel-powered engines, could limit energy demand growth in this sector to about 50 percent.

U.S.S.R.—In the U. S.S.R., transportation is responsible for about 12 percent of total fossil fuel carbon emissions (60). The most prevalent modes of passenger travel are public transportation (40 percent) and rail (25 percent).[1] The U.S.S.R. has about 45 personal cars per 1,000 people, roughly one-tenth the ratio in Western Europe and the United States. This situation is likely to change as more automobiles become available and as per-capita incomes rise. U.S.S.R. passenger car production increased dramatically during the 1970s; while growth plateaued during the early 1980s, at least three new auto assembly plants are planned and production is expected to increase again in the 1990s.

Freight transportation accounts for a much larger sham of transport fuel consumption in the U.S.S.R. than passenger transportation. In 1982,66 percent of freight transportation was by rail, 22 percent by river or ocean, and 9 percent by truck (60). Truck transportation traditionally has been based on gasoline engines, rather than diesel engines, which are more energy-efficient.[2] However, the portion of diesel-powered trucks is slowly increasing, which partly explains why total freight turnover increased by 40 percent between 1975 and 1985 even though total fuel consumption remained unchanged (60).

There is little doubt that energy use in passenger transportation will increase, but how fast demand will grow, how fast it will be satisfied by domestic production of passenger automobiles, and what type of fuel will be used are unknown. Soviet vehicles tend to be inefficient and highly polluting, so opportunities exist to reduce emissions by producing new cars using more modern technologies and new car designs. The U.S.S.R. also could attempt to strengthen and improve its well-developed urban transportation system, which would partially offset growth of passenger automobile use.

[1] **Private cars account** for 19 percent and air travel **accounts for 13 percent.**

[2] **In** 1984 diesel-engine **trucks** comprised only 19 percent of Soviet truck freight haulage, compared with over 80 percent m **Western** Europe, and more than 40 percent in the United States (60).

TECHNOLOGICAL AND INSTITUTIONAL INFLUENCES ON EMISSIONS

Three factors—population growth (especially in developing countries), miles traveled per person, and greenhouse gas emissions per unit of travel—will determine future world transport greenhouse emissions and the trajectory of emissions growth. These factors will in turn be influenced by the economic development of different countries or groups of countries and by a number of technological and institutional forces, many, but not all, of which are amenable to policy intervention (see last section of this chapter).

Reducing Vehicle Miles Traveled

Very little travel is done for intrinsic pleasure; people travel in order to get somewhere they want to be. In the United States, travel for work, travel for family business, and travel for recreation each account for roughly one-third of passenger vehicle miles traveled (VMT) (38). Existing settlement patterns, economic activity, and available transportation infrastructure determine both how much travel is needed and how it is accomplished.

Americans exhibit a strong preference for traveling in cars and light trucks, primarily alone. Since passenger travel consumed two-thirds of U.S. transport energy in 1985 and nearly 90 percent of that was in light vehicles (i.e., cars and light trucks), controlling light vehicle VMT would have a large effect on transport CO_2 emissions (11). However, the only ways to reduce light vehicle VMT are to displace single-occupancy driving with other transportation modes, reduce the need for trips through altered work scheduling (e.g., 4-day workweeks) or by combining errands, or to shorten each trip through better urban design.

The primary alternatives to single-occupancy driving are carpools and mass transit. American ridership shares of public transit remain low, in contrast to some non-U.S. cities (see box 5-C). Strategies to reduce the number of single-occupancy car trips include: improved mass transit, employer rideshare and mass transit incentives, parking management (higher parking meter fees, eliminating employer-subsidized parking, etc.), vanpool purchase incentives, auto use restrictions, and high-occupancy vehicle (HOV) lanes. Collectively such measures are referred to as transportation control measures (TCMs)

Several key generalizations about TCMs can be drawn from past programs to reduce air pollution in various cities (63). First, TCMs will be most effective if implemented as a package of several measures simultaneously. For example, ridesharing programs and mass transit are likely to be more successful if some highway lanes are restricted to buses and carpools, or if parking in business districts is restricted or expensive. A recent comparison of the business districts of San Francisco, Portland, Seattle and Denver found that transit shares were highest in the cities with the highest parking prices and most limited parking (26). In general, larger reductions in emissions are likely to be achieved if TCM programs are coordinated throughout an area and over an extended time horizon, than if measures are developed on a piecemeal or sporadic basis. Major capitol projects such as development of mass transit obviously require long lead times and sustained efforts.

TCM programs have to be tailored to each individual area, and thus must be implemented locally. Critical local characteristics that need to be considered in developing TCM programs include: population and employment distributions and densities, city layout and transportation routes, highway system capacity and level of congestion, access to mass transit, and parking availability and costs.

Finally, the success of many transportation control measures depends to a large degree on public acceptance and participation. In the absence of widespread support, past experience indicates that political resistance to involuntary restrictions on peoples' modes or amount of travel can be insurmountable.

The Role of Land-Use Planning

Land-use patterns play an important role in either tying people to their cars or facilitating other modes of transportation. As an illustration, people who live within a few miles of work might choose to walk or bike. But where urban areas consist of sprawling residential suburbs and separate business districts or industrial parks, few people have these options. A recent comparison of 10 U.S. cities found that per capita gasoline consumption is relatively low in cities with high population and job density, and relatively high in cities with abundant roads and parking. Per capita gasoline consumption is 10 times higher for residents of suburbs outside of Denver than for residents of Manhattan (39).

Between 1980 and 1986, about 85 percent of the population growth in the United States was in metropolitan areas. About three-fourths of that growth occurred in the suburbs of those areas. According to a task force formed to advise the

Photo credit: American Public Transportation Association

The Southwest Ohio Regional Transit Authority promotes public transportation with billboards like this one in Cincinnati, OH.

Box 5-C-Successful Urban Bus Systems

Every author who looks at public transit concludes that Americans just don't like it. This could change. Many cities in other industrial countries have efficient, heavily used public transit systems; some cities similar in many ways to American ones have attracted large numbers of motorists to public transit through service improvements.

Ottawa, Canada a metropolitan area of about 600,000, began a major transit improvement in the mid-1970s (coupled with the abolition of free parking downtown for Federal public servants).[1] The cornerstone of the program was construction of a 20-mile dedicated busway, separated from other traffic but with ramps feeding into arterial roads at major stations, spaced at about l-mile intervals. The program also included premium-priced express service between outlying suburbs and major employment centers, expanded connections to intercity terminals, mom buses, and many operating innovations.

The program 's success has been impressive. **A greater percentage** of people ride the bus in Ottawa than in any other medium-sized city in North America. Along major suburban corridors, 23 to 45 percent of ail trips are taken in buses. That is up from 2 to 20 percent in 1971. The system covers a steady 60 percent of operating costs from revenue.

Curitiba, Brazil, is a prosperous and rapidly growing metropolitan area with a population of about 1.5 milliom[2] Faced with bad traffic congestion in the early 1970s, the city developed a comprehensive public transport plan based on a 35-mile network of separated bus lanes along the medians of radial arterial roads. The lanes are not grade separated at intersections, but have signal priority. The system is operated by several private companies with coordinating management committees to oversee such matters as intercompany reimbursementfor transferring passengers. Fares are low, and the companies are profitable.

In 1970, about 40 percent of trips in Curitiba were made by private auto, indicative of the higher incomes here than in other Brazilian cities. (The nationwide average for metropolitan areas was 30 percent.) The remarkable success of the transport system is that between 1970 and 1980, while Curitiba's auto fleet grew by more than 10 percent per year, the fraction of metropolitan trips made by auto declined to 30 percent

The experiences of both Ottawa and Curitiba suggest that attracting riders from cars to public transit depends on comprehensive attention to details of service convenience and quality. Major gains can be made when, because of priority treatment on congested roads, public transit is faster and more convenient than driving.

[1] This section is drawn from ref. 36.

[2] This section is drawn from ref. 44.

Federal Highway Administration (FHWA), this pattern of growth is expected to continue (20). However, growth in the suburbs does not necessarily have to mean more and longer commutes in private cars. The FHWA's task force anticipates that the density of residential development in the suburbs will increase as rising housing costs and declining household sizes necessitate construction of apartments and compact townhouses rather than expansive subdivisions (20). This increase in density could facilitate transit service. And, some analysts have suggested, land-use policies could guide development to limit reliance on driving.

