Technology Assessment of Changes in the Future Use and Characteristics of the Automobile Transportation System—Volume II: Technical Report

February 1979

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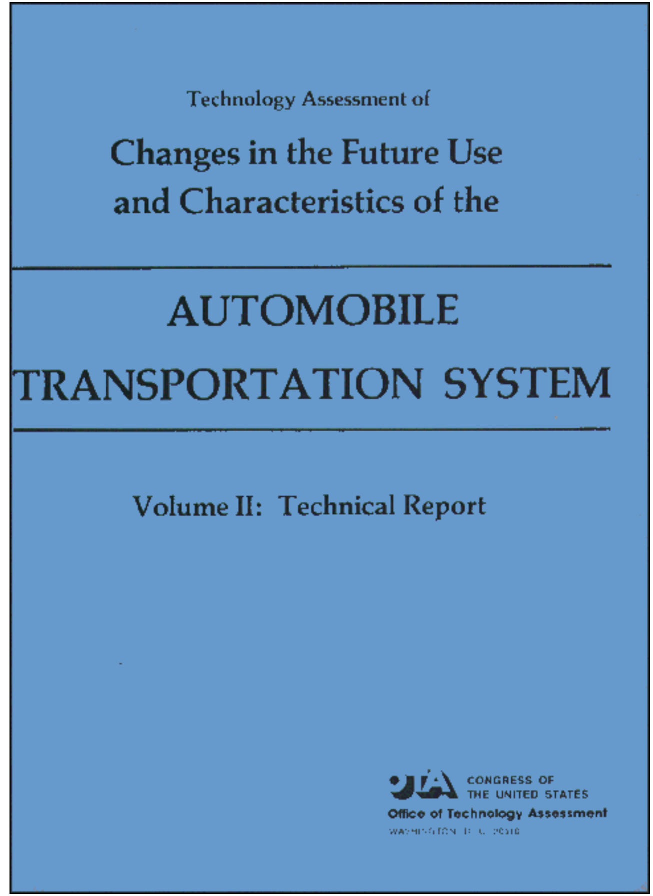

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Preface

Origin of the Assessment

This assessment of the automobile transportation system was undertaken at the request of Chairman Warren G. Magnuson of the Senate Commerce, Science, and Transportation Committee. It examines the automobile as a mode of personal transportation and considers issues and policy options pertaining to vehicles, highways, and related industries, services, and institutions. The assessment was authorized in February 1976 by the Technology Assessment Board, which approved a program to:

> "Assess the changes in the future use and characteristics of the automobile transportation system in the near term (to 1985) and the long term (to 2000 and beyond)."

The objectives of the automobile technology assessment were:

- To describe the factors that influence the characteristics of the automobile system, its use, and the services supporting its use,
- To identify and characterize potential changes in automobile characteristics and use,
- To assess the near-term and far-term effects of various alternative Federal Government policies relating to automobile characteristics and use,
- To present the findings of the assessment in a form useful to Congress and the public.

Study Approach

As a first step in the assessment, OTA identified a number of issues that now confront, or in the future might confront, the Congress in formulating policies related to the automobile. These issues were grouped in five areas:

- Energy—conserving petroleum as a motor fuel and making the transition to alternate energy sources,
- Environment—protecting the environment from the adverse effects of automobile use,
- Safety—reducing the toll of death and injury on the highways,
- Mobility—providing adequate personal mobility for all, either by automobile or by alternate modes of transportation, and
- Cost and Capital—dealing with the consumer costs of personal transportation and assuring the capital resources to support the evolution of the automobile transportation system.

With the assistance of the Automobile Assessment Advisory Panel and independent consultants, the OTA Transportation Group prepared a series of working papers describing these issues and identifying the interests of various stakeholders. These papers were issued in October 1977 and served as a framework for later activities in the assessment.

The major task of the assessment, analysis of policy alternatives, was carried out with the help of two contractors: SRI International and a team composed of System Design Concepts, Inc. (Sydec), Energy and Environmental Analysis, Inc. (EEA), and The Institute for Safety Analysis, Inc. The results of these contractor efforts are contained in two working documents:

Potential Changes in the Use and Characteristics of the Automobile, Stanford Research Institute International, January 1978.

Technology Assessment of Changes in the Future Use and Characteristics of the Automobile, System Design Concepts, Inc.; Energy and Environmental Analysis, Inc.; The Institute for Safety Analysis, Inc., January 1978.

Based on these studies, the OTA Transportation Group has prepared this report, which is a synthesis of the contractors' work and supplementary analyses by the OTA staff and consultants. Thus, while this report is derived from material prepared by contractors, OTA bears sole responsibility for interpretation of the information and presentation of findings.

Organization of the Report

This report consists of three basic parts. The first part—chapters 1 through 4—contains background information, a description of the elements of the automobile transportation system, Base Case projections, and delineation of the policy alternatives that were considered. These chapters provide a baseline of present and future automobile system characteristics that serves as the frame of reference for policy analysis.

The second part of the report—chapters 5 through 9—contains analyses of policy options in each of the five issue areas: energy, environment, safety, mobility, and cost and capital. Each chapter is similarly organized and contains a discussion of issues, a summary of present policy, a statement of policy options, and analysis of effects and impacts.

The third part of the report—chapter 10—is a survey of expected technological developments in the near term (through 1985) and in the far term (to 2000 and beyond).

A summary of major findings is presented at the beginning of each chapter. A detailed table of contents is also provided at the beginning of each chapter to facilitate reference to specific topics.

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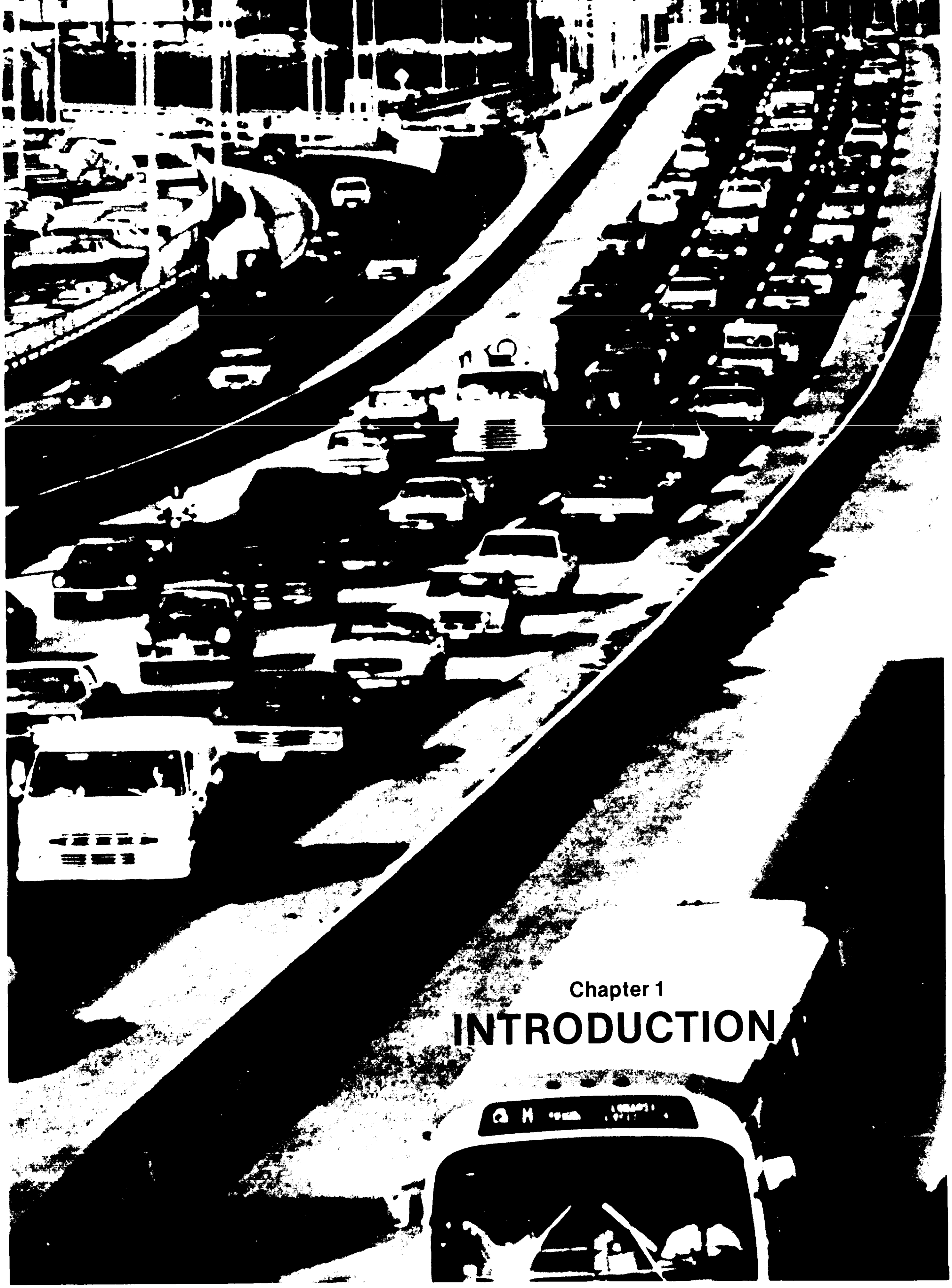
The OTA Automobile Assessment Advisory Panel provided valuable advice, critique, and assistance to the OTA staff throughout this assessment. Their participation, however, does not necessarily constitute approval or endorsement of this report. OTA assumes sole responsibility for the report and the accuracy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

Contents

NOTE: This report contains detailed projections, policy analyses, and technological forecasts. It is intended as a supporting document for the separately published summary and findings report, which presents a summary of study results and a statement of the major findings on issues, future trends, policy options, and technological developments.



Chapter 1

INTRODUCTION

Chapter I.—INTRODUCTION

INTRODUCTION

CHAPTER 1

BACKGROUND

During this century, the automobile has become a central feature of American society. The overwhelming proportion of personal travel in this country is now by auto. There are now over 100 million passenger vehicles in the United States—about one for each two people. Every year automobiles accumulate over 1 trillion miles of travel over a paved road and street network of nearly 4 million miles. The automobile influences personal decisions about where to live, work, and shop and about hundreds of other activities and pursuits. It has become fundamental to our way of 1ife.

The emergence of the automobile as the predominant form of personal transportation has been fostered by a wide variety of public policies. These include policies that provide direct support of automobile transportation, such as taxes to finance the vast roadway network, and those that provide indirect support, such as price controls to ensure low-cost gasoline. Other public policies have encouraged urban and suburban development patterns that are geared to extensive automobile use. At the same time, public transportation services, which provide alternative modes of urban and intercity travel, have been allowed to deteriorate. The combined result of these policies—intentional and otherwise—has been increasing reliance on the automobile for personal transportation.

In recent years, it has become evident that continued dependence on the automobile gives rise to conflicts with other needs or goals of our society. It is recognized that automobile use produces degradation of the environment. Automobiles consume a large share of increasingly scarce petroleum supplies. Automobile crashes are a principal cause of death and injury.

Clearly, the problems related to automobile use are important from the standpoint of public policy. Equally important are the opportunities and benefits that the automobile affords. These include the major role of the automobile manufacturing, supply, and service industries in the American economy and the extensive personal mobility that the automobile provides. The challenge confronting the policy maker is how to preserve and extend the benefits of automobile transportation while guarding against the adverse effects brought by present and future automobile technology.

The automobile transportation system is both large and complex. It encompasses not only the vehicle and the associated manufacturing, service, repair, fuel, and insurance industries but also the highway system, which includes construction, maintenance, policing, and traffic management. The highway system serves more than just private passenger vehicles. It also serves trucking and the various modes of mass transportation that use the public way. This assessment, however, concentrates on the passenger car and the industries, facilities, and services that support its *use* as a mode of personal transportation. Other modes of travel are considered only insofar as they represent alternatives to the automobile as means of personal transportation. For the purposes of this assessment, the automobile is defined as a vehicle designed primarily for private passenger use. [1]

Even with this limited definition of the automobile transportation system, the number of concerns that could be addressed is still quite large and some selectivity is necessary to

[1]Technically, the automobile is defined here as a four-wheeled passenger vehicle with a gross weight of less than 6,000 pounds. Coupes, sedans, and station wagons of all sizes are considered automobiles. Light trucks and vans, even though used as passenger vehicles, are not included. Motorcycles and mopeds are also excluded.

achieve a proper focus. This assessment concentrates on five groups of issues that now confront, or may confront, Congress in formulating policies relating to the automobile. They are:

- Energy—conserving petroleum as a motor fuel and making a transition to alternate energy sources.
- Environment—protecting the environment from the adverse effects of automobile use.
- Safety—reducing death and injury on streets and highways.
- Mobility—providing adequate personal mobility for all, either by automobile or other modes of transportation.
- Cost and Capital—controlling the consumer and public costs of automobile transportation and assuring the capital resources to support the evolution of the automobile transportation system.

ISSUES

Energy

Over the last 50 or 60 years, trillions of dollars have been spent structuring our transportation system, our cities, our jobs, and our lifestyles around the automobile. The dominance of the automobile has been made possible by a plentiful and inexpensive supply of fuel from petroleum. We now have 25 to 50 years (if current estimates of world reserves are accurate) to make the transition to alternate sources of energy. This period will be characterized by increasingly higher gasoline prices as the supply of petroleum diminishes.

The energy problem is complicated by uncertainties of both supply and demand. A point of particular uncertainty is how much time is available to make a transition to alternate energy sources before petroleum supplies are severely depleted or become prohibitively costly.

The problem is compounded by several factors. For example, the development of new energy supplies requires leadtime. Conservation measures can help in this regard, but implementation of these conservation measures also requires leadtime. In addition, petroleum will be required as fuel in the effort to develop alternative energy sources. Finally, the environmental and safety effects of alternate fuels and engines add considerable risk that industry investments may prove unwise in the light of future events and emerging conditions.

The energy issues explored in this assessment address the two fundamental ways of reducing

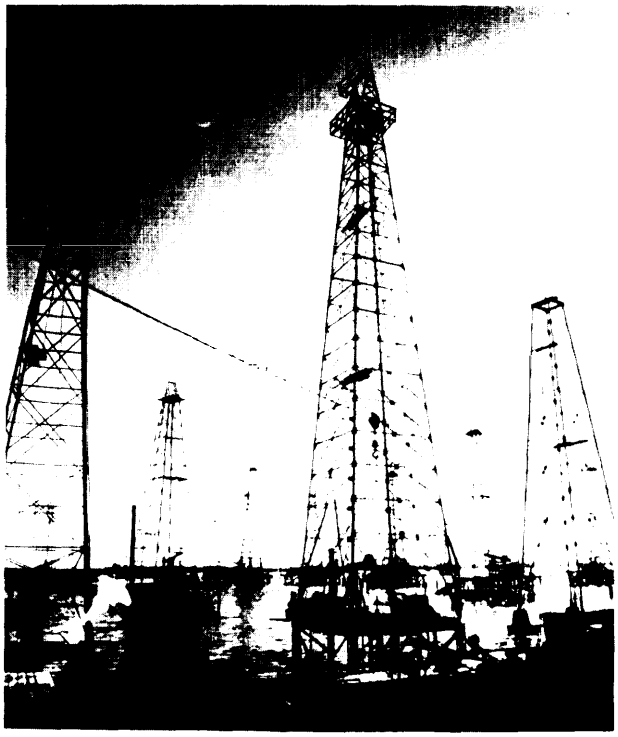


Photo Credit: U.S. Department of Energy

the dependence of the automobile on petroleum: expanding alternate energy supplies and limiting petroleum demand.

Since the gasoline shortage of 1973-74, the Federal Government has adopted policies to accomplish both petroleum conservation and development of new energy supplies. The regulation of the automobile, which now consumes 30 percent of the petroleum used in this country, has been an important part of the effort. Policies intended to reduce automobile fuel consumption have included regulation of automobile fuel economy, imposition of a nationwide 55 mph speed limit, and encouragement of ride sharing. In addition, the Federal Government now has programs for development of *new* engine technologies, for supporting the development and demonstration of electric and hybrid vehicles, and for the development of synthetic fuels from oil shale and coal.

With the clear prospect of diminishing petroleum supply, the need to pursue both conservation and the transition to alternate sources of energy is apparent. The pressures created by an energy shortage could alter many facets of American life, including the use of the automobile for personal transportation. These issues, and their important implications for this country and its citizens, form one of the focal points of the assessment.

Environment

There are two major trends in modern industrialized society that create concern about the environment. The first is the increasing amount of wastes produced by growing populations and expanding industrial and technological activities. The second is the changing nature of pollutants, many of which are hazardous to human health and the ecological systems that support human life. Although opinion in the scientific community is sharply divided about the danger of specific pollutants and the overall seriousness of the environmental problem, it is widely agreed that continued emission of increasing amounts of pollutants could cause grave, and perhaps irreparable, damage to the air we breathe, the water we drink, and the land where we grow our food.

Within the last two decades, attention has been drawn to the automobile system as a major source of pollution. The environmental effects of the automobile—most notably atmospheric pollution—have become subjects of widespread concern to the scientific community, governments, and the general public. This concern culminated in the passage of the Clean Air Act (and its subsequent amendments) and the National Environmental Policy Act.

With this legislation, particularly the 1970 amendments to the Clean Air P.et, Congress embarked on a major program to reduce atmospheric pollution caused by automobile emis-

Photo Credit: U.S. Department of Transportation

sions. The administration of the Clean Air Act and the modification and extension of its provisions in 1977 have generated deep controversy among the Federal Government, the automobile industry, and the public concerned about the environment.

The environmental effects of the automobile system are not limited to atmospheric pollution. The noise of vehicles, the disposal of solid wastes (scrap vehicles and major parts, such as tires and batteries), the contamination of water by spilled lubricants, spilled fuel and road salt, and the adverse impacts of automobiles and highways on cities, rural areas, and natural preserves are problems that also require attention.

The issues that emerge from the general problem of how to prevent environmental damage by the automobile system are highly controversial. Public health and well-being are at stake. But so, too, is the economic health of an industry that constitutes a major share of the economy and provides the dominant mode of personal transportation for American workers and families. The Federal Government has a clear responsibility to protect the public interest, but in so doing it must be mindful of the equity of the measures it adopts.

Thus, the issues of how to protect the environment from the adverse impacts of the automobile, and the policies available to the Federal Government to accomplish this, have an important place in this assessment.

Safety

Despite significant improvements in safety over the years, the automobile remains a principal cause of death and injury in the United States. The number of automobile deaths in this country since 1900 (2 million) is 3 times the number of battle deaths (652,000) suffered by the United States in all wars. In 1977 nearly 48,000 Americans died as a result of motor vehicle crashes, and over 4.4 million were injured.[2]

The earliest Federal response to the highway safety problem came in 1924, with the First National Conference on Street and Highway Safety. The conference dealt with matters such as traffic control, construction and engineering, education, and motor vehicle design. Many of these subjects are still controversial issues in highway safety today.

Additional conferences were held over the following three decades, but little specific action by the Federal Government resulted. Beginning in the 1950's, however, a more intense interest in highway safety was displayed by Congress and the executive branch, and several programs were initiated.

The Federal Government did not become heavily involved in automobile safety, however, until 1966 when Congress enacted the National Traffic and Motor Vehicle Safety Act and the Highway Safety Act. The former established safety standards and mandatory inspection programs for motor vehicles used in interstate commerce. The latter provided financial assistance to the States for highway safety programs.

At the present time, there are more than 50 Federal Motor Vehicle Safety Standards in force. Most of these apply to passenger cars. There are also 18 Federal Highway Safety Program Standards, dealing with highway design, driver licensing, police and medical services, and the like. This regulation of vehicle and highway safety features is considered to be partially responsible for the reduction in the rate of highway deaths that has occurred in the past decade. The rate, expressed in deaths per hundred million vehicle miles of travel, dropped from 5.7 in 1966 to 3.3 in 1977,

There are problems that may impede further safety improvements. The Federal Highway Administration claims, for example, that the highway safety problem is "aggravated by the diffusion of responsibility for safety."[3] Another problem which is cited is the reluctance of consumers to bear the increased costs of safety features. Also, there is a tug-of-war between consumers who are resisting mandated safety equipment as an infringement of civil rights and some citizen groups and insurance companies who are pushing hard for development and mandated use of more safety devices in cars.

[2] U. S. Department of Transportation, Fatal Accident Reporting System, 1977 data (republication); U.S. Public Health Service, Division of Vital Statistics, 1977 data (republication).

[3] U.S. Department of Transportation, Federal Highway Administration, *The Role of FHWA in Highway Safety, 1964-1976* (Washington, D. C., August 1977), p. 8.

In addition to these concerns, there is the potential for conflict between improved safety and automobile energy conservation. Smaller cars, which are desirable because of their fuel economy, may offer less protection for occupants in crashes. The introduction of features to improve crashworthiness may add to the weight of the vehicle and entail a penalty in fuel economy.

Safety is a complex problem that involves driver behavior, vehicle characteristics, roadway features, and driving conditions. Safety must be approached both as a question of vehicle and roadway design and as a question of use—driving habits, traffic regulation, law enforcement, risk management. Safety is not just an individual concern. Industry has an important part to play. All levels of government—local, State, and Federal—are involved. There is no single, simple solution to the problem of highway deaths and injuries, and the public policy questions relating to the safety of the automobile transportation system are among the thorniest that must be faced.

Mobility

One of the goals of society is to enable citizens to take part in activities that improve and maintain their social and economic well-being. Essential to the attainment of this goal is the ability to reach jobs, services, consumer outlets, recreation sites, and other locations. To this end, the Federal Government has acted as a major provider and regulator of transportation services. The challenge today is to find new technological and institutional solutions that will improve the individual's ability to reach desired and necessary activities in a way that is compatible with other national goals such as energy conservation, environmental preservation, and public safety.

Federal policies supporting automobile use date back to the beginning of this century. The first act providing Federal aid for highways was passed in **1916.** The series of highway acts which followed have provided increasingly greater Federal support and have expanded the extent of Federal involvement. In 1956, Con-

Photo Credit U S Department of Transportatlon gress enacted legislation that established the Interstate Highway System and provided a source of financing—the Highway Trust Fund. In recent years, Federal policy has imposed numerous conditions on the use of highway funds, such as requirements for comprehensive planning and for environmental impact assessment. Also, the types of activities that may be financed with Federal highway funds have been expanded considerably; for example, highway funds may now be used for certain types of public transportation projects,

Auto use has also been supported by Federal policy in less direct ways. Price controls on gasoline have kept fuel costs low. Suburban and exurban development, which is heavily dependent on auto use, has been encouraged by Federal mortgage assistance policies. Until recently, there was essentially no Federal support for public transportation. Transit systems in many urban areas deteriorated badly. Service levels were reduced, costs rose, private entrepreneurs went bankrupt, and local governments were forced to assume ownership and operation. Public transit, which could have provided an alternative to auto use, declined further and became even less attractive.

Several factors have come into play recently to force a reevaluation of Federal policy toward personal transportation in general, and auto use in particular. Concern about future energy supply and environmental protection has focused attention on the automobile as a contributor to these problems. There is increasing awareness that mobility itself is deteriorating as a result of traffic congestion. Finally, there is concern that some segments of the population cannot share in the mobility provided by the automobile. These include those who cannot afford to own and operate a car, handicapped persons, some elderly persons, and those who are too young to drive. The decline of public transit and the growing dominance of the automobile often deprives these persons of the mobility enjoyed by others.

The consideration of mobility in this assessment focuses on the future role of the automobile in providing mobility and on the broader issue of the role of the Federal Government in providing adequate personal mobility for all, either by automobile or by alternate modes of transportation.

Cost and Capital

The automobile has a far-reaching impact on the U.S. economy. The automobile transportation system, when defined in its broadest sense, accounts for approximately 10 percent of the gross national product and is the direct employer of about 1 out of every 18 American workers.[4] The employment opportunities created by the automobile transportation system are not only vast, but widely varied. Jobs exist in both the public and private sectors and require such skills as production and manufacturing, maintenance and repair, law enforcement, regulation, research and development, traffic management, international finance, economics, and construction.

Photo Crecfit U S Department of Housing & Urban Development

One of the most complex issues concerning the automobile is the cost of the system, on both a national and an individual scale. Along with food and housing, automobile transportation is one of the three major items in the average household budget. It amounts to an annual total outlay of **$130** billion and represents about 13 percent of personal consumption expenditures.[5]

[4]Transportation Association of America, *Transportation Facts and Trends*, Thirteenth Edition, July 1977, pp. 1, 3, 5, 23, A-2 and A-13.

[5]U.S. Department of Transportation, *National Transportation Trends and Choices (to the Year 2000)* (Washington, D.C.: U.S. Government Printing Office, 1977), pp. 85 and 87.

Thus, policies that change the costs of automobile ownership and use will have wide-ranging effects on the American consumer.

On a national level, the public cost of the automobile transportation system is most visible in expenditures for roadbuilding. The Federal Highway Administration estimates that approximately **$30** billion was spent for highway purposes by all levels of government in 1976. Federal aid, which was applied to 950,000 miles of road carrying about three-quarters of all vehicle traffic, [b] amounted to about $7 billion.

The Federal Government's investment in the automobile transportation system is not limited to road construction. Support is also given to the fuel and materials industries, *in* the *form* of depletion allowances. In addition, the types of highway projects that are eligible for Federal assistance have progressively been expanded. Federal aid is now available for relocation assistance for residents and business establishments displaced by road construction. Federal highway monies may also be used for research and development, land acquisition, highway beautification, safety programs, emergency relief, construction of parking facilities, education and training, noise abatement, and more.

The issues of cost and capital could have a powerful influence on the future development of the automobile transportation system. The assessment focuses on those areas where Federal policy could influence the economics of the system and the course of future technological development.

[b]Ellis L. Armstrong, ed., *History of Public Works in the United States 1776-1976* (Washington, D.C.: American Public Works Association, 1976) p. 54.

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Chapter 2.—CHARACTERIZATION OF THE AUTOMOBILE TRANSPORTATION SYSTEM

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CHARACTERIZATION OF THE AUTOMOBILE TRANSPORTATION SYSTEM

CHAPTER 2

The automobile transportation system can be described in many ways. Chapter 1 includes an informal description that offers some perspectives on the role that automobiles and highways play in our society, This chapter provides a different kind of description—a more formal characterization that defines the major elements of the automobile transportation system and shows the relationships among these elements. The purpose is to describe, in quantitative terms, the parts of the system and to delineate the effects that the automobile system has on society.

Figure 1 is a diagram of the major elements of the automobile transportation system. These elements are shown by the boxes lettered *A* through *M*, The arrows indicate the principal interactions among the elements of the system. For simplicity, no attempt has been made to diagram all of the relationships. Only those that represent the major links among the social, economic, political, and institutional parts of the system are shown. The diagram also illustrates how stakeholders influence the automobile system and, in turn, are affected by it.

Stakeholders

The stakeholders in the automobile system are many and diverse. In one way or another, everyone can be considered a stakeholder with interests in the benefits conferred by the automobile and in the costs that it imposes. Most individuals and organizations hold not one, but several stakes which may conflict at times. For example, there is the automobile owner and user who might favor policies to promote fast and uncontested driving conditions, but who might be opposed to a planned highway affecting his neighborhood and property values. Similarly, there might be unanimity within the auto industry on policies to promote the use of the automobile, but sharp division of opinion on a standard requiring some safety device. The parts supplier might view the standard as advantageous, while the automobile manufacturer might see it as cutting into sales.

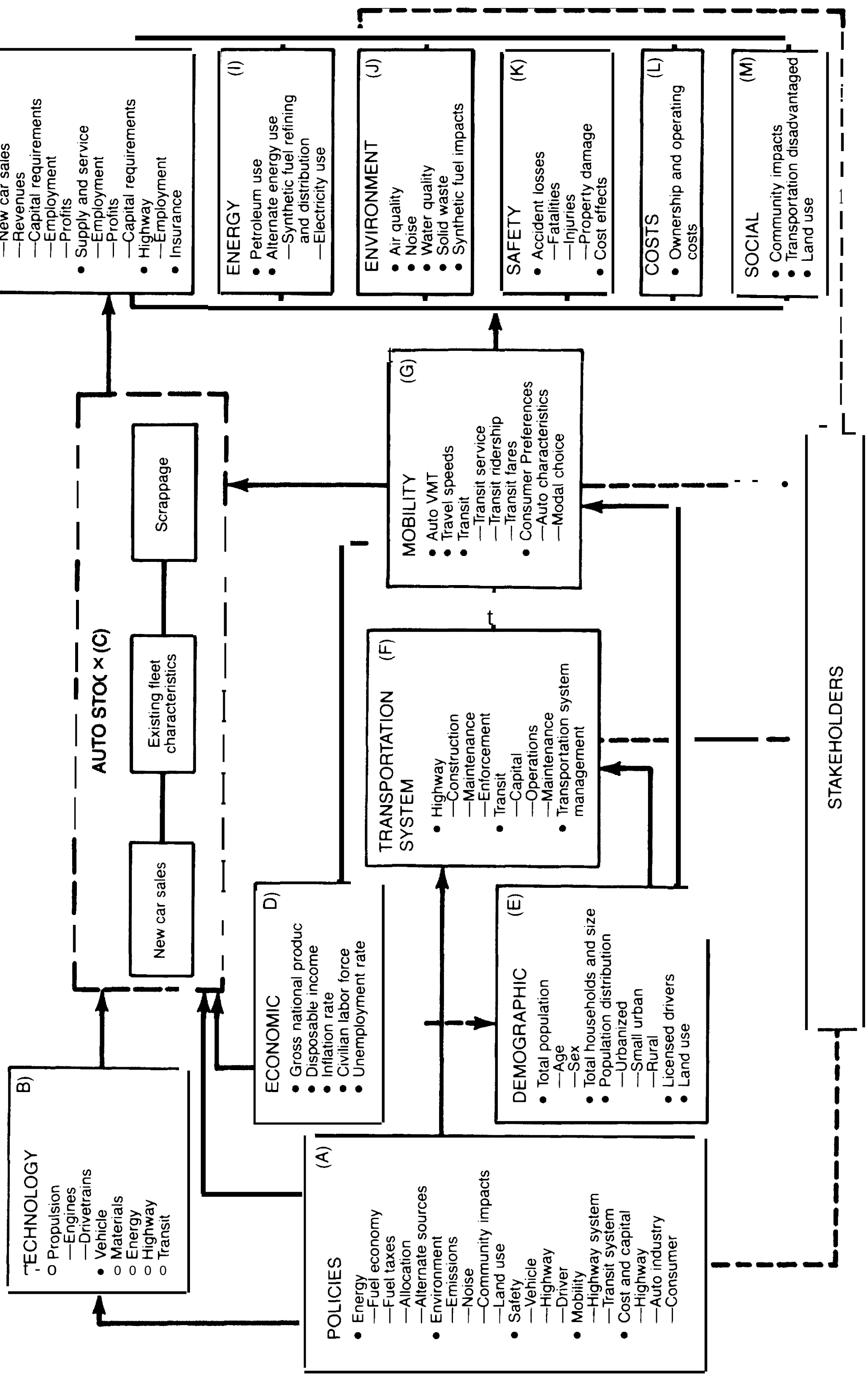
There are many examples where individuals, organizations, and institutions find different aspects of their self-interest in conflict. There are also many instances in which stakeholders may group together on one policy issue but realine with other stakeholders on other issues. Because stakeholder interests are so varied and conflicting, it is not possible to show their relationship to the automobile system in a simple diagrammatic *way.* The lines in figure 1 connecting stakeholders to the automobile system are intended only to suggest the major avenues through which stakeholder interests are brought to bear and through which stakeholder interests are affected.

