Technology Assessment of Changes in the Future Use and Characteristics of the Automobile Transportation System—Volume I: Summary and Findings

February 1979

Technology Assessment of

Changes in the Future Use and Characteristics of the

AUTOMOBILE TRANSPORTATION SYSTEM

Summary and Findings

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Foreword

This assessment deals with changes in the future use and characteristics of the automobile transportation system that are expected in the near term (by 1985) and those that might evolve over a longer period (through 2000 and beyond). The scope of the assessment is broad and includes not only automobiles but also highways, fuel supply and distribution, automotive repair and service, insurance, traffic management, and law enforcement—in short, all of the industries and services that contribute to use of the automobile as a mode of personal transportation.

The personal mobility provided by the private automobile will ensure its strong appeal for the indefinite future. This report analyzes the restraints of energy supply, environmental impacts, highway safety, and consumer cost on the further development of the automobile transportation system. It discusses Government initiatives that may be necessary to assure such further development.

Detailed projections, policy analyses, and technological forecasts incorporated in this summary and findings report are published in Volume II: Technical Report.

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The OTA Automobile Assessment Advisory Panel provided valuable advice, critique, and assistance to the OTA staff throughout this assessment. Their participation, however, does not necessarily constitute approval or endorsement of this report. OTA assumes sole responsibility for the report and the accuracy of the content.

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THE AUTOMOBILE–TODAY AND TOMORROW

The private automobile has provided us with a degree of personal mobility unparalleled in history. It allows great freedom of choice in places of employ= ment and residence; provides access to shopping, education, and essential services; and offers the means to reach recreational and cultural activities— all of which have contributed to improving the quality of life in the United States. In addition, the automobile manufacturing industry and its supporting service industries area major part of our economy.

Let's look at a few statistics. The automobile manufacturing, sales, and service industry employs about 5 million workers, representing almost 5 percent of the total U.S. labor force. If the picture is expanded to include all transportation-related industries, the employment figure is estimated to be as high as 1 out of every 6 to 8 U.S. workers, Annual revenue from manufacturing, sales, and supporting services is approximately $150 billion.

Today more than 80 percent of U.S. households own one or more cars, more than 90 percent of personal travel is by automobile, and there are now more than 100 million passenger vehicles* on our streets and highways.

Ironically, the remarkable success of the automobile transportation system has given rise to problems. In addition to the benefits it has provided, the automobile transportation system today is responsible for:

- consuming about one-third of the petroleum used in the United States each year, which contributes substantially to the balance-of-trade deficit, increasing oil imports, and inflation;
- discharging 80 million tons of carbon monoxide, hydrocarbons, and nitrogen oxides into the atmosphere annually;
- producing an annual toll of nearly 48,000 deaths, and 4.4 miIIion injuries, at a cost to society of over $4o billion dollars;[2] and
- increasing congestion on streets and highways, resulting in lost time and wasted energy.

Clearly there are both benefits and problems in the automobile system. Achieving a desirable balance among energy efficiency, emissions, safety, performance, comfort, and cost will involve tradeoffs between these sometimes competing attributes.

‘For purposes of this study, the automobile is defined as a vehicle designed primarily for private passenger use. Lightweight trucks and vans were excluded.

‘These figures are total highway deaths and injuries. Of the 47,700 fatalities in 1977, 32,600 were auto and light-truck occupants, 8,600 were pedestrians and cyclists, 4,100 were motorcyclists, and 2,400 were heavy-truck and bus occupants.

THE BASE CASE

To assist in evaluating these tradeoffs and to seine as a framework for comparing policy alternatives, we have projected a set of reference conditions, called the Base Case. The purpose is to indicate one possible set of outcomes if current trends persist and present policies are continued. In effect, the Base Case indicates for each issue the potential consequences of the fundamental option of adopting no new policy and continuing on the present course.

Base Case Assumptions

	1975	1985	2000
Demographic			
Population (millions)	214	233	260
Licensed drivers (millions)	130	151	177
Economic			
Gross national product ($ trillion)	$ 1.52	$ 2.22	$ 3.72
Disposable personal income (per capita) ($ thousand)	5.03	6.72	10.07
World oil price (dollars per barrel)	13.00	16.50	25.60
Gasoline price (dollars per gallon)	0.56	0.77	1.21
Policy			
New car fuel-economy standards (mpg)	—	27.5	27.5
New car emission standards (grams per mile):			
Carbon monoxide	28.0	3.4	3.4
Hydrocarbons	3.0	0.41	0.41
Oxides of nitrogen	3.1	1.0	1.0

NOTE: BASE CASE ASSUMPTIONS are derived from Bureau of Census forecasts and GNP projections. The continuation of present Federal policies regulating fuel economy, safety, and emissions is assumed. Dollar amounts are in constant 1975 dollars. Mpg is according to Government standards; actual road mileage is assumed to be 10 to 20 percent lower. Base Case assure ptions are described in detail in chapter 3 of the Technical Report.

Base Case Projections

Base Case projections indicate that, unless there is an extreme restriction of petroleum supply, automobiles will continue to be the dominant mode of personal transportation through the year **2000.** The Federal transit assistance programs assumed for the Base Case are expected to result in a 10- to 20-percent increase in ridership, but the effect on automobile travel would be small—less than 5 percent.

Base Case projections also indicate that, even though the number of automobiles and vehicle miles traveled (VMT) continues to rise, fuel consumption would peak by the early 1980's and then begin to fall as smaller fuel-efficient cars make up an increasingly greater share of the fleet. Between 1985 and 2000, consumption is expected to stay approximately at the 1985 level as progressive gains in fuel efficiency are offset by the continuing rise of VMT.

Supporting detail for this section of the Summary and Findings is contained in chapters 2 and 3 of the Technical Report.

A factor that has significant influence on Base Case projections regarding fuel consumption is the probability that the free world's production of petroleum could peak sometime after 1985, probably in the 1990's, and that the world supply of petroleum would be constrained by production capability. The implications of this potential supply shortage are profound and pose a

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Base Case projections indicate growing traffic congestion on highways and streets. Typical urban drivers in **2000** will encounter congested conditions and reduced travel speeds about one-quarter of the time, or about 2 or 3 times as often as today.

Under the Base Case it is projected that death and injury rates per mile in traffic accidents will decrease as a result of improved occupant protection and vehicle safety improvements. However, the absolute number of deaths and injuries will keep growing and could reach **64,000** deaths and over 5 million injuries per year by **2000.**

We must remind ourselves that the Base Case is only an analytic device and not a likely future. Actions on the part of Government, industry, and the automobile user can, and most probably will, mitigate or preclude some of the more adverse Base Case projections.

Base Case Projections

	1975	1985	2000
Automobile miles traveled (trillion)	1.03	1.43	1.80
Automobiles in operation (millions)	95	118	148
Annual new car sales (millions)	8.6	13.1	16.4
Fleet fuel economy (mpg)	13.5	19.4	24.6
Automobile fuel demand (MMBD)[a]	5.0	4.8	4.8
Gap between demand and domestic petroleum production (MMBD)	7.4	10.0	15.4
Automobile emissions (million ton/year):			
Carbon monoxide	69.3	32.6	27.3
Hydrocarbons	7.9	3.5	2.9
Oxides of nitrogen	4.0	2.7	2.9
Regions in violation of National Ambient Air Quality Standards:[b]			
Carbon monoxide	68	37	24
Oxidants	84	62	54
Annual highway fatalities (thousands)	46	58	64
Auto travel under congested conditions (percent)	10	14	24

[a]Millions of barrels per day of petroleum equivalent.

[b]There are 247 Air Quality Control Regions in the United States and its territories.

NOTE: BASE CASE PROJECTIONS show the results expected from continuation of current policy in view of evolving demographic, economic, and social trends. The Base Case should not be regarded as a prediction of a most probable future. The projections, which are given here as single values for the sake of simplifying the presentation, are not intended to suggest certainty about the future.

FINDINGS

From the Base Case we project that:

- **The Nation will face a serious petroleum shortage and a continuing problem of urban air pollution, in part attributable to the automobile transportation system, if present policies are continued unchanged and if current trends of increased automobile use persist.**

The Base Case also indicates that:

- **Highway fatalities and injuries will keep rising to a point where the public, the automobile industry, and the Federal Government may want to set new or more stringent safety goals and impose additional safety requirements for vehicles, highways, and drivers.**

In sum, we find that:

- Because of energy, environmental, safety, and economic considerations, further changes in both the characteristics and the use of the automobile transportation system will be necessary to minimize adverse impacts on society and the economy.

As a first step in this assessment, we identified a number of specific issues that may confront Congress in formulating policies relating to the automobile. These issues are grouped into five areas of concern:

- Energy
- Environment
- Safety
- Mobility
- Cost and Capital

In the following sections, we discuss each of the areas separately—although we are well aware that they are interrelated. In each area we sum= marize the major findings of the assessment and review some of the policy alternatives that Congress may wish to consider. In the final section we indicate the major technological developments that may influence the evolution of the automobile transportation system.

- **Is there a need to achieve greater conservation of petroleum in automobile use?**
- **Is there a need to accelerate the development of alternative energy sources for the automobile?**

Total U.S. petroleum demand has reached over 18 million barrels per day (MMBD), of which the automobile system, exclusive of trucks and buses, now uses over 5.2 MMBD or about 30 percent.

What of the future? Despite current conservation measures, the U.S. demand for petroleum will grow and could reach as high as 22.4 MMBD by 2000. The difference between need and domestic supply, about 15.4 MMBD, would have to be made up by imports and/or alternative energy sources— if available.

Will There Be a Petroleum Shortage?

The likelihood of a petroleum shortage over the next two to three decades depends on a number of factors or events:

- growth in total world demand for oil,
- conservation policies of major oil-consuming nations,
- drilling and finding rates for new oil,
- growth in oil refinery production capacity,
- production and price decisions, and associated political considerations, by oil-producing nations,
- U.S. Government regulatory and pricing policies,
- the time when the world production of oil peaks,
- rates of development and commercialization of alternative fuels,
- ability of some users to convert to other energy sources,
- environmental constraints on the production and use of alternative fuels, and
- the amount of conservation practiced in all sectors that consume liquid fuels.

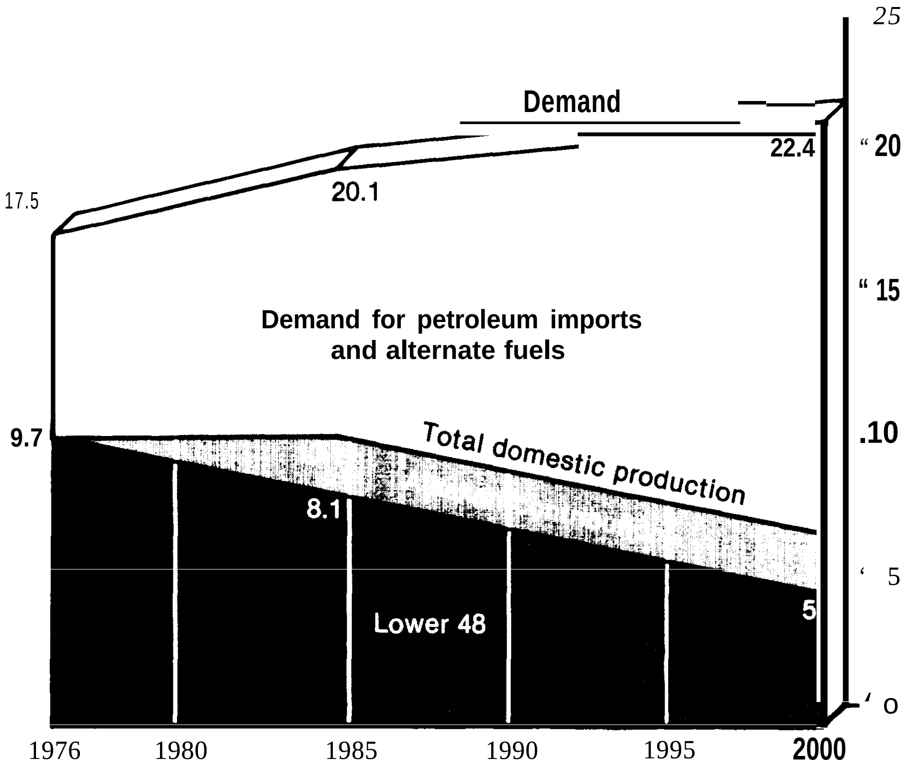
It is beyond the scope of the present study to investigate in detail 'all the factors affecting petroleum supply and demand. Several recent studies, of which the Workshop on Alternative Energy Strategies (WAES)[3] is probably the most exhaustive, point to the possibility that world demand for oil will outstrip the growth of oil-producing capacity by the middle or late 1980's. These studies show a high degree of uncertainty about the long-term forecasts for oil supply. For example, if the Soviet Union decides to, or finds it necessary to, import oil from the Middle East, the strain on the free world oil supply would increase significantly. If, on the other hand, the People's Republic of China finds quantities of oil and decides to become an oil-exporting nation, or if major new discoveries in Mexico and other parts of the world are brought to the market, the strain on oil supply would be lessened.