Land-use planning and regulation are traditionally activities carried out by local governments, whereas transportation planning is more apt to be a State or regional responsibility. Land-use policies are implemented through local zoning laws and permit requirements for subdivision and commercial site development. Permit reviews typically ensure that public works (e.g., water, sewers, roads, interchanges, and parking) are adequate to support the development. Interaction between transportation and land-use planning agencies usually takes the form of assessing the impacts of new developments. The number of trips that would be generated by a proposed development is estimated and compared with the capacity of nearby roads and intersections.

If a transportation system is inadequate to support new development, it maybe expanded, sometimes at a developer's expense. Increasingly, where funds are limited or congestion is already an issue, developers are being required to take steps such as providing convenience stores on site or providing transit shelters or bike paths, in order to reduce potential transportation impacts. Downtown developers in several cities have been faced with caps on the number of parking spaces they can provide. In Los

Angeles, area-wide land-use regulations are being developed to help reduce traffic congestion and air pollution. The guiding principles include: promoting development in areas with existing mass transit services; encouraging development within developed areas to increase population density and thus make transit services easier to provide; and promoting housing construction in job-rich areas or employment opportunities in residential areas. Due to the links between land-use policies, jobs, and tax revenues, local political resistance is apt to be the major problem in trying to modify land-use regulations (12).

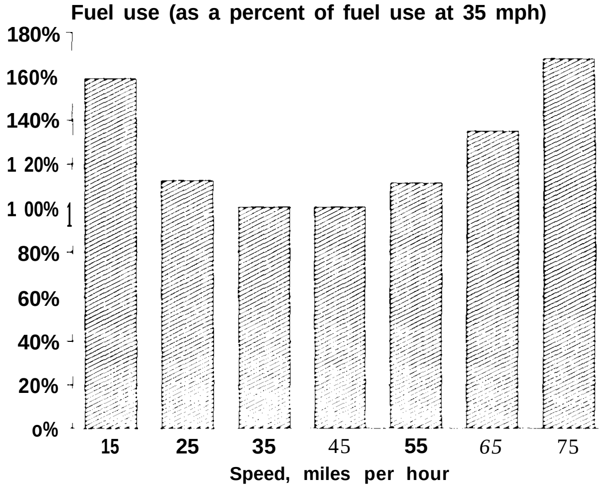
Factors Affecting Carbon Dioxide Emissions Per Mile

Carbon dioxide emissions per unit of travel are largely determined by two types of factors: operation and maintenance practices (including occupancy level, the speed at which vehicles are operated, and vehicle tuning) and vehicle efficiency technology (including such market-determined factors as the average size and power of vehicles in the fleet),

Vehicle speed has a significant effect on fuel use (figure 5-4). The lowest fuel use per mile (and thus lowest CO_2 emissions per mile) occurs in the range of 35 to 45 mph. Traveling at 65 mph typically results in 20 to 25 percent higher CO_2 emissions per mile than traveling at 55 mph. Traveling at 75 mph results in about 50 percent higher emissions. Speeds lower than 35 mph, often a result of highway congestion, result in higher emissions, as well. Increasing urban highway congestion has, and will continue to, cut overall on-road efficiency (see box 5-D).

Even if revived public transit reduces projected VMT growth, cars and light trucks (pickup trucks, minivans and four-wheel drive ' 'sport' vehicles) will continue to dominate U.S. transport. Assuming the mix of types and sizes of vehicles remains about the same, the single most important factor determining future transport energy use and CO_2 emissions will be the rate of light vehicle efficiency gains. Today's best production models and prototypes surpass 50 mpg and 80 mpg respectively, indicating that cars can be much more efficient than they are, on average, today (see table 5-4). More efficient cars make some sacrifices in performance and size, but, with further development, significant efficiency gains should be possible even with today's vehicle

Figure 5-4—The Effect of Vehicle Speed on Fuel Consumption



SOURCE: S.C. Davis, D.B. Shonka, and P.S. Hu, *Automated Transportation Energy* Data Book (Oak Ridge, TN: Oak Ridge National Laboratory, May 31, 1988), table 3.35.

size and performance. The rate of improvement possible for the entire fleet is discussed in detail in "OTA Emission Reduction Scenarios, " below.

In addition to efficiency gains from new technologies, additional improvement can be had by shifting sales to smaller cars. Difiglio et al, (14) estimate that by 2000, a new-vehicle fleet-average efficiency of about 39 mpg is the maximum technologically achievable without changing the size mix of the fleet. An additional 5 to 7 mpg average is possible if between 75 and 95 percent of car purchases are from the smaller, most fuel-efficient car lines. However, not all consumers would be satisfied with these vehicles. Moreover, shifting to smaller vehicles raises safety concerns (see box 5-E).

Large efficiency gains can be achieved if consumers will accept much smaller, lighter, and less powerful cars as second vehicles. While limited in applications, very small cars are suitable for some purposes such as urban commuting. If a substantial fraction of mileage was driven in cars sized for the number of passengers traveling and the purpose of the trip-say, 20 percent of vehicle miles in half-width cars getting 120 mpg and the remainder at 34 mpg (the average we forecast for the year 2010)--then fleet average efficiency would increase by about 6 mpg. Whether such vehicles could meet safety requirements is unknown, however.

Box 5-D-Congestion

Traffic is increasing in many cities. Average automobile speeds in London are reportedly as low as 8 miles per hour (mph), and in Tokyo speeds are even lower (46). In Los Angeles, average speeds are expected to decline from about 35 to 19 mph between 1984 and 2010 (55). A drop in average speed in the range expected in Los Angeles could result in a one-quarter reduction in average automobile fuel economy for these vehicles.[1]

According to the Federal Highway Administration, in 1987, congestion on U.S. freeways alone created about 2 billion hours of delay and wasted about 2.2 billion gallons of fuel due to the negative effects of stop-and-go driving on automobile fuel economy (33). This amounted to about 2 percent of total gasoline consumption in the United States in 1987. The cost of this loss in productivity (i.e., time lost sitting in traffic) and excess fuel consumption totaled about $16 billion in 1987. If no further improvements are made to our transportation system, by 2005, congestion-induced gasoline use on freeways is expected to contribute about 12 percent of the total consumption (68).

To mitigate the congestion wrought by the projected growth outlined above, we can choose to either improve the highway system or take steps to reduce the rate of growth in vehicle miles traveled (VMT). Increasing the capacity of, and the traffic flow on, existing highways could ease congestion, but the benefits may only be temporary since VMT growth could eventually meet and surpass future capacity. Reducing the rate of VMT growth, or demand through the adoption of transportation control measures can also help ease congestion, but such measures require region-wide cooperation among municipalities as well as public acceptance and participation. In a strategy that targets both transportation supply and demand, the Los Angeles area estimates that traffic delays in 2010 can be reduced by 50 percent over what they would have been without any further improvements.

[1]This estimate assumes that the relationship between fuel economy and speed is linear between 20 and 35 mph (see ref. 33), and that the average automobile fuel economy of late-model-year automobiles is about 25 miles per gallon at 20 mph and about 34 miles per gallon at 35 mph (see ref. 11).

Table 5-4:—Projected Fuel Economy Impacts of Auto Technical Changes

Source of change	Energy and Environmental Analysis study (2005) mpg improvement[a c] (percent)	Cheng study (2010) mpg improvement[b c] (percent)
Platform:		
Weight reduction	11-14.3 (2,450-2,600 tbs.)	10-20 (2,150-2,535 lbs.)
Aerodynamics	7.1-8.8	2-3
Rolling resistance and lubricants	3-4	2-.3
Accessories	1.5-2	2.3
Engine:		
Spark ignition	13-15.6 (includes 2-stroke)	5.3-6.5
Prechamber diesel		1.5
Direct diesel	—	6.2-11.6
Transmission:		
Conventional	4-6	2.75
Continuously variable transmission	0.9-1.5	3.4-5.9
Engine on-off		0.3-0.7
Overall new car test mpg	44.3 -48.1	35-41
Fleet on-road mpg	37-40[d]	29.6 -34.2

[a]EEA's gains are estimated relative to a typical 1987 car weighing 3,070 pounds and achieving 28.0 mpg.
[b]Cheng's gains are estimated relative to a typical 1985 car weighing 2,900 pounds and achieving 27.0 mpg.
[c]Gains shown here weight each author's estimated technical effect by his estimated market penetration.
[d]EEA does not present fleet on-road mileages. This figure is calculated assuming the same ratio between new and fleet figures as in Cheng.