Policies (A)[1]

There are hundreds of policies that have a direct or indirect effect on the characteristics and use of the automobile system. For this study, the list of present policies has been limited to those that have a major and direct influence on automobiles and highways, on industry structure, on institutional relationships, or on personal transportation. These policies are cited in table 1, where they are grouped according to the five categories of issues addressed in this study.

[1] The letters refer to the corresponding boxes in the automobile system diagram, figure 1.

Figure 1.—Automobile Transportation System Elements and Interrelationships



SOURCE: Office of Technology Assessment.

Table 1 .—Major Policies Affecting the Automobile Transportation System

Title	Provisions
Energy	
Emergency Highway Energy Conservation Act of 1974 (PL 93-239)	Required States to reduce speed limit to 55 mph on all highways Provided for carpool demonstration projects
Federal-Aid Highway Act Amendments of 1974 (PL 93-643)	Extended 55-mph speed limit indefinitely
Energy Policy and Conservation Act of 1975 (PL 94-163)	Standby authority for gasoline rationing Mandated new car fleet average fuel economy (27,5 mpg by 1985)
Electric and Hybrid Vehicle Research and Development Act of 1976 (PL 94-41 3)	Established program to develop and demonstrate electric or hybrid vehicles
Environment	
Department of Transportation Act of 1966 (PL 89-670)	Declared a national policy to protect and preserve natural, recreational, and historic sites from intrusion by highways
National Environmental Policy Act of 1969 (PL 91-190)	Established requirement for assessment of environmental impacts of public works projects (including highways) Established Council on Environmental Quality
Federal-Aid Highway Act of 1970 (PL 91-605)	Required development of guidelines to control adverse economic, social, and environmental impacts of highways Required Federal-State cooperation for long-range highway planning
Uniform Relocation Assistance and Land Acquisition Policies Act of 1970 (PL 91-646)	Established uniform policy for land acquisition and treatment of persons displaced by highways
Clean Air Act of 1970 (PL 91-614) and 1977 Amendments (PL 95-95)	Established standards for CO, HC, and NO_x emissions by new autos Required inspection and maintenance programs in certain urban areas
Noise Control Act of 1972 (PL 92-754)	Authorized establishment of noise standards for products distributed in interstate commerce (including automobiles)
Safety	
National Traffic and Motor Vehicle Safety Act of 1966, and Amendments (PL 89-563)	Established National Traffic Safety Agency (later NHTSA) Set safety performance standards for motor vehicles
Highway Safety Act of 1966 (PL 89-564)	Established National Highway Safety Agency (later NHTSA) Required States to have a highway safety program to reduce reduce death, injury, and property damage
Motor Vehicle Information and Cost Savings Act of 1972 (PL 92-513)	Required use of energy-absorbing bumpers
Highway Safety Act of 1973 (PL 93-87)	Authorized Federal-aid highway funds for safety programs and safety R&D
Mobility	
Federal-Aid Highway Acts 1954 through 1976	Appropriated funds for federally aided highway systems Designated the National System of Interstate and Defense Highways and appropriated funds therefore Provided for use of highway funds for certain mass transit improvements
Urban Mass Transportation Act of 1964 (PL 88-365)	Provided for Federal assistance in developing improved transit facilities, equipment, and techniques Encouraged planning and establishment of areawide mass transit Provided assistance to State and local agencies in financing transit capital improvements and operations
Cost *and Capital*	
Highway Revenue Act of 1956 (PL 85-823)	Imposed a Federal tax of 4¢/gal on motor fuel Established Highway Trust Fund Established pay-as-you-build principle
Motor Vehicle Information and Cost Savings Act of 1972 (PL 92-513)	Required a consumer information study to examine susceptibility to damage, crashworthyness, and characteristics of the repair system Provided for diagnostic demonstration projects Prohibited odometer tampering
Magnuson-Moss Warranty Act of 1974 (PL 93-637)	Established automobile warranty requirements Authorized FTC to make rules on unfair or deceptive warranty practices

Technology (B)

The basic technology of the automobile has changed very little over the years. Although major improvements and refinements have been added, the internal combustion (Otto cycle) engine remains virtually the only means of propulsion. The fuel is still almost exclusively gasoline. Transmission, suspension, chassis, and body designs are not fundamentally different from those of early automobiles. However, the modifications that have been made to the basic technology have made a difference, and the operating characteristics of the automobile have substantially improved over time. Among the innovations that have been introduced are the electric starter, the automatic transmission, power-assisted braking and steering, emission control, electronic regulation of ignition and carburetion, and improved occupant safety and comfort.

The development of the automobile system over the remainder of this century will be determined largely by technological changes that are already under development—alternate engines, improved drivetrains, safety devices, emission control equipment, and vehicle downsizing. These coming changes will be influenced more strongly by Government policy than were those in the past. They will place demands on the automobile industry to improve fuel economy, reduce emissions, and increase occupant safety. Consumer preferences and acceptance of public policy goals will also exert influence on automobile technology—either directly, through mechanisms of the marketplace, or indirectly, through the political process.

The effects of national policies on automobile manufacturers and parts suppliers will depend, in part, on the ability of the industry to generate the capital needed for development of new technology along the lines dictated by policy. Capital formation, in turn, depends on consumer acceptance of the products and on the profitability of the resulting sales mix.

Auto Stock (C)

The performance of the automobile transportation system depends on the composition of the vehicle fleet and changes in the characteristics of the fleet over time. (See table 2.)

Table 2.—Characteristics of the Automobile Stock, 1976

	Volume (millions)	Percent of new car sales[a]
New car sales		
Subcompact	2.23	22
Compact	1.92	19
Small luxury	0.51	5
Intermediate	2.83	29
Standard	2.02	20
Large luxury	0.61	6
Total	10.12	
Auto fleet		
Size	97,800,000	
Average age	6,2 years	
Annual scrappage rate	70/0	

[a]Does not sum to 100 because of rounding.
SOURCE: Sydec/EEA analysis of data from Motor Vehicle Manufacturer's Association, *Motor Vehicle Facts and Figures '77*, pp. 20 and 34.

Auto prices, operating costs, and the demand for travel influence the level and the mix of new car sales. Demographic factors also influence the growth of new car sales.

The annual introduction of new cars and the rate of retirement of old cars determine the range and average of fuel economies, emissions, and performance features of the auto fleet. These characteristics, in turn, help determine total gasoline consumption, emissions levels, and death and injury levels.

The rate of retirement of cars is primarily a function of age, although other factors such as cost of operation and repair, personal income, and changes in household composition also influence scrappage. Less than **6** percent of the cars on the road are over 13 years old, and the average age is slightly over **6** years. Between **6** and 10 percent of the fleet is scrapped each year.

Economics (D)

Macroeconomic conditions have a primary and direct effect on the use and characteristics of the auto system. The key economic factors include gross national product, disposable personal income, inflation rate, civilian labor force, and unemployment rate. (See table 3.)

Disposable personal income and employment are major determinants of consumer behavior.

Photo Credit General Motors Corporation

Table 3.—Selected 1976 Economic Data

Gross national product	**$1.7** trillion
Disposable personal income	$1.8 trillion
Disposable personal income per capita	$5,486
Consumer price index[a]	170.5
Civilian labor force	94.8 million
Unemployment rate	7.7 percent

[a]1967 = 100
SOURCE: U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, 1977

They influence the number and type of new autos sold, the length of time a car is kept in use, and the amount of travel. There is a close correlation among household income, the number of autos owned, and the number of miles traveled. When the economy is growing steadily, and when inflation rates are low and employment high, there is more personal income available for the purchase and use of automobiles.

Demographics (E)

Population growth, the number and size of households, their geographic distribution, and the number of licensed drivers are some of the factors that determine the size of the auto fleet and how it is used. In addition, the sex of the drivers also influences the amount of auto use. In 1975, over **90** percent of males of driving age had licenses. About 70 percent of driving-age females were licensed.[2] Male drivers *use* autos more extensively than females in all age categories; on the average, males drive about twice as many miles per year as females.[3]

Demographic factors, along with economic conditions, are determinants of residential location and, consequently, of population distribution. The important characteristics of the current population distribution are listed in table **4.**

Table 4.—Selected 1976 Demographic Data

Total population	215.1 million
Urbanized areas[a]	132.0 million
—Central cities	67.2 million
—Suburbs	64.8 million
Small urban areas[b]	29.3 million
Rural areas	53.8 million
Total households	72.9 million
Persons per household	2.9

[a]Areas of 50,000 or more population.
[b]Urban places of 2,500 to 50,000 population.
SOURCE: Sydec, from Bureau of the Census Series II data.

The nature and amount of auto travel is heavily influenced by land use—the pattern of residences in relation to business and recreational

[2]U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics Summary to 1975* (Washington, D.C.: U.S. Government Printing Office, 1977).

[3]U.S. Department of Transportation, Federal Highway Administration, *Nationwide Personal Transportation Study (1969-1970)*.

centers. Density of development is also an important factor. Demand for auto travel tends to be high where residential densities are low and where residences are distant from commercial and recreational sites. Auto travel demand is lower, on the other hand, in areas where commercial establishments and employment are interspersed with, and in proximity to, residences.

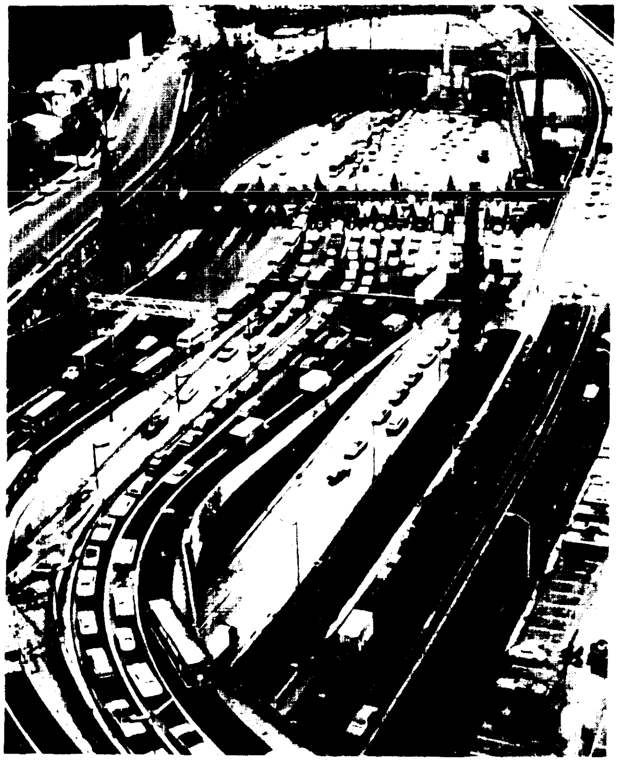


Photo Credit: U.S. Department of Transportation

Transportation System (F)

This portion of the system is made up of the facilities for personal transportation by auto and public transportation. It includes both highways and exclusive rights-of-way for public transportation. It also includes the transportation management system, which affects the relationship of highways and transit and determines the efficiency of their combined operation.

The location and type of highway facilities and the number of miles in the highway system are influenced by a variety of factors. The geographic distribution of population and, particularly, the juxtaposition and density of land uses determine the miles of highway needed and the feasibility of using mass transportation to satisfy some of the travel demand.

Federal policies strongly influence the size and location of highways by determining the amount of funds available, the types of facilities assisted, and the relative emphasis among transportation modes. (See table 5.) Other policies, such as fuel taxes and fuel-economy standards, affect Federal revenue and hence the funds available for highway construction, maintenance, and operation. Macroeconomic conditions also affect the amount of construction and maintenance that can be accomplished either with revenues from road users or with other legislatively appropriated funds.

Table 5.—Highway and Transit Expenditures, 1976 (billions of dollars)

	All government	Federal
Highways		
Capital	$14.30	$7.53[a]
Maintenance & other noncapital[b]	15.48	0.36
Total	29.78	7.89
Transit		
Capital	NA[c]	1.28[d]
Operating assistance	**1.65**	**0.43**
Total	—	**1.71**

[a]Includes $6.09 billion from the Highway Trust Fund, $1.07 billion of payments from other funds, and $0.375 billion in direct Federal expenditures.
[b]Includes administration, police, planning, research, and debt service.
[c]Not available.
[d]UMTA Section 3 authorizations; includes the transition quarter.
SOURCES: Federal Highway Administration, *Highway Statistics 1976*, table HF-10, p. 49. American Public Transit Association, *Transit Fact Book*, '76-'77 Edition, p. 20.

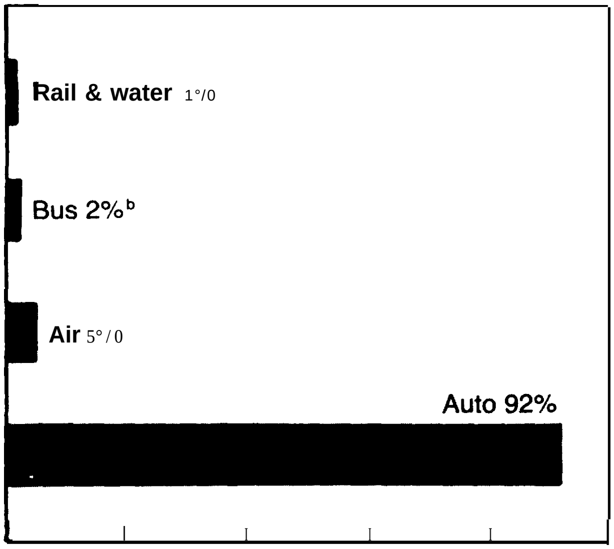
Mobility (G)

Mobility, defined as the satisfaction of travel demand, is the basic purpose of the automobile transportation system and the major benefit conferred by it. The parameters of mobility are number of trips, trip length, number of persons served, and the mode of transportation. Measured on any of these dimensions, the automobile is the dominant form of personal transportation in the United States. (See figure 2.) Each year automobiles accumulate over 1 trillion vehicle miles and account for over **90** percent of all passenger miles traveled. Mass transit, the major alternative to the automobile in urban areas, is an important substitute for some types of trips

Photo Credit: U.S. Department of Transportation

(notably the journey to work) but, in the national aggregate, accounts for under 2 percent of passenger miles traveled. (See tables 6 and 7.)

Figure 2.—Modes of Personal Transportation[a]



[a]1975 Data.
[b]Excludes school buses

SOURCE: U.S. Department of Transportation *National Transportation Trends and Choices (to the Year 2000)*, 1977, p. 85.

The magnitude of the effects of the automobile cannot be measured solely in terms of mobility, even though this is the ultimate purpose of the system. The characteristics and use of automobiles have important consequences in several areas. These are shown in boxes H through M of the automobile system diagram (figure 1) and described in the remaining sections of this chapter,

Table 6.—Passenger Car Use*

Purpose of travel	Percent distribution: Percent of trips	Percent distribution: Percent of travel (VMT)	Average trip length one-way (miles)
Work, including commuting	36	42	10.2
Family business, including shopping	31	19	5.6
Education, civic, or religious	9	5	4.7
Social and recreational	23	33	13.1

*1969 data.
SOURCE: Federal Highway Administration, *Nationwide Personal Transportation Study*, Report No. 10, "Purpose of Automobile Trips and Travel," 1974, p. 13.

Table 7.—Public Transit Ridership, 1977

Linked passenger trips[a]	(millions)
Rail	1,425
Trolley	51
Motor bus	4,247
Total	5,723
Average fare..,	37.7@

[a]Linked transit passenger trips are identical to revenue passengers, except that free-fare, originating passengers are included in linked trips.
SOURCE: American Public Transit Association, *Transit Fact Book*, '77-'78 Edition, pp. 27 and 32.

Automobile= Related Industries (H)

Some indication of the importance of the automobile system can be gained from the employment figures for industries directly involved in motor vehicle production and use.

- Motor vehicle and parts manufacturing—1,013,000
- Auto and parts retail dealers—1,152,000
- Auto and parts wholesale dealers–394,000
- Services and garages–476,000
- Gasoline service stations–624,000
- Construction of highways and streets—339,000
- Petroleum industries—427,000
- State and local highway departments—587,000.[4]

In addition to these 5 million employees, another estimated 400,000 people are employed by industries that serve as suppliers to auto manufacturers. [5]

Federal policies, in the form of automobile performance regulations, have a major effect on the automobile industry. Development of new technologies to satisfy these requirements bears directly on capital needs and on employment and profit levels in the manufacturing, auto supply, and service industries. The need for specialized diagnostic and maintenance equipment to service cars with new emission and fuel-saving devices, for example, could affect the concentration and size of firms in the auto service industry and add pressure on the labor market for skilled mechanics.

Personal disposable income is directly correlated with new car sales. Population distribution, the patterns and density of land use, and the nature and extent of the Nation's transportation system strongly influence auto travel demand, which in turn determines the size and composition of the auto fleet. Changes in fleet characteristics have a wide range of effects on auto-related industries, including the size and mix of new car sales, market shares among auto manufacturers, employment levels, profits, and the level of claims in the insurance industry. Table 8 presents some of the highlights of automobile industry economics.

Table 8.— Financial and Economic Data for the Automobile Industry[a] (1975 dollars)

Average new car price by size class		
Subcompact		$ 3,600
Compact		$ 4,200
Small luxury		$ 5,650
Intermediate		$ 4,600
Standard		$ 5,400
Large luxury		$ 8,000
Gross revenue per domestic car sold		$ 4,990
Annual domestic sales (thousands)		8,610
Annual domestic sales revenue (millions)		$42,950
Capital investment (millions)		$ 3,640
Auto manufacturing employment (domestic)[b]		948,000
Profit margin (1977) (percent)[c]		
U.S. auto industry		4.6
All manufacturing		4.5
U.S. auto industry net income (1977) (millions)		$4,590
GMC	$ 2,960	
Ford	$1,480	
Chrysler	$ 145	
AMC	$ 5	
U.S. auto industry net income as a percent of sales (1977)		4.6
GMC	6.1	
Ford		
Chrysler	(1.0)	
AMC	(0.3)	

[a]1976 data except as noted.
[b]Employment figures are for domestic manufacturers and include auto parts manufacture.
[c]Net income after taxes as a percentage of net sales.
SOURCES: Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures '76*, 1976, p. 16; Securities and Exchange Commission, Auto manufacturer's annual reports to the SEC; Wards Communications, Inc., *Wards 1977 Automotive Yearbook*, 1977; and Council on Wage and Price Stability, *Staff Report on 1977 Automobile Prices*, Washington, D.C., Oct. 27, 1977.

'Transportation Association of America, *Transportation Facts and Trends*, Fourteenth Edition (Washington, D. C.: Transportation Association of America, 1978), p. 23.

'Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures* '78 (Detroit: MVMA, 1978), p. 68,

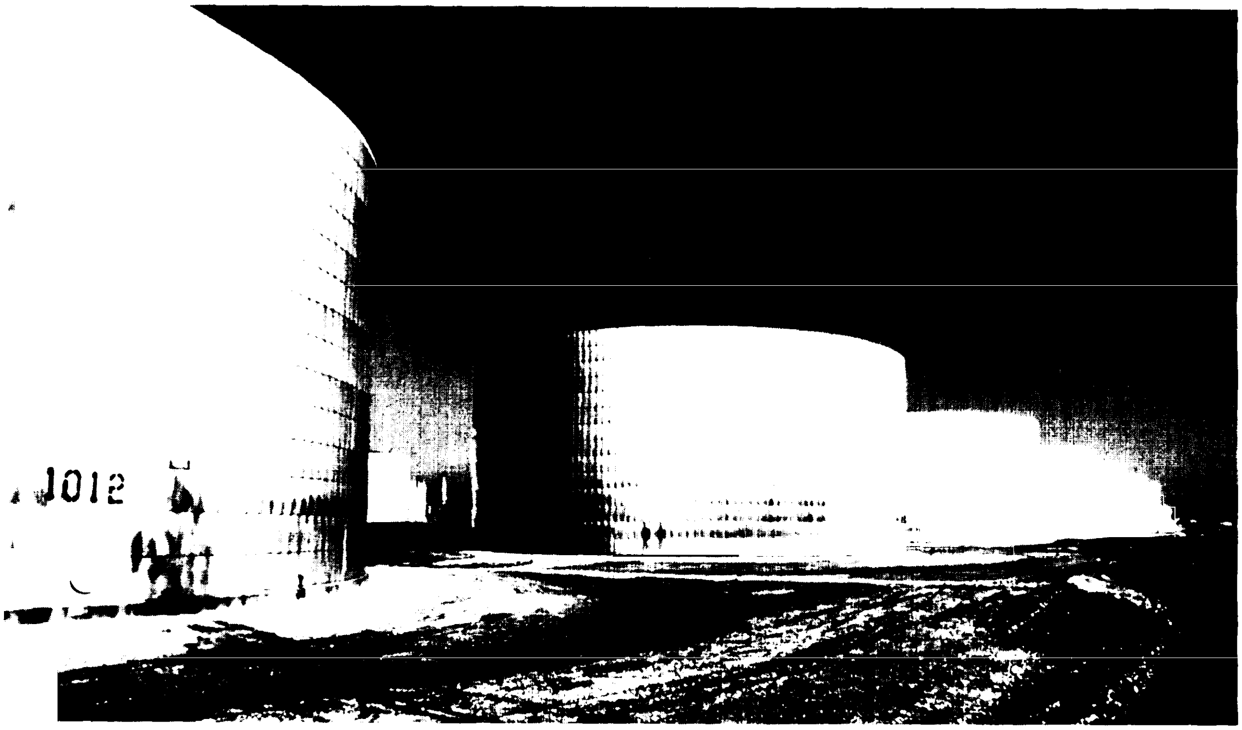


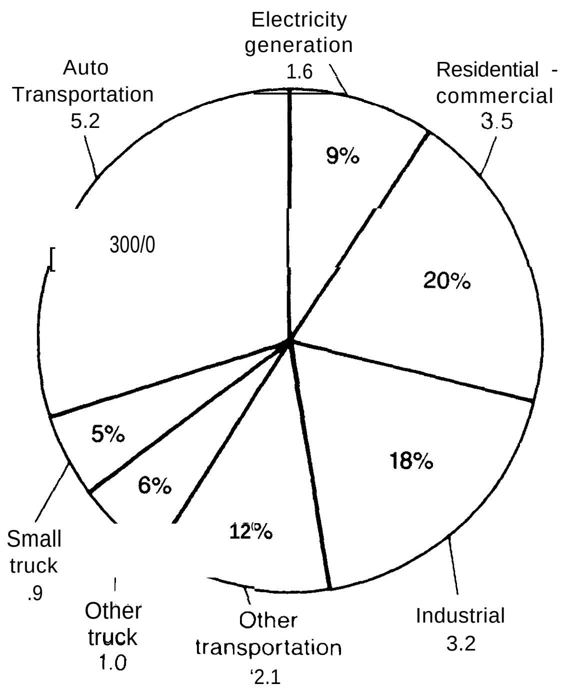
Photo Credit: U.S. Department of Energy

Energy (1)

Automobile transportation is the largest consumer of petroleum in the United States —5.2 million barrels per day, or about 30 percent of total demand. (See figure 3.) Virtually all of the petroleum consumed as automobile fuel is in the form of gasoline. Historically, gasoline consumption has grown at a rate of slightly over 4 percent per year. In the years immediately preceding the 1973-74 oil embargo, the annual growth reached nearly 5 percent. While the growth rate has slackened somewhat since, it is currently above 4 percent and rising. The annual consumption of petroleum by automobiles was over 78 billion gallons in 1976.

Energy consumption is directly influenced by automobile travel demand and by propulsion system technology. While gasoline is now the only significant auto fuel, diesel engines are beginning to penetrate the passenger car fleet. Synthetic fuels (coal liquids, shale oil, methanol, and ethanol) and electric power are potential alternatives to gasoline, but they are now only in the developmental stage.

Figure 3.—U.S. Demand for Oil in 1976 (MMBD)



Total: 17.5 MMBD (42% imported)

SOURCE: Executive Office of the President, *The National Energy Plan*, April 29, 1977.

Environment (J)

The effects of automobile use on air quality have received wide public attention since the **1960's.** Automobile emissions are considered to be a major contributor to air pollution, primarily in urban areas. Automobiles are major sources of carbon monoxide, hydrocarbons, and nitrogen oxides. Figure 4 shows the relative contribution by automobiles to atmospheric pollution.

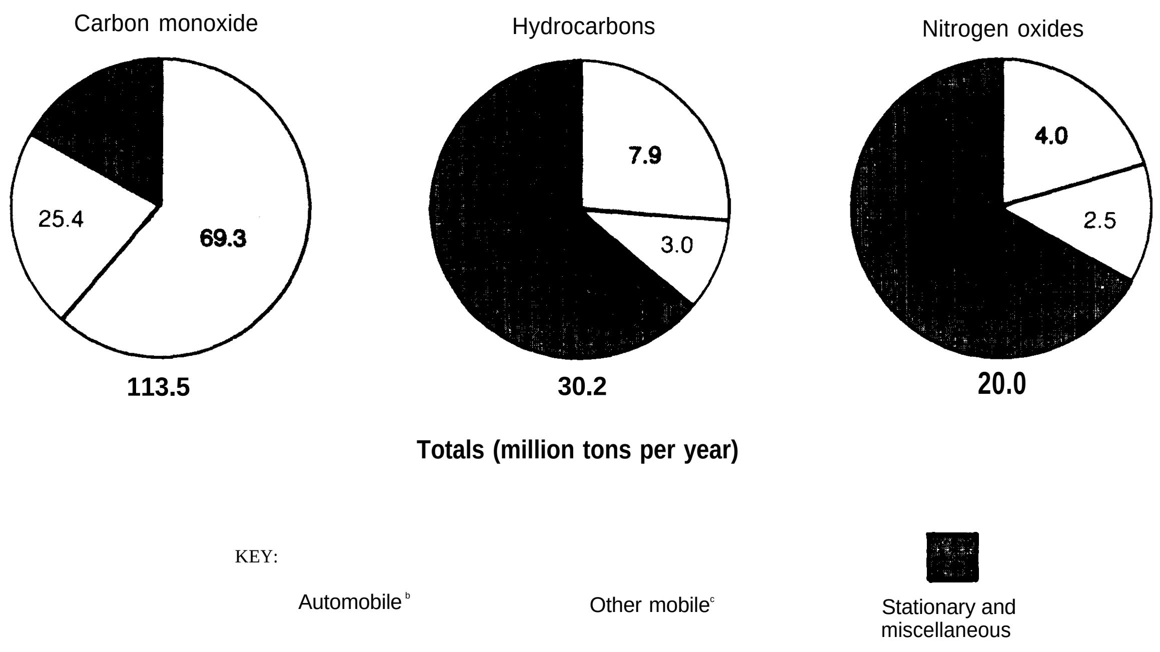
Noise, water pollution, and soil contamination are other environmental impacts of automobiles; however, in each case, other sources are larger contributors. The disposal of automobile wastes, notably scrap vehicles, is a problem of sizable proportion. Scrappage of automobiles accounts for about 7 percent of all commercial, residential, and municipal waste in the United States. Since the average weight of a vehicle is about 3,900 pounds, automobiles comprise over 13 million tons of solid waste that must be disposed of annually. Of this, 10 million tons, or about **80** percent, are salvaged and represent an important source of recycled iron, steel, and other metals. Figure 5 illustrates the composition of a typical 1978 model car.

Safety (K)

The safety of the automobile system—measured in terms of fatalities, injuries, and property damage—is a matter of profound concern. The 1977 data in table 9 show only the rough dimensions of the problem, but they serve to indicate the high price that Americans pay for mobility.