The WAES projections of petroleum supply and demand to the year 2000 found that, while potential (maximum) production of petroleum appears sufficient up to 1985, supply would drop rapidly thereafter. By the year 2000, large deficits of oil supply were projected for all WAES scenarios, such that one-quarter to one-third of previous demand would be unsatisfied. This projection was made even under assumptions of rising energy prices, WAES concluded

Supporting detail for this section of the Summary and Findings is contained in chapter 5 of the Technical Report.

'MIT Workshop on Alternative Energy Strategies (WAES), *Energy: Global Prospects* 1985-2000 (New York: McGraw-Hill, 1977).

U.S. Petroleum Supply and Demand (MMBD)



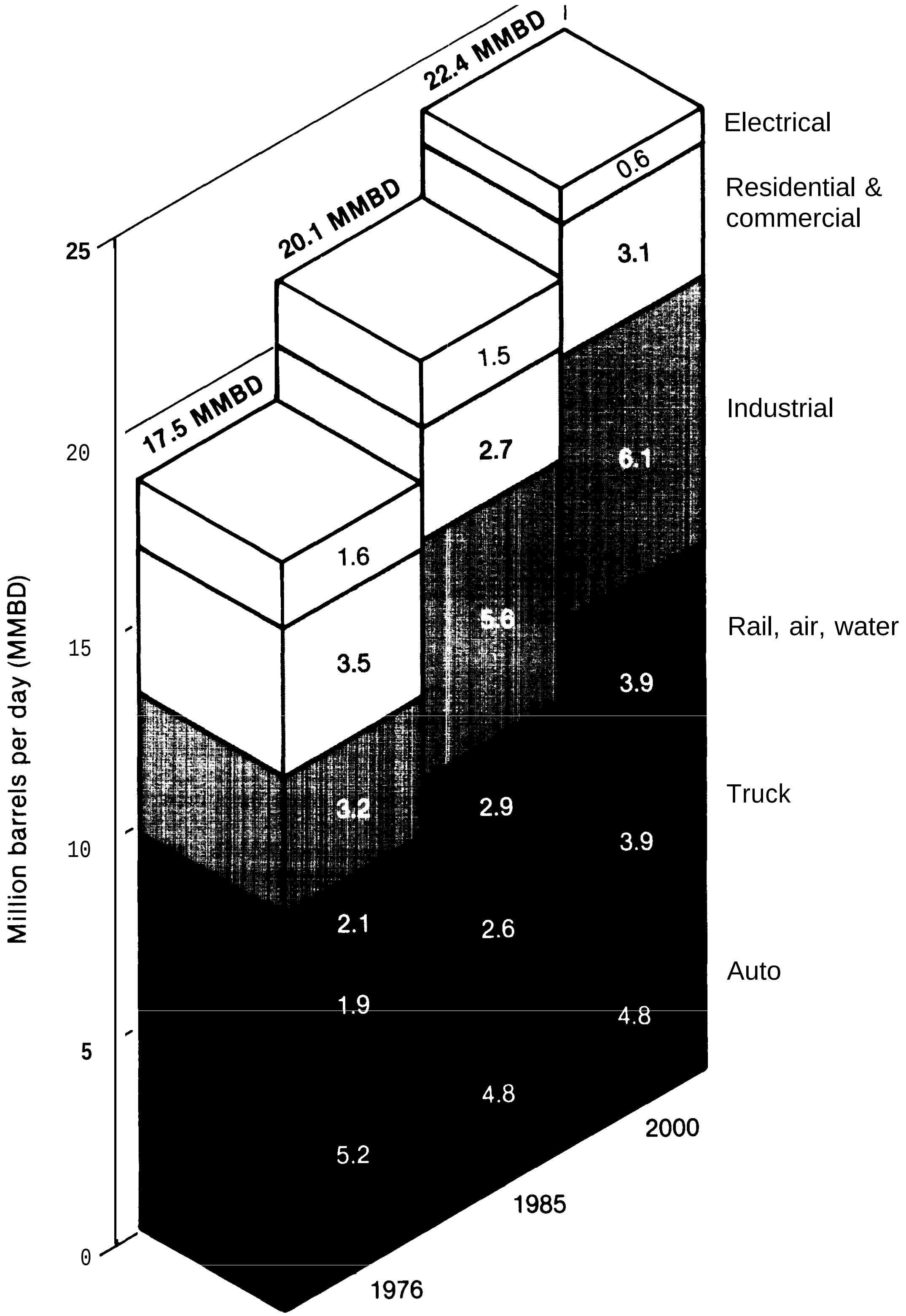
SOURCE Adapted from SydecEEA p III 2

that balancing energy supply and demand by the year 2000, while maintaining economic growth, would require a massive shift to nuclear energy and coal, with petroleum reserved almost exclusively for transport and petrochemical feedstocks. Domestic and industrial users of petroleum would need to shift to other energy sources. WAES also concluded that, while there is a range of opportunities for maintaining an adequate energy supply, all require enormous efforts in planning, intensive engineering efforts, and major capital investments, with lead-times usually of 10 or more years. To achieve this result, most of these efforts would have to be well under way by 1980-85.

Are the WAES projections too pessimistic? Although there is no question that there is only a finite amount of oil and that there are limits to the rate at which it can be recovered, differences of opinion do exist regarding estimates of the world's ultimately recoverable reserves. One basis for more optimistic forecasts is the expectation that new discoveries may be larger than assumed by WAES, particularly in countries such as Mexico that have not yet been fully explored. Another basis for a more optimistic projection is the expectation that major technological breakthroughs will make it possible to recover substantially more oil from known sources than was assumed by WAES. Neither of these possibilities can be ruled out. The effect of more optimistic estimates would be to postpone the projected date for an oil shortage beyond the year 2000.

Actually, the complete exhaustion of oil resources is not likely. As production by conventional methods declines and oil becomes more scarce, the price will rise and more expensive recovery methods and novel technologies will be used to produce additional oil. If major improvements in oil recovery techniques were to be made, they would probably not raise the

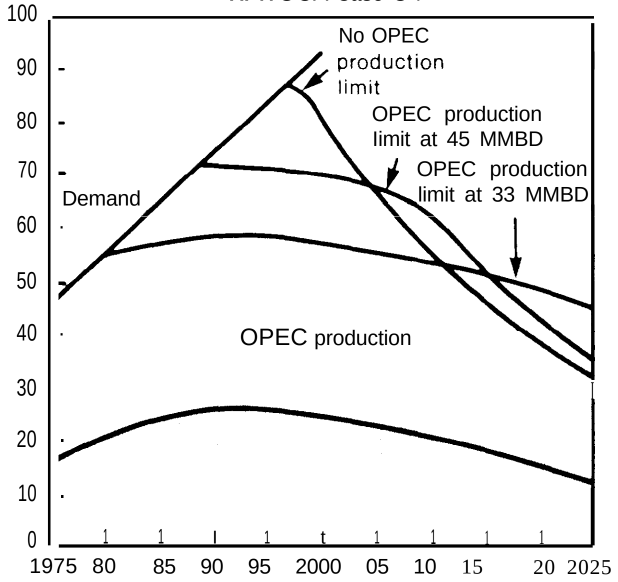
U.S. Petroleum Demand



NOTE: Assumes continuation of 27.5 mpg for new cars beyond 1985
SOURCE: Sydec/EEA and OTA estimates

Estimates of World Oil Production

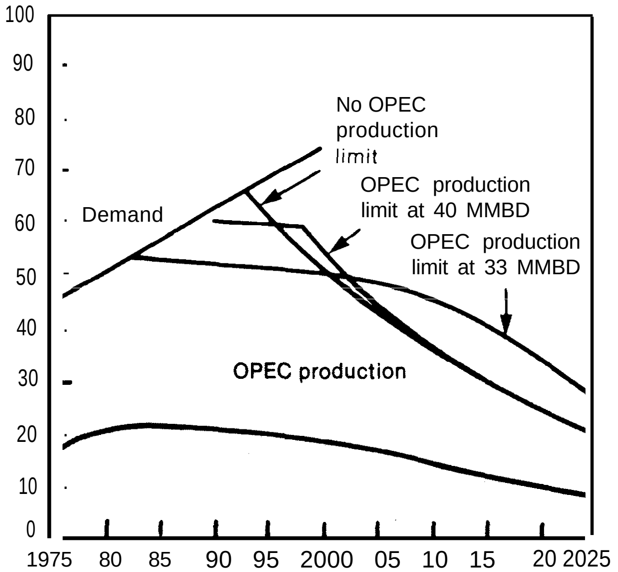
A. WOCA[a] **Case** C-I



C-1 Assumptions—high economic growth rate, rising energy price, vigorous government response, coal as the principal replacement fuel, and gross additions to oil reserves 20 billion barrels per year

[a]WOCA—World Outside Communist Area

B. WOCA Case D-8



D-8 Assumptions— low economic growth rate, constant energy price, restrained government response, nuclear as the principal replacement fuel, and gross additions to oil reserves 10 billion barrels per year

SOURCE Workshop on Alternative, Enerqy Strategies (WAESI Energy Global *Prospec!s 19852000 p 20*

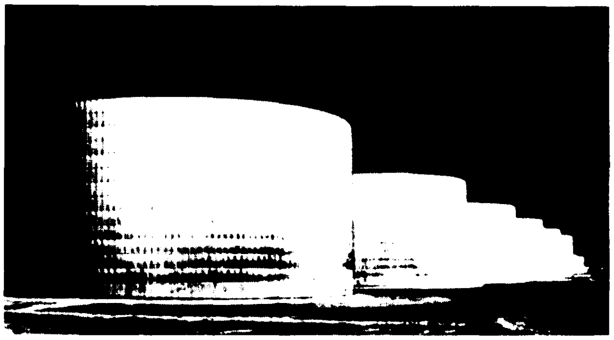


Photo Credit U.S. Department of Energy

. . . a decreasing supply of a nonrenewable resource . . .

peak production level. They would be more likely to create a plateau in the production curve or to make the decline from the peak less abrupt.

In the classic economic sense, demand and supply are the two sides of an equation, with price being the variable. To put it another way, demand cannot exceed supply if free-market forces are allowed to determine price. On the other hand, in the case of a decreasing supply of a nonrenewable resource such as oil, the price necessary to equate supply and demand would become so high as to price millions of former users out of the market. As the price of oil rises, there would be strong economic incentives to develop alternative fuels. The development process would take many years, however, and the decision to provide an alternate fuel supply would have to be made many years before the price rise signaled the need.

This study does not attempt a comprehensive analysis of energy supply and demand, and it is not our role to judge the validity of the opposing views. It is our responsibility, however, to consider the consequences for the U.S. automobile system of a possible petroleum shortage in the future.

Implications for the Automobile System

It is outside the purview of this study to consider policies to allocate petroleum between transportation and other sectors of the economy (industrial, residential, and power generation), or to promote conservation in other sectors. It is evident, however, that if the WAES projections are correct, all sectors of the economy will have to take further steps to limit petroleum usage in the future. Here we have focused on two kinds of policies affecting petroleum usage in the automobile sector:

- Conservation, and
- Transition to Alternate Energy Sources.

Conservation

The Technical Report considers a number of automobile fuel conservation policies, among which:

- more stringent auto fuel-economy standards,
- higher gasoline taxes,
- deregulation of oil and gasoline prices,
- gasoline rationing, and
- measures to encourage alternatives to auto use.

More Stringent Auto Fuel-Economy Standards

A progressive tightening of the new car fuel-economy standards to 35 mpg by the year 2000 would result in savings of about 0.6 MMBD compared to the Base Case. Increased fuel economy can be achieved by a continuation of current efforts to reduce automobile weight (substitution of materials and reduction of size) and to improve engines, transmissions, and other components. However, these measures to increase fuel economy might necessitate compromises in safety, utility, and performance.

A further improvement in fuel economy (beyond the 35-mpg new car average) by the year 2000 would be difficult to achieve and might produce greatly diminishing returns compared to raising fuel economy from 27.5 to 35 mpg. A fleet average fuel economy greater than 35 mpg would require fewer large cars in the fleet and much more efficient propulsion systems—either greatly improved spark-ignition and diesel engines or advanced Stirling or gas turbine engines. The availability of these advanced engines before 1995-2000 and their competitiveness with spark-ignition and diesel engines in terms of cost, performance, reliability, and maintainability are doubtful at the present time.

Higher Gasoline Taxes

Small, gradual increments in the price of gasoline would not make significant reductions in the use of fuel. Analysis of historical data shows that a 15-percent increase in the real price of gasoline would reduce VMT by only about 3 percent.