SOURCES: Derived from H.C. Cheng, "Potential Reductions in U.S. CO_2 Emissions in 1995 and 2010 by Technology Improvements in Electricity Generation and Transportation Sectors" (Upton, NY: Brookhaven National Laboratory, Process Sciences Division, April 1988); Energy and Environmental Analysis, Inc. *Developments in the Fuel Economy of Light-Duty Highway Vehicles*, draft final report for U.S. Congress, Office of Technology Assessment (Arlington, VA: June 1988).

Efficiency improvements are more readily adopted in other modes than in private vehicles for two reasons. First, commercial operators pay more attention to life-cycle costs. Second, each vehicle typically is operated more often so that fuel is a larger fraction of total life-cycle cost. As mentioned, the trend in freight is towards more energy-intensive modes (i.e., trucks) but also greater efficiency within those modes.

Box 5-E—Safety v. Efficiency

Are efficient cars necessarily more dangerous? Other things being equal, a larger and heavier car is both safer and less fuel-efficient (9). Any factor that shifts the vehicle fleet toward smaller and lighter cars-with other factors held constant-will increase fatalities; the National Highway Traffic Safety Administration (NHTSA) states that major downsizing of vehicles to increase fuel economy above *27.5* mpg would result in increased fatalities and injuries (72). This argument applies not just to standards, but also to any market or regulatory effect that pushes toward lighter cars.

NHTSA analyzed single-vehicle crashes involving passenger cars (through model year 1986) for the years 1970 to 1989 (72a). In nonrollover crashes, reduced car weight had little or no effect on the risk of fatality but was related to a small increase in the risk of nonfatal injury. In rollover crashes, however, smaller cars had art increased risk of fatal injury of about one-third; under the same crash conditions, narrow, light, short cars had higher rollover rates than wide, heavy, long cars.

The Insurance Institute for Highway Safety (IIHS) examined actual death rates in car crashes, by car size, body style, and age and sex of driver (27a). Only 1 small car was among the 10 with the lowest death rates, while 12 small- and 3 mid-sized cars were among the 15 with the highest death rates. Cars with high percentages of young and/or male drivers tended to have higher death rates.

However, good design and safety features can offset the effect of decreasing vehicle weight, as the steady decline in fatalities per mile traveled since the mid-1970s illustrates.[1] Moreover, the IIHS analysis reveals that **some small cars in several** of the body style categories exhibited actual fatality rates that are just as low as those of the best mid-sized and large cars.

Nevertheless, a substantial move to smaller and lighter cars while maintaining or improving occupant safety will continue to be a major engineering challenge.

[1] Between 1975 and 1988 new-ear fuel economy doubled and average weight declined by 1,000 pounds, but deaths dropped from 3.6 to 2.4 per hundred million vehicle miles. This decline represents a combination of technical advances, increased seatbelt use, and crackdowns on drunk driving.

Air efficiencies are also improving thanks to technological advancements and changed routing (which increases the number of passengers per trip). The next generation of aircraft, which could start to appear in the mid- 1990s, could make use of advances in engines, wings and general aerodynamics, and lightweight structural materials that would yield significant savings in energy per seat-mile. For example, current airplanes such as the Boeing 757 and 767 achieve 70 seat-miles per gallon (with a full airplane). Boeing forecasts that the 7J7 will achieve 130 to 150 seat-miles per gallon and that it might be possible to have an airplane operating at 200 seat-miles per gallon early in the 21st century (59). Similarly, innovations in nonrail freight (e.g., trailers that double as railroad cars and the use of wingsails to help power ships) can further reduce transport energy intensity.

This assessment assumes petroleum will remain the fuel of choice in both passenger and freight modes through 2015. However, other fuels are under development, including methanol derived from natural gas (and, past the timefrarne of this study, possibly from coal), ethanol derived from corn or wood, and natural gas in compressed or liquefied form.

These alternative fuels are being considered for reducing urban air pollution but not all are good candidates for lowering emissions of greenhouse gases (see table 5-5). Methanol made from natural gas will have a negligible to modest effect on reducing greenhouse gas emissions. Natural gas systems can leak and since methane-the prime constituent in natural gas—is a powerful greenhouse gas, even low leak rates can offset much of the at best modest gains achieved by switching from oil to compressed natural gas. Gas or methanol made from woody biomass offers considerable reduction potential, but only if emissions are offset with additional biomass growth. (Wood emits a high amount of CO_2 for every useful unit of energy it provides. See ch. 7.)

Electric vehicles will produce more CO_2 emissions than gasoline vehicles if recharged with electricity from coal-fired plants but almost no

Table 5-5—Greenhouse Gas Emissions From Alternatively Fueled Vehicles

Fuel and feedstock	Percent change from present
Methanol:	
M85, current natural gas conversion technology	-2
M100, improved vehicle and gas conversion technology	-17
M100, improved vehicle and best coal conversion technology	+25 to +30
Natural gas:	
Compressed, from domestic sources	-14 to 0
Biomass fuels:	
Ethanol from corn using coal for process heat	–10 to +30
Synthetic natural gas from woody biomass	-70 to –60
Methanol from woody biomass	-70
Electricity:	
Recharging from coal-fired plant	+5
Recharging from current electricity mix	-23
Recharging from best gas turbines	-45
Recharging from nuclear plants	-80
Recharging from solar or hydropower	-85
Hydrogen:	
Hydride vehicle, nuclear electrolytic hydrogen	-55
Liquid hydrogen, all solar hydrogen	-85

SOURCE: Modified from M.A. DeLuchi, State-of-the-art *Assessment of Emissions of Greenhouse Gases From the Use of Fossil and Nonfossil Fuels, With Emphasis on Alternative Transportation Fuels*, draft report (Davis, CA: University of California, June 3, 1990), table 10. Estimates recalculated by M.A. DeLuchi, Dec. 11, 1990.

emissions if renewable or nuclear sources are used. Improved vehicles recharged with electricity from the current U.S. mix of powerplants might lower emissions per mile by about 25 percent. Hydrogen (if generated from renewable or nuclear energy) offers significant long-term potential, but is the least technically advanced of any of the options. Table 5-5 compares greenhouse gas emissions from alternative fuel and gasoline vehicles. For more information on the status of alternative fuel vehicles, see a recent OTA report, *Replacing Gasoline: Alternative Fuels for Light-Duty Vehicles (64).*

OTA EMISSION REDUCTION SCENARIOS

OTA developed a general energy accounting model to track the effects of various policy measures on U.S. CO_2 emissions[4] (see app. A). Within the transportation sector, we forecast about a 35-percent increase from 1987 emission levels by 2015 as our "Base case" scenario. By simulating a series of Moderate control measures in the model, CO_2 emissions were held to about a 20 percent increase by 2015. Only under our Tough scenario did CO_2 emissions fall below current levels, to about 10 percent below 1987 emissions. Table 5-6 includes details about the control measures in the Moderate and Tough scenarios. We assume that gasoline prices rise to about $2.00 per gallon (1987 dollars) by 2015.

The Base Case

A basic assumption of the OTA Base case is that people will continue to place a high value on performance and vehicle size and continue to prefer single-occupancy driving to any other mode of transportation. The model projects combined auto and light truck VMT to grow at an average annual rate of 2.6 percent through 2000 and about 1.5 percent from 2000 to 2015. Thus, much of the growth in CO_2 emissions in the OTA Base case comes from a steady rise in VMT. This growth more than offsets the CO_2 reduction from a 25-percent improvement in auto fuel efficiency (to a new-car fleet average of about 37 mpg by 2010).

Moderate Control Measures

CO_2 emissions growth could be slowed but not reversed by implementing policies that would encourage measures that we classify as Moderate. If adopted by 1995, all of the Moderate measures together (see table 5-6) would lower transportation emissions by about 10 percent of 1987 levels by 2000 and by 13 percent by 2015 (see figure 5-5). However, emissions increases more than offset these savings: by 2015, CO_2 emissions still rise 20 percent relative to 1987 levels.