Traffic crashes in rural areas makeup approximately **30** percent of the total but account for 70 percent of the deaths and 35 percent of the injuries. The condition of rural roads, the higher prevailing speeds, and he unavailability of

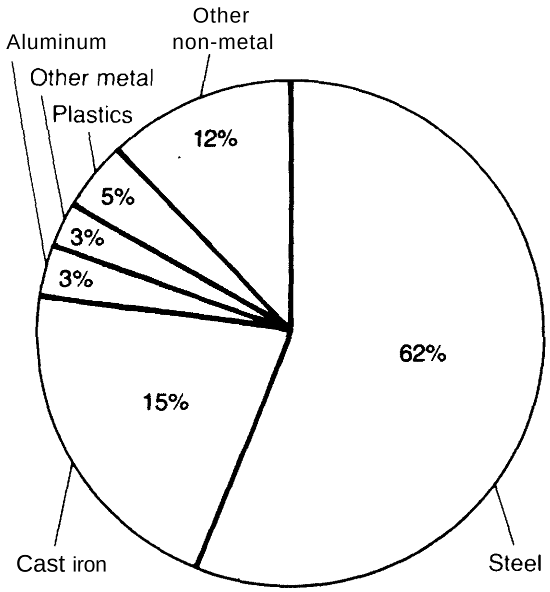
Figure 4.—Sources of Air Pollution[a]



[a]1975 Data,
[b]Passenger cars only,
[c]Light-duty trucks, heavy-duty trucks (gasoline and diesel), buses, motorcycles, aircratt, pipeline, marine craft, and military vehicles

SOURCES: EEA Gasoline Consumption Model.
TRC and Argonne National Laboratory, *Priorities and Procedures for the Development of Standards of Performance for New Stationary Sources of Atmospheric Pollution,* 1976.

Figure 5.— Materials in a Typical 1978 Model Automobile



SOURCE Ward's 1978 Automotive Yearbook, 1978

Table 9.—1977 Traffic Crash Data

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, van occupants	5,200
Motorcycle	4,200
Pedestrian, pedacycle	8,600
Truck, bus, and other	2,400
Estimated cost[d]	$44 bill ion

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

emergency medical services are major factors contributing to the disproportionate number of rural highway deaths and injuries.

Costs (L)

The costs of the automobile are distributed throughout the system, but they are eventually assumed by the public, either directly as automobile users or indirectly as taxpayers. Some of these costs have been discussed earlier—for example, highway and transit costs in connection with the transportation system (F'), new car costs under industry economics (H), and fuel costs under energy (I). The discussion that follows deals only with costs that fall directly on the consumer as an automobile owner and operator.

From 1962 to 1973, the real dollar cost of owning and operating an auto declined about 6 percent. Gasoline and motor oil costs in the same period declined more rapidly than total costs until the sharp OPEC price increase in 1973-74 brought fuel costs back to the 1962 level in real dollars. Auto repair and maintenance costs, constant through the mid-1960's, have gradually declined over the last decade by about 10 percent in real dollars. Significantly, new car costs have been declining steadily and at a greater rate than other auto-related costs—more than a 30-percent decline in 15 years in real terms. Table 10 is a summary of the costs of automobile ownership and operation in **1976.**

Table 10.—Costs of Owning and Operating an Automobile, 1976 (cents per mile)

Costs[a]	Type of auto		
	Standard	Compact	Subcompact
Depreciation	4.9	3.8	3.2
Maintenance, accessories, parts, and tires	4.2	3.4	3.1
Gas and oil (excluding taxes)	3.3	2.5	1.8
Garage, parking, and tolls	2.2	2.1	2.1
Insurance	1.7	1.6	1,5
State and Federal taxes	1.6	1.2	0.9
Total costs per mile	17.9	14.6	12.6

[a]Based on driving 10,000 miles per year.
SOURCE: Federal Highway Administration, *Costs of Owning and Operating an Autonrobl/e,* 1976, p 2

Social Effects (M)

The automobile system affords a myriad of social benefits, but it also has many adverse effects on individuals and communities. Generally, these adverse effects fall into three categories:

1. Increased highway travel creates pressure to build or expand highways, leading to disruption of communities by property acquisition and displacement of residences, businesses, and other activities.

2. Increased traffic volumes raise noise levels within neighborhoods and endanger pedestrian safety.
3. Increased reliance on the automobile by the population as a whole tends to draw passengers away from public transportation, shrinking its market, forcing reductions in service, and contributing to increases in fares. The elderly, the handicapped, the young, the poor, and others without cars may have their mobility reduced as a result.

One measure of community disruption by the automobile system is the number of homes and businesses displaced by highway construction. Table 11 shows the annual average of highway-related displacements during the period 1971-75. The level has declined from the **1960's,** when highway construction was at a peak. A part of this decline can also be attributed to Federal policies, notably uniform relocation assistance legislation and the National Environmental Policy Act, which have brought increased efforts to prevent or mitigate the disruptive effects of highways.

There are some members of society who cannot share fully in the mobility afforded by automobiles. Lack of access to an auto or lack of ability to use an auto is a particular problem for four segments of the population—the old, the poor, the handicapped, and the young. These segments of the population are sometimes called "transportation disadvantaged. "

Table 12 contains estimates of the size of the population groups in which lack of mobility is most prevalent. These estimates are given separately for adults and for the young (under 17) since many young people do not have independent travel needs. The young have been included for two reasons: to provide a complete account of those who lack the degree of mobility enjoyed by the rest of society and to indicate the extent to which children, who must rely on others for transportation, generate automobile travel demand.

Table 11 .—Annual Highway-Related Displacements

Type of displacement	Yearly average 1971-75
Residential	10,789
Business	2,510
Farm	209
Nonprofit organization	100

SOURCE: Sydec, using Federal Highway Administration Relocation Statistics reports

Table 12.—Transportation Disadvantaged Population* (millions)

	1970
Adults (over 17)	
Elderly (over 65, not poor, and not handicapped)	10.2
Poor (not handicapped)	9.9
Handicapped	17.1
Total adult disadvantaged	37.2
Total adult population	135.2
Percent of adult population	27.50/o
Young (17 and under)	
Handicapped	0.9
Not handicapped	68.8
Total young	69.7
Total population	204.9
Percent of total population	34.O%

*Figures are total estimated persons in each group and do not represent those who are known to be transportation disadvantaged.

SOURCES: Sydec estimates, based on *Transportation Requirements for the Handicapped, Elderly, and Economically Disadvantaged,* Transportation Research Board, Report No. 39, 1976, p. 11; HEW National Center for Health Statistics 1960 and 1970 Census of Population in *The Handicapped and Elderly Market for Urban Mass Transit* prepared by the Transportation Systems Center for the Urban Mass Transportation Administration, October 1973; and U.S. Census, Series II, Population Projections.

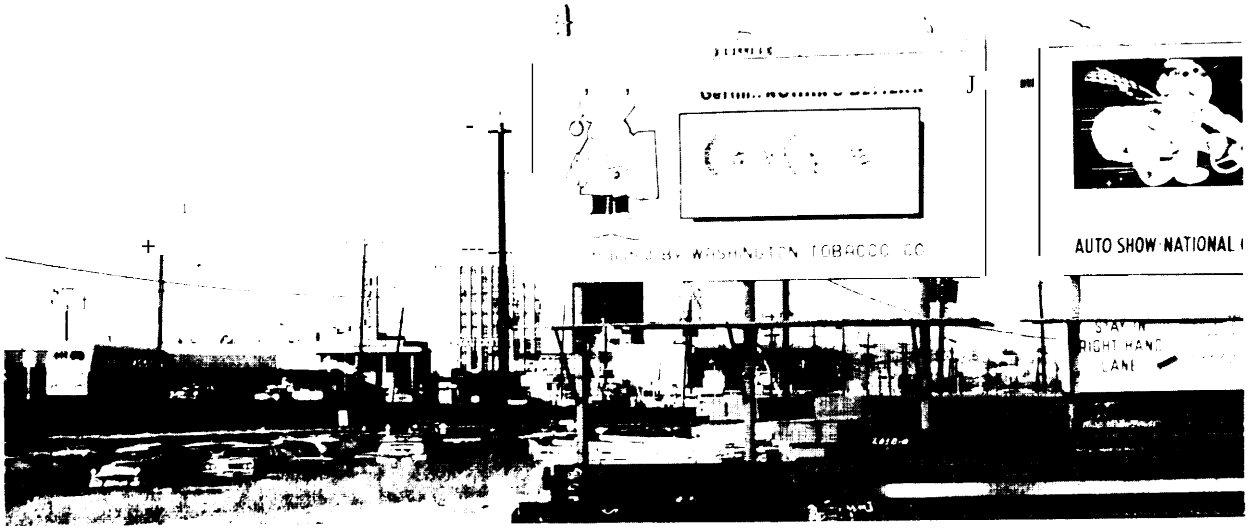
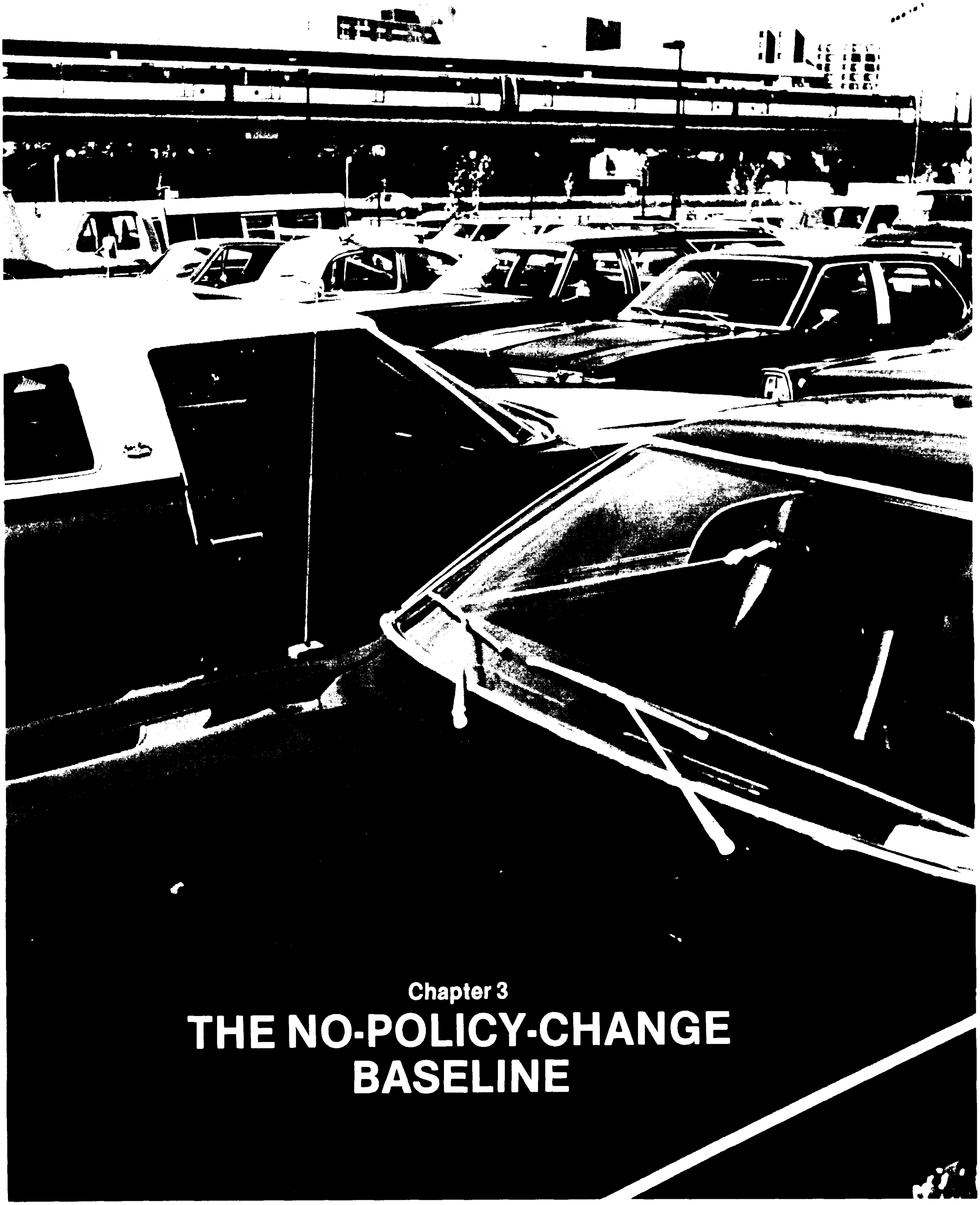


Photo Credit: U.S. Department of Transportation



Chapter 3

THE NO-POLICY-CHANGE BASELINE

Chapter 3.- THE NO-POLICY-CHANGE BASELINE

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THE NO-POLICY-CHANGE BASELINE

CHAPTER 3

SUMMARY

The no-policy-change baseline, or Base Case, serves as a reference for evaluation of policy alternatives affecting the future automobile transportation system. The Base Case is a projection of automobile system characteristics and use under the assumption that current Federal Government policies and programs are continued in substantially their present form until 2000. This provides a baseline for comparing the effects and impacts that could result from pursuing alternatives to present policy.

Base Case projections of some of the more important features of automobile system characteristics and use for 1985 and 2000 are shown in table 13. For comparison, corresponding figures are shown for 1975 which was selected as the base year for this study.

One of the significant projections is that, although the number of automobiles and automobile vehicle miles traveled (VMT)[1] will continue to rise, fuel consumption will remain roughly constant. To counter rising purchase

[1] All VMT figures in this report refer to automobile VMT unless otherwise stated.

Table 13.—Summary of Base Case Projections

	1975	1985	2000
Mobility			
Automobiles in operation (millions)	95	118	148
Automobile vehicle miles traveled (trillions)	1.03	1.43	1.80
Urban auto travel in congested conditions (percent)	10	14	24
Transit vehicle miles traveled (billions)	2.0	2.3	3.0
Transit ridership (billions)	5.6	6.5	6.5
Energy			
Fleet fuel economy (miles per gallon)[a]	13.6	19.4	24.6
Automobile fuel demand (MMBD)	5.0	4.8	4.8
Petroleum imports (MMBD)	7.4	10.0	8.8[b]
Environment			
Automobile air pollutant emissions (millions of tons per 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
Safety			
Highway fatalities (thousands)[c]	46.0	58.4	64.0
Highway fatality rate (per 100 million miles)	3.4	3.1	2.8
Cost and capital			
New car sales (millions)[d]	8.6	13.1	16.4

[a] Fuel economy under actual driving conditions; EPA certification procedures yield estimates 10 to 20 percent higher
[b] Assumes 2.75 MMBD domestic production of alternate fuels.
[c] Includes pedestrians.
[d] 18-percent imports.

costs and fuel prices, motorists are expected to switch to smaller, more fuel-efficient cars. By 1985, 70 percent of new car purchases will be small cars, compared to a little under 50 percent today.

Despite the increased number of vehicles on the road, the national aggregate of air pollutants from automobiles will drop sharply from 1975 levels as a greater part of the fleet is equipped with mandated emission control equipment.

Another direct result of the increase in automobiles and VMT will be growing congestion on highways, particularly in urban areas. The typical urban driver in 2000 will encounter congested conditions about one-quarter of the time, or 21/z times more often than today.

Death and injury rates in automobile crashes are projected to decrease steadily from now to 2000 as a result of improved occupant protection and vehicle crashworthiness. However, the absolute number of deaths and injuries will increase. For example, highway-related deaths are expected to reach **64,000** per year by **2000,** compared to 46,000 in 1975.

Providing there is not a severe restriction of the supply of petroleum or alternate fuels, 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 will result in a 16-percent increase in ridership by 1985, but the effect on automobile VMT will be negligible.

RATIONALE

The Base Case is a projection of automobile system characteristics and use over the next **25** years, based on the assumption that present Federal policies and programs will continue. The Base Case thus allows the results expected of current policy in light of evolving demographic, economic, and social trends. It provides a quantified baseline for evaluation of alternatives, and it highlights policy issues that may arise through pursuit of present policies.

The Base Case has several important applications in this study:

- Frame of Reference: The Base Case provides a series of reference points for comparing the effects and impacts of policy alternatives with conditions that would prevail in the absence of such policies.
- **Analytic** Tool: By providing a common set of assumptions and projections, the Base Case helps assure that analyses of policy options are consistent and that expected effects are compared systematically. The Base Case also contributes to policy definition by specifying a plausible economic and social climate in which policies must function.
- Yardstick for Current Policies: A number of Federal policies and programs relating to the automobile transportation system are now in force or are scheduled to be phased in over the next few years. The Base Case helps to define the nature and magnitude of the changes being brought about by these policies.
- Guide to Policy Alternatives: Projections of future conditions in the Base Case help to identify problems that could occur and ways to avoid or mitigate adverse impacts.

The Base Case is not a prediction of a most probable future. There is no intent to assert that the outcomes described in the Base Case will inevitably occur or are likely to occur. Conditions change in unforeseen ways, and Government policies would almost certainly not remain static over a period as long as 25 years. Instead, the Base Case is an analytic device that extrapolates the effects of present Government policies in light of anticipated changes in social and economic conditions.

Neither is the Base Case a “Do-Nothing” policy. The Federal Government already has many policies and programs affecting the automobile transportation system. All of these are assumed to remain in force or to be extended according to presently established schedules. It is for this reason that the Base Case has also been called the No-Policy-Change Baseline, to emphasize that it is a continuation of those policies now deemed appropriate for the automobile transportation system.

The Base Case was developed from assumptions and trend extrapolations for three classes of variables:

1. Population growth and distribution,
2. Economic conditions, and
3, Federal Government policy.

Population characteristics are important factors in the future automobile transportation system. The number of people of various ages and their location will determine the general demand for personal transportation (by automobile or other means) and the distribution of this demand between urban and rural areas and by geographic region. Macroeconomic factors are also major determinants of automobile system characteristics and use. The economic state of the country will have a powerful influence both on the automobile and the highway industry in general and on the resources that individuals will have to spend for personal transportation. The policies of the Federal Government will set the regulatory climate for the industry and will affect the cost and availability of personal transportation. Federal Government policy will also play a major part in determining the direction in which automobile technology will evolve over the remainder of this century.

These three classes of variables, combined with descriptive models of the structure and function of the system, serve as the basis for projections of future automobile characteristics and use. The demographic and economic conditions described below and their effects on automobile transportation are assumed to occur for the Base Case and for each of the policy alternatives treated later in this report.[2] Assumed demographic and economic factors have been held constant to allow comparison of the particular effects of policy options with the common reference of the Base Case.

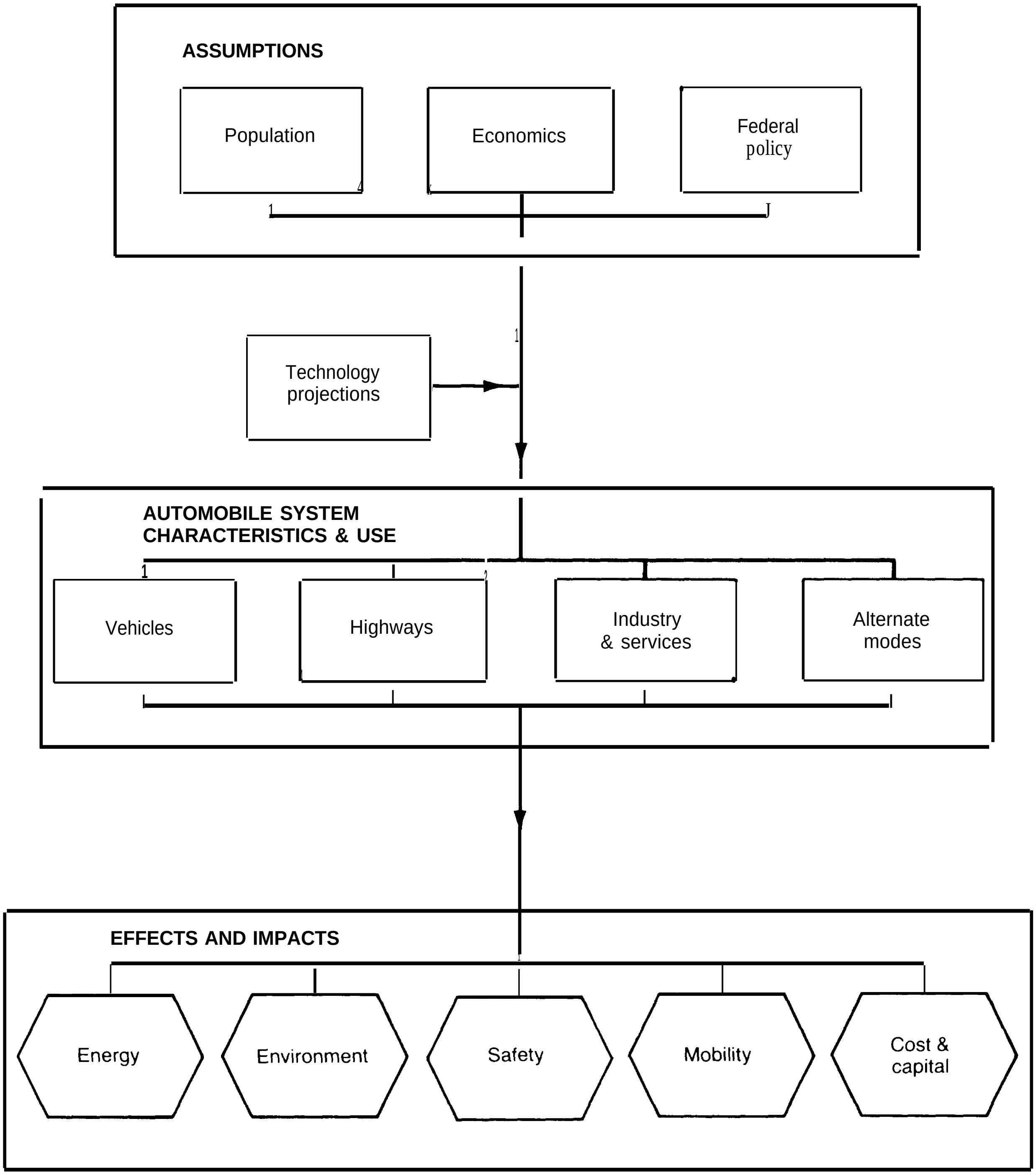
[2]Many of the projections presented in this report are based on the contractor reports of System Design Concepts/Energy and Environmental Analysis and Stanford Research Institute. Source references for these works are given as "Sydec/EEA" or "SRI."

Table 14.—Summary of Base Case Assumptions (dollar amounts in constant 1975 dollars)

Assumptions	1975	1985	2000
Demographic			
Population (millions)	214	**233**	**250**
Licensed drivers (millions)	130	151	177
Economic			
Gross national product ($ trillion)	1.52	**2.22**	3.72
Average income[a] ($ thousand)	5.03	**6.72**	10.07
World oil price (dollars per barrel)	13.00	16.50	25.60
Gasoline price (cents per gallon)	**56**	77	121
Policy			
New car fuel economy[b] (mpg)	—	27.5	27.5
New car emission standards (grams per mile)			
Carbon monoxide	**28.0**	3.4[c]	3.4
Hydrocarbons	**3.0**	0.41[c]	0.41
Oxides of nitrogen	**3.1**	1.0[cd]	1.0
Highway program funding[e] ($ billion)			
Capital expenditure	14.3	11.2	7.0
Maintenance	13.9	17.0	21.2
Total	28.2	28.2	28.2
Transit program funding ($ billion)			
Federal assistance	1.51	2.64	2.64
State and local contributions	1.71	2.70	4.90
Total	**3.22**	**5.34**	**7.54**

[a]Disposable personal income per capita.
[b]EPA certification values. Actual mileage on the road is assumed to be 10 to 20 percent lower
[c]Standards will take effect for the 1981 model year.
[d]A waiver for diesels of 1.5 grams per mile is assumed for 1981-83.
[e]All levels of government.
[f]Includes maintenance, police, administration, planning, and debt service.
[g]Excludes fare-box revenues.

Figure 6.—Derivation of the Base Case



FUTURE POPULATION CHARACTERISTICS

The size and distribution of the future population will have a significant influence on the automobile transportation system. As population grows, so will the demand for personal transportation, the number of licensed drivers, the number of automobiles, and the benefits and problems associated with the automobile.

Population Growth

The population growth assumptions selected for this study are Bureau of the Census' Series II forecasts. The most important assumption is the completed cohort fertility rate of 2.1 (the average number of children women are expected to have).

Mortality is the other important factor shaping the population projection. A person born in 1930 had a life expectancy of 59.7 years.[4] In 1975, life expectancy was 72.7. By 2050, it will be 76.5.[5] With these assumptions, the population is projected to grow from 213.5 million in 1975 to 232.9 million in 1985, and 260.4 million by 2000.[6]

Not only will the population in 2000 be about 22 percent greater than in 1975, it will also be older. The median age in 1975 was 29 years. By 2000, it is expected to be nearly 36. As shown in table 15, a greater proportion will be of driving age. Those 65 and over, who are less likely to drive, will number about 32 million, an increase of 42 percent from 1975.

Population Distribution

The trend toward more urbanization is assumed to continue. The percentage of the population living in urban areas will increase from 61 percent in 1975 to 68 percent in 2000. Central city population will continue to grow in absolute terms but will decline as a percentage of total urbanized area population as more people live in the suburbs. The rural population will decline in both number and percentage.[7] (See table 16.)

Households

As defined by the Bureau of the Census, a household is comprised of all persons who share common living quarters. In addition to the traditional family, a person living alone or a group of unrelated persons living together also constitutes a household. Based on the Series II projections, the number of households is expected to grow from 71.7 million in 1975 to 87.2 million in 1985 and 109.4 million in 2000. At the same time, household size will grow smaller, from an average of 3.0 persons in 1975 to 2.4 persons in 2000.[8]

[3] U.S. Department of Commerce, Bureau of the Census, *Projections of the Population of the United States: 1977 to 2050*, Series P-25, Number 704, July 1977.

[4] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1976* (Washington, D.C.: U.S. Government Printing Office, 1976), p. 60.

[5] U.S. Department of Commerce, Bureau of the Census, *Projections of the Population...*, p. 18.

[6] These estimates assume 100 males to 105 females.

[7] System Design Concepts, Inc, Energy and Environmental Analysis, Inc., and The Institute for Safety Analysis, Inc., *Technology Assessment of Changes in the Use and Characteristics of the Automobile*, Contractor Report, prepared for U.S. Congress, Office of Technology Assessment (Washington, D.C.: System Design Concepts, January 1978), p. III-11. (Hereinafter cited as *Sydec EEA*.)

[8] Ibid., p. III-15.

Table 15.—Size and Age of the Future Population (millions)

	1975		1975		1975	
	Number	Percent	Number	Percent	Number	Percent
Total	213.5		232.9		260.4	
15 and over.	159.9	74.9	181.2	77.8	203.3	78.1
65 and over.	22.4	10.5	27.3	11.7	31.8	12.1
Median age.	28.8		31.5		35.5	

SOURCE: U.S. Department of Commerce, Bureau of the Census, *Projections of the Population of the United States: 1977 to 2059*, table 8

Table 16.—Future Distribution of U.S. Population (millions)

	1975		1985		2000	
	Number	Percent	Number	Percent	Number	Percent
Total population	213.5		232.9		260.4	
Urbanized area population	130.1	60.5	149.0	64.0	177.0	68.0
(Central city).	(66.7)	(31.2)	(70.6)	(30.3)	(75.7)	(29.0)
(Suburban)	(63.4)	(29.7)	(78.4)	(33.7)	(101.3)	(38.9)
Small urban area population	29.6	13.9	30.3	13.0	31.3	12.0
Rural population	53.8	25.2	53.6	23.0	52.1	20.0

[a]Areas of 50,000 or more population.
[b]Urban places of 2,500 to 50,000 population.
SOURCE: *Sydec/EEA*, p. III-9.

Licensed Drivers

Automobile use is closely related to the number of licensed drivers. Projections of licensed drivers in the future population were developed from analysis of trends in the percentage of individuals with licenses in each age-sex cohort. Between 1975 and 2000, the percentage of male licensed drivers is expected to remain stable at roughly 90 percent of all males of driving age. For women, however, the proportion of licensed drivers in the population of driving age is expected to climb steadily from the present 71 percent to 83 percent by 2000. For the population as a whole, the number of licensed drivers will grow by 37 percent. (See table **17.**)

Table 17.—Projections of Population and Licensed Drivers

	1975	1985	2000
Total population (millions).	214	233	260
Driving age population (millions)			
Men. ., ...	77	87	97
Women.	83	94	106
Total	160	181	203
Licensed drivers (millions)			
Men.	71	78	89
Women.	59	73	88
Total	130	151	177
Licensed drivers as percentage of driving age population			
Men.	92%	90%	91 %
Women.	71	77	83
Total	81	83	87

SOURCE Sydec/EEA, p III-69

MACROECONOMIC ASSUMPTIONS

Civilian Labor Force

Two major factors affecting economic growth are the size of the labor force and labor productivity. Currently, the civilian labor force is growing more rapidly than the population.[9] The percentage of working males is relatively stable, but the percentage of women in the labor force is increasing markedly. In 1970, 43 percent of women aged 16 and over were in the labor force. This proportion is expected to grow to 51 percent by 1990.[10] Based on these trends, the civilian labor force of 92.6 million in 1975 is projected to grow to 105.6 million in 1985 and 122.9 million in **2000.**[11] Unemployment is assumed to decline from 8.5 percent in **1975** to 5.0 percent by 1985 and to remain at that level through 2000.

[9]U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract* . , pp. xiii-xviii.

[10]U.S. Department of Labor, Bureau of Labor Statistics, *New Labor Force Projections to 1990,* Special Labor Force Report 197 (Washington, D.C.: U.S. Govzrnment Printing Office, 1977).

[11]*Sydec/EEA,* pp. III-19 to III-21.

Growth in the productivity of the labor force had averaged about 3 percent per year until the early 1970's, when it dropped below 2 percent. Annual labor productivity growth is assumed to return to around 3 percent for the period 1985-2000.