To achieve major VMT reductions (on the order of 25 percent) would require that the real price of gasoline be 4 times higher than that projected for the Base Case in the year 2000.[4] Such large increases would place a heavy burden on low- and moderate-income families, particularly in rural and low-density suburban areas where alternate modes of travel cannot easily be provided. A tax rebate or gasoline stamp plan for such families would alleviate some of the hardship.

Oil Price Deregulation

Deregulation of petroleum prices would allow free-market forces to allocate the limited supply of petroleum and would serve to curtail demand. However, price deregulation could result in a major transfer of money from consumers of petroleum products to producers (oil companies, distributors, and leaseholders) with large windfall profits for some, unless excess profit taxes were imposed or unless provisions were made to ensure the use of these profits to explore for new sources or to develop alternate fuels. The increased costs of gasoline and other petroleum products could result in a substantial decrease in economic growth. There could be a reduction in employment in the petroleum supply and distribution industries, perhaps partially offset by an increase in the number of jobs in the alternate fuels production. It would also place a heavy burden on low- and moderate-income auto-dependent people.

Gasoline Rationing

Restricting fuel availability by rationing is an effective way of distributing the burden of conserving petroleum. Despite formidable administrative problems, rationing with marketable

[4]Based on current data on the price elasticity of gasoline.

coupons is a reasonably equitable short-term policy for achieving substantial and predictable petroleum conservation. Rationing would have limited value as a long-term policy because of its restrictive effect on economic growth and personal mobility.

Encouraging Alternatives to Auto Use

Several measures to constrain the use of the automobile were evaluated:

- expansion and encouragement of public transportation,
- ridesharing systems, and
- transportation system management programs emphasizing priority for high-occupancy vehicles.

Results of the analysis indicate that the potential of public transportation, ridesharing, and transportation system management to reduce auto travel is small—in most cases resulting in less than a 5-percent reduction in VMT nationally. However, the value of these measures in improving mobility may be considerable, as discussed later in the section on mobility.

Transition to Alternate Energy Sources

Petroleum reserves are finite, and as the supply is depleted, the price will rise. Sooner or later a shift will occur from petroleum to alternate energy sources for the automobile. Conservation policies can provide extra time and help smooth the transition, but they cannot forestall the need to develop alternate energy sources.

Roughly, these alternate energy sources fall into four categories:

- substitute liquid fuels derived from coal, tar sands, or oil shale;
- alcohol fuels or a combination of alcohol and gasoline (gasohol);
- electricity; and
- longer term alternatives such as hydrogen and fuel cells.

At this time there is no clear choice as to the most economical and practical alternate energy source for the period *1985* to *2000*. Most likely, a combination of alternative sources will be used.

Compared to petroleum, all of the alternative fuels:

- are more costly, and will remain so until the rising cost of petroleum meets the cost of alternatives;
- require more total energy (including recovery and distribution) per vehicle mile; and
- will not be available in quantity before the year 2000 unless an active development and investment program is undertaken soon.

An expeditious transition will require the joint efforts of private industry and Government and a stable long-term Government policy with respect to development of alternate energy sources. The risks are so great, the capital costs so high, and the rate of return so uncertain that private industry is unlikely to undertake development and large-scale investment at the present time without Federal Government action to moderate these factors.

The Federal Government has a number of policy options to promote development of alternate energy sources:

- expanded research, development, and demonstration (RD&D) programs with joint funding and attractive Iicense and patent policies;
- tax incentives to foster research, development, and use of alternate energy sources;
- financial assistance (loans and grants) for investment in extraction and production facilities;
- elimination of subsidies for production of oil and gas;
- import restrictions or taxes on petroleum;
- price guarantees for synthetic fuel products; and
- deregulation of petroleum price.

Even with these policies, the transition to alternate energy sources will be slow in coming. Under current Government policies, synthetic fuel production in the year *2000* will probably not exceed 3 MMBD. Higher production is dependent upon much stronger Government support and much greater private investment.

FINDINGS

- The current program to improve fuel economy will keep total auto fuel consumption at or below present levels to the year 2000.
- A petroleum scarcity and sharply rising prices severely affecting U.S. automobile usage are a real possibility in the late 1980's or 1990's with the severity depending primarily on OPEC production and pricing actions and U.S. Government policy.
- Deregulation of petroleum price would allow market forces to balance supply and demand but would have inflationary effects on the national economy, impose a disproportionate burden on low-income persons, and generally restrict the use of the automobile.
- If the Nation were to face a serious or prolonged scarcity of petroleum, only rationing or very large fuel price increases through taxation or deregulation would reduce petroleum consumption in the automobile sector by a significant amount.
- Sooner or later a shift will have to be made from petroleum to alternate energy sources for the automobile, and a strong Government program of support and incentives may be necessary to accomplish this in a timely manner.

ENVIRONMENT

- **Will additional automobile emission controls be necessary?**
- **Which of the various emission= control measures offer the greatest potential?**
- **What environmental problems are involved in the evolution of new technologies?**

Environmental problems created by widespread and intensive automobile use include air pollution, noise, disposal of scrap vehicles, and water contamination. The Technical Report examines each, but we consider air pollution to be the most important, and consequently most of our attention has been devoted to this problem.

Until recently, the amount of atmospheric pollutants emitted bv automobiles had been growing each year. Emission controls required by the 1970 Clean Air Act and its amendments are helping to reverse this trend. Base Case projections for the year *2000,* assuming compliance with the 1977 Clean Air Act amendments and no other automobile controls, show that automobile emissions for the country as a whole will be reduced from their current levels, even though automobile travel is expected to grow by 75 percent. Carbon monoxide and hydrocarbon emissions from automobiles are projected to decrease by about **60** percent each. The reduction in nitrogen oxide emissions will be smaller—about *30* percent.

Why then is there still an automobile emission-control problem? Base Case projections show that despite the progress made in reducing auto emissions, air quality in a significant number of our urban areas 'will fall short of the standards established by the Clean Air Act. In part, this will be attributable to automobile emissions because:

- Air pollution in congested urban areas at peak traffic times is and will continue to be caused largely by automobiles.

Supporting detail for this section of the Summary and Findings is contained in chapter 6 of the Technical Report.

- The emission-control devices now in use may lose much of their effectiveness if not properly maintained, resulting in higher levels of emissions from the average car on the road.

National aggregate air pollution figures do not fully reveal the effects on the population in areas of extensive and concentrated automobile use—chiefly the central parts of cities, but sometimes the surrounding suburbs as well. In urban areas, where population density and automobile use are the greatest and where air pollution from nonautomobile sources also tends to be high, it is estimated that between 125- and 150-million people are now exposed, at least once during the year, to concentrations of carbon monoxide or photochemical oxidants that exceed established Federal standards. The effects of this exposure on human health cannot be calculated with certainty. Estimates vary both as to the danger and its *importance* for the more vulnerable segments of the population — infants, the elderly, and those with respiratory or cardiac disorders. However, the evidence clearly indicates that atmospheric pollution (to which the automobile is a major contributor) is cause for serious concern.

Projections of regional air quality in 1985 and 2000 show that violations of the carbon monoxide and oxidant standards, though decreasing, will still be common occurrences. In 2000, about 10 percent of the 247 Air Quality Control Regions in the United States are expected to experience violations of the carbon monoxide standard. Violations of the standard for photochemical oxidants are expected in almost 25 percent of the regions. Because these violations will generally occur in the most populous areas, the number of persons exposed to hazardous con-

Automobile Emissions and Air Quality

	1975	1985	2000
Emissions (millicn tons per year):			
Carbon monoxide	69.3	32.6	27.3
Hydrocarbons	7.9	3.5	2.9
Nitrogen oxides	4.0	2.7	2.9
Particulate.	0.38	0.08	0.25
Air quality:			
Carbon monoxide:			
Number of AQCRS exceeding standard	43	34	22
Number of AQCRs exceeding 2 x standard	25	3	2
Total violations	68	37	24
Photochemical oxidants:			
Number of AQCRs exceeding standard	49	46	41
Number of AQCRs exceeding 2 x standard	20	11	8
Number of AQCRs exceeding 3 x standard	8	2	3
Number of AQCRs exceeding 4 x standard	7	3	2
Total violations	84	62	54

NOTE: CURRENT AND PROJECTED AUTOMOBILE EMISSIONS AND AIR QUALITY DATA indicate improvements in auto emissions but also show that air quality in a significant number of the 247 Air Quality Control Regions (AQCRs) in the United States will fall short of national clean air goals. The CO standard is 10 mg/m^3 in an 8-hour period. The oxidant standard is 160 μg/m^3 in a 1-hour period.

centrations of air pollutants will remain very high—perhaps as many as 135 million persons, or about half the population, in 2000. Since automobiles are particular] y heavy contributors to peak concentrations of carbon monoxide and photochemical oxidants, additional measures to control exhaust emissions may be needed to improve air quality in urban areas.

Automobiles are not the only source of air pollution. Other transportation modes, industrial plants, power-generating facilities, commercial establishments, and home heating also contribute substantial amounts of pollutants to the atmosphere. It seems evident that, if the Nation is to attain the air quality goals established by the Clear Air Act, measures to reduce all sources of air pollution must be considered.

However, the focus here is on automobile air pollution and means to reduce emissions from this source. We considered the following measures:

- further tightening of new car emission standards (specifically for nitrogen oxides);
- mandatory inspection and maintenance of emission-control devices; and
- control of automobile use in specific locations.

In addition to these three alternatives, we also considered the possible environmental effects of the introduction of new automobile propulsion systems or fuels.

Further Tightening of New Car NO_x Emission Standards

The various oxides of nitrogen (collectively designated NO,) are singled out for two reasons. First, projections of atmospheric pollution under Base Case conditions show that NO_x emissions will be the major air quality problem in coming years, and unless more stringent measures are adopted to control NO_x emissions from all sources, air quality in many urban areas in 1985 and 2000 will be little better than today. Second, the most serious aspect of the NO_x problem is likely to be how to controI the magnitude and duration of peak concentrations, which often coincide with rush-hour automobile traffic. Thus, a more stringent NO, standard for automobiles may be an important strategy.

Lowering the new car emission standard for NO, to 0.4 gram per mile could reduce the national aggregate of NO_x emissions from 2.9 to 2.2 million tons per year by 2000, However, compared with the potential improvement af-

Photo Credit: University of Tennessee

. . . peak concentrations . . . often coincide with rush-hour automobile traffic . . .

forded by measures directed at stationary sources, the total reduction produced by a 0.4-gram-per-mile standard for automobiles would be rather small, and the cost per ton of NO_x removed would be much higher. Also, lowering the standard to 0.4 gram per mile by 1990 could preclude diesel engines, which currently emit 2 grams per mile or more of NO_x. By 1990, the level of NO_x emissions from diesels might be reduced to 1 gram per mile, but probably not much lower—unless there is a major technological breakthrough. Elimination of diesels would, in turn, lead to a greater proportion of cars powered by conventional Otto-cycle engines in the new car fleet from 1990 to 2000. Such automobiles emit *more* hydrocarbons per mile than diesels. Our projections indicate that the tightening of new car NO_x standards could result in about **100,000** more tons of hydrocarbons per year from automobiles—an increase of 3 percent in comparison with the level of hydrocarbons expected under Base Case conditions.

Mandatory Inspection and Maintenance

This measure would involve a national program of annual or semiannual inspection of all cars, instituted with the cooperation of State and local governments. Vehicles failing to meet standards would be required to have adjustment, repair, or replacement of emission-control devices. It is assumed that inspection procedures would be limited to tests of CO and HC exhaust emissions since there is, at present, no practical test procedure for NO. emissions in general use.

It is projected that mandatory inspection and maintenance would reduce CO emissions by almost 17 million tons per year for the country as a whole in 2000. This would constitute a reduction of nearly 65 percent in automobile CO emissions and a reduction of 35 percent in CO from all sources. The reduction of HC would be less — slightly over 1 million tons per year in 2000, or 40 percent less than automobile HC emissions in the Base Case.

Mandatory inspection and maintenance thus appears to have great potential as a means to reduce automobile emissions.[5] However, a word of caution is needed about the magnitude of the projected effects. The benefits of inspection and maintenance depend heavily on esti-

[5]Inspection and maintenance could also produce important secondary benefits in terms of fuel economy and correction of safety defects.

mates of the deterioration rates of emission-control devices— oxidation catalysts and three-way catalytic converters. These devices have been in use for only a short time, and the data on their continued effectiveness over 50,000 or 100,000 miles of actual driving are limited. Estimates made by the Environmental Protection Agency (EPA) during the period *1975-77* indicated that the performance of emission-control devices would be relatively stable *over* time and that they would lose no more than half their initial effectiveness after 10 years of use.

More recent data from EPA indicate that emission-control devices deteriorate at a more rapid rate than originally expected. For example, CO emissions from a vehicle certified as meeting a standard of **3.4** grams per mile when new are now estimated to increase to 10 grams per mile after 5 years **(50,000** miles) and 22 grams per mile after 10 years (100,000 miles). Similar sixfold to eightfold increases are estimated for HC and NO_x emissions after 10 years on the road without maintenance or repair of the emission-control system.