Before the year 2000, the greatest savings come from those measures OTA categorized as "Operation and Maintenance of Existing Stock" (O&M). These measures include improving truck maintenance, reducing VMT through rideshare programs and parking controls, and enforcing a 55-mph speed limit.

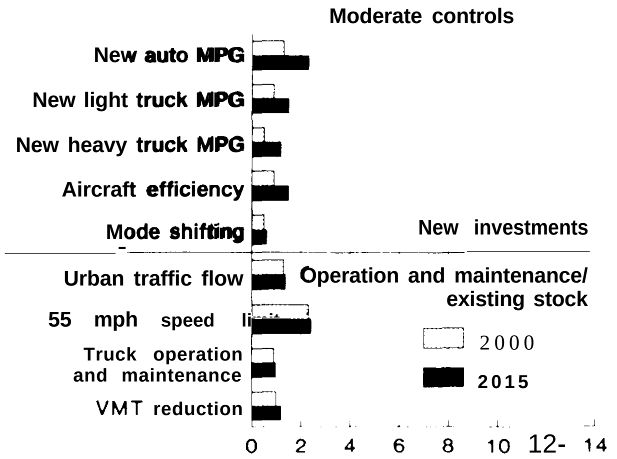
[4] For the transportation sector the Oak Ridge National Laboratory's "Alternative Motor Fuel Use Model" was used as the modeling framework for highway vehicles (41).

Table 5-6-Transportation Sector Conservation Measures

	Base case	Moderate measures	Tough measures
1. Operation & maintenance/ existing stock			
Operation & maintenance.		Truck inspection & maintenance--5°/0 improvement	Same as moderate measures
Other efficiency measures		Enforce 55 mph--4% savings for light vehicles	Same as moderate measures
		Traffic flow improved-20/~ fuel savings	Same as moderate measures
VMT reduction measures	Auto & light truck VMT increases at 2.6%/yr 1987-2000, 1.50/. post-2000	Ridesharing/parking control-reduce urban light vehicle VMT by 2°/0	Ridesharing/parking controls--reduce urban light vehicle VMT by 30% by 2000, 50% by 2010
Mode shifting ., ...		Urban public transportation innovations and improvements-1% savings	Same as moderate measures
2. New investments:			
New auto mpg (1995, 2000, 2010)	29.8, 31.9, 36.6 mpg (EPA rating, not in-use efficiency)	31.5, 35.0, 39.0 mpg	32.0, 39.0, 55.0 mpg
New light truck mpg	22.5, 25.4, 33.3	23.8, 27.9, 35.5 mpg	24.2, 31.1, 50.0 mpg
New medium truck mpg	8.5, 9.4, 11.5 mpg	9.0, 10.3, 12.3 mpg	9.1, 11.5, 17.3 mpg
New heavy truck mpg	5.5 mpg in all years	5.7, 5.8, 5.9 mpg	6.5, 7.6, 8.9 mpg
Mode shifting			Busway, urban light rail--50/~ decrease in urban light vehicle passenger miles High-speed intercity rail-50/0 decrease in non-urban light vehicle passenger miles, 10% decrease in air passenger miles Urban bike/pedestrian planning-5% decrease in urban light vehicle VMT
Nonhighway	Aircraft efficiency improved by 200/0	Aircraft efficiency improved by 30%	Aircraft efficiency improved by 50%
3. Accelerated new investments:			
Auto lifetimes			Average vehicle lifetimes 3 years shorter
New auto mpg (1995, 2000, 2010)			34.0, 42.0, 58.0 mpg due to smaller cars
Mix of autos and light trucks , . . .			Shift mix of autos and light trucks so that they increase at the same rate

SOURCE: Office of Technology Assessment, 1991.

Figure 5-5—CO_2 Emissions Reductions in 2000 and 2015 Expressed as a Percentage of 1987 Transport Sector Emissions, by Control Method, Under the Moderate Scenario



NOTE: The data presented above should be interpreted as the emissions reductions achievable in some future year expressed as a percentage *of* 1987 emissions from the transportation sector, not as a percentage decrease in emissions *below* 1987 levels.

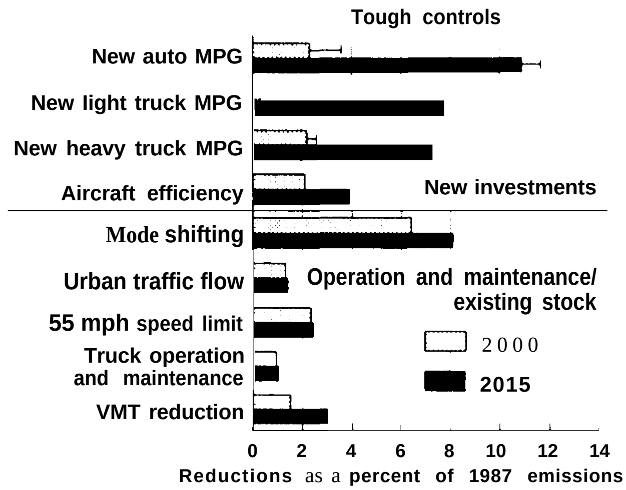
SOURCE: Office of Technology Assessment, 1991.

Though the contribution from these measures grows very little with time under the Moderate scenario, O&M still accounts for about half the total annual reductions by 2015. Over half of the total savings from Moderate O&M measures comes from returning the speed limit to 55 mph and improving traffic flow. The balance comes from better truck maintenance and reductions in VMT through carpooling and vanpooling and parking controls. In this scenario no additional funds are devoted to mass transit infrastructure.

Improving fuel efficiency starts out as an important but modest part of the saving and increases over time. Measures to increase vehicle fuel efficiency can reduce transport emissions by about 2 percent of 1987 levels by 2000 and 7 percent by 2015. Autos and light trucks account for the greatest proportion of savings.

In our Base case, we assume that new cars will average about 32 mpg by 2000 and 36.5 mpg by 2010. Under the Moderate scenario, new car efficiency averages 35 mpg by 2000 (15) and 39 mpg by 2010.

Figure 5-6--CO_2 Emissions Reductions in 2000 and 2015 Expressed as a Percentage of 1987 Transport Sector Emissions, By Control Method, Under the Tough Scenario



NOTE: The data presented above should be interpreted as the emissions reductions achievable in some future year expressed as a percentage *of* 1987 emissions from the transportation sector, not as a percentage decrease in emissions *below* 1987 levels. The thin horizontal bars show additional reductions possible if existing vehicles are replaced sooner than expected.

SOURCE: Office of Technology Assessment, 1991.

Tough Control Measures

In OTA's Tough scenario, CO_2 emissions from the transport sector fall to about 5 percent *below 1987* emissions by 2015 even with light vehicle size and performance more or less at current levels. If some consumers can be moved into smaller or less powerful cars and old cars are retired somewhat more rapidly, then emissions could fall to 10 percent below 1987 levels.

Reductions from the O&M component are similar under the Moderate and Tough scenarios (see figure 5-6). Note, however, that O&M plays a smaller role under the Tough scenario (about one-fifth of the total saving) than it does in the Moderate one (one-half of the savings).

New-car efficiencies of 34 mpg by 2000 and 55 mpg by 2010 might be possible with an aggressive introduction of technical improvements, including a shift to diesel engines. This assumes that consumers buy cars of the same size and performance as today's (14), If the majority of consumers are willing to purchase smaller cars, new car fleet average efficiencies of 42 mpg by 2000 and 58 mpg by 2010 might be achievable (14). Assuming such efficiencies (and policies that encourage people to buy fewer light trucks and buy new cars an average of 3 years earlier than they would otherwise) car emissions might be reduced by about 12 percent of 1987 levels by 2015. In addition, 8 percent reductions from light trucks and 7 percent from medium- and heavy-duty trucks are achievable under our Tough scenario,

Measures to move people out of their cars and into mass transit under the Tough scenario would yield reductions of about 11 percent of 1987 levels, To achieve this, however, urban auto traffic would have to be reduced by 10 percent through urban light rail, subways, and urban bike paths. High-speed intercity rail would have to lower interurban car travel by 5 percent and air traffic by 10 percent.