Gross National Product

The Base Case assumes continued economic growth through **2000.** The gross national product (GNP) is projected to rise from $1.5 trillion in 1975 to $3.7 trillion by **2000** (in 1975 dollars) .12 (See table 18.) These figures represent an annual GNP growth rate of 3.5 percent—roughly equivalent to the average annual rate between 1960 and 1975, The GNP growth projection assumes a labor force increase of 1.2 percent annually to 1985 and 1.0 percent thereafter, and an assumed labor productivity growth of 3 percent.

Table 18.—Summary of Macroeconomic Assumptions for the Base Case[a]

	1975	1985	2000
Gross national product (billions)	$1,516	$2,218	$3,716
GNP growth rate (percent)	3.4 [b]	3.5	3.5
Disposable personal income (billions)	$1,081	$1,564	$2,620
DPI growth rate (percent)	3.6[b]	3.5	3.5
DPI/GNP	0.71	0.71	0.71
DPI/capita	$5,025	$6,717	$10,068
Consumer price index	161.2	261.7	471.3
CPI growth rate (percent)'	4.1[b]	5.0	4.0

[a]Dollar amounts are in 1975 dollars.
[b]1960-75 annual average.
[c]CPI growth rate was 9.1 percent for 1974-75.
SOURCES: U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, 1976; Projections from *Sydec/EEA*, pp. III-19 and III-20.

Disposable Personal Income

Disposable personal income (DPI)—income after taxes and social insurance payments—represents how much money people have for personal expenditures, including automobiles and travel. Based on an analysis of historical data, it is assumed that the ratio of DPI to GNP will be 0.71 for the period 1975-2000. This value is consistent with the recent trend. Using this ratio, it is projected that DPI will grow from $1.08 trillion in **1975** to **$2.62** trillion in **2000.** DPI per capita will double in constant dollars—from $5,000 to $10,000 during this period. '3

Inflation

There is great uncertainty in long-run projection of prices because of the unpredictable effects of inflation. In the past 10 years there have been large fluctuations in the Consumer Price Index (CPI). For example, inflation reached 11 percent in **1974** but dropped to about 6 percent per year by 1977. Recently, however, the CPI has begun to rise again. (See figure 7.)

Since the main concern in this study is with long-term trends, no attempt has been made to forecast the magnitude and timing of short-term variations. For the Base Case, it is assumed that inflation—as a long-term average—will decline to about **5** percent per year by 1985 and then to 4 percent per year by 2000. Under these assumptions, the CPI would rise from the 1975 value of 161 to 262 in 1985 and 471 in 2000. However, since DPI will be growing more rapidly than the CPI, the net effect will be that consumers will have about twice as much to spend (in constant dollars) in **2000** as they do today.

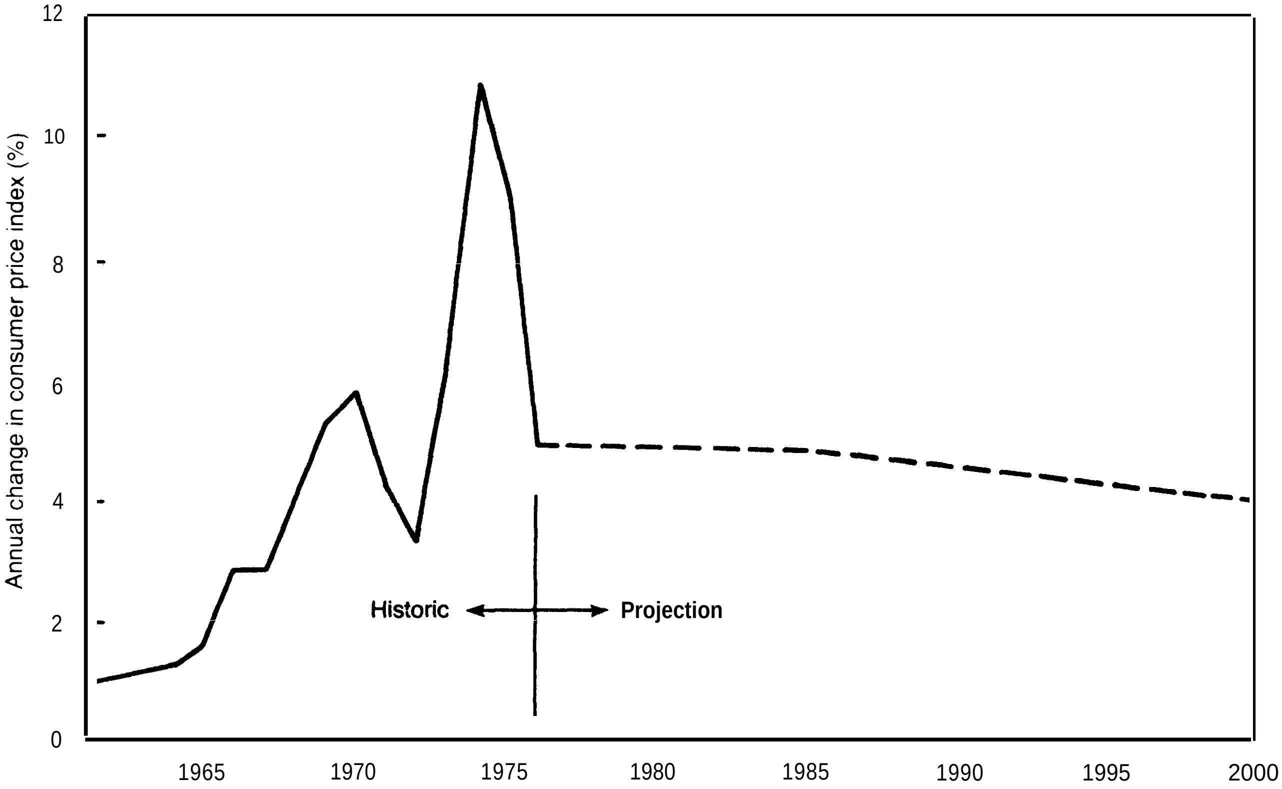
TECHNOLOGY PROJECTIONS

Chapter 10 contains a detailed discussion of prospective changes in automobile technology. This section presents a summary of the assumed changes in technology that have been incorporated in the Base Case.

[12]To remove the effects of inflation and allow direct comparison of economic changes, monetary values are expressed in constant 1975 dollars and so noted throughout this report.

[13]*Sydec/EEA*, pp. III-19 and III-20.

Figure 7.—Annual Change in Consumer Price Index



SOURCES: U.S. Dept. of Commerce, Bureau of the Census, *Statistical Abstract of the United States*, 1977, p. 478. Projections from Sydec/EEA. p. III-16.

Automobiles

Weight Reduction and Materials Substitution

It is assumed that domestic manufacturers will continue their current downsizing program, which is expected to be completed by 1981. Downsizing and a shift of consumer preference to smaller cars will lead to a reduction in average automobile weight of about 1,000 pounds. The basic elements of downsizing are materials substitution to reduce weight and significant body restyling to shed weight while maintaining interior and trunk room. The use of plastics and aluminum will increase, while the use of steel and cast iron will be reduced. Lighter cars will also permit the use of smaller engines and other components.

Fuel Economy

It is expected that the Environmental Protection Agency (EPA) goals for fuel economy—27.5 mpg[14] for new cars in 1985 and thereafter—will be attained.[15] As a result, fuel consumption for the automobile fleet as a whole is projected to average 19.4 mpg in 1985 and 24.6 mpg by **2000.** For comparison, the fleetwide average for 1975 is estimated at 13.5 mpg,

[14]As measured by EPA certification procedures. The fleetwide averages stated here are assumed to be under actual driving conditions.

[15]Fuel economy improvements beyond 27.5 mpg are possible. They have not been assumed for the Base Case, but they are considered under energy policy options in chapter 5.

Automobile Emissions

It is assumed for the Base Case that automobile manufacturers will be able to meet the emission standards specified in the 1977 Clean Air Act Amendments. A waiver on the nitrogen oxides (NO_x) standard (from 1.0 gram per mile to 1.5 grams per mile) would be granted for diesels from 1981 to 1983, but thereafter, it is assumed that diesels would meet the 1.0-gram-per-mile standard.

Safety

New automobiles will meet the Federal Motor Vehicle Safety Standards. It is assumed that passive restraints will be phased into all new cars over the period **1982-84** at *a* cost of about $200 per car.

Transmission and Drivetrain

The most significant changes expected in this area are:

- Lockup torque converters for automatic transmissions,
- More manual transmissions,
- More front-wheel-drive vehicles, and
- Improved lubrication.

Engines

The Base Case assumes that no new engines will achieve extensive commercialization before 2000, but that substantial modifications will be made to what is currently available. The spark-ignition engine is assumed to predominate, but the percentage of diesels will rise to 10 percent of new car sales in **1985** and **25** percent by **2000.** It is assumed that the diesel will have a more difficult time meeting the NO_x standard and will be granted a waiver to 1.5 grams per mile for 1981 through 1983. After 1984, the diesel is assumed to meet the 1.0-gram-per-mile standard and any particulate standards that may be imposed.

Some of the more significant improvements expected in spark-ignition engines are:

- Stratified charge (single or auxiliary chambers),
- Turbocharging,
- Wider use of fuel injection,
- Microprocessors to control air-fuel mixture more closely, and
- Greater use of aluminum.

The Base Case assumes that other types of engines, even if proven successful in research, will not achieve substantial market penetration by **2000.**

Fuels

Petroleum is assumed to be the main source of automotive fuel through 2000. Production of alternative fuels[16] will be limited but might reach **2.75** MMBD by **2000** under the most favorable circumstances. The use of methanol or gasoline-methanol blends is uncertain and has been given low probability for the Base Case. Electric vehicles will not constitute a significant part of the passenger car fleet, but may have increased use as delivery vehicles after 1985.

Highways

The basic elements of highway construction and design are not assumed to change significantly by 2000. Some improvements in pavement durability and skid resistance are expected to occur.

Modifications in the technology of highway operation may occur, particularly in urban areas. The technology is available for wider implementation of Transportation Systems Management (TSM) techniques such as high-occupancy vehicle lanes and ramp metering. Signing and traffic control signal systems are also expected to be improved by **2000.**

Public Transportation

Buses will remain the backbone of urban public transportation. Minor improvements in comfort and ride quality are expected. There will be improvements in accessibility for the handicapped and elderly, since a major part of the urban bus fleet is expected to be equipped for their use by **1990.**

There will be some shift in emphasis from heavy rail to light rail for new urban rail transit systems. Only a very small number of cities will

[16] The term "fuels" includes all substances that can be burned in automobiles. Fuels such as alcohol, alcohol blends (gasohol), and synfuels (from oil shale or coal) are considered alternatives to conventional petroleum.

start building new systems before 2000. However, the 8 to 10 systems that now exist or are under construction will be completed, expanded, or modernized. Technological advances beyond the San Francisco and Washington, D. C., systems are not foreseen.

Automated Guideway Transit (AGT) will see only limited application. It is assumed that four AGT systems will be operating by 1985 under the Urban Mass Transportation Administration (UMTA) Downtown People Mover Demonstration Program. After 1985, a few others may be put in operation, but they are not assumed to represent a significant substitute for other modes of personal transportation.

Intercity buses, which now serve more communities than any other public mode of transportation, are expected to remain the principal alternative to the automobile for trips between cities or between rural areas and cities. No major changes in bus technology are assumed for the Base Case.

BASIC PATTERNS OF AUTOMOBILE OWNERSHIP AND USE

From the assumptions set forth so far, it is possible to project some of the basic features of automobile ownership and use. These features form a pattern that can serve as a point of departure for examining the expected effects and impacts of current policies under base case conditions. (See table 19.)

Two of the more significant aspects of the future new car market expected in the Base Case will be a long-term trend of increasing sales and a marked shift to smaller cars. The number of autos in the fleet will continue to rise and at a rate slightly higher than population growth. The number of vehicles per licensed driver will increase from the present **0.73** to **0.84** by **2000.**

Federally mandated fuel economy standards will probably have more influence on the type of automobile in the fleet than any other current policy. To meet the tighter fuel economy standards, manufacturers will offer smaller, lighter vehicles and more diesels.

Table 19.—Base Case Automobile Ownership and Use

	1975	1985	2000
Annual new car sales (millions)	8.6	13.1	16.4
Percent of small cars[a]	46	66	66
Percent of diesels	—	10	25
Total automobiles in operation (millions)	95	118	148
Automobiles per licensed driver	**0.73**	**0.78**	**0.84**
Automobile vehicle miles traveled (trillions)	**1.03**	**1.43**	**1.80**
Automobile vehicle miles traveled per licensed driver	**7,900**	9,500	10,200
EPA fuel economy standards (mpg)	None	27.5	27.5
Auto fuel consumption (MMBD)	5.0	4.8	4.8

[a]Includes subcompact, compact, and small luxury cars

ENERGY PROJECTIONS

Historically, the growth of the automobile transportation system has been aided by an abundant and inexpensive supply of petroleum, a condition that is expected to change markedly by **2000.** The Base Case assumes that the supply of petroleum will be reduced and that other sources of energy will have to be found. The price and availability of energy—from petroleum or alternate sources—will be powerful influences on future automobile characteristics and use.

No attempt is made in the Base Case, or elsewhere in this study, to deal with the broad national problems of energy supply and demand. These include the prospects for sustaining or increasing domestic and foreign petroleum production, conservation of petroleum or substitution of alternate sources by nontransportation users, and reallocation of supply across and within domestic economic sectors. These issues are fundamental to national energy policy and will clearly affect the future of the automobile, but they lie beyond the scope of this assessment.

The Base Case concentrates on projecting energy consumption by the automobile system and the energy supply needed to satisfy this demand. Broader projections of supply and demand for the economy as a whole cannot be ignored, since they are inextricably bound to the automobile system. However, they are incorporated in the Base Case only to the extent necessary to define the context in which the automobile system will have to operate.

Energy Policy and Assumptions

The Base Case projections of energy consumption by the automobile system rest on the following assumptions:

- The automobile fleet will continue to depend on petroleum as its primary fuel to the year **2000.**
- The diesel engine will be the only alternative to the spark-ignition engine to obtain a significant market share through **2000.**
- The number of electric vehicles in use by **2000** will be insignificant in terms of petroleum conservation unless there is a breakthrough in battery technology. No such breakthrough is assumed for the Base Case.
- Any transition to alternate fuels will not come about as a result of Federal Government subsidy of the production and use of such fuels.
- The new car fuel economy standard will be **27.5** mpg for the 1978- model year and thereafter until 2000.

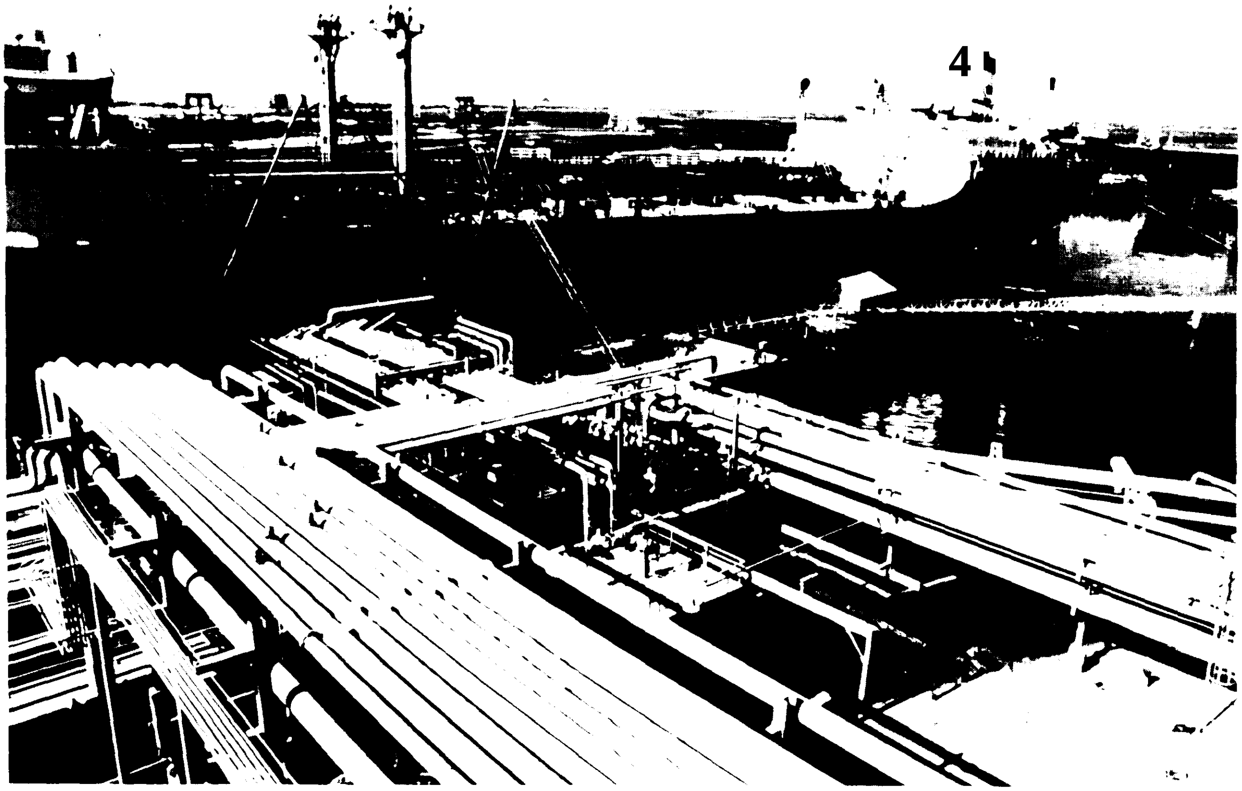


Photo Credit: U.S. Department of Energy

- Domestic manufacturers will meet these standards through vehicle downsizing, materials substitution, and other energy efficiency improvements.[17]
- Smaller cars will make up an increasingly greater share of the fleet.
- There will be no change in the degree of enforcement of the 55-mph speed limit.
- The Federal Government will continue to control the price of gasoline,
- Gasoline taxes will rise so as to keep revenues at their present level in constant dollars.
- No graduated excise (gas guzzler) taxes on automobiles will be imposed by the Federal Government.
- There will be no oil embargo or abrupt interruption of supply.

Fuel Economy Standards

The most significant Federal policy affecting energy consumption by the automobile system is the 1975 Energy Policy and Conservation Act (EPCA), which sets standards for new car fuel economy between the 1978 and 1985 model years. (See table 20.) Compliance with these standards is determined for each manufacturer separately on the basis of average (sales-weighted) fuel economy of the full line of passenger vehicles sold by that manufacturer during the model year. Beginning in 1980, captive imports (such as Ford Fiesta and Dodge Colt) cannot be included in the manufacturer's average. Therefore, domestically produced automobiles will have to make significant improvements in fuel economy by that time. It is also important to note that the values listed in table 20 are based on a test cycle of combined street and highway driving used by EPA to measure compliance. Estimates of the fuel economy attained under actual driving conditions run 10 to **20** percent lower.[18]

[17]Most import manufacturers will have little difficulty meeting the 27.5 mpg standard. A group of manufacturers accounting for 20 percent of all imports may face difficulties, however. *Federal Register* 42, (June 30, 1977): 33549.

[18]U.S. Environmental Protection Agency, Office of Mobile Source Air Pollution Control, Emission Control Technology Division, *Evaluation of the Representativeness of EPA Fuel Economy Estimates*, January 1978, p. 23.

Table 20.— Fuel Economy Standards Assumed for the Base Case

Model year	Sales-weighted new car fleet average, mpg
1978	18[a]
1979	19[a]
1980	20[a]
1981	22[b]
1982	24[b]
1983	26[b]
1984	27[b]
1985	27.5[a]
1990	27.5/30.0[c]
2000	27.5/35.0[c]

[a]Mandated by EPCA.
[b]Administratively determined by the Secretary of Transportation.
[c]Fuel economy assumptions for Case A and Case B, respectively

EPCA now sets fuel economy standards only to **1985,** but there is the clear possibility that standards might be raised in the period **1985-2000** as an extension of present policy. To assess the effects of fuel economy standards until **2000,** an alternative set of assumptions was incorporated into the Base Case. In Case A, the standard is maintained at **27.5** mpg from **1985** to 2000. In Case B, the standard is raised to 30 mpg in **1990** and 35 mpg in **2000.** It is assumed that higher fuel economy would be achieved, in part, by a greater use of diesel engines. In Case B, the penetration of the new car market by diesels reaches 40 percent by 2000. Table 21 summarizes the different assumptions for Case A and Case B.

Petroleum Prices

Petroleum demand by the automobile system will be partly determined by price. Based upon an examination of several recent projections of worldwide supply and demand, it is assumed that the price of a barrel of petroleum will rise from the current level of **$13** to **$16.50** by 1985 and to $25.60 by 2000 (all prices in 1975 dollars).[19] This is equivalent to an annual in-

[19]The Energy Research and Development Administration (ERDA) (now DOE) Phase II (Pass III) runs of Market Oriented Planned Programming Study Model as reported by ERDA transportation working group, June 20, 1977 (MOPPS); MIT Workshop on Alternative Energy Strategies (WAES), *Energy: Global Prospects 1985-2000* (New York: McGraw-Hill, 1977; Information from Department of Energy personnel working on the Project Independence Evaluation System (PIES), using model runs 823B72L DO1 HM4U (for 1985) and C829C72L DO1 RE1 U (for 1990), 1977; Electric Power Research Institute, *Fuel and Energy Price Forecast* (Washington, D.C.: Electric Power Research Institute, August 1967).

Table 21.—Alternative Assumptions for Base Case Fuel Economy Standards

		Base Case A	Base Case B
New car fuel economy standards. . . . .“.	1985	27.5 mpg	27.5 mpg
	1990	27.5 mpg	30.0 mpg
	2000	27.5 mpg	**35.0** mpg
Diesel share of new car sales.	1985	10 percent	15 percent
	2000	25 percent	40 percent

[a]EPA certification values

Table 22.—Base Case Petroleum and Gasoline Prices (1975 dollars)

	1975	1985	2000	
			Case A	Case B
World oil price ($/barrel) . . .	$13.ooa	$16.50	$25.60	$25.60
Gasoline price (c/gallon)				
Without tax	44.5¢	65.3¢[b]	109.4¢[b]	109.4¢[b]
State and Federal taxes .	11 .7¢	12.4¢	12.4¢	14.1¢
Pump price.	56.2¢	77.7¢	121 .8¢	123.5¢

[a]Open market price for *new* oil, as of January 1976.
[b]Includes effects of oil equalization tax.
SOURCE: 1975 data, Oak Ridge National Laboratory, *Transportation Energy Conservation Data Book: Edition 2*, prepared for U.S. Energy Research and Development Administration, Office of Conservation, 1977, p. 354.

crease of 3 percent per year in constant dollars.

The price of gasoline (excluding taxes) is also assumed to rise a t 3 percent per year.[20] Gasoline taxes (State and Federal) are assumed to rise at a rate that would keep revenues at the 1975 level in constant-dollar terms. The resulting change in the price of gasoline a t the pump is a rise from **$0.56** per gallon in 1975 to $1.21 per gallon by 2000. (See table 22.)

Automobile Energy Demand

During the *1960's*, fleet fuel economy declined steadily. This trend was reversed by the mid-1970's as a result of domestic manufacturer's efforts to improve fuel economy and the growing popularity of smaller cars, particularly fuel-efficient imports. The estimates prepared for the Base Case, shown in figure **8,** assume that manufacturers will meet the 1985 fuel economy standard of 27.5 mpg.

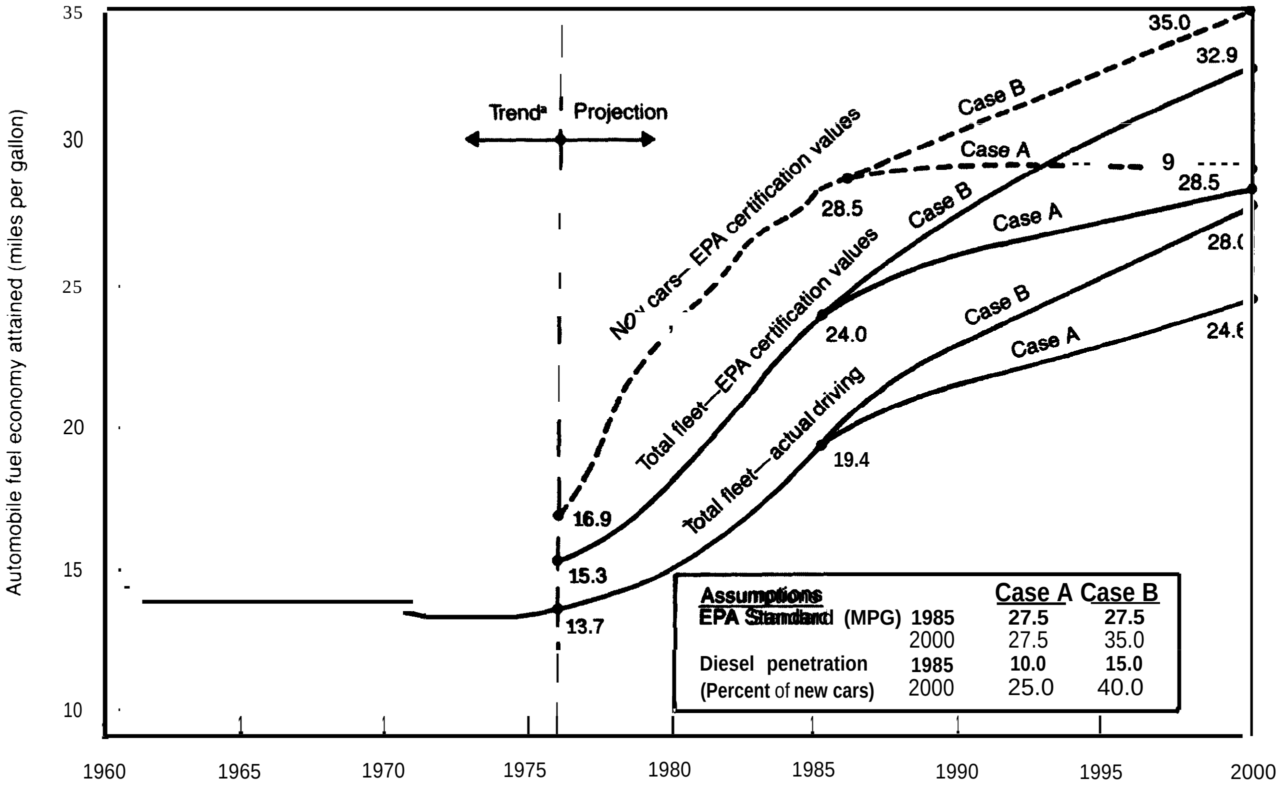
Fuel consumption projections for the Base Case are shown in table **23.** Two measures of fuel economy are shown—the EPA certification values used to determine compliance with EPCA standards and estimates of mpg under actual driving conditions.

Under the Case A assumptions, automobile fuel consumption in 1985 would be **5** percent lower than in 1976. Thereafter, consumption would stay close to the 1985 level, as further fuel efficiency gains would be counterbalanced by rising VMT. However, under Case B, auto petroleum consumption could fall an additional 12 percent by **2000.**[21] Whereas diesel fuel consumption by automobiles is negligible today, it would rise to 18 percent of automobile fuel used by **2000** in Case A and **29** percent in Case B. Between 1975 and **2000,** fuel economy for the fleet as a whole under actual driving conditions is projected to increase **82** percent in Case A and 107 percent in Case B. Since fleet size and VMT are identical for the two cases, the difference is attributable solely to higher fuel-economy standards and the increased use of diesels assumed for Case B.

[20]An oil equalization tax was also included in this computation

[21]Beyond 2000, if fuel economy standards were not to change, if the market penetration of diesels were not to increase further, and, if no new engines were introduced, automobile fuel consumption would again be on the rise in both Case A and B.

Figure 8.—Projection of Base Case Fuel Economy



[a]Motorcycle travel Included in fuel economy 1960-64

SOURCES Trend data, Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures* '77, p 62.
Projections, OTA and *Sydec* EEA, pp. III-101-109

Table 23.—Summary of Base Case Automobile Energy Demand

	1975	1985[a]	2000 Case A	2000 Case B
Automobiles in operation (millions)	95	118	148	148
Automobile VMT (trillions)	1.03	1.43	1.80	1.80
Diesel penetration (percent of new car market)	(b)	10	25	40
New car fuel economy (mpg)				
EPA standard[c]	None	27.5	27.5	35.0
Attained—EPA certification value	15.6	28.5	29.4	35.0
Attained—actual driving	14.0	23.2	25.0	29.8
Fleet fuel economy (mpg)				
Attained—EPA certification value	15.1	24.0	28.5	32.9
Attained—actual driving	13.6	19.4	24.6	28.0
Annual fleet fuel consumption rate (billions of gallons)				
Gasoline	76.0	70.6	60.2	45.7
Diesel	(b)	3.3	13.1	18.7
Total	76.0	73,9	73.3	64.4
Fleet fuel consumption (MMBD)	5.0	4.8	4.8	4.2
Percent of domestic consumption	30.6	23.9	21.4	19.3

[a]The differences between Case A and Case B in 1985 are insignificant.
[b]Insignificant.
[c]The EPA certification value for a particular car is the weighted average of performance in the EPA urban cycle (55 percent weight) and rural cycle (45 percent weight)

Total Domestic Petroleum Demand

The projected consumption of petroleum by the automobile system must be set in the context of the projected unconstrained demand for fuel by the country as a whole in 1985 and 2000. Estimates of unconstrained domestic petroleum demand[22] are presented in figure 9.