Thus, the benefits of inspection and maintenance are proportional to the assumed deterioration rates of emission-control devices and the assumed degree of correction that can be accomplished by maintenance. The findings presented here and in the Technical Report are based upon the most recent (1978) EPA data. If the EPA estimates are accurate, the benefits of mandatory inspection and maintenance would be very great, If, however, the EPA estimates are overly pessimistic and emission-control devices do not lose their effectiveness as rapidly as now believed, the benefits of inspection and maintenance would be lessened accordingly, although they still might be large enough to warrant imposition of a mandatory inspection and maintenance program. A full assessment of this policy must await more definitive information about the continued effectiveness of emission-control devices under actual driving conditions.

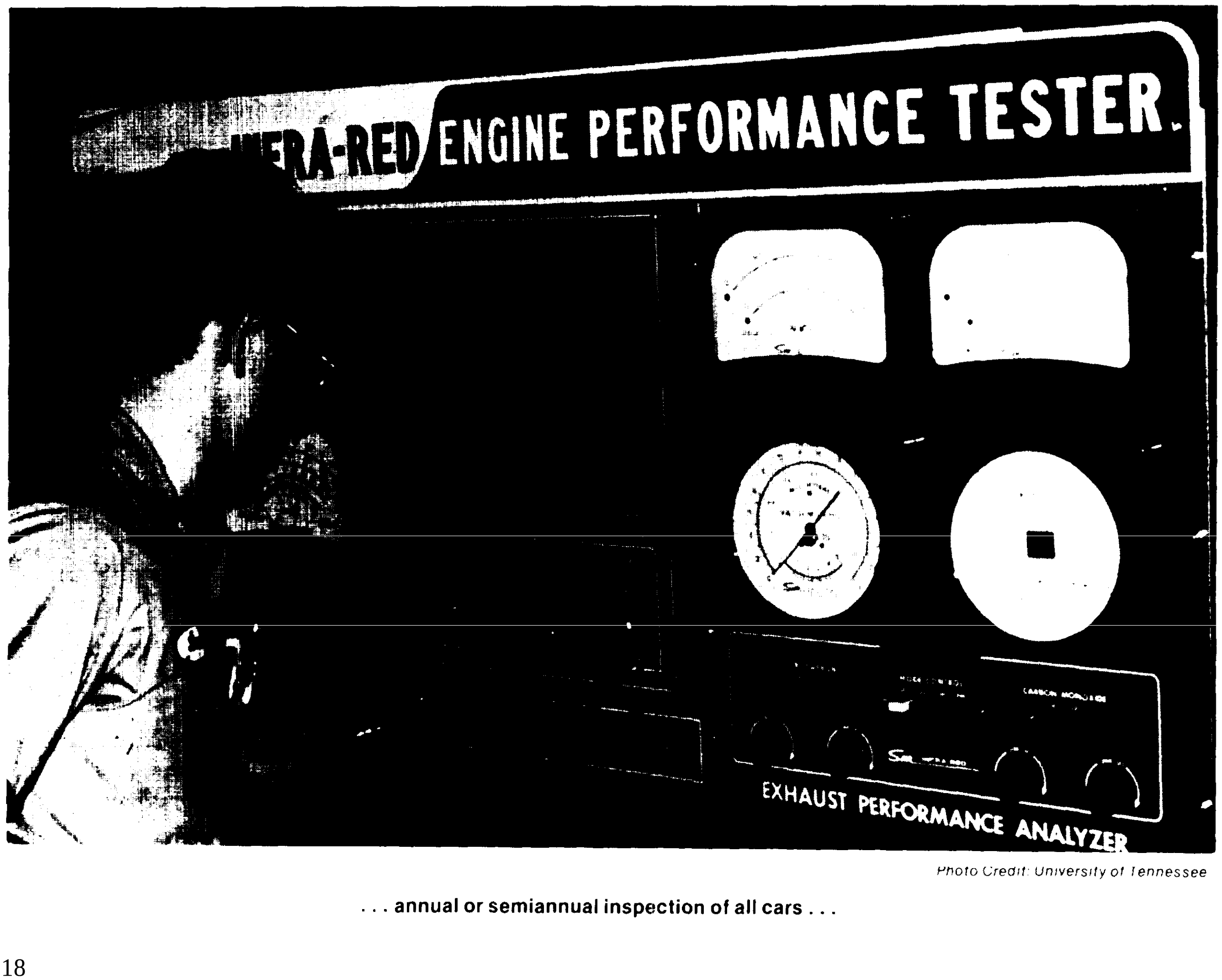


Photo Credit: University of Tennessee

. . . annual or semiannual inspection of all cars . . .

Changes in Automobile Emissions From Base Case Year 2000 (million tons)

Measures to reduce emissions	Carbon monoxide	Hydrocarbons	Nitrogen oxides	Particulates
Stricter NO_x standard	—	+ 0.098	-0.690	-0.199
Inspection and maintenance	-16.730	-1.040	—	—
Decreased auto travel (4 percent)	- 0.840	-0.164	-0.190	-0.007
Net	-17.570	-1.106	-0.880	-0.206

NOTE: COMPARISON OF MEASURES TO REDUCE emissions from automobiles indicates that major improvements could result from a nationwide program of inspection and maintenance. At present there is no test for NO_x in general use, and no inspection technique for NO_x was assumed for this comparison. Also indicated are the tradeoff penalties that could result from stricter NO_x emission standards. Decreased auto travel assumes improvements that could result from auto use disincentives and mass transit system improvements.

Control of Auto Use in Specific Locations

Air pollution is basically a localized urban problem, and we have examined approaches to discourage auto use in urban areas during rush hours. Possible measures that could be adopted are auto-free zones, restricted access by time of day or type of vehicle, and limitation of commuter traffic (either by tax or outright prohibition) except for multiple-occupancy vehicles. Automobile use could also be discouraged through restriction or elimination of parking in congested areas by means of parking surcharges, elimination of on-street parking, bans on parking for nonresidents, and limits on construction of new parking lots. Disincentives for "drive alone" commuting could include priority lanes and special parking for carpools and vanpools .

For such programs to be fully effective, it would also be necessary to improve public transit as an alternative mode of personal transportation and as compensation for the restriction of automobile use.

Environmental Impacts of New Technology

The advent of new technology for automobile propulsion systems and fuels raises the prospect Of new or more serious effects on the environment. Experience with the automobile has made us more alert to these possibilities, and the growth of environmental sciences has increased our ability to detect and forestal I these effects before environmental damage occurs.

One concern is the environmental effect of the growing use of diesel engines in passenger cars as a way of getting higher fuel economy. Diesels emit 2 to 4 times more NO_x per mile than spark-ignition engines, Diesels also emit more particulate. Results of an EPA research program on health effects indicate that diesel particulate emissions produce a strong mutagenic response under laboratory conditions and may be carcinogenic. Additional testing is needed before diesels can be given a clean bill of health.

There may also be major environmental impacts associated with the production of synthetic fuels from coal and oil shale. Air quality standards in regions of coal or oil shale conversion and refining might be violated. There will also be a need to assure that mining areas are adequately restored and that water pollution is prevented in the Western United States, where the bulk of mining and production would take place.

Liquid fuels derived from coal contain high levels of benzene (a known carcinogen). Gasoline contains approximately 2 percent benzene, while coal liquids can contain up to 10 or *15* percent. Measures to protect worker health and safety at coal liquefaction plants would be required. The benzene content of the fuel might have to be reduced before it could be used in motor vehicles.

Electric vehicles emit virtually no pollutants on the road. However, the extensive use of electric vehicles would create increased demand for electricity y, with a resulting increase in particulate, NO_2, and SO_2 emissions if the electricity came from coal-fired powerplants. Still, the net effect on the environment could be favorable since powerplants could be sited outside of urban areas and emissions from a point source might be more easily and economically controlled than those from multiple mobile sources.

FINDINGS

- Additional measures to control automobile emissions will be necessary to meet air quality standards in urban areas.
- Further tightening of new car emission standards— particularly for nitrogen oxides— would be only marginally effective.
- A nationwide program of inspection and maintenance of vehicles in use could produce substantial reductions in automobile emissions and consequent improvement in air quality.
- Control of automobile use would be effective as a supplementary measure in specific locations. However, as a general nationwide strategy, automobile use controls appear to be of limited value.
- The introduction of new technology for automobile propulsion systems and synthetic fuels may create new adverse impacts on the environment. Diesel particulate emissions are of special concern because of their possible carcinogenic properties.
- Projections of other environmental impacts of automobiles and highways— noise, community disruption, intrusion in recreational and wilderness areas, and disposal of scrap vehicles and parts—do not indicate the need for major new policies by the Federal Government. Present policies appear to be adequate.

- **What is the expected severity of the problem?**
- **What should be the role of the Federal Government in traffic safety?**
- **What are the major issues and policy options?**

The Safety Problem

Our most popular transportation system, the personal automobile, is also a significant cause of death, injury, and property damage. Most of us recognize this, and few would argue against the desirability of reducing traffic crashes. Controversy arises about how best to improve auto safety. The definition of "reasonable" levels of safety, establishing the amount we are willing to pay for a safer system, and the division of responsibility for safety improvements between private industry, the Government, and the individual are all keenly debated issues.

Cars are leading killers of young people in the United States according to the Public Health Service. This age group has less driving experience; and they are less susceptible to other killers such as heart disease and cancer. But the fact remains that in the 15 to 34 age group, traffic crashes are the leading cause of death.

Congress has recognized the need to improve motor vehicle safety. With the passage of the National Traffic and Motor Vehicle Safety Act of 1966 and the Highway Safety Act of 1966, Congress set the goal of reducing traffic crashes and the resultant deaths and injuries. This action resulted in new car performance standards, vehicle defect investigations, and enactment of safety standards for highways, drivers, and other elements of the automobile transportation system.

Through the combined efforts of Federal, State, and local governments and with the help of industry, we are making progress. Since 1966 the rate of traffic fatalities per vehicle mile has been reduced nearly 40 percent. Nevertheless, the statistics indicate that we still have a problem.

The issues raised in this section are discussed in more detail in chapter 7 of the Technical Report.

Traffic Safety Data, 1977

Crashes[a]		17,600,000
Vehicles involved[a]		29,800,000
Injuries[b]		4,392,000
Deaths[c]		47,700
Auto occupants	27,400	
Pickup and van occupants	5,200	
Motorcycle	4,100	
Pedestrian and cyclist	8,600	
Truck, bus, and other	2,400	
Estimated costs[d]		$44 billion

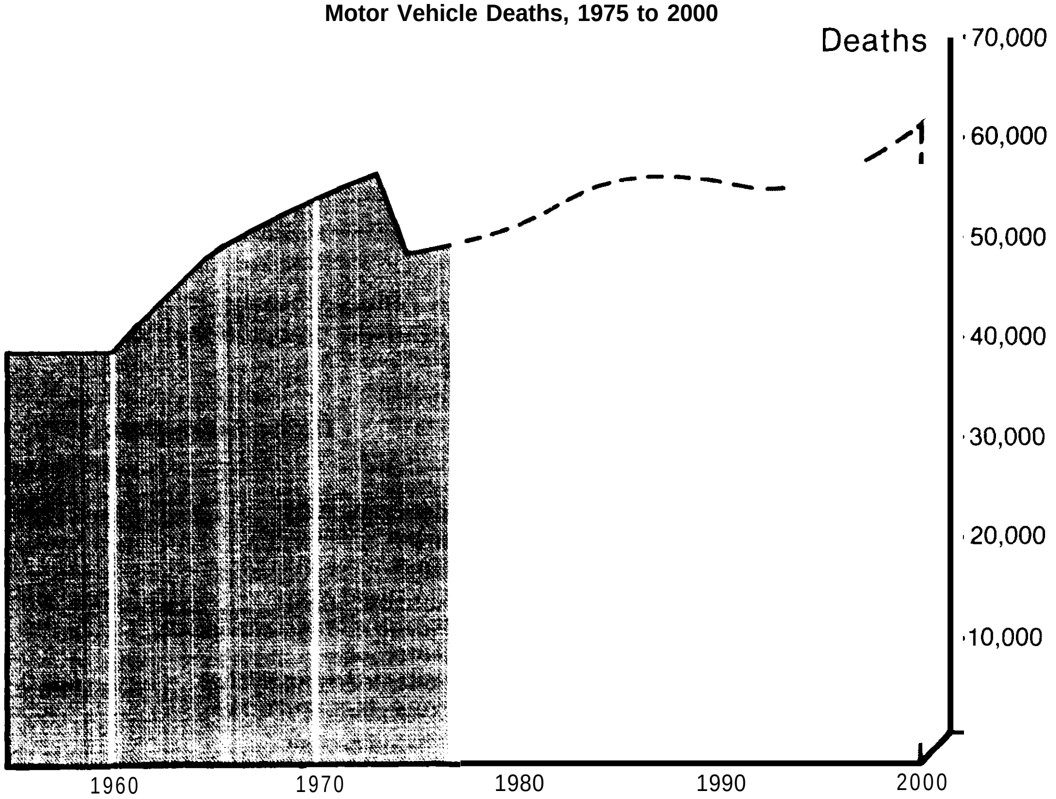
[a]OTA estimates from National Safety Council data.
[b]U.S. Public Health Service estimates.
[c]U.S. DOT Fatal Accident Reporting System, figures rounded.
[d]U.S. DOT, updated data, originally from "1975 Societal Costs of Motor Vehicle Accidents." This figures does not include costs associated with pain, suffering, loss of relationship, etc.