Summary of the OTA Scenarios

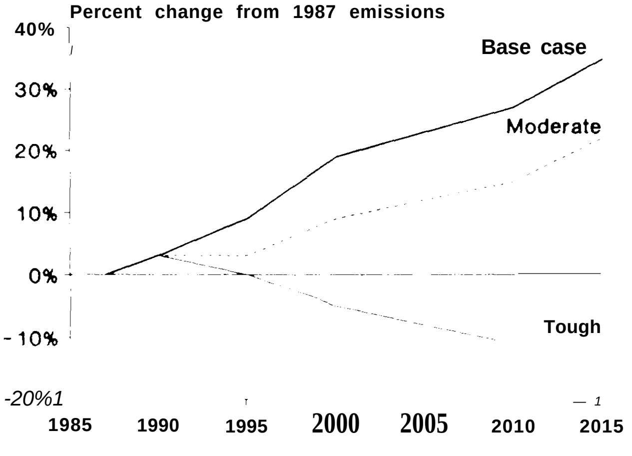
Figure 5-7 summarizes the aggregated results for the Moderate and Tough scenarios through 2015. Figure 5-8 summarizes the results by mode of travel. As shown, all of the Moderate measures together are able to reduce the growth of emissions but not eliminate all growth above 1987 levels. Under the Tough scenario, emissions drop to about 10 percent below current levels. If future VMT growth turns out to be lower than we forecast, then greater reductions are possible. However, if vehicle miles traveled keep increasing at the rates we assumed and if those miles continue to be dominated by private cars of current—or increasing—size and performance, it will be difficult to hold down $C0_2$ emissions. The critical factors are how fast society is willing to adopt more efficient technologies and the extent to which society will accept changes in how it moves people and goods.

Costs of the Tough Scenario

We estimate that the net costs (increased cost of the measures minus fuel savings) of the Tough scenario range between *savings* of about $35 billion per year to costs of about $38 billion per year (1987$) in 2015. The range is quite large because cost data exist for only some of the measures. For others, we assumed that costs were comparable to similar measures (e.g., truck efficiency improvements cost about the same as car efficiency improvements). Details on the calculations are presented in appendix A.

Overall, we estimate that the Tough new-vehicle efficiency measures will save money by 2015, given the expected rise in the price of gasoline (to about $2.00 per gallon). They are considered "Tough" primarily because they are technically challenging goals. We assume that the additional cost of fuel efficiency improvements to achieve a 55 mpg new-car fleet average by 2010 will be in the range of $500 to $750 per car (1987$) (14). Achieving a 58 mpg car fleet by encouraging consumers to buy smaller cars might require a subsidy of about $250 to $500 per vehicle (1 5). Thus we use $750 to $1,250 as our range of new car costs, Assuming light-duty truck efficiency improvements under the Tough scenario will also cost $500 to $750 per vehicle, we

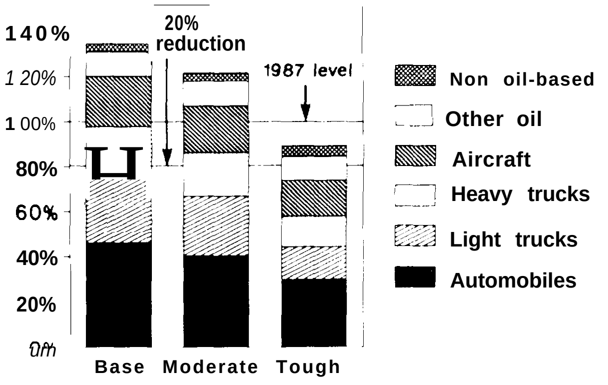
Figure 5-7—Summary of CO_2 Emissions Under the Base Case, Moderate, and Tough Scenarios, by Year



NOTE: The data presented above shows emissions reductions achievable in some future year expressed as a percentage decrease in emissions *below* 1987 levels.

SOURCE: Office of Technology Assessment, 1991,

Figure 5-8—Summary of $C0_2$ Emissions by 2015, by Transportation Mode



NOTE: The data presented above should be interpreted as the emissions reductions achievable in 2015 expressed as a percentage *of* 1987 emissions from transportation, not as a percentage decrease in emissions *below* 1987 levels.

SOURCE: Office of Technology Assessment, 1991.

estimate total passenger vehicle costs will be about $30 to $50 billion per year.

However, the higher efficiency under the Tough scenario saves about $58 billion in fuel costs. Thus, *net* costs for improved light-duty vehicle efficiency are in the range of savings of $8 to $28 billion per year. The cost effectiveness of these measures is in the range of –$340 to –$100 per ton of carbon.

Lacking estimates for the costs of heavy-duty truck improvements, we assume similar dollar per ton costs as for light-duty vehicles. Savings amount to between $7 and $15 billion per year. For lack of a better estimate, we assume that cost of the aircraft efficiency improvements will equal fuel savings.

The cost of the O&M measures in figure 5-6 varies widely. We estimate that using mass transit costs about $0.13 to $0.21 per passenger mile more than using cars. Mass transit and intercity rail costs under our Tough scenario total $26 billion to $55 billion per year, or about $1,200 to $2,500 per ton of carbon. Urban traffic flow improvements, truck inspection and maintenance programs, and improved urban planning are all probably low cost measures. Fuel savings from these programs amount to about $15 billion per year. The remaining measures-55 mph speed limit, ridesharing, parking controls, etc.—all have associated inconvenience costs. Depending on what we assume for the value of these inconvenience costs, we estimate net costs in the range of savings of' $9 billion to costs of $9 billion per year.

Alternatively Fueled Vehicles

Though discussed in an earlier section, we do *not* include use of alternative fuels as one of our near-term Tough control measures. Two of these fuels, however, offer considerable potential for lowering emissions past the 25-year time horizon of this assessment: methanol made from sustainably harvested wood and electricity generated from nonfossil fuels. Thus Congress may choose to adopt an alternative fuel program that will serve as a demonstration program for possible wide scale use of alternatively fueled vehicles after 2015.

Table 5-5 included comparisons of greenhouse gas emissions between current gasoline and alternatively fueled vehicles. Under our Tough scenario, the ultimate effectiveness of alternatively fueled vehicles will depend on:

1. how rapidly the efficiency of alternatively fueled vehicles can be improved in comparison to efficiency improvements possible with gasoline and diesel fuels; and
2. whether these fuels (methanol and electricity) will be made from low emitting primary sources, i.e., sustainably grown biomass fuels for methanol and nonfossil sources to generate electricity.

To provide insight into the *near-term gains* from a large-scale, alternative fuel demonstration program, we estimated the emission reductions assuming that 15 percent of new passenger cars purchased between 2000 and 2015 use alternative fuels, evenly split between electricity and biomass methanol. By 2015, about 1 out of every 10 vehicles would be alternatively fueled.

In our scenario, electricity is generated according to our Tough supply scenario discussed in chapter 3. The potential for biomass fuels is sufficient to supply the feedstock for all of the methanol vehicles in the program (about 1 quad of biomass, see ch. 7). We assume that both electric and methanol vehicles improve through time, faster than under our base case but not as rapidly as gasoline or diesel vehicles under our Tough scenario.[5]

Assuming that the alternatively fueled vehicles substitute for those under our Tough scenario, such a program would achieve reductions equal to about 3 percent of 1987 CO_2 emissions. The program would also lower petroleum consumption by the transportation sector by about 5 percent.