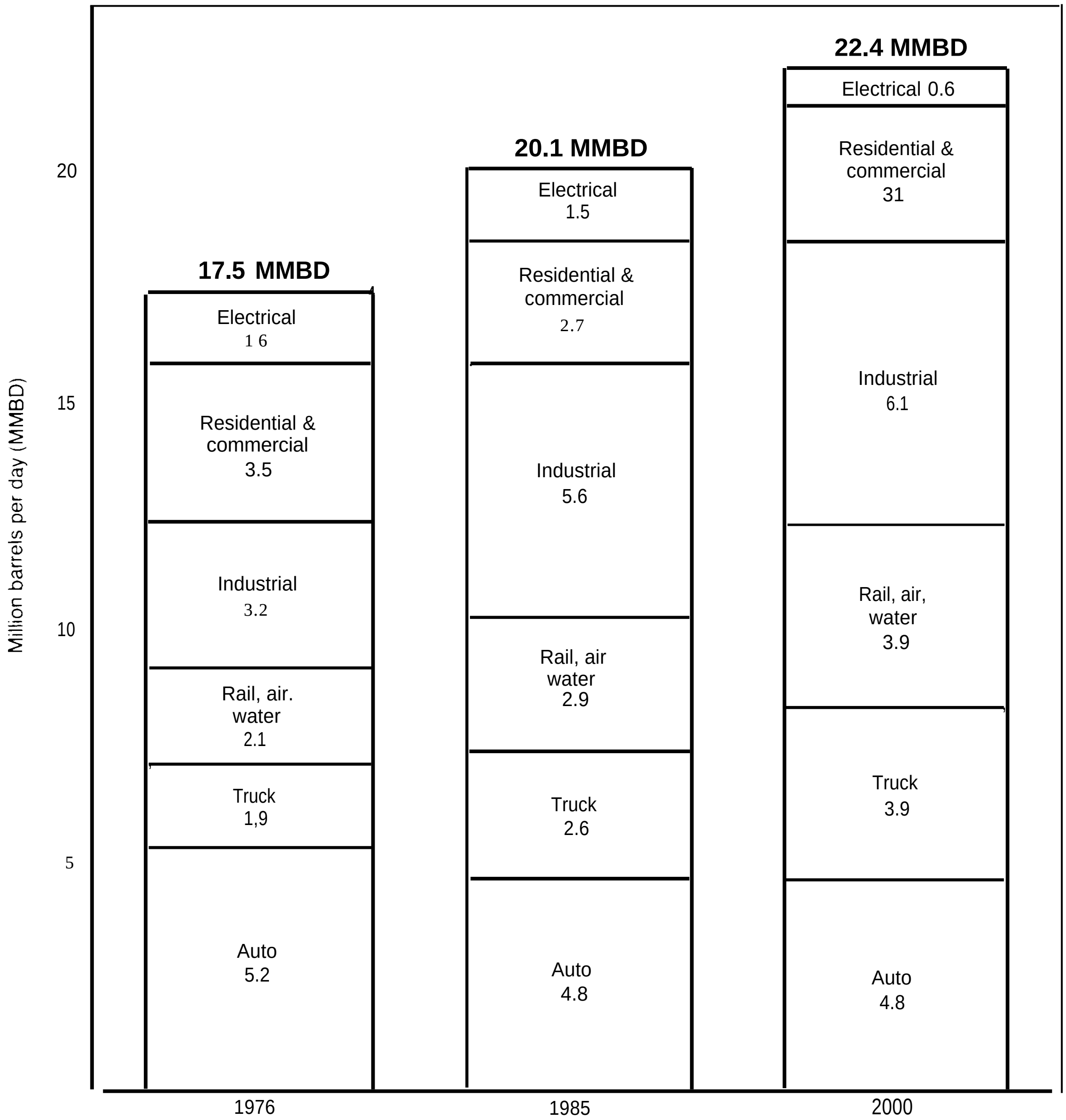
[22] A discussion of the domestic demand estimates is contained in *Sydec/EEA*, pp. III-89 to III-92.

The assumptions made in reaching these estimates are:

- The fuel economy of small trucks will remain unregulated.[23]
- There will be no significant improvements in the fuel efficiency of large trucks.

[23] While this report was in preparation, the National Highway Traffic Safety Administartion promulgated standards for fuel economy of trucks under 8,500 pounds gross vehicle weight. The potential effects of these standards have not been included in this analysis.

Figure 9.—U.S. Petroleum Demand



NOTE: Assumes continuation of 27.5 mpg for new cars beyond 1985.

SOURCE: Sydec/EEA and OTA estimates

- Petroleum consumption by other transportation modes (rail, air, and water) will continue to rise with expansion in the economy and population growth.
- The use of oil by industry will grow with the economy and the inability to expand natural gas supplies. Regulation, such as in the National Energy Plan, which could significantly lower the growth in industrial use has not been assumed for these estimates.
- Demand in the residential and commercial sector will fall slightly by 1985 because of greater use of electricity in new homes and the installation of energy-saving measures by homeowners and businesses. The benefits of these trends will be offset after 1985 by population growth, and consumption in this sector will begin to rise again.
- There will be an increase in the use of coal for generation of electricity.

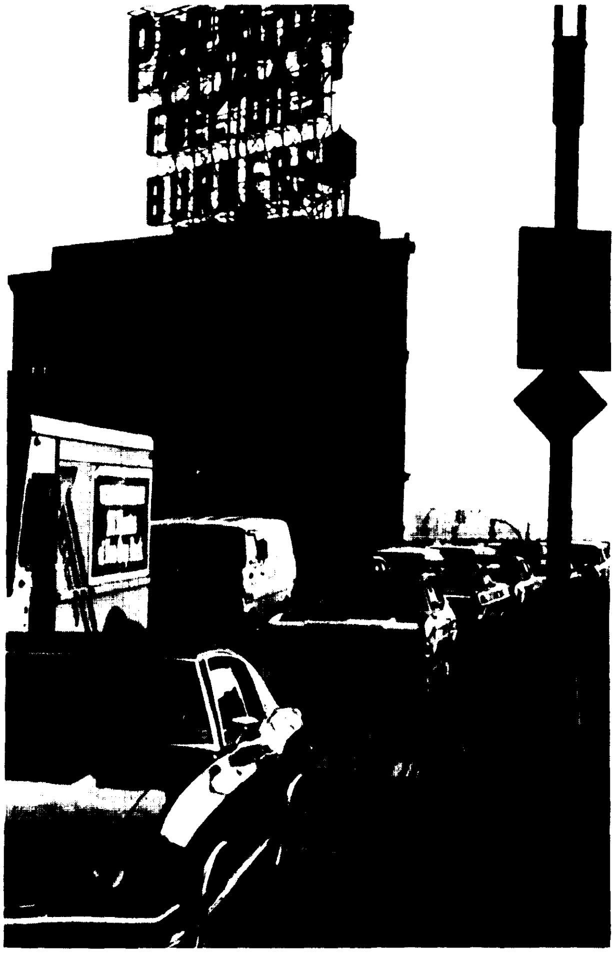


Photo Credit: Sydec

Domestic Fuel Supply

The supply of conventional petroleum from domestic sources is assumed to rise slightly through 1985 with the introduction of production from the Alaskan North Slope. North Slope oil production is expected to reach a maximum of 2 MMBD and hold steady at that rate until 2000. This would raise the total domestic supply to 10.1 MMBD in 1985. Beyond 1985, the supply from the lower 48 States (including the Outer Continental Shelf) is expected to taper off, declining to a production of 5 MMBD by 2000. Thus, the total domestic supply in 2000 would be only 7 MMBD, or about 30 percent of the total unconstrained demand. To meet the domestic demand of 22.4 MMBD in 2000, it would be necessary to find 15.4 MMBD of fuel, either as petroleum imports, alternative fuels or equivalent electrical energy from nonpetroleum sources. (See figure 10.)

Alternate Energy Sources

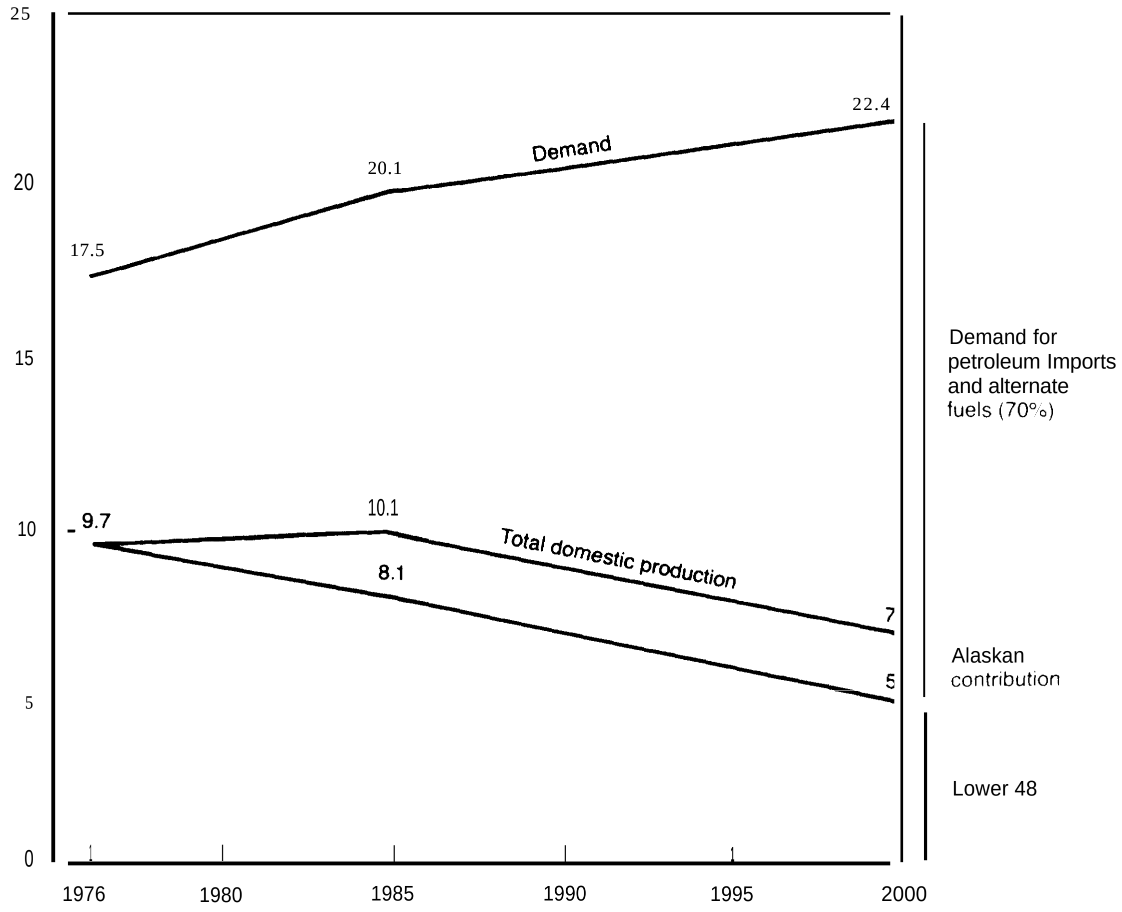
There are a number of resources that can be used to produce motor fuels similar to conventional gasoline or diesel fuel. These fall into four general categories.

1. Synthetic liquid fuels (synfuels),
2. Alcohol fuels,
3. Electricity, and
4. Fuel cells using hydrogen, hydrazine, or blended fuels.

Synthetic fuels and alcohol or alcohol blends are assumed to be the most likely alternate automobile energy sources by 2000. No significant production of synthetic fuels is foreseen before 1985. By 2000, however, technical and economic factors point to production of liquid fuels from oil shale and coal. Extensive commercialization of alcohol fuel (ethanol or methanol) is inhibited at present by economic factors. However, the disparity between alcohol and conventional petroleum prices is expected to be reduced by the mid- to late-1990's. [24]

[24]For a discussion of alternate fuel prospects see Stanford Research Institute International, *Potential Changes in the Use and Characteristics of the Automobile*, Contractor Report, prepared for U.S. Congress, Office of Technology Assessment (Menlo Park, Calif.: SRI International, January 1978), appendix C, and *Sydec/EEA*, pp. III-56 to III-61.

Figure 10.—U.S. Petroleum Supply and Demand (MMBD)



SOURCE: Adapted from *Sydec/EEA*, p. III-2

The Electric and Hybrid Vehicle Act calls for the demonstration of 200 vehicles by 1979 and **7,500** by **1984.** ”[25] The major obstacle to the use of electric power for automobiles is the development of improved batteries that can perform better than the present lead-acid battery, which is considered unacceptable in terms of performance, range, and weight, No major breakthrough in battery technology is assumed for the Base Case, and it is expected that the market penetration of electric vehicles (while it might reach as much as 10,000 vehicles per year by 2000) will cause negligible changes in national petroleum consumption.

[25] *Electric and Hybrid Vehicle Act, Statutes at Large* 90, 1260 (1976), *U.S. Code*, vol. 15, sec. 2501-1514, vol. 42, sec. 2451 and 2473, as amended by *The ERDA Authorization Act of 1978*, P.L. 95-238, 95th Congress, 2nd Session, Feb. 25, 1978, S. 1340, Title VI; *Sydec/EEA*, pp. III-103 to III-106.

Fuel cell technology for automotive application is still in its infancy and is not expected to be an important alternative to fossil fuels by **2000.**

World Petroleum Supply and Demand

The Base Case projections of U.S. fuel consumption indicate that the combined unconstrained demand of all sectors will exceed domestic supply by as much as 10 MMBD in 1985 and *over* 15 MMBD by **2000.** There is grave doubt on technical, political, and economic grounds that the level of petroleum imports needed to meet this shortfall could be, or should be, reached or sustained.

In **1976,** the combined demand of the World

Outside Communist Area (WOCA) nations, including the United States, was 49.4 MMBD. Of this, OPEC supplied 30.7 MMBD, and the United States supplied 10.1 MMBD. (See table 24.) In order to meet the demand of **84** MMBD projected for WOCA in **2000,** OPEC production would have to increase to **62** MMBD, about double current production.[26] The ability of the OPEC nations to double the rate of petroleum production over the next two decades is technically doubtful. OPEC (principally Middle Eastern) reserves are generally estimated to be large enough to fulfill such a world demand, but it is not certain that it is physically possible to pump oil from the fields at a rate of **62** MMBD. There is also doubt that present production, transportation, and refining facilities could be expanded as rapidly as necessary. Analysis performed in connection with this study indicates an optimistic value of **56** MMBD and a pessimistic value of **34** MMBD. A middle estimate of 45 MMBD was thought to be realistic in terms of portraying background world petroleum supply for the Base Case. However, this figure is an assumption more than an estimate and could still be too high on purely technical grounds .27

Even if it is assumed that the technical problems of production could be surmounted, there remains doubt about the economic feasibility of an OPEC production rate in the range of **50** to **60** MMBD. The OPEC nations may conclude that their petroleum is more valuable” to them in the ground as a future resource than it is on the immediate market. OPEC already has difficulty in making efficient use of present petroleum revenues. For economic reasons, the OPEC nations—severally or collectively—may choose to husband production to keep pace with their ability to utilize capital, especially since deferred production may lead to greater future profits.

The Base Case assumptions about world petroleum supply are also extremely sensitive to international political factors. The United States now uses more energy per capita than any other major country,[28] and the rest of the world is

[26]This assumes that the Communist nations do not become net importers of petroleum by that time. The eventuality that the Communist Bloc would become competitors for WOCA petroleum was explored in a recent CIA report, which concluded that the probability was high. U.S. Central Intelligence Agency, *The International Energy Situation: Outlook to 1985*, ER 77-102400, April 1977.

[27]More detail on the assumptions underlying these estimates can be found in *Sydec/EEA*, p. III-93.

[28]U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract. . . .* p. 881.

Table 24.—World Petroleum Supply and Demand (MMBD)

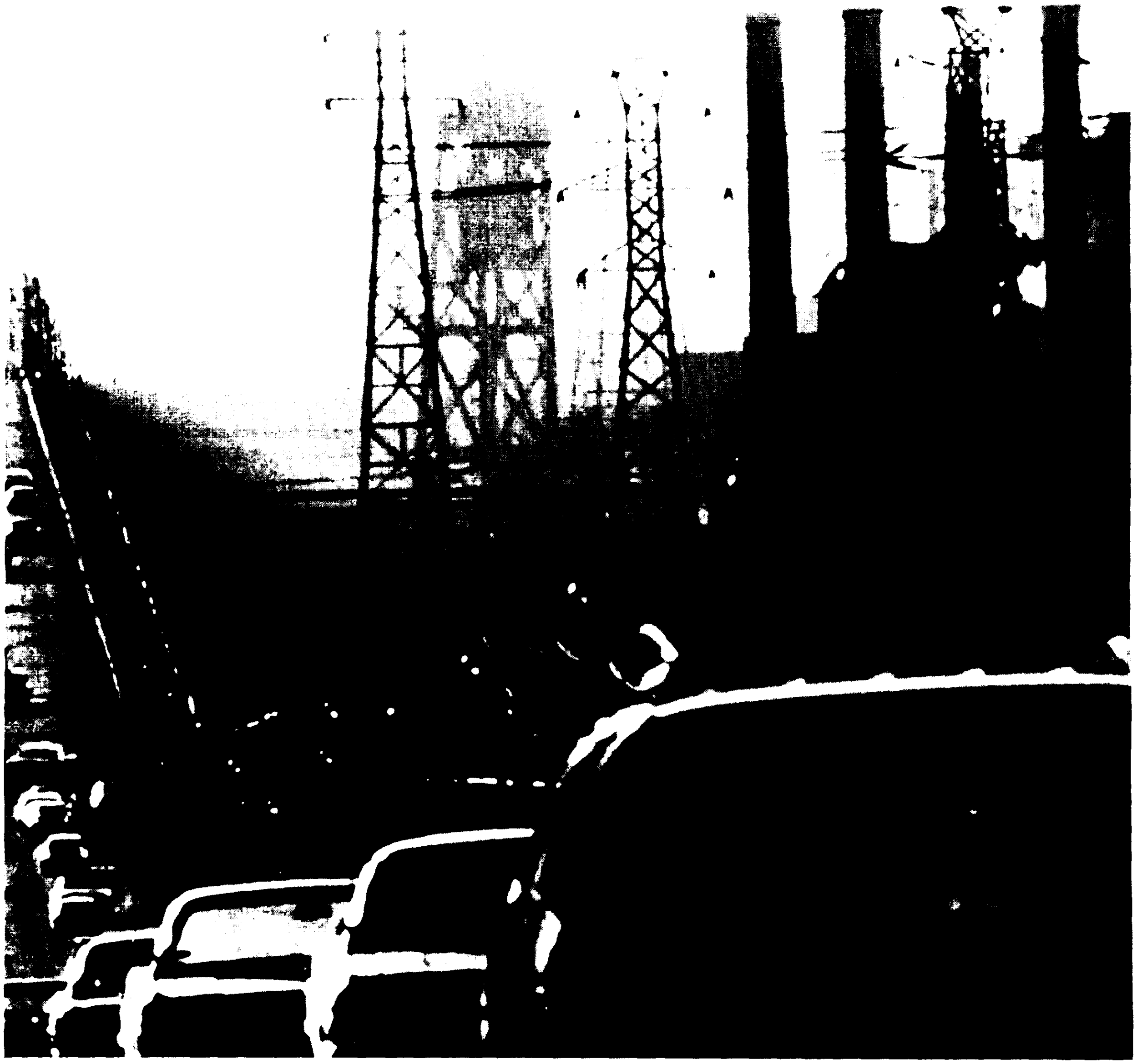
	1976	1985	2000	
			Case A	Case B
Domestic demand				
Automobile	5.2	4.8	4.8	4.2
Other transportation	4.0	5.5	7.8	7.8
Other sectors	8.3	9.8	9.8	9.8
Total domestic	17.5	20.1	22.4	21.8
Other WOCA[a]	31.7	41.0	62.0	62.0
Total WOCA demand	49.4	61.1	84.4	83.8
Domestic supply				
Lower 48 and OCS[b]	10.1	8.1	5.0	5.0
Alaska	—	2.0	2.0	2.0
Total domestic	10.1	10.1	7.0’	7.0’
OPEC	30.7	38.0	45.0	45.0
Other WOCA	6.7	13.0	15.0	15.0
Total WOCA supply	47.5	61.1	67.0	67.0

aWorld Outside Communist Area
bOuter Continental Shelf
cExcludes Base Case alternate fuels estimate of 2.75 MMBD
SOURCES: WOCA data, U.S. Central Intelligence Agency, *The International Energy Situation: Outlook to 1985*, April 1977
CPEC Data, U.S. Department of Energy, *Monthly Energy Review*, January, 1978.

conscious of this extravagance. The future inability of the United States to conserve energy (especially petroleum) could lead to serious political disagreement with other WOCA nations on how to share the available level of OPEC petroleum, whatever it may be. Within the OPEC nations, there are additional political pressures that might militate against satisfying WOCA (or U. S.) demand.

From the viewpoint of the U.S. economy, the present level of imports has already damaged the U.S. position on balance of payments. Increasing the percentage of imports to between 55 and 70 percent by 2000 (depending upon whether 2.75 MMBD of alternative fuels can be produced) may prove to be *a* burden that the United States cannot sustain for either economic or political reasons.

Thus, the fundamental conclusion to be drawn from the Base Case projections of energy demand for the United States as a whole and for the automobile system in particular is that the Nation faces the possibility of a severe shortage of petroleum before **2000.** The automobile will still be a major user of petroleum at that time, and a determination will have to be made as to how much further to reduce automobile fuel consumption.



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ENVIRONMENTAL PROJECTIONS

Environmental protection has been a focal point of Federal Government policy since the **1960's.** An important, and often controversial, feature of this policy has been the effort to reduce or mitigate the effects of widespread and intensive automobile use. Heaviest emphasis has been placed on control of automobile emissions and environmental impacts of highways, but other effects–noise, disposal of solid and liquid wastes, and water contamination—deserve attention.

Air Quality Policy and Assumptions

The Clean Air Act of 1970 (Public Law 91-614) and its amendments provide for control of six forms of atmospheric pollutants—carbon monoxide, nitrogen dioxide, photochemical oxidants, hydrocarbons, suspended particulate matter, and sulfur dioxide. Of these, all but the last two are emitted by automobiles in significant quantities. The current standards for automobiles, established in the 1977 amendments to the Clean Air Act, apply to emissions by new cars through the 1981 model year. The standards specify the permissible levels of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x) that an automobile may emit per mile over its useful life (defined as 50,000 miles). The standards and the schedule for their attainment are shown in table 25.

Table 25.—Automobile Emission Standards for the Base Case

Model year	Standard (grams/mile) CO	HC	NO_x
1975	15	1.5	3.1
1976 -79	15	1.5	2.0
1980	7	0.41	2.0
1981-83 (spark-ignition)	3.4	0.41	1.0
1981-83 (diesels)	3.4	0.41	1.5
1984-2000 (all vehicles)	3.4	0.41	1.0

For the Base Case, it is assumed that the 1981 standards remain in force until 2000. During the period 1981-83, when automobile NO_x standards will be 1.0 gram per mile, it is assumed that diesels are granted a waiver to 1.5 grams per mile to allow time for improvement in diesel emission control technology. It is further assumed that by **1983,** these improvements will have been effected and that thereafter all automobiles (whether powered by a diesel or a spark-ignition engine) will be able to meet the 1.0 gram-per-mile standard.

An important factor in estimating future automobile emissions is the rate at which emission control devices deteriorate in use. The current certification procedure is based on an estimated average level of emissions over the useful life of the vehicle, which is defined as 5 years or **50,000** miles. For this study, the deterioration rates assumed are the January **1978** estimates issued by EPA. These estimates cover not only the 50,000-mile certification period, but the full life of the car.[29] The emission rates assumed for other mobile sources and stationary sources are also those currently estimated by EPA.[30]

The Clean Air Act Amendments provide for the application of an inspection and maintenance program for vehicles in use in areas where National Ambient Air Quality Standards for carbon monoxide or oxidants are not expected to be attained by **1982.**[31] To date, few such programs have been instituted under the Act, and the Base Case assumes that none will be mandated by the Federal Government by **2000.**[32]

Air Quality Projections

Base Case projections of automobile emissions are shown in table **26. CO,** HC, and NO_x emissions are expected to decline from current levels by 1985, and further still by 2000. The greatest reductions are in CO and HC emissions

[29] U.S. Environmental Protection Agency, Office of Transportation and Land Use Policy, "Memorandum on Revised Mobile Source Emission Factors," January 1978.

[30] U.S. Environmental Protection Agency, Office of Air and Waste Management, *Automobile Emission Control—The Development Status, Trends, and Outlook as of December 1976.* A Report to the Administrator prepared by Emission Control Technology Division, Mobile Source Air Pollution Control, April 1977; U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards, *Compilation of Air Pollutant Emission Factors,* Part A, AP-42, 3rd edition, August 1977.

[31] *Clean Air Act of 1970. Statutes at Large* 91, 745 (1970), *U.S. Code,* vol. 42, sec. 7502 (August 1977).

[32] The potential benefits of a nationwide mandatory inspection and maintenance program are examined in chapter 6 as one of the policy alternatives for environmental improvement.

Table 26.—Projected Base Case Automobile Emissions

Pollutant	1975 Million tons/ year	1985 Million tons/ year	1985 Percent of 1975	2000 Million tons/ year	2000 Percent of 1975
Carbon monoxide.	69.3	32.6	47	27.3	39
Hydrocarbons[a]	7.9	3.5	44	2.9	37
Nitrogen oxides	4.0	2.7	68	2.9	73
Particulates[b].	0.38	0.08	21	0.25	66
Lead[c].	0.15	0.04	27	0.03	20

[a]Includes crankcase emmissions and fuel system evaporative losses
[b]Total suspended particulate matter
[c]Based on projected gasoline consumption and the present EPA schedule for phasing out lead additives
SOURCE: *Sydec/EEA*, p. III-13

(over 60 percent for each by **2000**). **NO_x** emissions are expected to decline by **1985** but to rise again by **2000** as a result of the growing use of diesels.

Projections of particulate emissions are sensitive to the proportion of diesels in the fleet. Particulate emissions would drop by three quarters between **1975** and **1985**, but would climb back as diesel penetration increases.

It should be noted that all types of vehicle emissions reach the lowest levels in the mid-*1990's*. Assuming a 13-year vehicle turnover, almost all of the vehicles on the road at that time will be of a vintage designed to meet the currently programmed standards. As travel increases, the reductions due to lower vehicle emissions are offset by increased VMT.

A projection of aggregate emissions from all sources was prepared using EPA data on emissions from nonautomotive mobile and stationary sources. (See figure 11.) Automobiles are expected to account for only minor fractions of CO, HC, and NO_x emissions from all sources by **2000.** The improvement due to control of automobile emissions will be offset by a much slower decrease (and in some cases an increase) in emissions from other sources. As a result, air quality is not anticipated to reach the levels specified by National Ambient Air Quality Standards in many areas of the country by **1985** and **2000.**

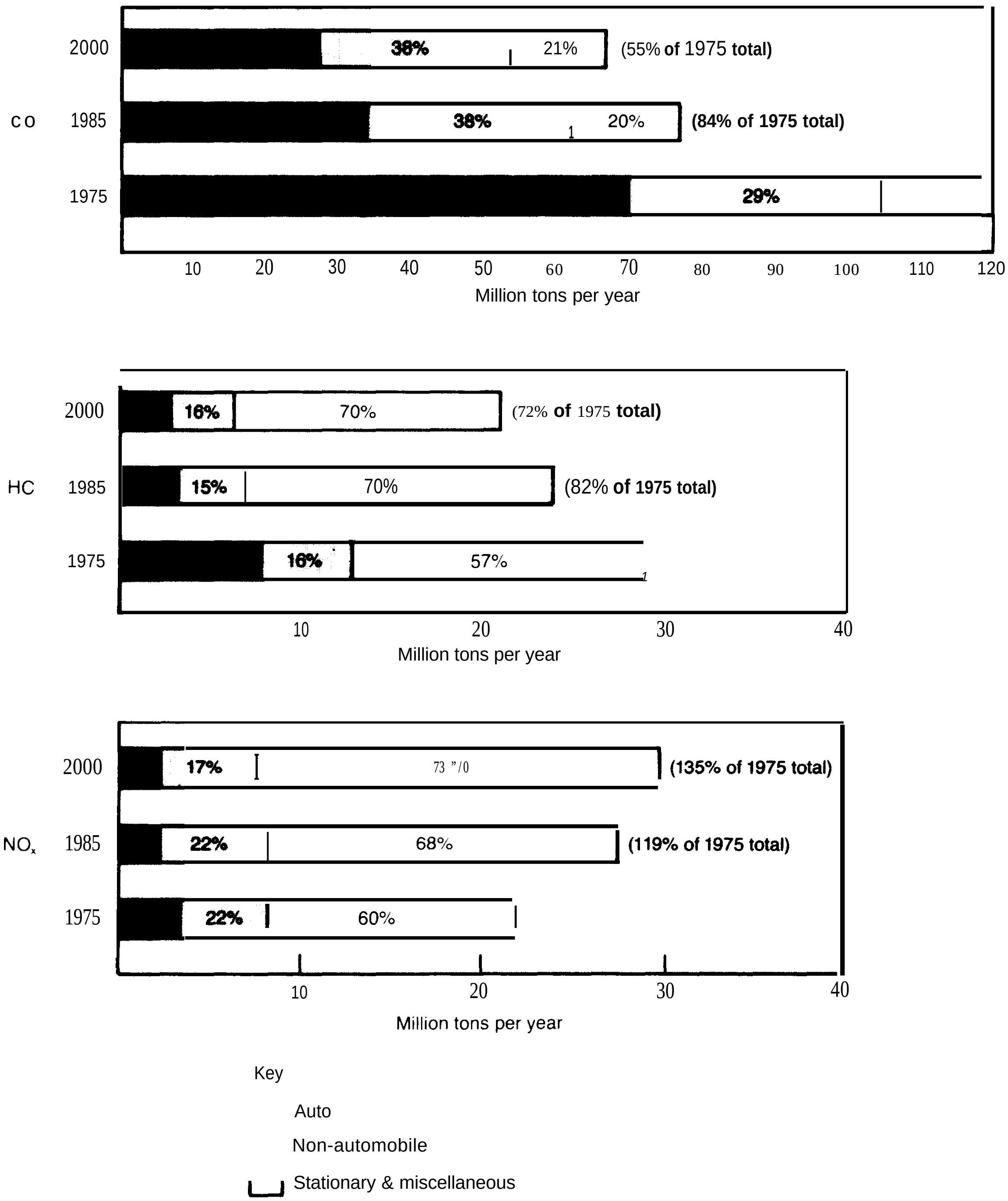
Table 27 indicates the number of Air Quality Control Regions (AQCRs) where violations of air quality standards are projected for 1985 and 2000. Violations of the 8-hour CO standard (10 mg/m^3) in **2000** are expected to fall to about one-third the 1975 level. Extreme violations (twice as high as the permissible level) show the most dramatic decrease, falling from **25** in **1975** to 2 in **2000.** Violations of the oxidant standard **(160** $\mu g/m^3$ in a l-hour period), although expected to show some decline, will continue to be high. It is projected that the oxidant standard

Table 27.— Projected Violations of Air Quality Standards, Base Case

Pollutant	1975	1985	2000
Carbon monoxide			
Number of AQCRs[a] exceeding standard[b]. . .	43	34	22
Number of AQCRs exceeding 2X standard. .	25	3	2
Total violations.	68	37	24
Oxidants			
Number of AQCRs exceeding standard[c]. . . .	49	46	41
Number of AQCRs exceeding 2X standard. .	20	11	8
Number of AQCRs exceeding 3X standard. .	8	2	3
Number of AQCRs exceeding 4X standard. .	7	3	2
Total violations.	84	62	54

[a]AQCR: Air Quality Control Region. There are 247 AQCRs in the United States and its territories.
[b]The CO standard used here is 10 mg/m^3 in an 8-hour period.
[c]*The Oxidant standard is 160 $\mu g/m^3$ in a 1-hour period.*
SOURCES: 1975 data, U.S. Environmental Protection Agency, *Monitoring and Air Quality Trends Report. 1974.* February 1976. Data were modified when more recent and accurate information was available.
Projections, *Sydec/EEA*, III-120.