Trends to the Year 2000

Historically, the number of crashes per vehicle mile traveled has been decreasing, but the number of crashes and resulting injuries and deaths have steadily risen, largeIy because there are more drivers, more vehicles, and more miles traveled. There are several factors that may increase the severity and magnitude of the safety problem in the future.

- VMT is expected to rise, as is the number of vehicles and drivers.
- The proportion of small cars in the vehicle fleet is expected to rise.
- The percentage of trucks in the fleet and truck VMT are expected to increase.
- Highways are deteriorating at a rate faster than they are being maintained. Unless maintenance is emphasized, the condition of roads could contribute to an increase in crashes.

Motor Vehicle Deaths, 1975 to 2000



SOURCE OTA projection uslng Base Case VMT adjusted for total vehicle travel

Federal Involvement

With the passage of the National Traffic and Motor Vehicle Safety Act of 1966, and the Highway Safety Act of the same year, the Federal Government embarked on a course of large-scale involvement in the U.S. automobile-highway system. The issue was safety and the clear need to act in the public interest.

New vehicles must comply with some **50** performance standards before they can be sold to the public. A recent study by the General Accounting Office estimates that the enforcement of these standards may have saved as many as 28,000 lives from 1966 to 1974.[6]

In addition, the National Highway Traffic Safety Administration has an aggressive vehicle defect and recall program. In the period 1966 to 1975, 52 million vehicles, or 43 percent of automobiles produced, were recalled for safety defects.

Other Federal activities under the Highway Safety Act include driver education, highway design, traffic laws, and accident investigation.

Analysis of Safety Factors

The widespread use of seat belts would bring about an immediate reduction in vehicle occupant deaths and injuries. Both the Department of Transportation (DOT) analysis and our own study indicate the most effective approach to achieving greater seat belt usage is by means of a mandatory seat belt law. Whether or not this action is politically acceptable is debatable. other incentives for increasing seat belt usage, such as insurance rate penalties, also merit investigation.

Passive restraints are mandated for all new passenger cars by the 1984 model year, but the fleet will not be fully equipped until the 1990's. Of the future restraint systems being considered, the most effective is expected to be the air cushion with the use of a lap belt.

[6]*Effectiveness, Benefits, and Costs* of *Federal Safety Standards for Protection of Passenger Car Occupants*, Report to Committee on Commerce, U.S. Senate, by the Comptroller General of the United States, July 7, 1976.

In 1974, the number of traffic fatalities decreased 9,000 from the previous year. The enactment of the 55-mph speed limit is considered to have been an important factor in this reduction. Again, studies by DOT and our own analysis indicate that strict enforcement of the 55-mph speed limit would be an effective means for reducing deaths and in juries.?

The strong correlation of alcohol use and fatal crashes has been demonstrated. Our analysis confirms this correlation and indicates that methods — policy-related or technical —designed to reduce drunk driving could have a high payoff.

At present, passenger vehicles meet Federal standards for crashworthiness in impacts of up to 30 mph. Higher levels of crashworthyiness are possible and would help reduce death and injury. Preliminary results of the Research Safety Vehicle program of DOT indicate that high levels of vehicle safety can be achieved at an acceptable cost, while also meeting fuel-economy requirements.

The design and condition of the highway and its surroundings have an important influence on the incidence and severity of crashes. About half of all crashes fatal to automobile occupants involve only one vehicle—most frequently collision with a fixed object in the roadside. Important safety benefits could be realized by removal of roadside obstacles and improved highway design.

Goals

Specific quantitative goals and the resulting standards for vehicle emissions and fuel economy have proved to be an effective approach. A first step to achieving better highway safety might be the establishment of specific and quantitative goaIs. These goals could be expressed either as targets for reduction of highway death, injury, and property damage, or as a scheduled reduction in the rate of crashes as a function of VMT.

We recognize that setting safety goals—as well as establishing the plan and lines of responsibility for achieving them—would be a difficult process. Still, the possible effectiveness of goals as a means of promoting automobile and highway safety is a topic that deserves further study.

‘The 55-mph speed limit also contributed to reduced fuel consurnption,

FINDINGS

- . Traffic safety remains a perennial problem that will probably grow as the auto fleet and number of drivers increase.
- . Federal involvement in automobile safety has been effective in the past, and continued Federal presence appears needed.
- . The establishment of specific quantitative safety goals may be an effective first step to achieving improved safety, and the subject should be evaluated further.
- . In the near term—the next 5 to 10 years—the greatest safety benefits could be realized from:

  —increased use of seat belts,
  —strict enforcement of the 55-mph speed limit, and
  —reduction of alcohol use associated with driving.

- . To achieve a higher level of vehicle safety, a long-range plan should include:

  —improved auto crashworthiness,
  — improved occupant restraint systems, and
  —improved vehicle designs to mitigate pedestrian injuries.

- . There are a number of highway improvements, primarily elimination of roadside hazards, that appear to be cost-effective.

MOBILITY

- **Are there foreseeable problems that may affect personal mobility?**
- **Are there Federal actions that can assure or improve personal mobility?**

Americans have come to regard personal mobility as an inalienable right, and the automobile is viewed as the principal means to achieve this end. To assist personal mobility, all levels of Government have taken an active part in promoting the automobile highway system. However, there has been growing awareness in the last decade of some shortcomings in our expansive system of highways and our use of automobiles.

It is recognized that the automobile provides great benefits but at the same time imposes great costs on society because of its energy consumption, environmental pollution, and safety problems. While the automobile is the primary mode of transportation for many, it does not serve well the mobility needs of the handicapped, the elderly, the young, and the poor. Remedial policies to improve mobility for these segments of the population need to be considered.

Supporting detail for this section of the Summary and Finding is contained in chapter8 of the Technical Report.

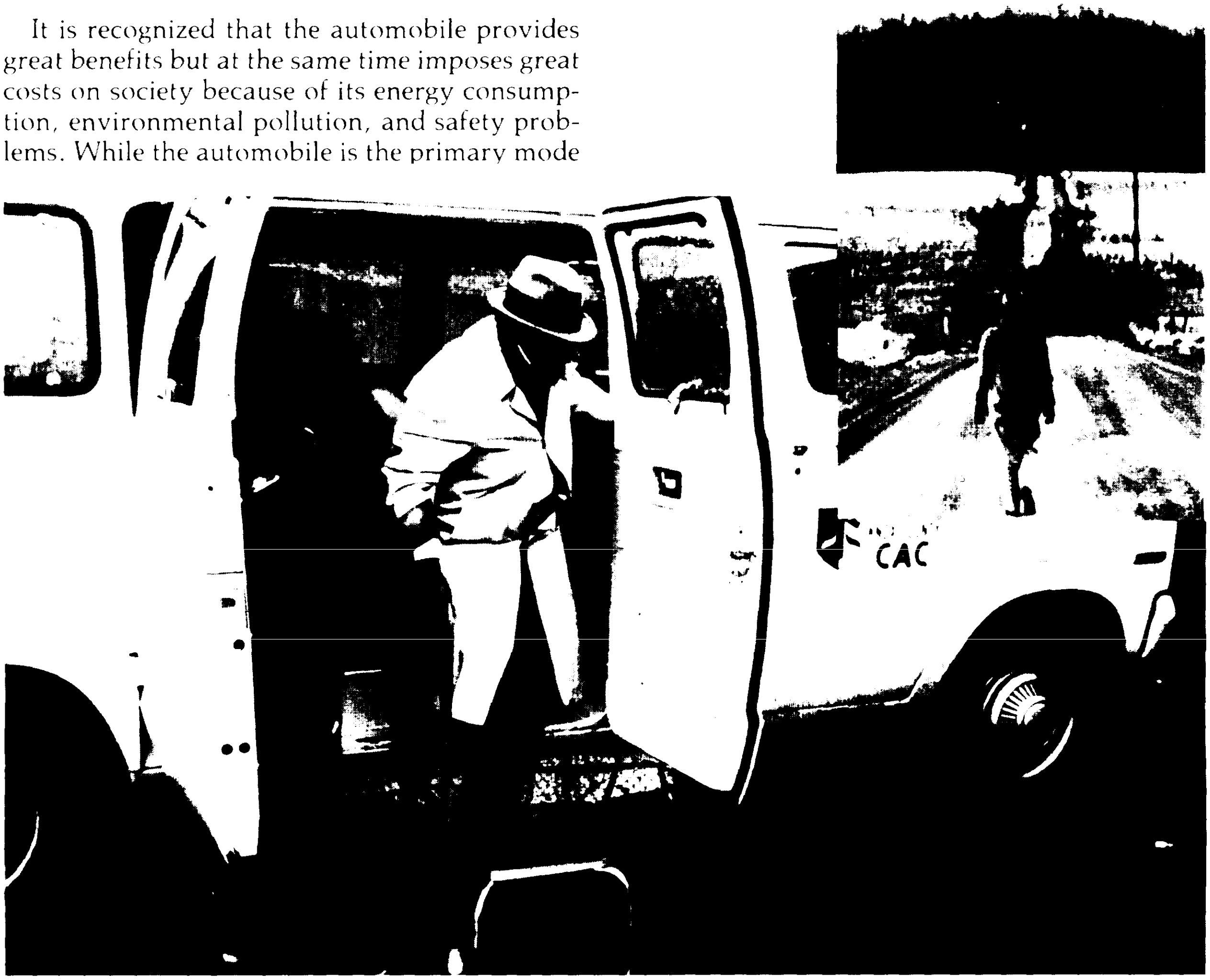


Photo Credit: University of Tennessee

. . . the mobility needs of the handicapped, the elderly, the young, and the poor . . .

Congestion

The future mobility of the population will be influenced by demographic trends, economic conditions, and Federal transportation policies. Between 1975 and 2000, it is projected that the population will increase by about 20 percent. Urbanization will continue. More persons (particularly women) will be in the labor force, and real income will double. Thus, by 2000 it is expected that there will be 36 percent more licensed drivers than in 1975 and 56 percent more cars on the road. The total amount of automobile travel is projected to increase by 75 percent, to 1.8 trillion vehicle miles annually.

The Base Case assumes that new highway construction will taper off and not keep pace with the growth in personal automobile travel. It is assumed that total highway spending by all levels of Government will remain about what it is now in constant dollars, but by 2000 the share spent on new construction and other capital outlays will decline by half as an increasing share of the highway budget is spent for maintenance. Travel times will therefore increase, particularly in urban areas, where average speeds will be 10 to 15 percent slower. Motorists will encounter congested conditions up to 3 times as often as today.

To avoid this congestion and to maintain present levels of service on the highways through the year 2000 would require construction expenditures more than 60 percent higher than those assumed for the Base Case. Highway maintenance will also be an important concern. The quality of streets and highways will deteriorate greatly, unless strong initiatives are taken for restoration, rehabilitation, and repair.

Other Means to Improve Mobility

We considered several measures to improve mobility. Major expansion of assistance for public transit could increase transit ridership by over 50 percent in major urban areas, if accompanied by appropriate auto disincentives. Such a program would cost the Federal Government more than $7.2 billion annually (in 1975 dollars), or about 5 times more than the 1975 expenditure of $1.5 billion. This program would also reduce State and local transit burdens in 2000 from the Base Case projection of $4.9 billion to $1.9 billion, close to today's level.

Within metropolitan areas, ridesharing has the potential to reduce petroleum consumption, emissions, consumer costs, and traffic congestion. Increased acceptance of this form of transportation depends more on institutional changes than on financial assistance.