POLICY OPTIONS

Urban passenger travel in cars and light trucks (i.e., light vehicles) consumes the largest share of transport energy in the United States. It is also in light vehicles that the market for fuel efficiency seems to operate least effectively. Consequently, policy to lower transport's CO_2 emissions could be directed, first, at measures to increase the energy

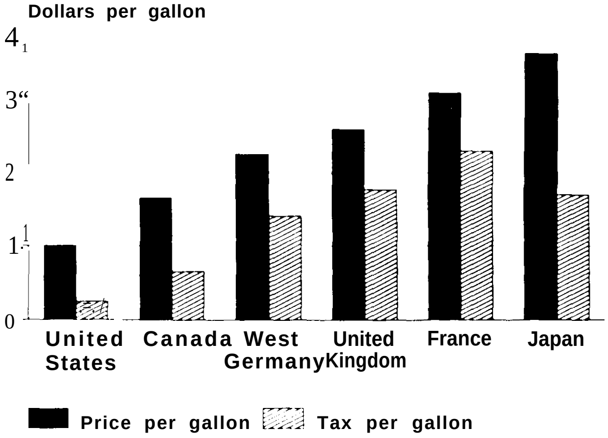
[5] We assume that in 2000 the efficiency of methanol vehicles is 15 percent higher than our Moderate scenario vehicle and that efficiency will improve by another 15 percent between 2000 and 2015. We assume that the efficiency of electric vehicles will improve by 25 percent between 2000 and 2015. These estimates are consistent with the ranges presented in ref. 13.

efficiency of light vehicles, and second, at measures to encourage urban passengers to drive less by ride-sharing, switching to more energy-efficient modes, or reducing travel.

To increase efficiency and reduce VMT, a combination of several policy initiatives would seem to be best. These might include:

1. taxes on fuel and/or sales or registration taxes based on efficiency,
2. fuel efficiency standards,
3. rebates on new fuel-efficient automobiles,
4. programs to change the way people meet their transportation needs, and
5. government support for research, development, and demonstration of new technologies and fuels.

Figure 5-9-international Gasoline Prices and Taxes, 1989



SOURCE: *Business Week,* Jan. 30, 1989, p. 20.

Fuel Taxes

The United States has relatively inexpensive fuel prices relative to other industrialized countries, primarily due to low fuel taxes (see figure 5-9). A higher fuel tax would create incentives for increased efficiency and travel reduction for all modes. Its theoretical attractiveness is that it allows consumers to choose how they adjust their behavior to use less fuel: spend money on fuel economy technologies, use mass transit, carpool, or simply travel less. In practice, taxes do send powerful signals throughout the economy and can enhance the effectiveness of other policies such as fuel economy standards (see below). But there are several problems with fuel taxes. First, they are regressive-that is, they affect the poor relatively more than they affect the rich. For example, in 1985, households with incomes greater than $35,000 per year spent about 4 percent of their income on gasoline. Those with incomes in the range of $10,000 to $15,000 per year spent about 9 percent and those households between $5,000 and $10,000 per year spent about 11 percent of their income on gasoline (23).

Second, the effectiveness of taxes is hard to predict, hence it is difficult to set a tax to achieve a desired result. Studies document a wide range of past consumer response to gasoline price increases. Over the short term, one might expect a 10-percent gas hike to yield a 2-percent drop in gas consumption (though some studies indicate a 6-percent drop; others, less than 1 Percent).[6] A 50-percent increase in the price of gasoline might yield about an 8-percent drop (between 5 and 20 percent). Assuming one can extrapolate in this fashion, a doubling or tripling in price-similar to prices in Europe and Japan—might yield a 13- to 20-percent drop in gasoline consumption.

Over the long term (i.e., allowing enough time for consumers not only to change their driving habits but also the efficiency of the cars they buy), the response is likely to be greater. A 10-percent gas hike might yield about a 7-percent drop in gas consumption in the long run. However, uncertainty with respect to the long-term response is even greater than uncertainty as to the short-term response, and it grows as prices increase. About half of the long-term response might be attributable to driving less and the rest to more efficient vehicles. Unfortunately, the data on which these estimates rest are from the 1970s. Fuel efficiency improvements may be more expensive today, hence consumer response to gasoline price increases may be lower. Thus, the long-term response one might expect from a relatively large price hike might be stifled by a lack of cost-effective technology. Still, one would expect that a doubling of gasoline price would elicit a long-term response somewhat greater than the short-

[6]Two recent studies (refs. 4 and 10) reviewed the relationship between gasoline price and consumption, based on dozens of published papers that have estimated the "elasticity" of gasoline consumption to price, i.e., the ratio of the percentage change in consumption to the percentage change in price. We use 0.2 as a best guess of short-term elasticity and 0.4 to 0.8 as a range for long-term elasticity (with the lower end of the range applying when technology changes are constraining).

Photo credit: Office of Technology Assessment

Highway congestion leads to greater fuel consumption and CO_2 emissions. When traffic slows to speeds below about 35 mph, fuel use per mile increases.

term response, possibly as high as a 25- to 30-percent drop in gasoline consumption. A tripling of gasoline price might lower consumption by as much as 35 to 40 percent.

If Congress deems that a fuel taxis a desirable part of a program to reduce CO_2 emissions, it might also pursue policies to minimize the problems described above. To make the tax program less regressive, it could, for example, provide lump-sum rebates to low-income households. Congress could also phase in the tax to give consumers time to adjust their purchasing decisions and operation and management practices.

Fuel Economy Standards

Fuel economy standards influence tradeoffs among cost, performance, size, and efficiency that underlie new model design and introduction decisions. The current fuel economy standards for light vehicles, in place since 1978, have helped to increase auto fuel economy. Renewed and possibly redesigned standards offer significant benefits as a component of a fuel economy policy.[7]

New standards must take account of engineering time scales and thus are somewhat slower to take effect than fuel taxes. Typically a vehicle reaches market 4 years after manufacturers make initial design decisions pertinent to its fuel economy; manufacturers need adequate lead time to respond to new standards.

Redesigned standards might compensate for differences in manufacturers' size mixes. The present Corporate Average Fuel Efficiency (CAFE) scheme imposes unequal burdens on different automakers—full-line manufacturers get hit harder than those specializing in small cars. An efficiency regime that varies with vehicle volume could meet these concerns, One such regime is the proposed Volume

[7]The pros and cons of fuel economy standards are still the subject of some debate. For a summary, see ref. 19.

Average Fuel Economy (VAFE), which sets fuel efficiency standards based on the interior space of a car (35). Further, by using load capacity instead of interior room, light trucks could be pushed to the same level of technical effort as automobiles.[8]

The VAFE approach is not without problems, however. First, it does not recognize efforts some manufacturers have already taken to downsize their fleet to achieve higher corporate average fuel economy (Chrysler Corp. has frequently pointed this out). Second, since there is no minimum fuel economy standard for a manufacturer's overall fleet, shifts from small to large cars could occur, reducing the net improvement in fleet average fuel efficiency. Finally, a large potential for fuel economy performance resides with downsizing to lighter vehicles. The VAFE approach does not inherently include this downsizing incentive (whereas CAFE does).

As with taxes, the 'right level for new standards is difficult to define. It will depend to a large degree on the intent of the standards. If Congress desires standards that are cost-effective (i.e., fuel cost savings about equal to increased vehicle costs), the Department of Energy (DOE) estimates that standards by 2000 should be set at between 32 and 36 mpg (12a). In 2000 (assuming unchanged real gasoline prices), a fleet economy of 32 mpg would be cost-effective for a car's first owner (4-year ownership); over the car's 10-year life, 36 mpg would be cost-effective.

If Congress wanted to push consumers to conserve even further, standards would have to be higher. DOE calculated that the toughest standard that is technically achievable (without requiring significant size shifts, disrupting the orderly development of new models, or unduly disrupting the required flow of earnings) would be 39 mpg by 2000. The 39-mpg car would be cost-effective at $1.70 per gallon (1989 dollars) or more (assuming consumers are willing to accept the technology changes necessary to achieve this level of fuel efficiency) (15). The corresponding maximum-technology figure for 2010 was 40 to 55 mpg, depending on the assumed penetration of diesels or other new engines (15).[9] These estimates assume that size, luxury, and performance of the fleet is frozen at 1987 levels (though the recent trend has been toward larger or more powerful vehicles).

J'chicle Taxes and Rebates

Taxes and rebates on vehicles can create incentives to sacrifice some size and performance for economy. Taxes on inefficient vehicles would be most effective if accompanied by rebates for highly efficient cars. The program could be designed so that it was ''revenue neutral' '—all the money taken in from the taxes would be recycled through the rebates. To achieve this over an extended period, the thresholds for both tax and rebate will have to increase over time as average fuel economy increases.