Figure 11 .—Projected Base Case Emissions by Source, 1975-2000



SOURCE: Sydec *EEA*, p. Ill-119

will be violated in about **25** percent of the AQCRs in 1985 and in slightly over 20 percent of the AQCRs in **2000.** However, as shown in figure 11, the principal contributors to the high levels of oxidants will be stationary sources (about 70 percent). Of the remainder, automobiles will account for about one-third, or roughly 10 percent of the total.

Figure 12 shows projected cumulative population exposure to CO and oxidants in 1985 and 2000. The number of people exposed to CO concentrations above the standard is expected to decline sharply by 1985, and further still by 2000. The projection for oxidants, however, shows only marginal improvement between 1975 and 2000. Although the number of AQCRs in violation of the oxidant standard will decrease, the population in the areas that remain in violation will increase. The net result is that by **2000,** the number of people exposed to hazardous concentrations of oxidants is expected to be about the same as today. Obviously, not every person in a given AQCR will be exposed to exactly the same level of pollutants and for the same duration. The projections shown in figure 12 are only approximations, but they do indicate the magnitude of the air pollution problem that is expected to persist.

Other Environmental Projections

Base Case projections of environmental impacts were limited to air quality, the most significant environmental concern in the future development of the automobile system. No attempt was made to develop estimates of other types of environmental impacts. However, the Base Case does include general projections of other environmental trends that are expected to result from continuation of present policies.

Noise

Efforts to control motor vehicle noise have followed two approaches—control of the source (the vehicle itself) and highway planning and design standards for noise abatement, EPA has established noise standards for medium and heavy trucks, which call for the noise level to be reduced to 75 dBA (decibels absolute) by 1983. EPA has announced its intent to issue regulations for motorcycle and bus noise during **1978.** EPA is now evaluating noise test data for automobiles, which may become candidates for regulation by the 1980's. The Federal Highway Administration (FHWA) has established design noise levels for highways, and assessment of noise impacts is a regular part of the planning and approval process for federally assisted highway projects.

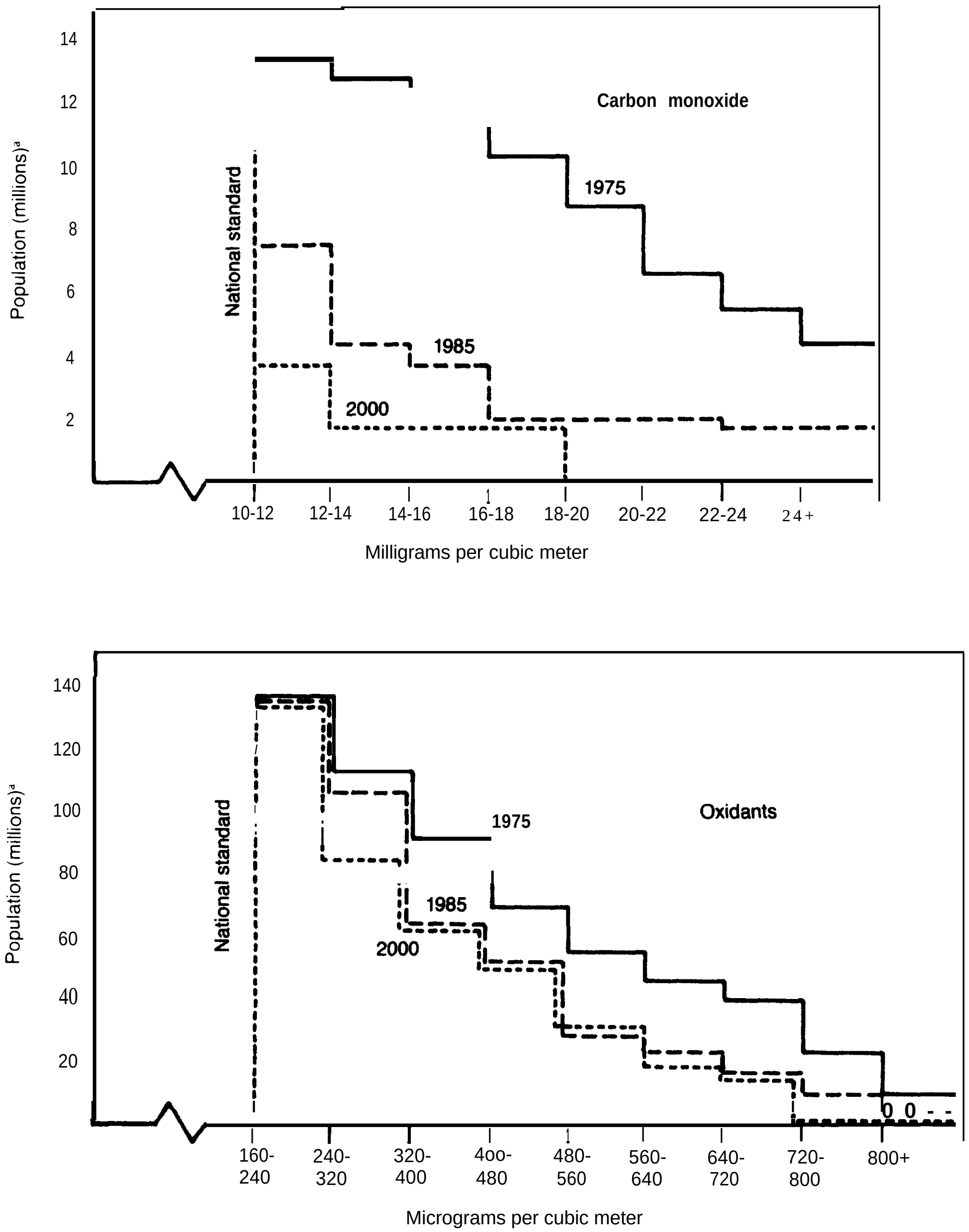
In the Base Case, noise conditions are not expected to change substantially in the short term. However, in the long term and for specific communities with severe automobile congestion, motor vehicle noise could reach levels that require Federal or local government intervention, either to control noise sources or to restrict the conditions of motor vehicle use. The quieting of medium and heavy trucks under EPA regulation will reduce traffic noise levels in many areas, particularly where commercial truck use is concentrated and on arterial routes carrying significant truck traffic. Restricting bus engine noise will reduce sound levels in central business districts and in residential neighborhoods along bus routes. However, these reductions will be partially offset by the increased volume of truck and bus use forecast under Base Case conditions.

It appears that automobile noise will not become so severe that stringent controls will have to be imposed. For the automobile traffic volumes projected in the Base Case, automobile noise is not expected to rise significantly above present levels or to become a general environmental problem. Continuing attention to noise impacts in highway planning and to noise abatement measures in highway design will combine to improve noise conditions in many areas in the future.

Solid Waste

The problem of disposing of solid wastes from automobiles (including scrap vehicles and commonly replaced parts) varies with the size of the fleet and the weight and composition of the vehicles. In the Base Case, the automobile fleet is projected to increase approximately 50 percent by the year 2000. Assuming that the scrappage rate remains about as it is now, the number of vehicles to be salvaged or otherwise disposed of will reach 11 million per year by the end of

Figure 12.—Estimated Population Exposed to Air Pollution, Base Case



[a]Population in Air Quality Control Regions exposed to above-standard levels of air pollutants. For CO, populations of AQCRs were divided by 10 to account for the localized effect of CO.

SOURCE: *Sycfec EEA,* p 111-120,

the century. However, because of the downsizing trend, the total weight of scrapped vehicles will increase by only **20** to **30** percent.

An important part of the downsizing program is the substitution of lightweight alloys, aluminum, and plastics for iron and steel. Table 28 illustrates the material composition of present and future automobiles, By 1990, the ferrous metal component is expected to decrease; aluminum, plastic, and nonmetallic components are expected to increase. Difficulty in the recovery or disposal of these nonferrous components may tend to increase the problem of how to handle solid wastes from the automobile in an environmentally acceptable manner.

Table 28.—Change in Materials Used in a Typical Automobile

Material	Percent 1975	Percent 1990
Steel	61	54
Cast iron	16	8
Aluminum	3	12
Other metal	4	3
Plastics	4	9
Other nonmetal	12	14

SOURCE: Automotive News, *Automotive News 1976 Market Data Book Issue* Apr. 28, 1976. Original data from International Research and Technology Corporation

The diesel engine is heavier than the conventional spark-ignition engine. Although some weight reduction would be possible in diesel automobiles, the engine weight is expected to keep the diesel auto heavier than a conventional auto. There is expected to be little substitution for steel and cast iron in the diesel engine, and processes for recovering these metals are expected to remain in use.[33]

Two other components may pose special problems—the catalyst materials in catalytic converters, and batteries. Problems with the latter could become much more significant if electric vehicles begin to be used in significant numbers.

Water Quality

Both highway construction and use cause water quality impacts. So, too, does the disposal of liquid wastes from automobiles (spilled fuels, Lubricants, coolants, battery acid). Since these impacts vary principally as a function of local conditions, no national projections of water quality have been attempted for the Base Case.

Water pollution from automobiles or highway runoff has not been the subject of major control efforts, In most areas, discharges from industrial facilities and sanitary sewage systems pose much greater water pollution problems than automobiles and highways. However, as these major sources come under stricter control, attention may shift to highway runoff and automobile liquid wastes—both of which will be increasing as a result of more highway mileage, more vehicles, and more VMT.

The composition of water pollutants from the automobile transportation system is not expected to change greatly in the next **25** years. However, there are two possible exceptions. First, there could be a change in the type and amount of certain pollutants due to the increasing number of diesel vehicles on the roads. Second, the increasing use of electrically powered vehicles may create problems due to spillage or disposal of battery acids. At this time, only limited information is available on the nature and magnitude of the problems of treating and disposing of these liquid wastes.

Highways and the Community

One of the impacts of the highway program is the disruption caused by the displacement of homes and businesses. To indicate the amount of community disruption, estimates were made of the displacements of residences, businesses, farms, and nonprofit organizations. (See table **29.)** The methodology relating these displace-

Table 29.— Projected Displacements Due to Highway Construction, Base Case

	Average annual displacements: Actual 1971-75	Projected 1985	Projected 2000
Residential units	10,800	5,500	4,300
Businesses	2,500	1,800	1,600
Farms	200	200	160
Nonprofit organizations	100	80	70

SOURCE Sydec *EEA* p III 191

[33] Sydec EEA, p. III-129

ments to Federal highway expenditures took into account both the cyclical nature of these statistics and projected long-term averages. As the rate of capital spending decreases in real dollars, fewer miles of new highways will be constructed, and displacements are expected to decline on an average basis. The rate of residential units displaced yearly will decline to about **40** percent of today's rate by **2000.** Other indicators will also decline, but not as much.

SAFETY PROJECTIONS

Safety Policy and Assumptions

The safety of the automobile system of the future will depend upon changes in the design of automobiles, in the design of the highway system, and in the performance of drivers, as well as on changes in the amount and distribution of driving exposure (VMT). Of the large number of possible Federal policies that would bring about such changes, either alone or in combination, the most significant new policy included in the Base Case is the assumed introduction of passive occupant restraints in automobiles.

Passive restraints are assumed to be introduced in new cars according to the schedule recommended by the Secretary of Transportation:

- All large cars sold in 1982 will be equipped with passive restraints.

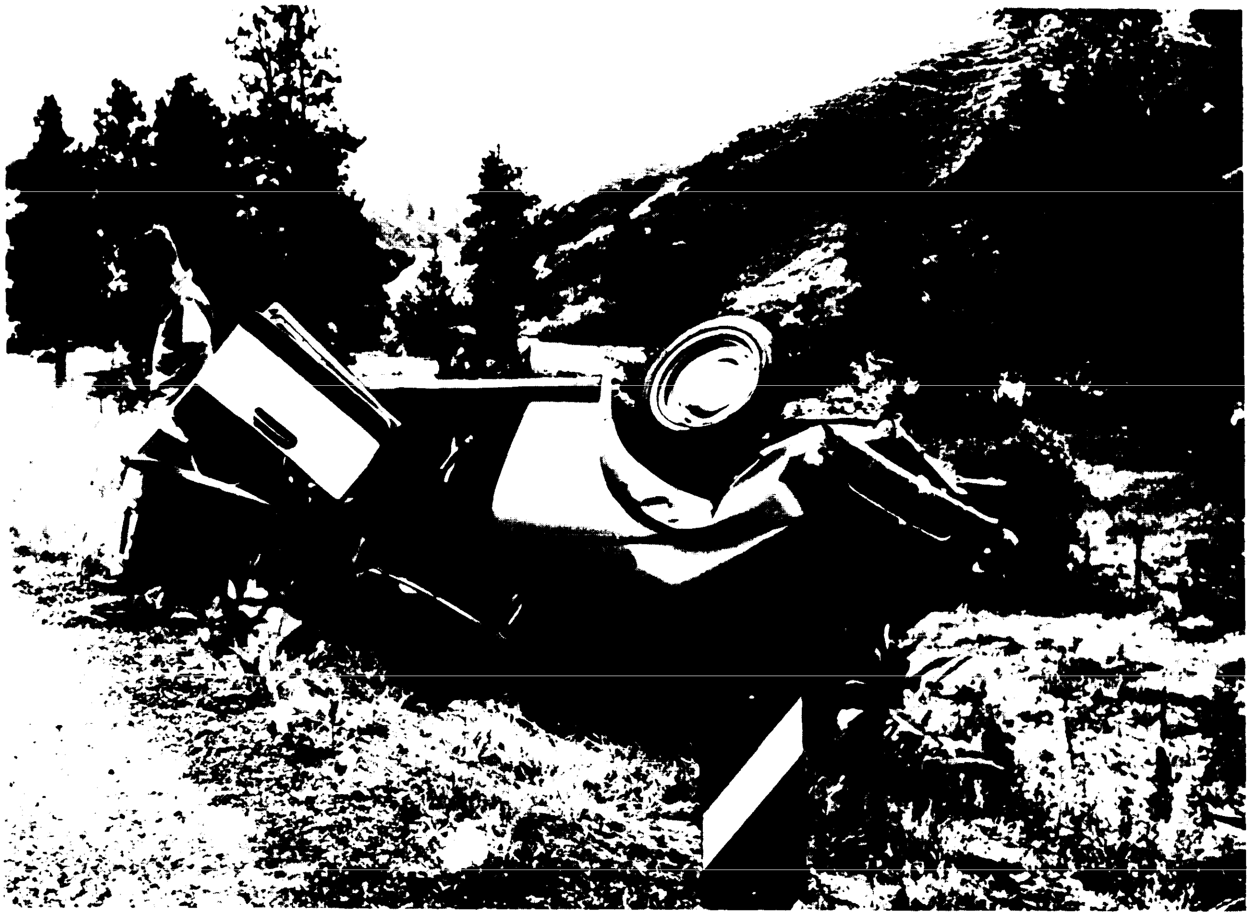


Photo Credit U S Department of Transportation

- All intermediate cars sold in **1983** will have passive restraints.
- All cars sold in **1984** and after will have passive restrain ts.[34]

Estimates of the cost of the air cushion restraint system or its equivalent vary widely. The Department of Transportation forecasts a cost of $112 per vehicle for production in quantity. Ford and General Motors estimates are $193 and $235, respectively. " For the Base Case, it was assumed that air bags would add $200 to the price of a new car.

The existing Federal Motor Vehicle Safety Standards that have been incorporated in current new car designs are assumed to remain in effect in the future. These standards have been adopted over a period of several years and include requirements for specific safety -related equipment and performance specifications for vehicle design elements. The changes being brought about by these regulations are assumed to affect most of the auto fleet by 1985. The Base Case also assumes that other Federal automobile and highway safety programs will continue, but at current levels of funding and effectiveness. These include:

- Alcohol and drug use countermeasures,
- Improved driver skills and awareness,
- Enforcement of the 55-mph speed limit,
- Roadside hazard and grade-crossing elimination,
- Improved highway design and control systems,
- Improved emergency medical services,
- Improved crashworthiness, and
- Automobile safety inspections.

Projected Fatalities and Injuries

The most important factor affecting crash rates between now and 2000 will be the growth in VMT. Generally speaking, fatalities and injuries will increase in direct relation to the number of vehicles on the road and the amount of travel. Other contributing factors will be the increase in urban congestion and the growing proportion of small cars in the fleet. Two factors could have a countervailing effect. A greater proportion of travel is expected to occur on the Interstate System, which is designed for a high level of safety. The introduction of passive restraints in all new passenger cars after 1984 will help reduce deaths and lessen the severity of injury.

These factors were taken into account in developing the Base Case projections of deaths and injuries which are presented in table 30. These values fall within the range of estimates obtained in other recent studies of future highway and automobile safety .[36]

From table **30,** it can be seen that the number of crashes increases proportionately with VMT. The number of deaths and injuries in 2000 are expected to be about 40 percent greater than in 1975. However, the rate of growth will be only about half that of VMT. The growth in the number of fatalities is illustrated in figure 13.

Table 30.—Base Case Traffic Safety Projections

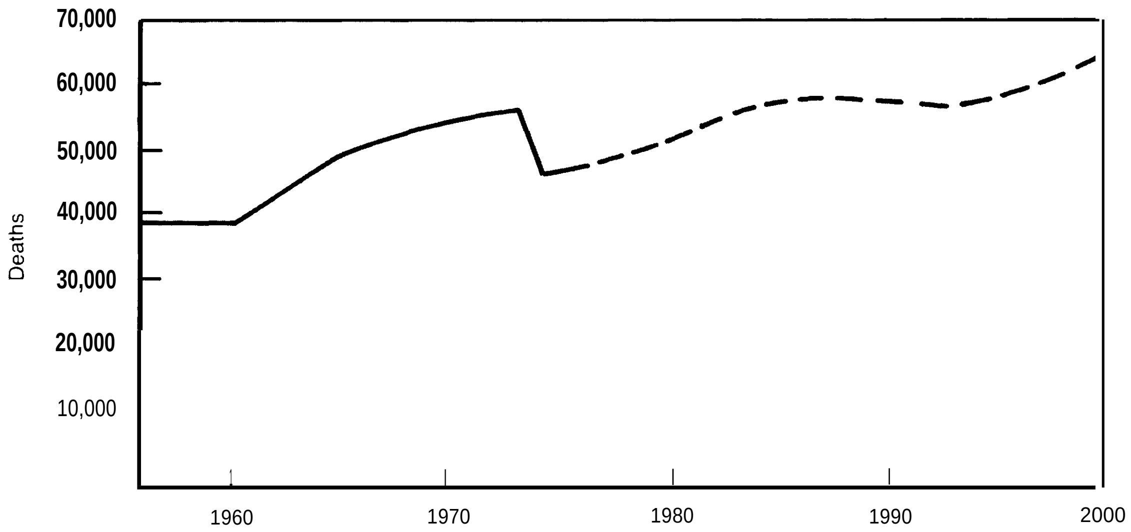
	1975	1985	2000
VMT (trillions)[a]	1.33	1.84	2.32
Traffic crashes (millions)[b]	16.5	22.9	28.8
Total injuries (millions)	4.0	5.0	5.5
Debilitating injuries (millions)[c]	1.8	2.2	2.5
Fatalities (thousands)	46[d]	57	64
Fatality rate per 100 million VMT	3.4	3.1	2.8

[a]Includes all types of vehicles.
[b]Includes all crashes on public roadways involving automobiles, trucks, motorcycles, bicycles, buses, and pedestrians.
[c]An injury that restricts normal activity for at least 1 day after the accident.
[d]Of the 46,000 fatalities in 1975, 27,500 were auto occupants.
SOURCES: 1975 VMT, Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures '77*, p. 62. Other 1975 data, National Safety Council, *Accident Facts, 1976*, p. 40. Projections by OTA

[34]*Federal Register*, (June 30, 1977): 33534-33570.
[35]U.S. Department of Transportation, National Highway Traffic Safety Administration, *Economic Impact Assessment Amendment to Federal Motor Vehicle Safety Standard No. 208 (Occupant Crash Protection)*, July 1977.

[36]Hans Joksch, *Analysis of the Future Effects of the Fuel Shortage and Increased Small Car Usage Upon Traffic Deaths and Injuries*, prepared for U.S. Department of Transportation, Office of the Assistant Secretary for Systems Development and Technology (Hartford, Conn.: Center for the Environment and Man, Inc., January 1976); U.S. Department of Transportation, National Highway Traffic Safety Administration, *National Highway Safety Forecast*, September 1976; U.S. Department of Transportation, *The Report By the Federal Task Force on Motor Vehicle Goals Beyond 1980*, volumes I-III (Washington, D.C.: U.S. Government Printing Office, 2 September 1976).

Figure 13.—Motor Vehicle Deaths, 1975 to 2000



SOURCE: OTA projection using Base Case VMT adjusted for total vehicle travel

The fatality rate per 100 million miles of travel is expected to decline from 3.4 to 3.1 between now and 1985 and to 2.8 by 2000. The major contributing factor will be the introduction of passive occupant restraint systems beginning in 1982. By 2000, virtually all cars on the road will be equipped with such devices.

HIGHWAY PROJECTIONS

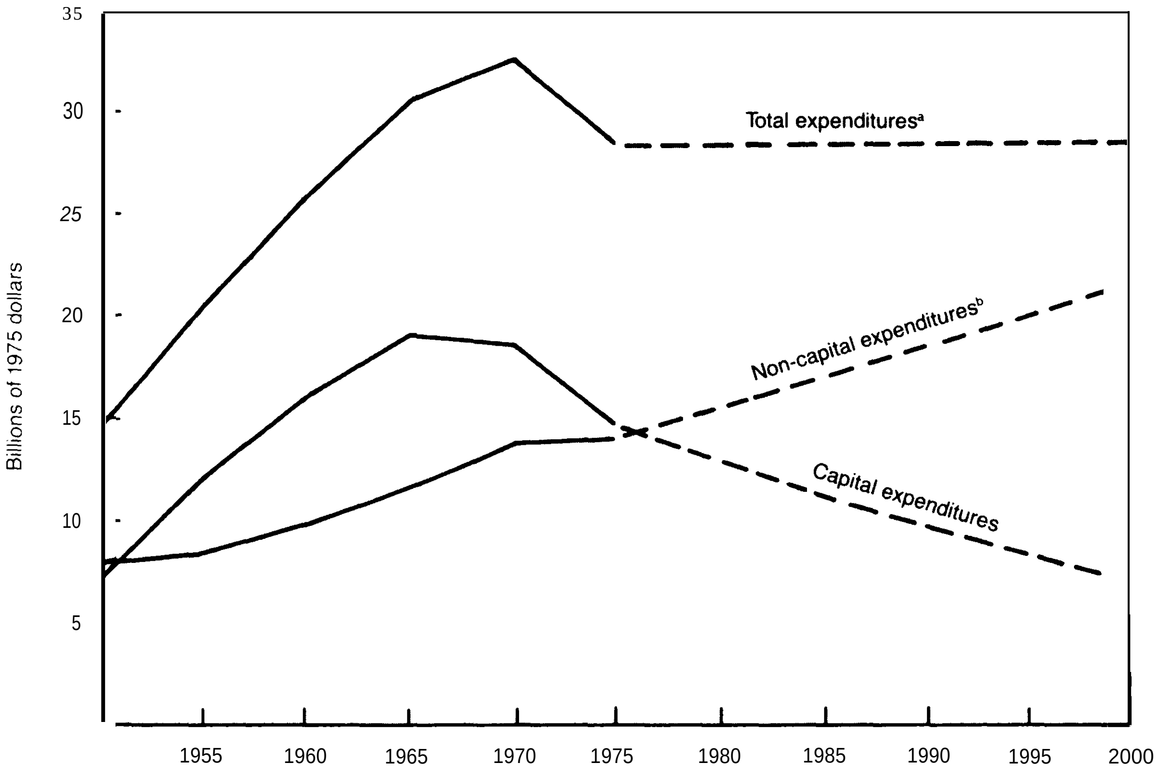
Assumed Highway Expenditures

Since 1960, total highway expenditures by all levels of government have been relatively stable in constant dollars. However, the distribution of these expenditures between capital improvements and noncapital expenses has been shifting. Capital expenditures have declined steadily to approximately half of the total. (See figure 14.)

For the Base Case, it is assumed that the trend will continue and that noncapital items, especially maintenance, will constitute a growing share of highway expenditures by Federal, State, and local governments. Specifically, the Base Case assumptions on highway expenditures are as follows:

- Total highway spending by all levels of government will remain constant in real dollars from 1975 to 2000.
- Capital expenditures, as a proportion of total expenditures, will continue to drop by 1 percent per year from 50 percent in 1975 to 25 percent in 2000.
- Maintenance and other noncapital items will continue to increase 1 percent per year as a proportion of total highway costs.
- The Interstate System will be completed by 1990, using about $38 billion of the cumulative $257 billion (1975 dollars) capital expenditures for the period 1976-2000.
- The Highway Trust Fund and other financing mechanisms will continue in their present form.
- To qualify for Federal assistance, urban area plans will have to include provisions for Transportation System Management (TSM), but no special funding category will be created for this purpose.

Figure 14.—Future Highway Expenditures Assumed for the Base Case



[a] Expenditures by Federal, State, and local governments
[b] Includes maintenance, administration, police, planning, research, and debt service
SOURCE Sydec *EEA, III-33*

- Federal matching shares in all categorical grant programs will not change.
- There will be no new sources of funding for transit within the highway program.
- Technically, there is no Federal funding now available to States for maintenance. However, some of the Federal assistance classified as capital is authorized for resurfacing, rehabilitation, and restoration of roads and bridges. Federal aid for these "3-R" activities is assumed to continue[17]

Table 31 is a summary of the highway expenditures assumed for the Base Case.

Table 31 .—Assumed Highway Expenditures, Base Case

Item	Expenditures (billions, 1975 dollars)		
	1975	1985	2000
Capital outlay	14.3	11.2	7.0
Maintenance	7.1	8.7	10.8
Other (administration, police, debt)	6.8	8.3	10,4
Total	28.2	28.2	28.2

SOURCE 1975 data, Motor Vehicle Manufacturers Association, *Mofor Veh/c/e Facts and F(gures '77,* p 89

Assumed Highway Taxes and Revenues

The primary source of funds for Federal and State highway programs has been the gasoline tax. In 1976, $12.6 billion was collected from this source by all levels of government. Other sources include tolls, parking fees, property taxes, and general fund appropriations. Table 32 summarizes the sources of revenue for highway purposes in 1975.

Approximately two-thirds of all highway revenues in 1975 came from direct user charges. However, fuel tax revenues, which make up a large share of such direct charges, have been

[17] For the Base Case, the current level of 3-R assistance is considered expenditure for capital improvement. Projected increases in 3-R assistance are treated as noncapital items.

Photo Credit: U.S. Department of Transportation

declining slightly in real terms since 1970. (See figure 15.) While the amount of driving (and hence fuel tax revenues) has begun to increase again since the dip caused by the 1973-74 oil embargo, it is expected that automobile gasoline consumption will level off in the 1980's because of mandated fuel economy improvements. (Under Case B assumptions on fuel economy, automobile fuel consumption would actually decline.)