Transportation System Management (TSM) techniques could be used to improve the movement of persons and vehicles in urban areas at

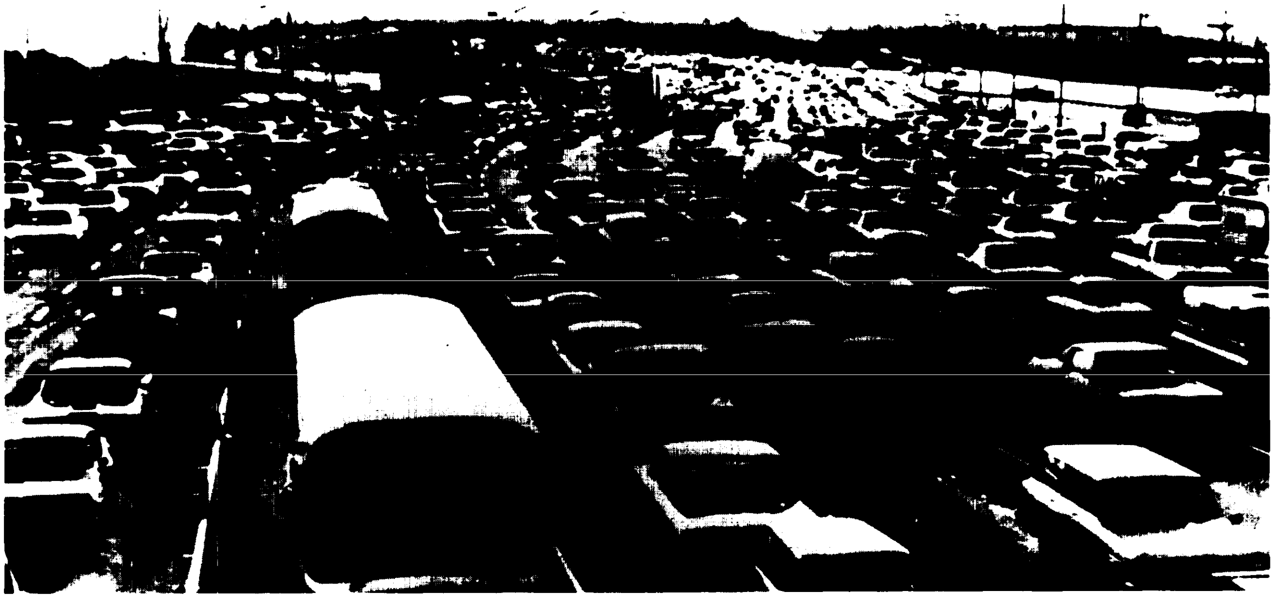


Photo Credit: U.S. Department of Transportation

. . . motorists by the year 2000 will encounter congested conditions up to three times as often as today . . .

relatively low cost. Both the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA) are encouraging the use of TSM to avoid costly capital projects such as new expressways and rail rapid transit systems.

In the long run, the need to travel could be reduced by changes in urban development policies to channel growth into "high accessibility" areas. Development of telecommunications as a substitute for travel might also have significant impacts on the auto system, but probably not before 2000.

Highway and Personal Travel Projections

	1975	1985	2000
Highway expenditures ($ billion):			
Capital outlays	$14.3	$11.2	$ 7.2
Noncapital outlays	13.9	17.0	21.2
Total	28.2	28.2	28.2
Transit:			
Federal capital assistance ($ billion)	1.21	1.71	1.71
Federal operating assistance ($ billion)	0.30	0.43	0.43
State and local subsidies ($ billion)	1.71	2.70	4.90
Average fare (cents)	33¢	20¢	20¢
Vehicles (thousands)	62.3	72.0	91.1
Vehicle miles (billions)	2.0	2.3	3.0
Ridership (billions)	5.6	6.5	6.5
Auto:			
Urbanized area population (millions)	130	149	177
Personal disposable income per capita (thousands)	5.03	6.72	10.0
Percent of population with licenses	61	65	68
Cars per licensed driver	.73	.78	.84
Auto VMT per licensed driver	7,900	9,500	10,200
Percent of urban driving under congested conditions	10	14	24

NOTE: BASE CASE PROJECTIONS OF MOBILITY COSTS are in 1975 constant dollars. Noncapital outlays include maintenance, administration, police, debt retirement, research, and planning.

FINDINGS

- **Stricter fuel-economy standards, reduced highway construction, and auto disincentives to conserve petroleum and improve urban air quality will have little effect on the amount of auto travel. Only a severe petroleum shortage requiring gasoline rationing or other allocation measures, would produce major reductions in auto use.**
- **Urban mobility will be hampered by increased congestion in the 1985 to 2000 time period.**
- **Continuation of current policies can be expected to increase the transit operating deficits borne by local governments in the future. If more Federal funds were made available for public transportation, mobility in both urban and rural areas could be improved, but the overall effect on the amount of automobile travel would be small.**
- **Increased funding for conventional transit, supplemented by special programs, could be highly beneficial for the transportation disadvantaged.**
- **A policy of promoting population shifts to high-accessibility areas could, in the long-range future, reduce dependence on the automobile as a means of personal transportation. The effects, however, might not be significant on a national basis for as long as 50 years.**

COST AND CAPITAL

- **Is there a need to revise Federal highway and transit financing policies?**
- **Should the Federal Government seek to influence capital investment by the automobile industry?**
- **Should the Government act to influence the direct and indirect costs of automobile ownership?**

Public and private costs of the automobile transportation system include the direct private costs of owning, operating, and maintaining automobiles and the indirect costs that are paid in the form of taxes to support the system of streets and highways. There are also the social costs—borne by automobile users and nonusers alike—which include air pollution, highway death and injury, disruption of communities, and effects on the quality of life.

These costs give rise to three major issues:

- the appropriate distribution of public funds for the automobile transportation system;
- the role of the Federal Government with respect to the automobile transportation industry; and
- the private costs of owning and operating an automobile.

Underlying these issues are fundamental questions about the form and degree of Federal Government intervention in the future automobile transportation system. The following is a brief summary of these issues and questions.

Public Financing of the Highway System

Historically, a major role of the Federal Government in transportation has been financial contribution to development of the highway system. The Federal Government—mostly from the Highway Trust Fund—now provides about $7 billion of the $28 billion expended each year on the highway system. Federal assistance for mass transit, which amounts to about $2 billion per year, is funded from general revenues.

Supporting analysis for this section of the Summary and Findings is contained in chapter 9 of the Technical Report.

Our analysis indicates three major questions with regard to highway financing over the next two decades:

- Should the Highway Trust Fund, in its present form, be the primary mechanism for Federal Government financing of highways?
- How much Federal support should there be for highway maintenance?
- Should the Federal Government foster road-pricing systems as a means to reduce congestion, to promote more efficient use of highways, and to achieve more equitable distribution of highway costs?

Advantages and disadvantages of transportation financing options are examined in detail in chapter 9 of the Technical Report. These financing mechanisms include: (1) a continuation of the present Highway Trust Fund, (2) a unified transportation trust fund, (3) separate trust funds for each mode of transportation, and (4) financing from general funds.

Important to the future of the highway transportation system is the issue of highway maintenance. Our study indicates that the Nation's highways are deteriorating twice as fast as they are being repaired. An adequate program of maintenance would place a growing, and perhaps an unsupportable, financial burden on State and local governments. The use of Federal funds for maintenance may be required.

Analysis indicates that 40 percent of all urban interstate travel in the last 5 years was characterized by congested conditions, and these conditions are expected to worsen. Road-pricing schemes are one method to relieve highway congestion.

Several Federal agencies have been evaluating congestion cost-pricing schemes to restrain traffic growth. These schemes call for special licenses in designated areas during peak hours, parking fees, and promotion of alternative modes of transportation. The net value and acceptability of congestion-pricing is yet to be determined, but it is a promising subject for further analysis.

Financing Requirements of the Automobile Industry

The auto industry's return on equity and profit margins are higher than many other manufacturing industries. In addition, the growth in sales projected in the Base Case improves the outlook for industry profitability. However, the need for capital investment to meet Government standards and changes in consumer demand will increase the volume required by each firm to realize a profit. Should a firm fail to achieve this increased sales volume, it would have to rely to some extent on external sources of funds. While Ford and General Motors are conservatively financed and would have many options open to them, other manufacturers would probably find it difficult to raise funds in the market.

Automobile Industry Sales and Revenues

	1976	1985 Base Case
New car price by size class:		
Subcompact.	$3.600	$4,080
Compact.	4,200	4,710
Intermediate.	4,600	5,090
Standard.	5,400	5,890
Small luxury	5,650	6,130
Large luxury	8,800	9,270
Gross revenue per domestic car sold	4,990	5.220
Annual domestic sales (thousands)	8,610	10.710
Annual domestic sales revenue ($ millions)	$42,950	$55,940
Auto manufacturing employment (domestic).	808,800	790,800

NOTE PROJECTED SALES AND ECONOMIC DATA for the U S auto industry are expressed in 1975 dollars Employment figures include only passenger car and auto parts manufacture

Photo Credit: University of Tennessee

... highways are deteriorating faster than they are being repaired ...

The capital and cost requirements associated with meeting Federal standards will probably limit the ability of the smaller and less-financially secure firms to invest in both regulation-induced activities and those related to product improvement and productivity.

In view of the interrelationship between the industry and the national economy, the Federal Government might be pressed to consider regulatory retrenchment or to adopt policies of indirect or direct involvement in the automobile industry.

Private Cost of Automobile Use

How much does it cost to own and operate an automobile? How much will it cost in the future? These are questions of concern to every motorist in the United States.

Costs of automobile travel represent a substantial portion of personal consumption expenditures in the United States—between 13 and 20 percent of annual household expenditures.

The costs of owning and operating an automobile, in constant dollars, have not changed significantly over the past several years. However, the percentage of the household budget actually spent on automobile transportation has risen because the number of households owning more than one car has increased and the number of those without cars has declined. The size of the personal investment that individuals make in automobile transportation can be seen in the fact that, in virtually all but the lowest income categories, expenditures for automobile transportation have replaced food as the second largest item in the household budget.

It now costs the average driver between $1,300 and $1,800 per year to own and operate a car, and this is expected to rise. Maintenance costs, in particular, are projected to increase by 10 to 20 percent in real terms between 1976 and 1985. Improved emission-control equipment is expected to add between $50 and $200 to the price of a new car. Improved safety can be achieved at an incremental cost comparable to luxury options now sold on most cars. If improved safety measures are not implemented, death and injury will unquestionably rise and result in higher insurance rates. The savings due to improved fuel economy of smaller cars will, it is expected, be offset by increased gasoline prices.

What could Congress do about the rising cost of automobile ownership? We selected three cost components that may rise steeply between now and the year 2000—insurance, repair, and maintenance—and examined specific policies to control these costs:

- a Federal law providing for no-fault insurance,

Costs of Owning and Operating an Automobile (cents per mile)

Type of automobile	Depreciation	Maintenance accessories, parts and tires	Gas and oil (excluding taxes)	Garage, parking and tolls	Insurance	State and Federal taxes	Total costs
1976 Standard	4.7	4.0	3.1	2.1	1.6	1.5	17.0
1976 Compact	3.6	3.2	2.4	2.0	1.5	1.1	13.9
1976 Subcompact	3.0	3.0	1.7	2.0	1.4	0.9	12.0
1974 Standard	4.6	3.7	3.5	2.2	1.8	1.6	17.4
1974 Compact	3.2	3.0	2.8	2.2	1.6	1.3	14.1
1974 Subcompact	2.5	2.7	2.2	2.2	1.6	1.0	12.2
1972 Standard	5.7	3.3	2.7	2.3	1.8	1.7	17.5
1972 Compact	3.5	2.8	2.3	2.3	1.7	1.3	13.9
1972 Subcompact	2.7	2.7	1.8	2.3	1.5	1.0	12.1
19704 door sedan	4.4	2.6	2.6	2.5	2.4	1.9	16.5
19684 door sedan	4.3	3.3	2.6	2.8	2.2	1.9	17.0
19604 door sedan	4.5	3.6	2.9	2.0	2.4	2.2	17.8
19504 door sedan	3.1	2.9	3.1	2.0	2.0	1.6	14.8

NOTE: COSTS OF OWNING AND OPERATING AN AUTOMOBILE, Itemized above, are shown in cents per mile, 1975 dollars, These costs are estimated to total between $1,300 and $1,800 per year.

- State and local regulation of repair practices, and
- Federal incentives or regulations to increase automobile durability and maintainability.

In all three cases, it is our finding that appropriate Federal Government action could significantly benefit the automobile owner and user.

FINDINGS

Given the Base Case assumptions, we find that:

- **Highway construction will decrease through the year 2000, such that the new highway miles added to the system will fall far short of meeting the demand created by growing automobile travel. In addition, meeting increased highway maintenance needs and providing moderate improvements in transit service will place a growing financial burden on State and local governments. Major increases in Federal assistance for transit operations and highway maintenance will be needed to retain the current level of mobility and protect the investment in the highway system.**
- **Capital requirements for the automobile industry will increase sharply in order to respond to changing demand and Government regulations. To achieve fuel-economy, emission, and safety standards, the additional capital needed through 1985 may be in the range of $7 billion to $8 billion. The increase in capital requirements and the shift to lower revenue car sizes will require increased sales volumes if this capital is to be generated internally. The smaller domestic manufacturers will face severe financial difficulties that could affect their survival.**
- **The personal cost of automobile ownership and operation (in constant dollars) will increase in the years ahead due primarily to rising fuel prices, mandated emission controls, safety features, higher insurance costs reflecting increased damageability and loss susceptibility of smaller sized cars, and increased costs of repairs and maintenance. Federal policies could be major determinants of these future costs.**

TECHNOLOGY

- **What major technological developments in automobile systems can we expect by 1985?**
- **What advanced automobile technology may be available by 2000?**

Most technological changes in the automobile system have been evolutionary and have been directed toward improved performance, handling, comfort, convenience, versatility, and styling. Manufacturers have developed and introduced those features which they felt could be successfully marketed as standard equipment or extra-cost options. Starting in the *1960's*, however, Government regulations concerning safety, followed by emissions and fuel-economy standards, caused technological development to take new directions.