The Federal Gas Guzzler Tax,[10] already applies to cars whose economy is below certain thresholds. Until recently, the tax started at $500 for cars below 22.5 mpg, increasing to $3,850 for those below 12.5 mpg, Legislation passed in the 101st Congress doubled the tax to between $1,000 and $7,700 per vehicle.[11] The tax was originally intended to be coupled with a rebate for extremely efficient cars, but the rebate was never enacted.

An expanded program of vehicle taxes and rebates could complement fuel economy standards and taxes, but it could pose serious trade difficulties as long as the high-efficiency end of the auto market is dominated by imports. Such measures would discriminate against domestic manufacturers. And, any such measure that set out to protect domestic manufacturers might conflict with General Agreement on Tariffs and Trade (GATT) rules.

Incentives for Manufacturers

Government-sponsored competitions could be used as incentives to induce manufacturers to develop high-efficiency cars. A bill proposing this was introduced in Congress in 1982.[12] However, it

[8]For further discussion of size-class standards, see ref. 61.

[9]Forty mpg with no additional diesel penetration, 55 mpg with 100 percent penetration. Note that representatives of Ford and General Motors at OTA'S workshop disputed these figures. They asserted that economy gains achievable from the technologies listed were smaller, and their costs were larger.

[10]Public Law 95-618, the Energy Tax Act of 1978.

[11]Public Law 101-508, the Omnibus Reconciliation Act Of 1990.

[12]The Shamansky bill would have sponsored a competition to produce an 80-mpg gasoline car or a 100-mpg diesel car meeting minimum performance, safety, and emissions criteria To win, the car would have to be put into limited production.

is unlikely that the government would pay enough in prize money to induce major manufacturers to participate (3).

A variant of the incentive scheme injects competitive elements into a high-efficiency rebate program (48). The government could identify a few classes of vehicles most in need of economy improvement and offer a competitive reward in the form of large (e.g., $500) consumer rebates on a large production run (e.g., 200,000 units) of a new vehicle achieving the best fuel economy above a specified threshold.

Policy Directed at Operation and Maintenance

Government action targeting the way vehicles are maintained and operated can help lower transport CO_2 emissions. These offer smaller potential reductions—typically ranging from less than 1 up to 5 percent each in the OTA model. Still, they may be important because they move in the right direction, may bring other benefits, or may be reminders of a commitment to energy efficiency. More significantly, most of the measures that these polices promote have short start-up times and do not require large, up-front capital investment. They include reimposing (and enforcing) the 55-mph speed limit; requiring fairings for trucks to lower wind resistance, enforced through efficiency inspections; requiring high-efficiency tires and oils on Federal vehicles; preferential use of rail and intermodal freight (i.e., freight that can travel on both roads and railroad tracks) for Federal shipping; and charging efficiency-promoting parking fees at Federal offices and contractors.

Transportation Control Measures

Several American cities are now experimenting with policy measures intended to reduce travel in private automobiles. While many cities have experimented with a few of these, the most ambitious program is just beginning in Los Angeles (see box 5-F). The advantage of these measures, collectively called Transportation Control Measures or TCMs, is that they directly address urban passenger miles traveled. They also share some of the characteristics of the operation and maintenance steps described above: individually, they only slightly reduce CO_2 emissions but have short startup times, low capital costs, and can reduce energy use and CO_2 emissions even within existing settlement and employment patterns.

However, TCMs are in a very early stage of adoption. Moreover, the range of possibilities and the complexity of interactions among different measures means that any major TCM initiative must proceed by trial and error.

A recent study summarizing U.S. experience with several major categories of TCMs (5) concluded that information on TCMs was incomplete and quantitative data was lacking on the effects of several promising categories. Some of the TCMs evaluated by the authors, Cambridge Systematic, include:

- Areawide Ridesharing: Promotion and matching services achieved areawide reductions of 0.1 to 3.6 percent in VMT (average 0.3 percent) in 32 programs now in place.
- Employer-based Transportation Management: Comprehensive programs are run at the workplace to get people out of single-occupancy cars and into any alternative--carpools, vanpools, bike, or transit, The programs combine high parking charges for solo drivers with transit or vanpool subsidies and expedited transactions-e. g., bus passes, van leasing, and insurance are all on sale at work. Such programs have achieved movements of 30 to 80 percent of all workers into nonsolo modes at large workplaces, with reductions of commuting VMT from 10 to 50 percent. Feasible areawide VMT reduction depends on the concentration of workplaces, but is estimated around 1 percent.
- High-Occupancy Vehicle **(HOV) Lanes:** Restricting lanes on freeways to cars with three or four occupants or to buses can reduce congestion and give time incentives for ridesharing. The 14 examples operating in the United States as of 1985 showed reductions of 5 to 10 percent in peak corridor VMT during peak commuting times. (Some of this reduction comes from commuting at a different time rather than finding different ways to commute.)
- Bicycling Promotion: Comprehensive programs including bike lanes or paths, secure locking facilities and showers, and public education and promotion can reduce areawide VMT by 0.05 to 0.1 percent. The data are very weak, though, and American experience with bicycling promotion programs is very limited.
- **Parking Management: This** includes parking taxes or development surcharges, restricting street parking, and mandating high parking

charges at workplaces (usually with special rates for carpools). American data are very weak, but the experience of Ottawa suggests that the impact can be large, especially if coordinated with improvement of alternatives to driving.

- Park-and-Ride: There are two approaches. Remote park-and-ride tries to reduce VMT by intercepting drivers near to their origins, but the remote lots pose theft problems; peripheral park-and-ride seeks principally to reduce downtown congestion and has little effect on total VMT. Cambridge Systematics estimates a potential of 2- to 4-percent VMT reduction within specific corridors.
- Transit Improvements: Even large investments in rail systems have achieved at most 3-to 5-percent reduction in areawide VMT. Short-range improvements including bus service expansion, operational changes, and fare changes have been much more successful. Cambridge Systematic cites experience in nine cities showing increases in transit ridership from 8 to 50 percent and reductions in VMT from 0.1 to 0.5 percent.
- Travel Substitution (telecommunications, work-at-home, and flexible hours): Views are still mixed on the potential for telecommunications and work-at-home to reduce travel. The Los Angeles plan takes an ambitious stance and projects 20-percent reduction in worktrips due to telecommuting and 10 percent due to alternative work schedules, for a net decrease in areawide VMT of 6.8 percent. Cambridge Systematic estimates the total impact of flexible schedules as only 0.1- to l. O-percent reduction in areawide VMT.
- Traffic Flow Improvements (sophisticated signals, ramp metering, intersection improvement): These measures are principally intended to reduce congestion, but secondarily reduce energy and greenhouse emissions because less fuel is burnt idling in stopped traffic and average speeds increase. Reductions in fuel consumption up to 6 percent have occurred on particular routes, but areawide impacts have not been measured in American cities. If faster traffic induces people to drive more, such measures can *increase* fuel consumption, though. A recent study in Perth, Australia found just this unintended effect (39).

In aggregate, transportation control measures appear to hold modest promise for reducing VMT, but much more experimentation and data are needed before their potential impact can be assessed. However, even modest VMT reductions in congested areas can improve traffic flow, thereby reducing *both* miles traveled and fuel consumption per mile.

Controlling Settlement Patterns

Emissions can be reduced in the long run by changing patterns of settlement to reduce the need for travel or to increase the utility of mass transit. This can be accomplished through higher densities, or through mixing uses so that residences, jobs, and services are roughly balanced at a local scale. When more destinations are close to home, more trips can be made by foot, and public transit can serve more trips effectively.

In the United States, except possibly for some high-growth areas in the South and West, efforts to change the shape of settlement in major cities is likely to have limited impact in the near term. Because we are entering a period of slower population growth, the shape of cities might not change as drastically as it did in the 1950s and 1960s. In a period of slow population growth, change in urban shape proceeds only marginally faster than the replacement of the standing building stock, which takes 50 to 100 years.

Nevertheless, some changes are feasible, particularly in the balancing of homes and workplaces in the suburbs. The Los Angeles air quality plan, for example, includes measures to balance jobs and housing through a combination of market and regulatory measures. It projects that 12 percent of jobs and 6 percent of housing in the region will be affected by the measures, and reductions of about 10 percent in VMT will be achieved (55).

Changes in density are also possible in the United States through changed zoning and infilling. The difficulty will be that urban residents often strenuously resist increasing densities. Paradoxically, traffic congestion is often cited as one of the reasons to oppose higher density development, although with fixed travel needs, congestion is often higher in lower density areas.