To support a constant level of highway expenditure through 2000, it is assumed that taxes on gasoline and diesel fuel would be increased as needed to maintain revenues at their present level. The assumed fuel consumption and taxes are listed in table 33. Other sources are assumed to provide the same proportion of revenues as in 1975.

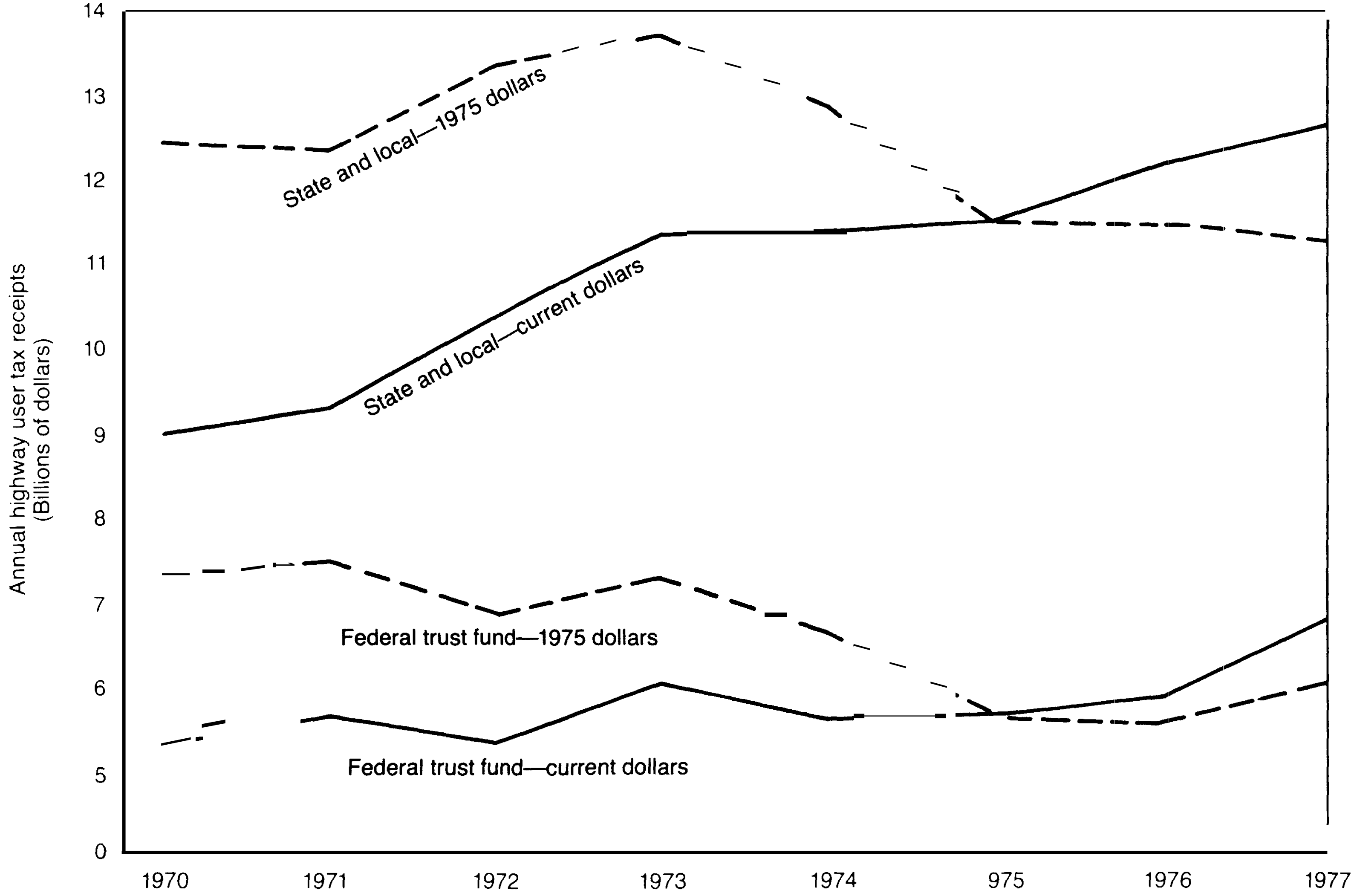
Table 32.—Highway Revenue Sources, 1975 (millions)

Receipts	Amount	Percent
Highway user taxes		
Federal trust fund revenues	$ 5,699	19.9
State and local	11,542	40.3
Tolls	1,263	4.4
Parking fees	120	0.4
Subtotal	$18,624	65.0
Other taxes and fees		
Property taxes and assessments	1,662	5.8
General fund appropriations	4,077	14.2
Miscellaneous taxes and fees	408	1.4
Subtotal	6,147	21.5
Other income[a]	3,877	13.5
Total receipts	$28,648	100.0

[a]Includes income from investments and bond issue proceeds

SOURCE: Motor Vehicle Manufacturers Association, Motor Vehicle Facts and Figures '77, pp 85-89

Figure 5.—Recent Trends in Highway User Tax Receipts



SOURCE: Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures '77*, p. 89.

Table 33.—Automobile Fuel Consumption and Gasoline Taxes

	1975	1985	2000 Case A	2000 Case B
Annual fuel consumption (billion gallons)	76-0	73.3	73.9	64.4
Percent of 1976 consumption	100	96.4	97.2	84.7
Gasoline tax necessary to hold receipts at 1975 level (1975 cents/gallon)	11.7	12.0	12.1	13.8

Projected Highway Travel Speeds and Congestion

The amount of travel, highway speeds, and the level of congestion are indicators of how the highway system serves the needs of motorists. Under Base Case assumptions, total annual vehicle miles traveled by automobiles is projected to increase from 1.03 trillion to 1.43 trillion in **1985** and 1.80 trillion in **2000.** The average annual rate of growth in automobile VMT over the 25-year period is **2.3** percent per year— considerably lower than the 3.8-percent annual rate during 1960-75. The amount of automobile travel per capita also would continue to increase, but at a rate much lower than the 1960-75 trend.

Between 1975 and 2000, VMT on rural roads are expected to increase by 60 percent. Because these roads are now used well below their capacity, it is anticipated that they can accommodate increased demand without affecting travel conditions. Since the projected rural travel growth is expected to be greatest on the higher class roads (for example, a 115-percent increase is forecast for rural interstates), average rural traffic speeds will remain virtually unchanged

In urban areas, where there is already considerable congestion in peak periods, congestion will worsen under Base Case assumptions since road construction is not expected to keep pace with traffic growth. Three main effects are anticipated:

- Peak periods will increase in duration.
- A growing proportion of automobile travel will occur under congested conditions—lo percent in 1975, 14 percent in 1985, and 24 percent in 2000. (See table 34.)
- Average daily speeds will drop on all classes of urban roads, with urban freeway travel in 2000 about 30 percent slower than today. (See figure 16.)

Table 34.—Projected Daily Urban Travel and Congestion

	1975		1985		2000	
	Daily auto VMT (millions)	Percent occurring under congested conditions[a]	Daily auto VMT (millions)	Percent occurring under congested conditions	Daily auto VMT (millions)	Percent occurring under congested conditions
Interstate	288	10	447	18	643	34
Other freeways and expressways	170	11	262	18	382	30
Other principal arterials	465	16	606	21	796	29
Minor arterials	331	8	431	10	564	22
Collectors	150	5	196	7	259	15
Local	230	N.A.	285	N.A.	355	N.A.
Total	1,634	10	2,227	14	2,999	24

[a]Congested conditions occur when the ratio of traffic volume to road capacity is greater than 0.95
SOURCE: *Sydec/EEA*, p.III-78

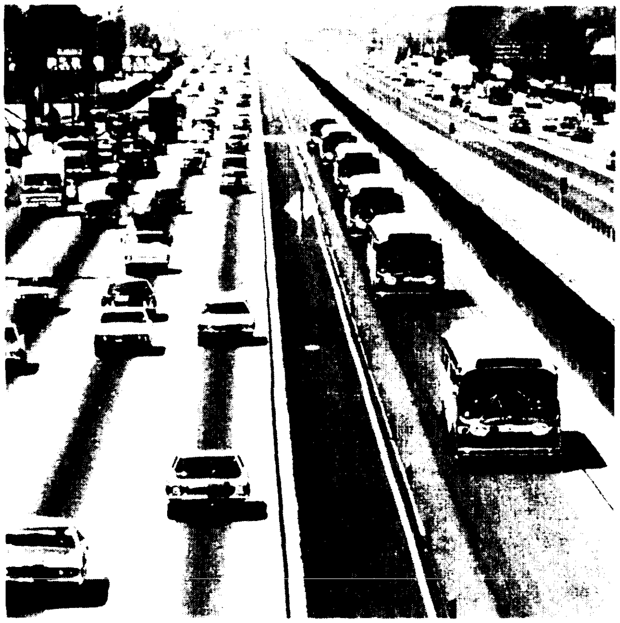
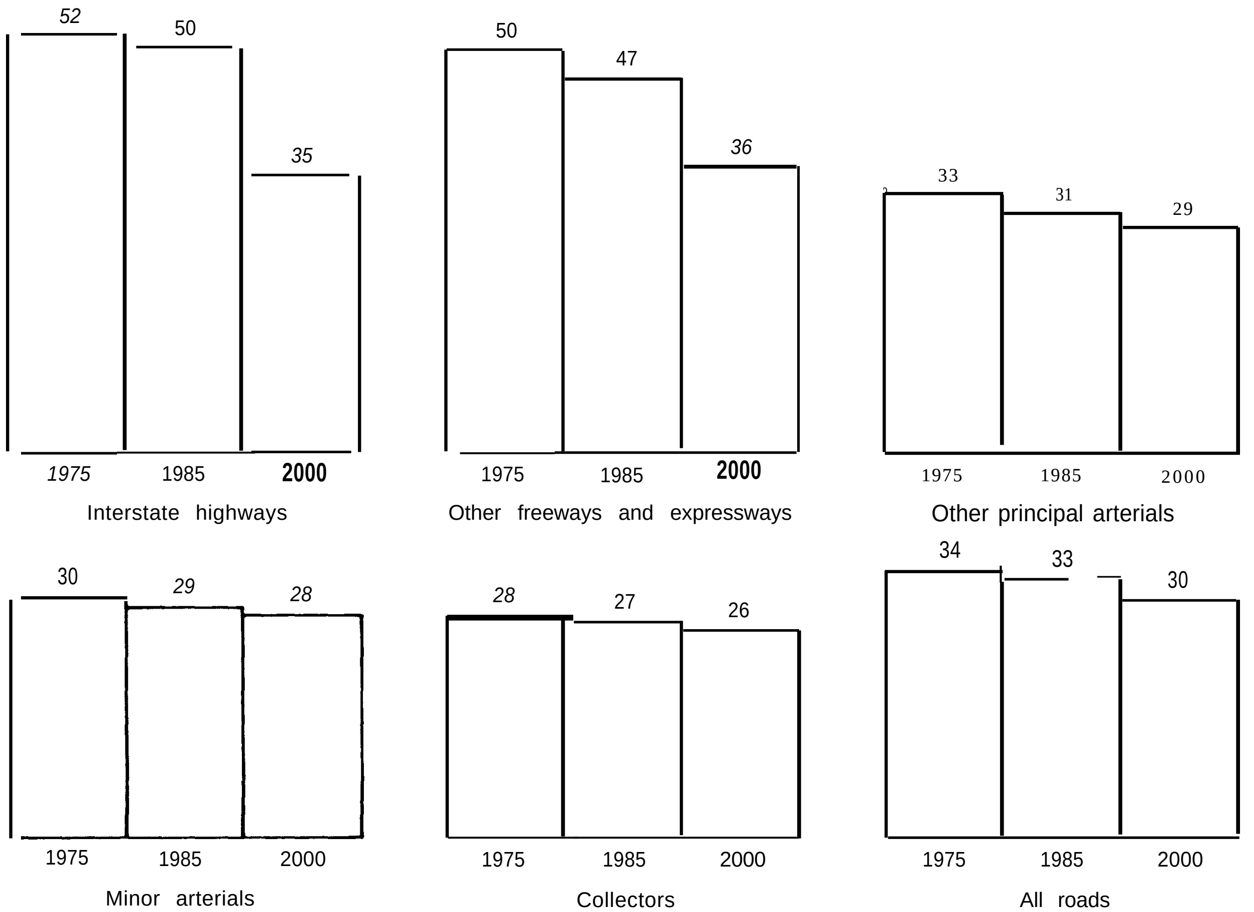


Photo Credit U S Department of Transpor!afjon

Figure 16.—Projected 24-Hour Average Speeds in Urban Areas, Base Case (Miles per hour)



SOURCE *Sydec EEA,* p III-79

Future Roadway Condition

For the Base Case, it is assumed that non-capital highway expenditures, in proportion to total highway expenditures, will increase 1 percent per year. Assuming that highway maintenance expenses retain their current share of non-capital spending, total maintenance spending by all levels of government would increase from $7.0 billion in **1975** to **$10.5** billion in **2000** **(1975** dollars). This increase does not necessarily mean that the Nation's roads will be in better condition. In considering the impact of these expenditures, the following factors must be taken into account:

- As the highway system continues to expand, there will be more roads to maintain.
- Because VMT are expected to grow faster than the highway system, roads will require more maintenance.
- Highway maintenance costs have been increasing faster than the Consumer Price Index. Although some automation in interstate highway maintenance is expected, there will still be a continuing increase in maintenance costs per lane mile.
- Some of the increasing maintenance requirement will be classified as minor reconstruction and will be eligible for Federal aid.

Quantitative estimates of the future condition of highways and streets have not been attempted for the Base Case. However, given the projected travel demand and the assumed funding for construction and maintenance, it is expected that the condition of roadways will deteriorate considerably over the coming 25 years.

The assumed highway programs for maintenance and capital improvements do not include any appropriations above current levels for bridge repair. At present, there are about 105,000 bridges needing rehabilitation or replacement, at an estimated cost of $23 billion. The 1977 fiscal year Federal funding for this purpose was $176 million per year, drawn from Highway Trust Fund monies. The need to improve the condition of the Nation's highway bridges may diminish the amount of Federal and State money available for other forms of road maintenance and repair between now and 2000.

TRANSIT PROJECTIONS

Assumed Federal Assistance

Section 3 of the Urban Mass Transportation Act of 1964 authorizes UMTA to make grants or loans to assist States and local governments in financing the acquisition, construction, reconstruction, and improvement of mass transportation facilities. The appropriations for this program, which began at **$60** million in 1965, reached $175 million by **1970.**[38] Currently, the 1978 Surface Transportation Act authorizes nearly $1.7 billion. In addition, $400 million are made available to localities that choose to substitute public transit projects for interstate highway segments.[39]

The assumed future Federal program of capital assistance for transit is based on the following considerations:

- There is great uncertainty in future appropriations for this program because Government agencies are budgeted for 1 year at a time and Federal fiscal planning rarely looks as far as 5 years ahead.
- UMTA and DOT support for the capital program is strong, although there has been some question recently about the effectiveness of rail transit.
- The **1978** Surface Transportation Act created a single program for surface transportation and authorized approximately $3.2 billion for FY **1979.** Appropriations under

[38] U.S. Department of Transportation, Urban Mass Transportation Administration, *Urban Mass Transportation Act of 1964 and Related Laws* (Washington, D. C.: U.S. Government Printing Office, 1976), p. 9, footnote 28.

[39] When a State takes advantage of this provision, the highway mileage may be redesignated to another State. The Federal share of the transit project is then appropriated from general revenues. The amount so appropriated may not exceed the amount which would have been spent on the highway segment, nor may it exceed 80 percent of the cost of the substituted transit project. See U.S. Congress, Congressional Budget Office, *Urban Mass Transportation: Options for Federal Assistance*, p. 54, and *U S Code*, vol. 23, sec. 103(e)(4).

this Act are programmed to rise to about $3.7 billion by FY 1982,

- The cost of new buses is increasing, partly due to Federal regulations requiring provisions for the elderly and handicapped. These regulations will also affect costs of rail vehicles and stations.
- There are increasing pressures to expand transit systems to conserve energy and reduce air pollution. However, there is some question whether new rail systems will result in overall energy savings .[40]
- UMTA has made formal commitments or commitments in principle to at least six heavy or light rail systems. ”
- UMTA has begun a demonstration program for Downtown People Movers. Although the current budget is only **$220** million, funding for additional systems may be approved if the first four test installations prove successful.
- The cost of bus and rail transit systems is greater than local or State governments can afford on their own. UMTA regards these systems as one of the keys to improving the quality of life in urbanized areas.[42]

Table 35.—Base Case Transit Financing Assumptions (millions, 1975 dollars)

	1975	1985	2000
Federal capital funds[a]	$1,210	$1,710	$1,710
Local matching share[b]	300	430	430
Operating revenue	2,000	1,420	1,420
Operating cost	3,710	4,620	6,820
Operating deficit	1,710	3,200	5,400
Federal operating assistance	300	930	930
Local share of deficit	1,410	2,270	4,470
Total Federal aid[c]	1,510	2,640	2,640
Total local burden[d]	1,710	2,700	4,900

[a]Includes Federal aid for transit projects built in lieu of interstate highways.
[b]Assumed at 20 percent of project capital cost.
[c]Excludes approximately $60 million to $70 million in special projects for the transportation disadvantaged.
[d]Excludes some small transit operations.
SOURCE: *Sydec/EEA*, pp. III-36 to III-40, p. IV-44.

[40]U.S. Congress, Congressional Budget Office, *Urban Mass Transportation. . . .*

[41]U.S. Congress, Congressional Budget Office, *UMTA Funding: Is It Adequate?*, Staff Draft Analysis, March 1977, p. 8.

[42]U.S. Department of Transportation, Urban Mass Transportation Administration, Office of Public Affairs, *Federal Assistance for Urban Mobility*.

In view of these factors, it is assumed for the Base Case that the Federal Government will continue to increase capital assistance for public transit by 10 percent a year in current dollars until 1985, This will result in a 1985 capital assistance program of $1.7 billion (1975 dollars), compared with $1.2 billion in 1975. Between 1985 and 2000, it has been assumed Federal capital assistance for transit will remain at $1.7 billion per year. Assumptions for Federal assistance to public transit are listed in table 35.

The assumed level of Federal assistance would allow the transit fleet to grow by about **46** percent between 1975 and 2000. Fixed guideway miles would increase by 54 percent. (See table 36.)

Table 36. —Base Case Transit Service Levels

	1975	1985	2000
Fixed guideway miles	560	650	860
Rail cars,	10,800	11,800	15,700
Buses	51,500	60,200	75,400
Transit vehicle miles (millions)			
Bus	1,540	1,800	2,260
Rail	450	520	690
Total	1,990	2,320	2,950

SOURCE: 1975 data, American Public Transit Association, *Transit Fact Book* '76-'77 Edition, p. 23.

In addition to capital assistance, Federal aid is also provided for transit system operation under section 5 of the Urban Mass Transportation Act—the so-called “Formula Grants Program. ” Funds are allocated to urban areas with populations over 50,000 by a formula weighted according to population and density. These funds may be used either for capital expenditures or for defraying transit operating costs. To date, 94 percent of the grants have been used for operating assistance, and cover about 20 to 25 percent of the annual national transit operating deficit .[43]

Through 1985, the Federal formula grants program is assumed to increase at a rate of 10 percent a year in current dollars and then to remain constant until 2000. However, operating costs will continue to increase because of the service expansion resulting from the capital pro-

[43]U.S. Congress, Congressional Budget Office, *Urban Mass Transportation . . .*, pp. 7 and 53.

gram and because of inflation.[44] As shown in table 35, the annual operating deficit would grow from $1.7 billion in 1975 to $3.2 billion in 1985 and $5.4 billion in **2000.** The assumed $930 million in Federal operating assistance would cover only 17 percent of the deficit by 2000.

Continuance of transit operations would be a major burden on State and local governments. Their contributions to cover operating deficits would triple over the next 25 years—rising from $1.4 billion in 1975 to nearly $2.3 billion in 1985 and $4.5 billion in **2000.** In contrast, local capital expenditures, which are assumed to follow Federal capital aid at a 20:80 matching ratio, would rise only 40 percent—from $0.3 billion in 1975 to $0.43 billion annually between 1985 and 2000. The total annual subsidy required of State and local governments in 2000 would be $4.9 billion.

Projected Transit Ridership

The projections of transit ridership are based on three factors:

1. Changes in fares,
2. Changes in service levels, and
3. Changes in personal income.

For a number of years, transit fares rose gradually in constant-dollar terms. However, Government support for transit in the early 1970's generally stabilized fares. Between now and 1985, average transit fares are assumed to remain at their current-dollar levels (a decrease from 33 cents in 1975 to 20 cents in 1985 in constant-dollar terms). Between 1985 and 2000, average fares are assumed to remain at 20 cents (in 1975 dollars). The effect would be a 40-percent reduction in real fares, which, by itself, would lead to a 16-percent increase in ridership.

As shown in table 36, transit vehicle miles are assumed to increase by 17 percent from 1975 to 1985 and an additional 30 percent by 2000. The effect of this, by itself, would increase transit ridership by 6 percent between 1975 and 1985 and 10 percent more by 2000.

Disposable personal income per capita is assumed to double between 1975 and 2000. Thus, individuals will have more money to spend for automobile transportation and will be able to afford more easily the higher costs of using an automobile as compared to using transit. Additionally, it is expected that the public will attach greater importance to travel time differences than to cost differences between automobiles and transit. The result of increased personal income, by itself, would cause a 15-percent decline in transit travel by the year 2000.

From the combined effects of lower fares, increased service, and higher disposable income, transit ridership is expected to grow from **5.6** billion passengers in **1975** to 6.5 billion passengers in 1985, an increase of 16 percent. Ridership would remain at the 1985 level through 2000. This transit rider increase is expected to have a negligible effect on miles of automobile travel. Despite the increase in ridership, real transit revenues are projected to decline **29** percent in the 1985-2000 period due to the significantly lower transit fares. (See table 35.)

Part of the rationale for Federal involvement in public transportation is concern for the special mobility problems of those referred to as "transit dependent" or "transportation disadvantaged. " Four groups, recognized as having a high degree of dependence on public transportation or poor access to automobiles, are the old, the physically handicapped, the poor, and the young. Estimates of the present and future size of these groups are given in table 37.

In each of the first three groups, many of the individuals are in fact quite able to manage their personal travel, either by walking, auto, or public transit. For many of the poor, the high costs of auto ownership preclude this mode as the prime means of travel. In **1974, 84** percent of all households owned a vehicle.[45] In comparison, automobile ownership in households with annual incomes under $3,000 was **46** percent. In households earning between **$3,000** and **$5,000** per year, auto ownership was **64** percent. "

The youngest of the young are parent-dependent, and most would not be allowed to travel far from home without adult supervision. However, those who are over 10 and capable of

[44]The cost per vehicle-mile of transit service is assumed to increase 1 percent per year in constant dollars.

[45]Includes cars, pickup trucks, vans, and recreational vehicles.

[46]Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures '77*, p. 38.

unsupervised travel find that, without public transit, most metropolitan area activities are inaccessible. Travel by the young who are driven by their parents involves costly double round trips, with associated increases in energy consumption, environmental effects, and inconvenience to the driver.

The elderly and handicapped will benefit less from improvements in conventional transit but will continue to receive limited service from various special programs provided for their needs. Since the funding for such programs is assumed to remain constant while the number of elderly will be growing, these special services will meet a diminishing share of their transportation needs.

Base Case transit ridership projections, including those for the transportation disadvantaged, are shown in table **38.**

The preceding estimates are for conventional public transit, which consists of buses, heavy

Table 37.—Transportation Disadvantaged Population (millions)

	1970	1985	2000
Adult *disacdvantaged (over* 77)			
Elderly (over 65) not poor and not handicapped	10.2	13.4	15.7
Poor(not handicapped)	9.9	11.6	13.0
Handicapped.	17.1	17.1	17.2
Total adult disadvantaged	37.2	43.6	46.9
Total adult population . . .	135.2	170.6	191.4
Percent of adult population.	27.5%	25.6%	24.5%
Young population (17 and under)			
Handicapped.	0.9	0.9	1.0
Not handicapped	68.8	61.4	68.0
Total young	69.7	62.3	69.0
Total population	204.9	232.9	260.4
Percent of total population .	34.00/.	26.7%	26.5%

SOURCE Adapted from Sydec *EEA* p Ill 42

Table 38.— Projected Annual Transit Ridership, Base Case (millions)

	1970		1985		2000	
	Rides	Percent of total rides	Rides	Percent of total rides	Rides	Percent of total rides
Conventional transit						
Elderly and handicapped (not poor)	440	7	520	8	560	9
Poor (over 17, not elderly, not handicapped) ... , . .	820	14	1,040	16	1,170	18
Total young[a].	1,390	23	1,360	21	1 , 5 2 0	23
All transportation disadvantaged.	2,650	44	2,920	45	3,250	50
Other riders	3,280	55	3,560	55	3,230	50
Total conventional riders hip.	5,930[b]		6,480		6,480	
Services for **elderly** *and handicapped*						
Conventional transit.	440	91	520	93	560	93
Special services	40	9	40	7	40	7
Total service	480		560		600	

[a]Excludes school bus riders.
[b]Ridership in 1975 was 5.6 billion.
SOURCE: Adapted from *Syndec/EEA*, p. III-195

rail, and light rail. Two other forms of transit, Automated Guideway Transit and paratransit, were considered in the Base Case. It was concluded that neither would have a substantial effect on automobile use or on transit service in the 1975-2000 period.

Paratransit refers to types of public transportation that do not operate on fixed routes or schedules, and that bridge the gap between the services provided by the private automobile and those of conventional public transit. Paratransit includes taxis, jitneys, dial-a-ride, vanpools, and other shared-ride systems. With the exception of shared-ride systems that are privately organized, most paratransit has a higher cost per ride than conventional transit and requires a heavy subsidy to survive. The Base Case assumes no special Federal funding of paratransit service. Funding of any expansion of paratransit service that might occur under Base Case conditions is assumed to be part of the overall Federal transit assistance described earlier. The aggregate effects of paratransit on automobile and public transportation are anticipated to be minor for the Base Case.

COST AND CAPITAL PROJECTIONS

Automobile Manufacturing and Sales

Sales of new cars are extremely sensitive to the business cycle, to changes in travel demand, and—as observed in 1974—to the availability of gasoline. For the Base Case, no attempt was made to forecast annual fluctuations in sales. Base Case projections were limited to estimating long-term trends in new car sales and in the size of the automobile fleet.

Although new car prices are expected to increase slightly in real terms under Base Case conditions, the impact on sales will be offset by the generally positive trend in the economy as a whole and by relative stability in the combined costs of ownership and operation. As a result, new car sales are projected to increase from 10.1 million in 1976 to 13.1 million in 1985.[47] The average annual increase in the rate of sales during this period would be 2.9 percent (compared was 2.1 percent in the past decade). After 1985, when the growth in population, licensed drivers, and VMT would be somewhat slower, sales are expected to increase at an annual rate of 1.7 percent —resulting in 16.4 million new car sales in 2000. (See figure 17.)

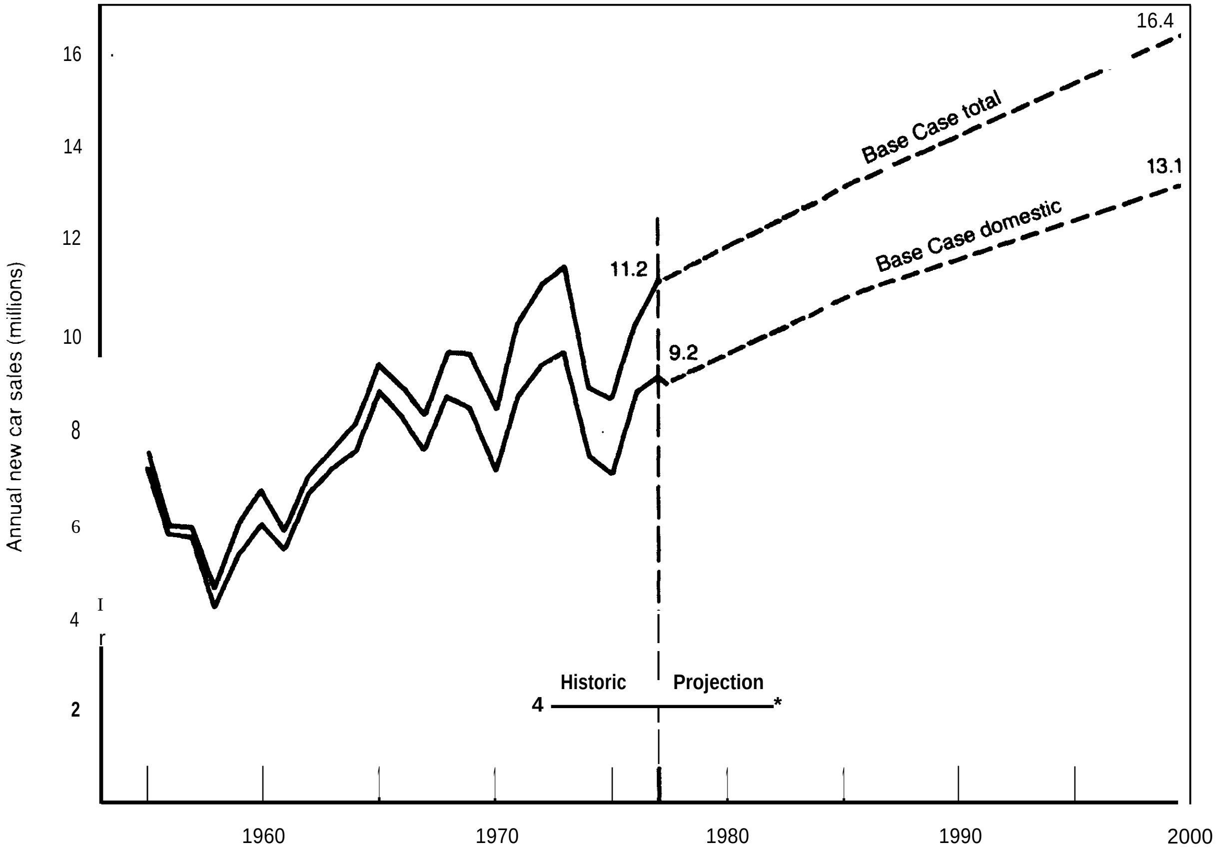
One of the most important developments in automobile technology in the near future—brought about by the influence of the EPCA fuel economy standards—is the expected increase in the number of passenger cars and light trucks equipped with diesel engines. In 1978, it is expected that about 1 percent of the new cars sold will be diesels. The degree of market penetration by diesels in the 1985-2000 period will depend on a number of factors:

- Public acceptance of the diesel as a substitute for the spark-ignition engine,
- The ability of diesels to maintain their current fuel economy advantage (about 25 percent) over the spark-ignition engine and other propulsion systems,
- Fuel economy standards beyond 1985,
- The ability of diesels to meet NO_x emission standards and the willingness of the Government to grant a waiver until the necessary technology can be developed to control NO_x from diesels,
- The need to control the high level of presently unregulated diesel particulate emissions,
- Public tolerance of odor and smoke from diesel exhaust, and
- The operating cost, reliability, and maintrainability of diesels in large-scale production and use.