Some of these new directions are summarized in this section. The discussion is divided into two parts: near-term technical developments to 1985, and long-term technical developments in the period from 1985 to 2000 and beyond.

Technical Developments to 1985

Leadtimes in the automobile industry are such that technological developments that can be expected by 1985, as a result of either Federal Government stimulus or industry enterprise, are already well underway.

The basic technological concerns of the U.S. automobile industry in the near term are:

- achieving the currently mandated 1985 fuel-economy standards,
- meeting the 1981 emission standards, and
- improving vehicle safety, notably occupant protection.

These objectives cannot be approached separately. Technical achievement in one area must be carefully balanced against possible losses in the others.

A more thorough discussion of the subjects addressed in this section is contained in chapter 10 of the Technical Report.

Fuel Economy

The Energy Policy and Conservation Act of 1975 mandated fuel economies of 20 mpg by 1980 and 27.5 mpg by 1985 on a fleet-average basis for each manufacturer. It appears that these goals can be met. Many new models now on the market have fuel-economy ratings equal to or higher than 27.5 mpg. Methods for meeting the goals include weight reduction, more fuel-efficient engines, improvements in transmission and drive-train efficiency, reduced power requirements for accessories, and improved aerodynamics. The engineering and production problems in introducing these technological changes are not insurmountable. The challenge lies in achieving a proper combination that will attain the required fuel economy while satisfying consumer demand for performance, capacity, durability, low cost, and general subjective appeal.

The diesel engine is appearing on the passenger-car market in increasing numbers. Diesels have a significant advantage over spark-ignition engines in fuel efficiency, and they are viewed as a way of meeting fuel-economy standards while retaining the large passenger car. At present, diesels are heavier for a given horsepower and more expensive than a spark-ignition engine. Also, diesels may not meet the 1981 Federal standards for NO_x emissions. A further disadvantage is that diesel exhaust contains high concentrations of particulate matter that is suspected to be carcinoqenic.

Emissions

The early approach to control of vehicle emissions involved "detuning" the engine and resulted in penalties in fuel economy. This approach has been abandoned in favor of technologies, such as after-treatment and cleaner burning engines, that allow substantial reductions in emissions and operation at near optimum fuel economy.

Progress toward meeting regulatory emission goals is being made along two lines. Improved after-treatment systems, such as the three-way catalytic converter, have been developed and are now being placed in use. Advances are also being made in reducing the pollutants created in the combustion process through techniques such as stratified-charge engines and electronic control of ignition timing and fuel-air mixture. There is a high probability the industry will meet the 1981 Federal emission standards of 3.4 grams per mile for CO, 0.41 gram per mile for HC, and 1.0 gram per mile for NO_x and still be able to attain fuel-economy goals. Different manufacturers will choose different combinations of emission-control techniques, but it is expected that electronic control of ignition and fuel-air mixture will be virtually universal by the earl y 1980's.

The 1982 California NO_x standard of 0.4 gram per mile introduces a more difficult technical problem than the 1981 Federal standard of 1.0 gram per mile. To date, no method has been demonstrated to meet the California standard with typical large U.S. spark-ignition engines. Volvo, Saab, and GM have shown, however, that they can meet the 0.4 gram per mile requirement with a three-way catalyst system on a four-cylinder engine.

Safety

Vehicle safety improvement falls into two categories—accident avoidance and occupant protection.

Accident avoidance includes features such as better brakes, improved lighting and visibility, and improved handling. Such features are marketable commodities, but some of them can be costly. Evidence that they would contribute significantly to reductions in the number of traffic crashes is not clear for all of these features.

Occupant protection, on the other hand, is effective and is reasonably amenable to evaluation. Because occupant protection is partly a function of crush distance and relative vehicle weights, the expected shift to small cars could lead to increased occupant injury and fatality rates. Improved vehicle crashworthiness would be required to reduce the hazards of small cars.

Safety and fuel-economy goals are sometimes in opposition (i. e., a higher margin of safety or additional safety equipment may mean more weight and, hence, lower fuel economy). Although an integrated approach to safety design has not been thoroughly examined, the Department of Transportation's (DOT) Research Safety Vehicle (RSV) program indicates that higher levels of safety can be attained without unreasonable penalties in weight or cost.

Passive restraint systems are currently mandated for automobiles in the 1982-84 model years. This technology is reasonably well-developed, and no insurmountable technical difficulties are foreseen.

Summary

Several major technological developments are expected by 1985:

- Downsizing programs will reduce the average size and weight of the vehicle fleet. Waste space from styling and image requirements will be greatly reduced.
- Materials substitution—greater use of lightweight materials such as aluminum, plastics, and high-strength low-alloy steels—will reduce vehicle weight further.
- Changes in vehicle layout, such as front-wheel drive, will allow further size and weight reduction.
- Additional improvements in fuel economy will be achieved by improvements in transmission and drive-train efficiency and by reduced power requirements for accessories. The application of electronic controls for fuel metering and ignition will help the engine maintain efficient performance and reduce the need for tuneups.
- Several new or refined engines may be widely offered:
  –diesels (several now offered),
  —stratified charge (now offered by Honda),

—single-chamber stratified charge (under development by Ford, GM, and Texaco),
—valve selector (expected on the market by 1980), and
—turbocharging (now offered by GM and Ford),

These engines will afford greater fuel economy and/or reduced emissions.

- Vehicle safety will be improved by the addition of passive restraints. However, the decrease in vehicle size may offset these gains unless additional crashworthiness is designed into small cars.
- Advanced propulsion technologies (such as Stirling and turbine engines) and electric vehicles will not significantly penetrate the market by 1985.

Technological Developments Beyond 1985

The principal factors influencing automotive technology in the period after 1985 are expected to be:

- The need to develop and utilize energy sources other than conventionally derived petroleum,
- The need for further fuel-economy improvement—up to 35 or **40** mpg by 2000, and
- The need to reduce hydrocarbon, carbon monoxide, and nitrogen oxide emissions and to control other pollutants—such as sulfates, particulate, and nitrosamines — present in automobile exhaust or associated with the production of alternate fuels.

Substitute Fuels

The technology for producing, distributing, and utilizing alternate energy sources, as a supplement or replacement for conventional petroleum, may be the most significant development in the 1985-2000 period. These fuels could be:

- liquids from oil shale and tar sands,
- liquids from coal,
- alcohol, and
- hydrogen.

Oil Shale and Tar Sands.—Oil shale is a rock containing a petroleum-like substance called kerogen. The recovery process involves heating the shale to evaporate the oil, which is then drawn off and condensed. The resulting crude shale oil can then be refined to produce a synthetic fuel with properties close to those of gasoline or diesel fuel produced from petroleum. Tar sands are sand and clay saturated with a heavy oil. The extraction and refining processes are similar to those for oil shale. The final product has properties similar to conventional motor fuel.

There are large reserves of oil shale in the Western United States, and oil shale conversion could reach the commercialization stage by 1990-2000. The technology to advance from pilot plants to full-scale production has not yet been fully tested. At present, the estimated cost of fuel from oil shale is not competitive with motor fuel refined from petroleum. The price differential at present deters investment in commercial facilities—the cost of which is estimated at $1 billion for a 50,000 barrel-per-day plant. Uncertainty about Federal Government policy on petroleum and substitute fuels also contributes to industry's reluctance to invest in full-scale commercialization of oil shale processing.

A major obstacle to large-scale exploitation of oil shale is the environmental impacts of extraction and processing. These include land disturbance and subsidence, disposal of spent shale, gaseous emissions from shale retorting, and contamination of ground water. Also, processing requires large amounts of water—a scarce commodity in the semiarid regions of the Western United States, where the shale deposits exist. If these production problems can be resolved, fuel from oil shale can be readily substituted for petroleum products since it would not necessitate a different engine technology.

Commercial production of fuel from tar sands presents many of the same technical, environmental, and economic problems as oil shale. Compared to oil shale, the United States has only very small deposits of tar sands—about 2 percent of the world supply. The bulk of tar sand reserves are in Canada and South America. Consequently, tar sands are not considered a major domestic energy resource.

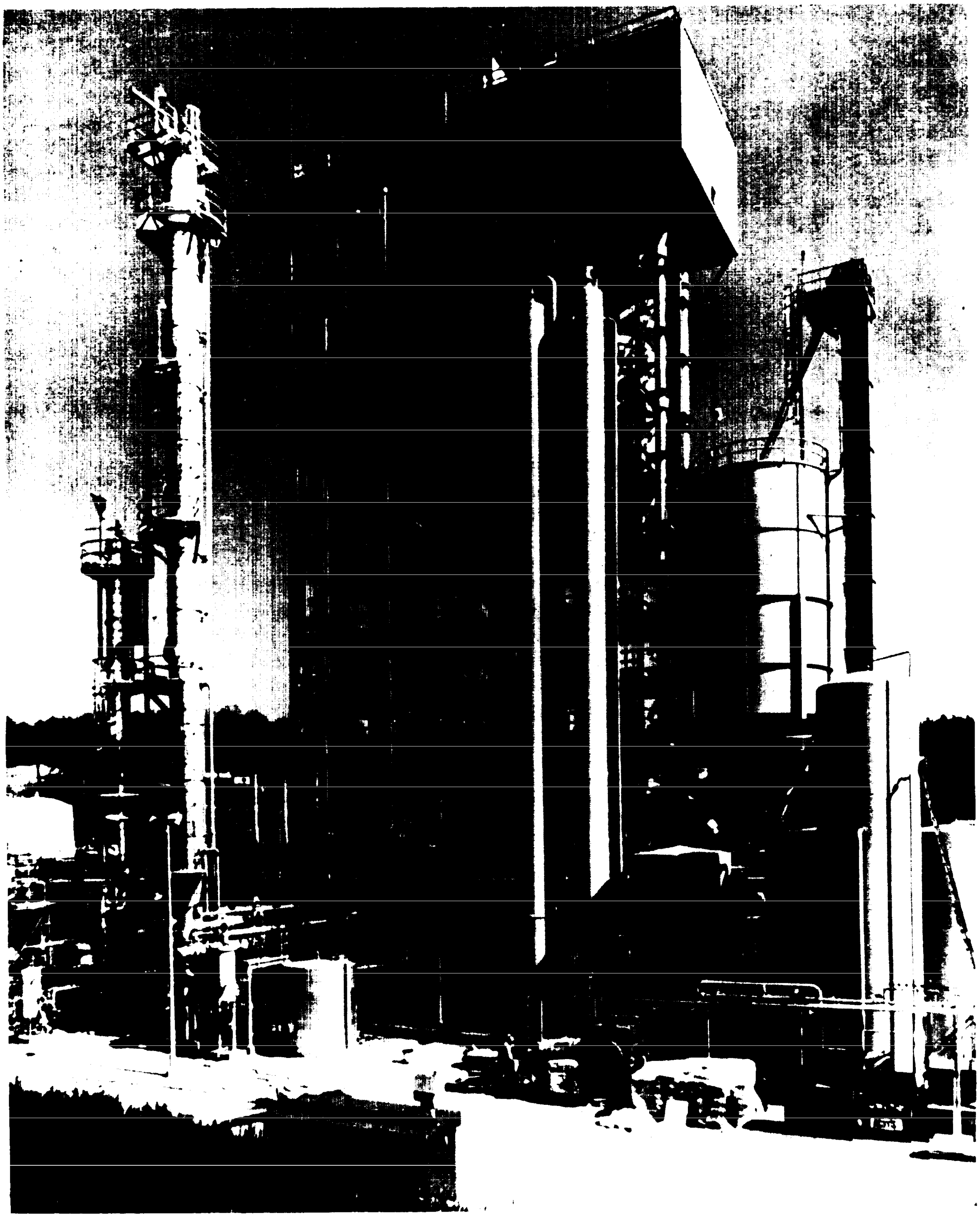


Photo Credit: U.S. Department of Energy

. . . utilizing alternate energy sources . . .

Coal.—The basic process for producing liquid fuel from coal involves breaking down the hydrocarbon molecules, removing contaminants such as ash and sulfur, and enriching the hydrogen content. The resulting liquid can be refined to a product suitable for use as a motor fuel.

Coal liquefaction on a large scale was carried out in Germany during World War II, and a commerical facility is now in operation in South Africa. There are several pilot plants in the United States, but extensive commercialization is not expected until the 1990's at the earliest.