Box 5-F—The Los Angeles Air Quality Plan

The Los Angeles area is notorious for its air pollution problems. Despite numerous control measures, the region still exceeds Federal standards for ozone, carbon monoxide, nitrogen oxides, and suspended particulates--giving it the worst air quality in the Nation. The South Coast Air Quality Management District and the Southern California Association of Governments have recently completed a comprehensive Air Quality Management Plan (AQMP) designed to bring the region into compliance with all standards except the strict State standards for ozone and particulate by the year 2007 and hold total vehicle miles traveled (VMT) to a 30-percent increase (rather than the projected 72 percent) by 2010 (22, 54).

Although the AQMP does not directly **address the problem** of global climate change, it contains many transportation control measures that may serve as models for other local, State, and national governments in their attempts to reduce CO_2 emissions.

The Plan's control methods are divided into three sections, or "tiers," depending upon their readiness for implementation. Since cars and trucks contribute the majority of carbon monoxide, reactive organic compounds, and nitrogen oxides emissions in the Los Angeles Basin (53), each of the tiers contains a number of measures designed to modify transportation methods and behaviors.

Tier I—The first phase of the Plan provides controls on motor vehicles, transportation systems, and land use that can be implemented within the next 5 years and that will encourage alternative fuel use, improve efficiency, and lead to reductions in congestion and VMT (54, 55).

New buses in the region will be fueled by methanol and current transit buses will be retrofitted to accommodate other alternative fuels such as ethanol, propane, and compressed or liquefied natural gas. Owners of commercial and public fleets (15 or more vehicles) will also be required to purchase vehicles capable of operating on an alternative fuel when replacing units or expanding operations. Conversion to such fuels can be positive or negative in terms of global warming depending 011 what type of feedstock is used to produce the fuel.[1]

Transportation control measures focus on trip reduction programs (to ease the congestion and associated emissions; see box 5-D) and strategies to shift use toward more efficient modes. They promote the use of alternative work schedules, telecommuting, ridesharing, public transit, and vanpool-purchase incentives and better parking management in addition to the current Los Angeles trip reduction ordinance. Tier I measures also require merchants to provide incentives for public transit and facilities for nonmotorized transportation users (e.g., advertised bus passes and bicycle lockers).

Local ordinances would require special-event centers (stadiums, amphitheaters, etc.) to establish and operate park-and-ride programs and provide incentives for public transportation use. The plan also calls for designating auto-free zones in areas with dense pedestrian activity in conjunction with park-and-ride services. The transportation infrastructure will be improved through the construction of more high-occupancy-vehicle (HOV) facilities and at least 80 miles of light rail service. Finally, truck traffic patterns will be modified through rerouting, changing delivery times, and diverting port-related truck traffic to rail to increase efficiency and ease congestion at peak hours.

Land use is to be modified through growth management designed to attain job/housing balances in local jurisdictions. Implementation methods include modified zoning, development fees, density bonuses, and fast-track permit processing for those developments beneficial to the job/housing balance targets. The plan also calls for new job- or residence creating public facilities to be located in strategic areas to minimize commuting.

Tier II—Unlike Tier I, the second phase of the AQMP will require significant advances in current applications of existing technology and strong regulatory action for successful implementation by the year 2007 (54, 55).

To further encourage trip reduction through telecommuting, Tier II calls for implementation of tax incentives for telecommunications development and local ordinances requiring employers with multiple facilities to devote five percent of the building space to satellite work centers.

To ensure progress in alternative fuels technology, research and development will be funded by a $30 million alternative fuels program, which also contains provisions for demonstration projects and fuel infrastructure enhancement. In addition, Tier II contains supplemental measures for imposing technology-forcing standards and limitations on the number of gasoline- and diesel-powered vehicles registered in the L.A. Basin.

Tier III—The final tier of the AQMP depends on ". . . commitments to research, development, and widespread commercial application of technologies that may not exist yet, but maybe reasonably expected given the rapid technological advances experienced over the past 20 years" (54). These technologies may include improved fuel cells, solar cells, storage batteries, and superconductors for use in private and public transportation. Short-term actions to be taken by air-quality management agencies to promote RD&D in these areas area part of the current Plan and will be updated regularly.

Tier III also anticipates extensive electrification of transportation modes, which, although eliminating the mobile sources of pollution, does not necessarily reduce overall carbon emissions and will increase demand for power generation. To mitigate these effects, the Plan contains proposals for energy conservation and noncarbon fuel promotion.

Finally, Tier III presents a number of contingency measures of last resort (including emission charges on vehicles, parking lots, and gasoline) that will be imposed if the control measures previously enumerated are not implemented or fail to perform as well as expected.

[1]For example, if coal is used as the feedstock to make methanol, greenhouse gas emissions can *increase* by 30 percent compared to gasoline; if woody biomass is the feedstock, greenhouse gas emissions can *decrease by* about 70 percent (see table 5-5).

[2]The 1987 ordinance applies to all employers of 100 or more people (about 8,000 businesses). Employers are required to prepare comprehensive trip reduction plans, with the goal of reducing the number of private motor vehicle trips by 10 percent. While falling short of this goal does not violate the ordinance, failure to submit a plan or annual update or to provide any stipulated incentives exposes the employer to possible civil penalties (63).

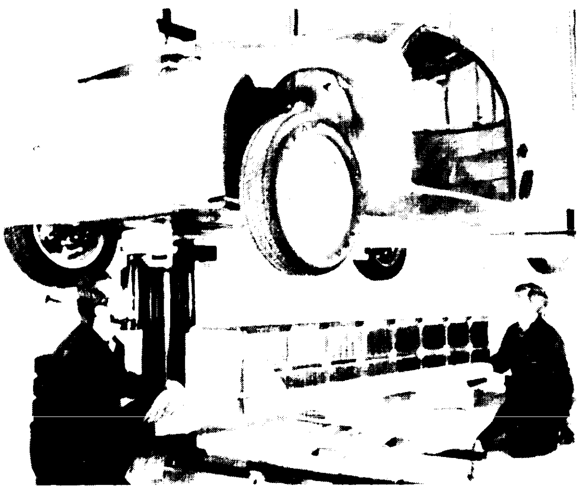


Photo credit: Genera{ Motors Corp.

General Motors' prototype electric vehicle, the Impact. The Impact's battery pack, shown being installed, takes up the center portion of the vehicle. The current range of the vehicle is over 100 miles between charges. If recharged with electricity generated from natural gas or nonfossil sources, CO_2 emissions per mile are much lower than from gasoline vehicles. With improved batteries- key hurdle facing this technology-both range and efficiency would increase.

Traffic congestion is already prompting some remarkably stringent suburban restrictions on development—some apply only to commercial and industrial development, some apply to new residential development as well (16). However, these measures will have little effect on congestion unless coordinated over entire metropolitan areas, and may even increase congestion if they reduce opportunities for people to live near work.

Research and Development

Large R&D efforts will be essential for further technical efficiency advances beyond the turn of the century. A recent study of the state of fuel efficiency research and development in the auto industry found that American automakers lag far behind their Japanese and, to a lesser extent, European, counter parts---especially in moving research results to the market (3). During the late 1970s, the Department of Transportation funded the Cooperative Automotive Research Program (CARP) to support more aggressive research and development in the American auto industry. Unfortunately, it foundered in the prevailing atmosphere of mistrust between the industry and government and was cut back under the Reagan administration (3).

For such a program to be successful, domestic automakers, their suppliers, and innovative research companies all need to be key players. The program could target medium-term technologies such as continuously variable transmissions and energy-storage systems. Other areas where federally supported R&D could have substantial impact include new engine design for heavy trucks, improved safety for lighter vehicles, and innovations to permit increased intermodal freight.

One area of longer term research that deserves special attention is development of truly clean, cost-effective, alternative fuels. Those fuels with the greatest potential-hydrogen or electricity from nonfossil sources (e.g., solar or nuclear power) and woody biomass fuels grown on a sustainable basis—are the furthest from large-scale technical viability. Expanded research programs are needed to envision and expand the range of options available. At the same time, demonstration programs can assess the actual performance of a variety of fuels.

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