Coal liquids are attractive as an alternative automobile fuel because the United States has an abundent supply of coal. The major barriers to large-scale production of coal liquids are technical, economic, and environmental. Coal liquefaction generally requires high pressures, carefully controlled temperatures, and large reactors for coal conversion. Research is continuing on the development of equipment and facilities for commercial application. Because of the need for specialized equipment, coal liquefaction plants are highly capital-intensive, and the cost of the resulting fuel exceeds the present price of petroleum products. In addition to the environmental problems associated with coal mining, there are air- and water-pollution problems at refining facilities and the inherently hazardous nature of some of the compounds present in the resulting motor fuel. The effects on air quality of extensive use of coal-derived fuels in automobiles have not been fully explored. It is conjectured that automobile exhaust would be higher in NO_x and various aromatic and benzene compounds if coal liquids were used.

Alcohol.—Alcohols such as ethanol or methanol can be used in pure form or in **a** mixture with gasoline (gasohol) to fuel automobiles. Methanol can be produced from organic waste, natural gas, heavy petroleum residues, or naphtha. It can also be derived from coal. Ethanol can be produced from biomass, which includes municipal and agricultural waste, grain, plants, and other biological matter. Alcohol fuels offer the attractive possibility of a renewable source of energy for the automobile. With present production techniques and volumes, the price of pure alcohol as a motor fuel is not competitive with gasoline. The price of gasohol in mixtures of 10 to **20** percent, if the alcohol is not subject to Federal fuel tax, is close to the current price of gasoline.

Ethanol blends have been used as an automobile fuel in Brazil for several years. Gasohol is now being sold in Illinois, Iowa, and Nebraska. California has initiated a gasohol program, and Colorado has approved one. It is estimated, however, that it would take 10 to 15 years to build the industrial capacity sufficient to meet 10 percent of our daily automotive fuel demand.

Alcohols have the inherent advantage of a high octane rating, which permits more efficient engine operation. The emissions from an engine burning pure alcohol or gasohol are lower in HC, CO, and NO_x. However, it is suspected that there would be a higher proportion of unburned fuel in the exhaust and an increase in aldehyde emissions. The significance of these emissions in terms of reactivity and toxicity is not fully understood at present.

Gasohol containing less than **20** percent alcohol can be burned in present-day automobile engines with only slight carburetor adjustment. The use of alcohol as a motor fuel, either in pure form or in blends of more than **20** percent with gasoline, requires some modification of the engine and fuel system to maintain proper carburetion and to prevent corrosion and deterioration of parts in contact with the alcohol. Transportation, storage, and distribution of alcohol requires special precautions to prevent contamination by water.

Hydrogen.—Hydrogen is an ideal fuel for heat engines because its energy content is very high per pound and because it burns cleanly. However, the use of hydrogen in automobiles presents technical problems. As a gas, it is of very low density and has to be stored and transported under high pressure. As a liquid, hydrogen must be kept at an extremely low temperature, which requires thermal insulation and special handling. Hydrogen can be stored in solid form as a metal hydride, but it is heavy and bulky— making it impractical with present technology to store in a passenger car.

Although hydrogen is the most plentiful element in the universe, processes to obtain hydrogen by breaking down natural compounds such as water or coal are very costly under present methods and consume more energy than they deliver. Extensive use of hydrogen as a motor fuel depends on development of a practical, low-cost, energy-efficient process to extract hydrogen, probably from water.

Advanced Propulsion Systems

The desire for cleaner and more efficient propulsion systems has stimulated a search for alternatives to the conventional spark-ignition engine. Among the candidates are:

- gas turbines,
- Stirling engines,
- compound engines, and
- electric and hybrid vehicles.

All are in various stages of development now, but more work will be needed to determine their potential. However, each can be considered a contender to provide a partial or complete substitute for the conventional spark-ignition engine of today. The advantages and disadvantages of each are discussed in chapter 10 of the Technical Report and summarized briefly here.

Interest in the gas turbine (Bray ton cycle engine) has been prompted by the need to develop an automobile engine with emission characteristics superior to those of the spark-ignition engine. The turbine is also of interest because it is theoretically a very efficient engine that can use a wide variety of fuels. However, to achieve high operating efficiency a turbine must run at a very high temperature. This necessitates using high-temperature metal alloys or ceramics for engine components. High-temperature alloys are expensive and difficult to mass produce. Ceramic technology has not yet been perfected. If the problem of production of high-temperature materials can be solved, the gas turbine promises to be a small, efficient, and durable automobile engine with smooth operation, low emissions, and ease of maintenance.

The Stirling engine is an external combustion engine, The heat from burning fuel is used to expand a confined working fluid (usually helium or hydrogen under high pressure) which drives a piston to provide motive power. The expanded working fluid is recompressed and reheated for the next piston stroke.

The Stirling offers the potential of very high fuel economy and can use nearly any liquid, gaseous, or solid fuel. Since it is an external combustion engine, it is theoretically cleaner than an internal combustion engine burning comparable fuel. The Stirling engine can also be made quiet and smooth running.

There are many technical problems that will have to be solved before the Stirling engine can be put to use in passenger cars. The engine operates at very high temperature and pressure. Special high-temperature materials are required. Maintaining tight seals is a problem. The Stirling is mechanically complex, which makes it difficult to produce in quantity at a competitive cost. For these reasons, the Stirling engine is not expected to be on the market until 1990 or later.

Along with research on turbine and Stirling engines, attention is also being given to other advanced propulsion systems that augment one type or another of heat engine with additional power cycles such as turbocharging, regeneration, compounding, and other mechanical and thermodynamic variations. One such engine is the adiabatic turbocompound diesel that is currently being developed for trucks. The efficiency of the diesel is improved by shielding the engine to prevent radiant heat loss and then adding a turbine driven by the exhaust gases, which serves to capture some of the energy that would otherwise be lost. As a further refinement, a Rankine cycle power system (a steam engine) can be added to utilize even more of the waste heat in the exhaust stream. These features can raise the thermal efficiency of the engine to perhaps twice that of a conventional diesel or spark-ignition engine but may result in a large weight penalty. The adiabatic turbocompound diesel, or some other form of compound-cycle engine, could find its way into automobile use, but probably not before the end of the century.

In the early days of the automobile, the battery-powered electric motor was a strong competitor with the gasoline-powered spark-ignition engine, which eventually prevailed because of its superior power, range, and convenience. Recently, interest in the electric vehicle has been revived because the EV can derive energy from sources other than petroleum and because the vehicle itself emits virtually no air pollutants. The EV is also quiet in operation.

The electric vehicle has some major disadvantages, however, that deter its use as an all-purpose passenger car. The performance of the EV does not compare favorably with that of the conventional automobile in terms of speed, acceleration, range, and load-carrying capacity. The solution to these problems lies in the development of a battery that will provide higher energy and power density than the present lead-acid battery at a moderate cost. One possible alternative, the nickel-zinc battery, which offers about twice the energy capacity of the lead-acid battery, is nearly ready for production. Other advanced high-temperature batteries such as the lithium-sulfide battery, are in early stages of development.

Electric automobiles have been given a boost by the passage of the Electric and Hybrid Vehicle Development and Demonstration Act of 1976. This act emphasizes the near-term deployment and demonstration of vehicles using available technologies. This demonstration program is helping to define the attributes, deficiencies, and problems of electric vehicles. The marketing of a special-purpose, limited-range vehicle may become a reality in the period 1985 to 2000.

Research is also being directed toward methods to supplement the performance of the basic electric vehicle. One approach is to use regenerative braking, which converts some of the vehicle's momentum back into electrical energy. Another approach is to store energy mechanically by means of a flywheel, which can be used separately or in combination with a battery storage system. Further improvements in EV performance can be obtained by combining a combustion engine with the electrical energy storage system. This combination, known as a hybrid vehicle, provides greater range and performance than can be obtained with a vehicle powered by electricity alone. Demonstration of hybrids is also a part of the program being conducted by the Department of Energy (DOE), but so far very few have been built and tested. It is too early to predict the role that hybrid vehicles might play as a future form of automobile transportation.

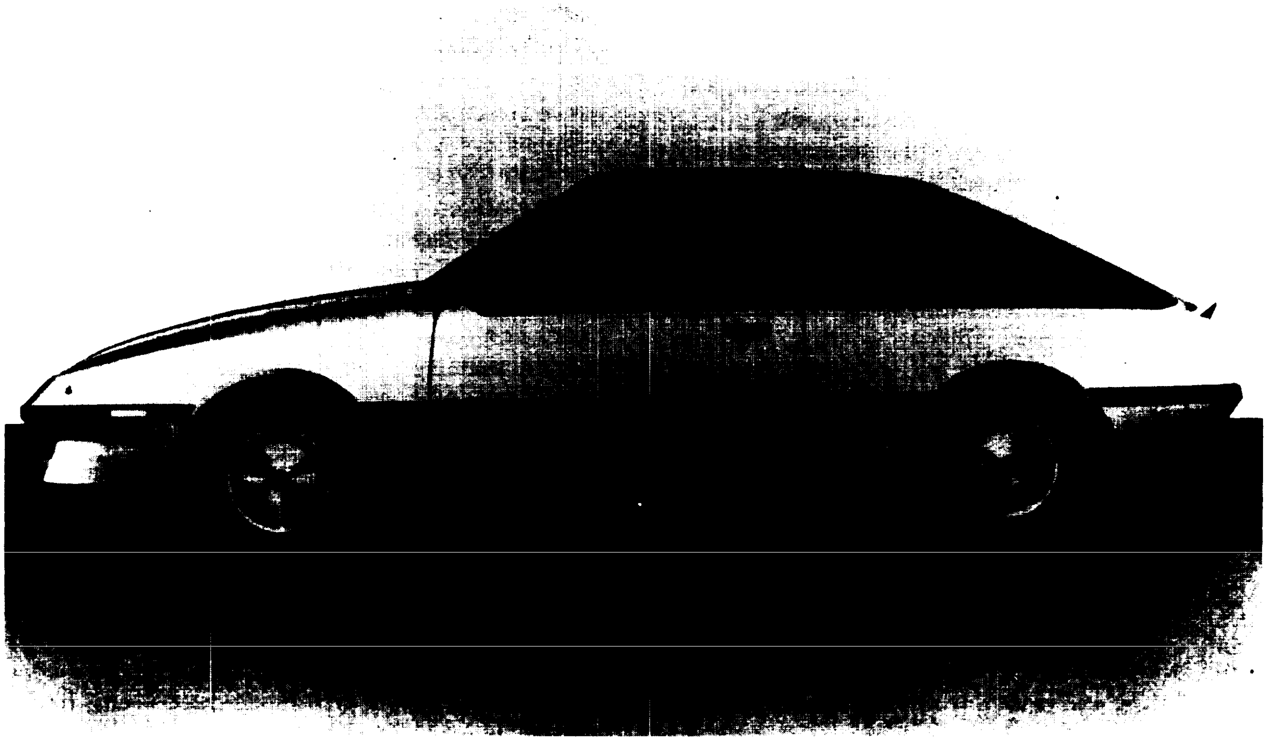


Photo Credit: General Electric

. . . interest in the electric vehicle has been revived . . .

FINDINGS

Based on analysis of near-term and far-term prospects for development of automobile technology, we find that:

- The 1985 fuel-economy goal appears to be technologically achievable, but at the expense of some large-car production.
- It is possible to meet the currently mandated emission standards without serious penalty in fuel economy.
- Small cars can be designed to be more crashworthy at a nominal weight and cost penalty.
- Diesels presently offer a substantial advantage in fuel economy over spark-ignition engines, but the problem of particulate emissions must be solved before the diesel can be suitable as a wide-scale substitute for the spark-ignition engine.
- Liquid fuels from oil shale, coal, and tar sands can be used to power automobiles, but deposits of only the first two are sufficient to be considered significant domestic energy sources for automobiles. Production of liquid fuels from either oil shale or coal is not expected to reach commercial scale until the 1990's at the earliest, and even then only if large capital investments in extraction and processing facilities are made soon. The environmental and safety hazards of producing and using these substitute fuels need further examination.
- Alcohol is an attractive fuel that can be used as a blend with gasoline in present engines at a cost slightly greater than gasoline. The use of pure alcohol as a motor fuel requires some changes in the engine and may require modification of the fuel transport, storage, and distribution system. Pure alcohol is not cost-competitive with gasoline at present. The environmental impacts of alcohol fuels need further study.
- The use of hydrogen as a motor fuel is not a practical alternative until sometime after 2000. There are many problems of production, storage, and handling to be overcome.
- As long-term options, the gas turbine and Stirling engines are attractive in terms of fuel economy, reduced emissions, and multifuel capability. Development is under way, but they are not expected to reach the automobile market until 1990 at the earliest.
- The benefits of electric vehicles are reduced petroleum consumption and the virtual elimination of air pollution from the vehicle itself. The development of improved batteries is the critical technological problem. Electric vehicles, designed for special purposes and limited use, may be on the road in significant quantities by the mid-1980's.

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