Alternative sets of assumptions were made for the Base Case, as summarized earlier in table 21. For the higher fuel economy standard of Case B to be met, a higher penetration of diesels

[47] Sales for 1977 were 11.2 million. Jenny L. King, "Good Year for U.S. Sales," *Automotive News*, Jan. 16, 1978, pp. 2 and 6.

Figure 17.—Base Case New Car Sales Projections (Domestic and total sales)



SOURCES Historic sales, Motor Vehicle Manufacturers' Association, *Motor Vehicle Facts and Figures '77*, p. 21 and Jenny L King, "Good Year for U.S. Sales," *Automotive News*, Jan. 16, 1978, pp. 2 and 6. Projections from *Sydec/EEA*, p. III-24 and III-166

would have to come about—is percent of new car sales in **1985** and 40 percent-in 2000. Also, the waiver provision for the NO_x emission standard would be applied to diesels for the period 1981-83 to encourage their development. The difference in fuel consumption in 2000 between Cases A and B iy 12 to 13 percent.

The penetration of imports[48] is also important in assessing impacts on domestic auto-related industries. Between 1966 and 1977, imports rose from 7.3 percent to 18.6 percent of domestic sales.[49] For the Base Case, it is assumed that imports will be about 18 percent of domestic sales from 1978 to 2000.

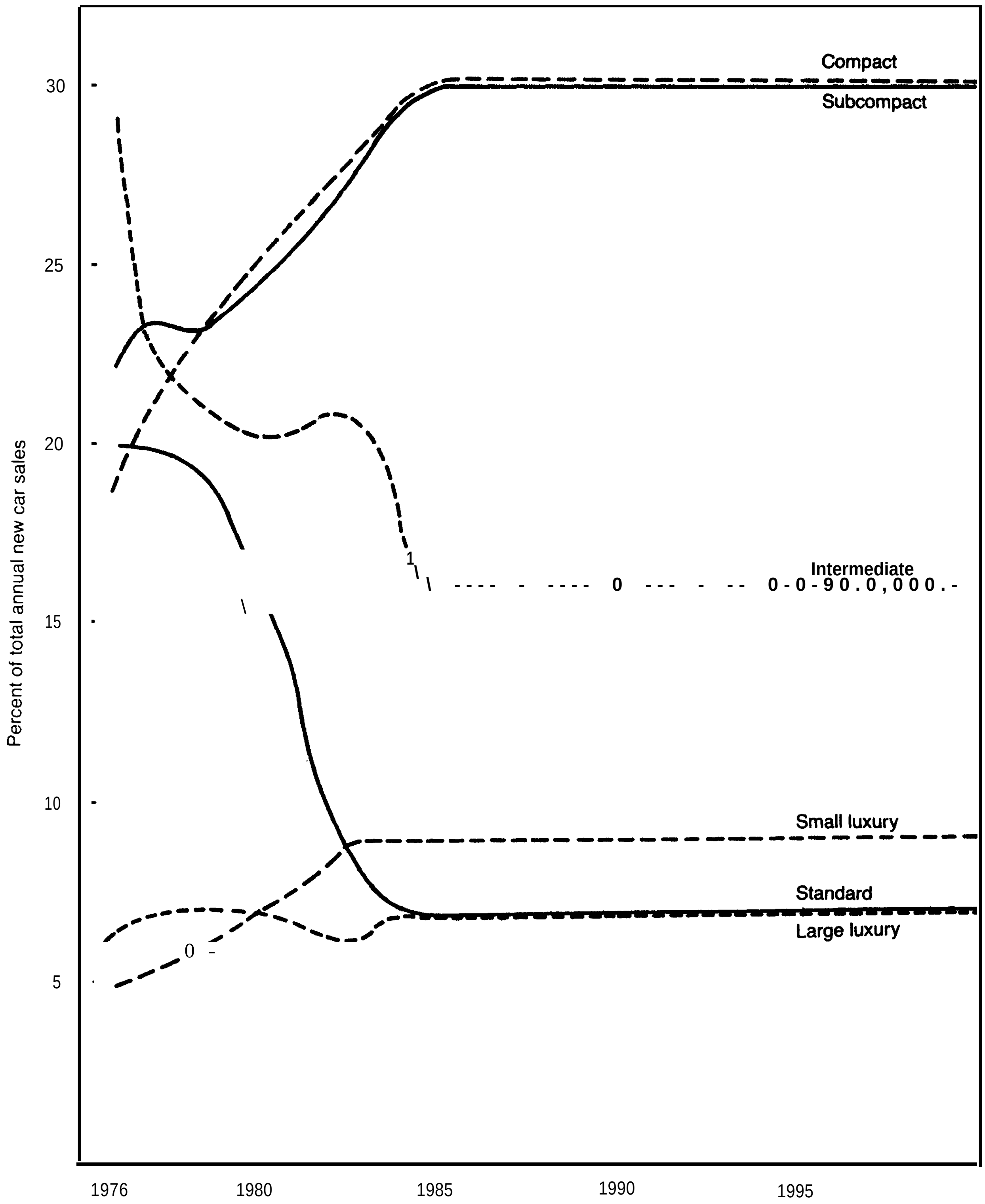
Another important trend is the expected shift in the composition of the auto fleet by size and class. As shown in figure 18 and table 39, small cars (subcompacts, compacts, and small luxury) are estimated to rise significantly as a proportion of the fleet—growing from 46 percent in 1976 to 69 percent in 1985. It **was** not deemed realistic to project any further change in the size-class distribution between 1985 and 2000, Therefore, the 1985 new car market shares were assumed to remain constant to 2000.

For the Base Case, the general projection is that the size of the automobile fleet will continue its steady growth through 2000. The total num-

[48] Imports are defined as autos manufactured outside the United States, except that Canadian-produced U.S. cars are treated as domestics. In 1976, 826,000 Canadian cars were sold in the United States. *Sydec/EEA*, p. III-186.

[49] Jenny L. King, pp. 2-6.

Figure 18.—Distribution of New Car Sales by Size-Class
Base Case



SOURCE: *Sydec/EEA,* Supplementary Report.

Table 39.—Change in the Distribution of Total New Car Sales, Base Case

	Percentage		Volume (thousands)		
	1976	1985[a]	1976	1985	Percent change
Subcompact	22	30	2,225	3,940	+ 77.1
Compact	19	30	1,921	3,940	+ 105.1
Small luxury	5	9	506	1,196	+ 136.4
Intermediate	29	16	2,831	2,111	– 25.4
Standard	20	7	2,022	936	– 53.7
Large luxury	6	7	606	936	+ 54.4
Totals[b]			10,110	13,059	+ 29.2

[a]These percentages are assumed to hold constant from 1985 to 2000 for the Base Case
[b]Columns do not sum because of rounding
SOURCE: *Sydec/EEA*, p. III-169 and Supplementary Report

ber of autos in operation is expected to increase from 95 million in 1975 to 118 million in 1985 and 148 million in 2000. As a consequence, the general picture for the automobile industry (manufacturing, sales, service, fuel distribution, and other auto-related enterprises) is one of sustained growth.

Automobile Manufacturing Revenues

The revenues of domestic automobile manufacturers will be influenced by changes in price, volume, and mix. It is estimated that Government-mandated equipment to achieve fuel economy, emissions, and safety standards will add $400 to $500(in 1975 dollars) to the price of a car by 1985 over the price of a comparable 1976 car. Since the cost of achieving Government standards is assumed to be roughly the same for all cars regardless of size, the effect will be a greater percentage increase for low-priced models than for expensive cars.

It is anticipated that the average revenue per domestic car sale in the United States (including dealer markup and preparation) will not increase in proportion to the volume of sales because of the change in mix. Gross revenues (including dealer markup) are projected to increase from an estimated **$42.9** billion in 1976 to $56.0 billion in 1985 in **1975** dollars, with the price of the average new car increasing from **$4,988 to $5,224. (See** table 40.) This estimate assumes that the relative prices of cars (excluding the impact of Government standards) will remain the same among size classes. However, some of the change in mix represents downsizing, with little or no change in options or interior space. Consequently, the relative prices for downsized cars may be higher. Furthermore, changes in price structure may result from pricing policies designed to reflect consumer demand patterns or to encourage consumers to buy smaller cars in order to meet the corporate average fuel economy standards.

Table 40.— Estimated Gross Revenue[a] From Domestic Car Sales Base Case

	1976		1985	
	Per car sold	Total revenue (million)	Per car sold	Total revenue (million)
Subcompact	$3,600	$ 3,276	$4,083	$ 9,176
Compact	4,200	8,068	4,706	18,540
Small luxury	5,650	1,825	6,126	3,296
Intermediate	4,600	13,023	5,089	10,745
Standard	5,400	11,424	5,888	5,513
Large luxury	8,800	5,333	9,274	8,671
Totals	$4,988	$42,949	$5,224	$55,940

[a]Gross revenue includes dealer markup; amounts are in 1975 dollars
SOURCE: *Sydec/EEA*, pp. III-168 and III-169

Capital Requirements

Production of the kind of automobile dictated by consumer preference and Government requirements will impose major demands on the industry to raise capital for product development and new plant and equipment. No attempt was made to project the total capital requirements of the industry between now and 2000. However, the following partial estimates serve to indicate the probable magnitude of the industry's need for capital.

The U.S. Department of Transportation has estimated the industry investments that would be necessary for various technologies to meet fuel economy standards.[50] The total capital requirement through 1985 is approximately $7.6 billion, or about $1 billion per year. (See table 41.) For comparison, the annual capital investment by the industry for all purposes—annual model change, improvement of plant and facilities, and tooling—averaged about $3.7 billion for the period 1969-76. For the years 1973 and 1974, it averaged about $4 billion annually .51 52

[50] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis 1981-1984 Passenger Automobile Fuel Economy Standards*, Summary Report, Feb. 28, 1977, pp. 33-50.

[51] An industry estimate of total capital requirement for the period 1978-1985 is $78 billion, about $10 billion per year. However, it is not known how much of this is spending required to meet Government regulations. Robert W. Irwin, "Big Four Spending Jacked Up Again by 41% to $78 Billion," *Automotive News*, June 5, 1978, p. 1.

[52] *Sydec/EEA*, pp. III-168 and 169.

Profits

The profitability of motor vehicle manufacturing varies considerably from year to year and from company to company. On the whole, the industry's return on equity and profit margins compares favorably with manufacturing generally.[53] For Base Case conditions, the key factors affecting profits are:

- The anticipated growth in sales,
- The increased capital and manufacturing costs resulting from meeting Government standards, and
- The change in the new car sales mix. 54

The rate of growth in sales projected for the Base Case represents a significant increase over the rate of growth experienced in recent years and tends to improve the outlook for industry profits. The costs of meeting Government standards are expected to increase the price of new cars, but not to the point where sales or profits are affected significantly.

The impact of sales mix on profitability is

[53] *Sydec EEA*, pp. 111-174 to 111-177.

[54] "NO attempt is made to assess the impact on profits of trends in other lines of business engaged in by manufacturers—including foreign operations, trucks and truck parts, and nonautomotive enterprises. The impact of each on the overall profits of the auto companies is considerable. For instance, GM sold more than 3 million trucks in 1976, manufactured 1.6 million cars and trucks overseas, and genera ted $7.5 billion in overseas sales and $438 m i 1 lion in defense and space work. General Motors Corporation, *Anuual Report*, 1976.

Table 41 .—Added Capital Requirements for Technology to Meet Fuel Economy Standards: Cumulative 1977-85

Technology	Units (millions)	Total capital requirement (millions)	Capital per unit
Downsizing	10	$6,250	$625
Material substitution	10	375	37.5
Improved spark-ignition engines	10	250	25
Three-speed automatic transmission with torque converter lockup	10	200	20
Diesel engines	1.5	562	375
		$7,637	

SOURCE: *Sydec/EEA* from U.S. DOT, National Highway Traffic Safety Administration, *Data and Analysis 1981-84 Passenger Automobile Fuel Economy Standards*.

assumed to be adverse. Projections indicate an increase of $486 in the average price per car, but an increase in revenue per car of only $230, due to the shift to smaller cars. A 1976 study of two domestic manufacturers indicates that the variable profit margin is less for small cars than for large ones. ”

Several factors could offset the possible decline in profitability caused by the growing share of the market captured by small cars:

- Savings in material costs due to downsizing (possibly **$200** per car),
- Improvements in productivity, due to producing smaller cars in greater volume,
- General improvements in technology and efficiency, and
- Sales volume growth above expectations, which would result in lower fixed costs per car.

No quantification of future industry profits was attempted,

Employment and Productivity

In recent years, productivity (output per employee) in automobile manufacturing has grown at the rate of **2.7** percent per year. If productivity continues to increase at this rate, a slight decline in automobile manufacturing employment could come about by 1985. However, because of expected increases in other types of motor vehicle manufacturing (trucks and buses), overall employment in the industry is expected to remain relatively constant, as it has since **1967.**[56] **(See** table **42.)**

[55]Pioneer Engineering and Manufacturing Company, *Development of a Motor Vehicle Materials Historical, High-Volume Industrial Processing Rates Cost Data Bank*, Volumes I and II (Warren, Mich.: Pioneer Engineering and Manufacturing Co., May 1976 and November 1976).

[56]This projection is at variance with the Bureau of Labor Statistics (BLS) forecast for 1985. The BLS forecast sees motor vehicle output growing at 2.2 percent per year and productivity at 3.7 percent, with motor vehicle industry employment declining from 860,000 in 1976 to 800,000 in 1985. See *Sydec/EEA*, p. III-180.

Table 42.—Employment in Passenger Car and Parts Manufacturing

	Domestic new car sales[a]	Employment in domestic automobile manufacturing[b]	Domestic new car sales per employee
1974	7,454,000	796,000	9.36
1975	7,053,000	772,000	9.13
1976 ...., ...	8,611,000	809,000	10.65
1985 Base Case.	10,707,000	791,000	13.54

[a]Assumes 18 percent of all U.S. sales are imports.
[b]The employment figures are for the major domestic manufacturers (GMC, Ford, Chrysler, AMC) and relate solely to passenger and automobile parts manufacturers. Total employment in motor vehicle and parts manufacturing (including trucks and buses) was 850,000 in 1976.
SOURCES: U.S. International Trade Commission, *The Fuel Efficiency Tax Proposal*, July 1977; *Sydec/EEA*, based on data from U.S. Department of Commerce, Bureau of Economic Analysis.

Chapter 4

OVERVIEW OF POLICY ALTERNATIVES

Chapter 4.—OVERVIEW OF POLICY ALTERNATIVES

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OVERVIEW OF POLICY ALTERNATIVES

CHAPTER 4A

SCOPE OF POLICY ALTERNATIVES CONSIDERED

The automobile assessment considered policies to deal with the five groups of issues: energy, environment, safety, mobility, and cost and capital. As the first step in selecting the policies to be examined, the Office of Technology Assessment (OTA) held workshops attended by advisory panel members, consultants, and contractors. The purpose of these workshops was to identify a range of policy alternatives and to select those that seemed most promising for study. The two contractors reviewed the workshop results and, with the guidance of OTA, made a further selection of those that would be subjected to detailed analysis.

One contractor, SRI, was directed to use a relevance tree approach to policy selection.[1] The relevance tree is a hierarchical classification of issues, response strategies, general policies, and specific measures to implement policies. The array of policies thus identified was very broad—too broad for all to be examined within the time and funds available. In consultation with OTA, SRI therefore narrowed the list of prospective policies to the following sets:

- Energy: Reduction of petroleum consumption and development of alternative energy sources,
- Environment: Reduction of automobile emissions,
- Mobility: Alternatives and complements to the automobile,
- **Cost and** Capital: Highway supply, financing, and pricing decisions and control of consumer costs of automobile use.

No safety policies were considered by SRI.

The System Design Concepts team (which included Energy and Environmental Analysis and The Institute for Safety Analysis) was directed to take a somewhat different approach.[2] Policies were aggregated in four sets, each designed to accomplish a general objective:

- Petroleum Conservation
- Improved Environment
- Increased Mobility
- Improved Accessibility

Policies relating to safety and cost and capital were incorporated in each of the policy sets, but they were not treated as principal and motivating concerns. Potential changes in automobile system technology were also incorporated in each policy set.

[1] SRI International, *Potential Changes in the Use and Characteristics of the Automobile*, Contractor Report, prepared for U.S. Congress, Office of Technology Assessment (Menlo Park, Calif.: SRI International, January 1978).

[2] System Design Concepts, Inc., Energy and Environmental Analysis, Inc., and The Institute for Safety Analysis, Inc., *Technology Assessment of Changes in the Use and Characteristics of the Automobile*, Contractor Report, prepared for U.S. Congress, Office of Technology Assessment (Washington, D.C.: System Design Concepts, January 1978).

SRI POLICY ALTERNATIVES

The Relevance Tree Approach

The relevance trees used by SRI are intended to illuminate the relationships between the automobile system and public policy. Basically, the relevance tree is a classification of types of Government responses to problems, sets of policies appropriate to deal with these problems, specific policy measures within the policy sets, and (if the relevance tree is appropriately extended) effects and impacts that may be expected from the policies. Thus, the relevance tree identifies a hierarchy of elements to be included in the analysis of alternative policies affecting the automobile system. Separate relevance trees were developed for each issue area in the automobile assessment. (See figures 19 through 23.)

In the construction of a relevance tree, successively more specific levels are defined in the progression from issues to policy implementation.

- Level 1: Issue Area.—The issue area or subject of concern is a general class of problems related to the automobile system. For this study, the five areas of greatest concern are energy, environment, safety, mobility, and cost and capital.

- Level 2: Policy-Related Problems.—A policy-related problem is one that may require legislative or executive action to resolve. For example, a policy-related problem in the energy area is the possibility of a gasoline shortage resulting from inadequate supplies of petroleum (due to an embargo, political unrest abroad, or lack of success in exploiting domestic reserves). The problem may be real and present, or potential. There is no shortage of gasoline now, and it is not certain there will be one within the next two or three decades. But the possibility of such **a** shortage exists, and its impacts would be sufficiently severe that anticipatory action should be considered. In genral, a problem is listed on the relevance tree if it meets three criteria: there must be a significant probability that it could occur; if it occurs, the consequences must be severe; and the Government can initiate action to reduce the likelihood of occurrence or the severity of the consequences.

- Level 3: Issues.—An issue is a matter of disagreement or dispute between two or more parties. It involves value judgments and possible jeopardy to the interests of one or more parties. Statement of the issue for the relevance tree requires that it be formulated in a way that identifies possible Government responses.

- Level 4: Strategies.—Entries at this level identify the general strategies that might be adopted to deal with the issue: regulations, taxes and subsidies, Government-sponsored research and development, operation of free-market forces, public information programs, or Government reorganization. These listings will be virtually the same for all issues, since they are simply the common and proven ways of dealing with problems. To limit the number of policies and policy sets included in the relevance trees, primary consideration has been given to the first three strategies listed above,

- Level 5: Policy Sets.—A policy set is a general solution to a problem, within an adopted strategy. It does not include the specific measures that might be employed to implement the policy. For example, in the environmental area, amendment of automobile emission standards would be a policy set within the strategy of regulation. The definition of emission standards for individual pollutants would constitute a specific policy within this set and would be listed at the next level on the relevance tree.

- Level 6: Individual Policies.—In the example just given—amendment of emission standards—it would be possible to devise almost any number of different specific standards for automobile emissions. Judgment must be exercised in choosing a number large enough to cover the spectrum of technical and political possibilities but small enough to avoid proliferation of the relevance tree. The policies listed later in the relevance trees for each issue area are those that, in the judgment of OTA, represent reasonable and realistic choices. Since others might also be considered appropriate, the policies shown should be regarded as only illustrative.

- Level 7. —Additional levels could be added to the tree to gain either more specificity in the definition of policies or greater comprehensiveness in the structuring of the policy analysis. Sequentially, these levels are:
  - —Implementation methods,
  - —Categories of effects and impacts,
  - —Specific effects and impacts,
  - —Consequences for stakeholders,
  - —Measures to mitigate the adverse impacts of the policy, and
  - —Effects and impacts of mitigation measures.

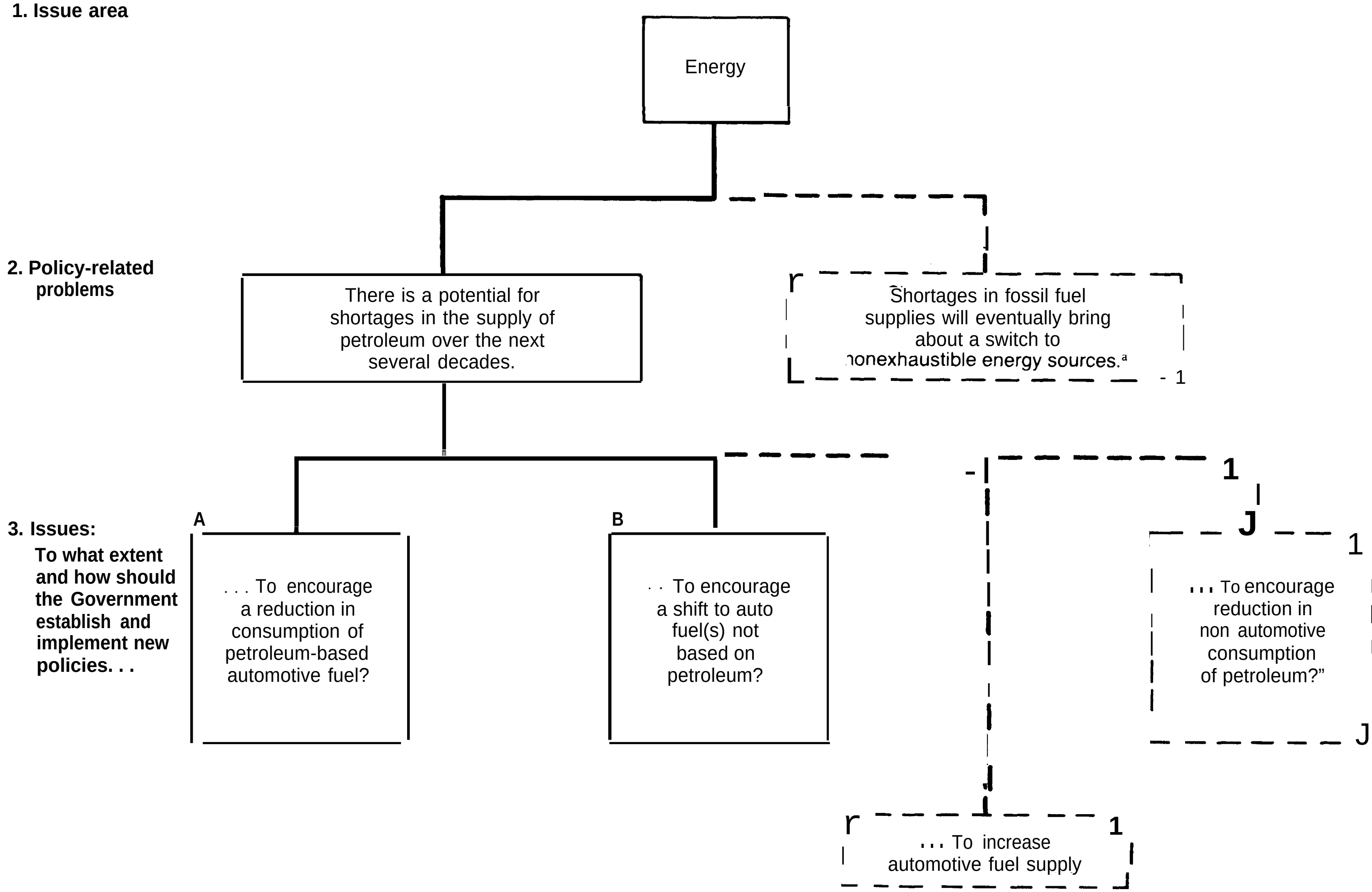
  No attempt was made to elaborate the relevance trees to this detail since the first six levels of the tree were considered adequate to define a wide range of alternative policies affecting the automobile system.

Policies Analyzed by SRI

Figures 19 through 23 show the relevance trees developed for each of the five issue areas. Each tree identifies a range of policy alternatives that could be adopted to deal with the issues. Since the range is broad and the number of individual policies is large, only a few could be treated during the assessment. These are shown by shaded boxes at Level 6 of the relevance trees.

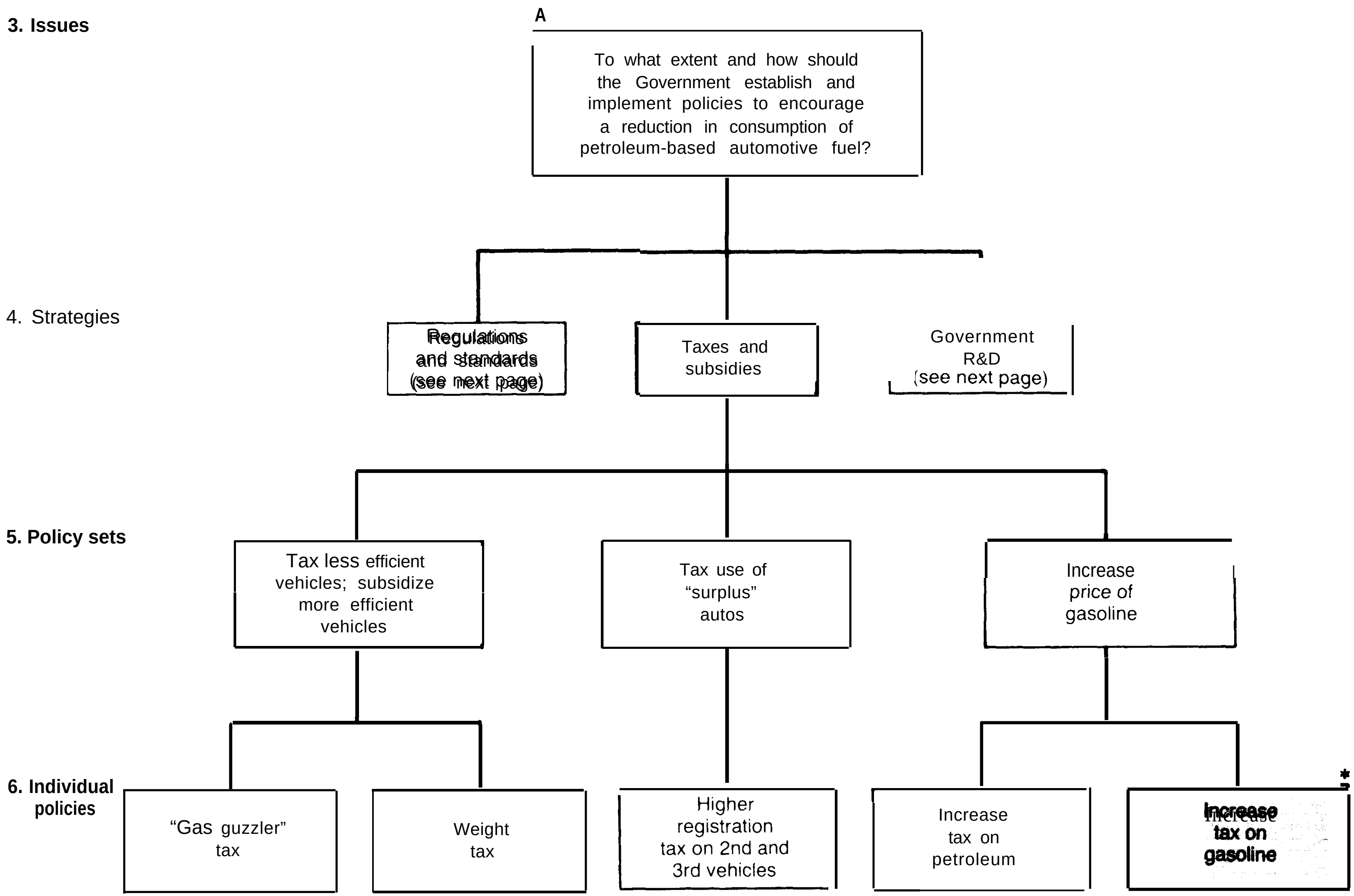
Some of the policies enumerated on the SRI relevance trees were also analyzed by System Design Concepts (Sydec), as described in the following section of this chapter. For reference, the policies examined by Sydec are indicated by an asterisk on the relevance trees.

Figure 19.—Relevance Tree for Energy Issues



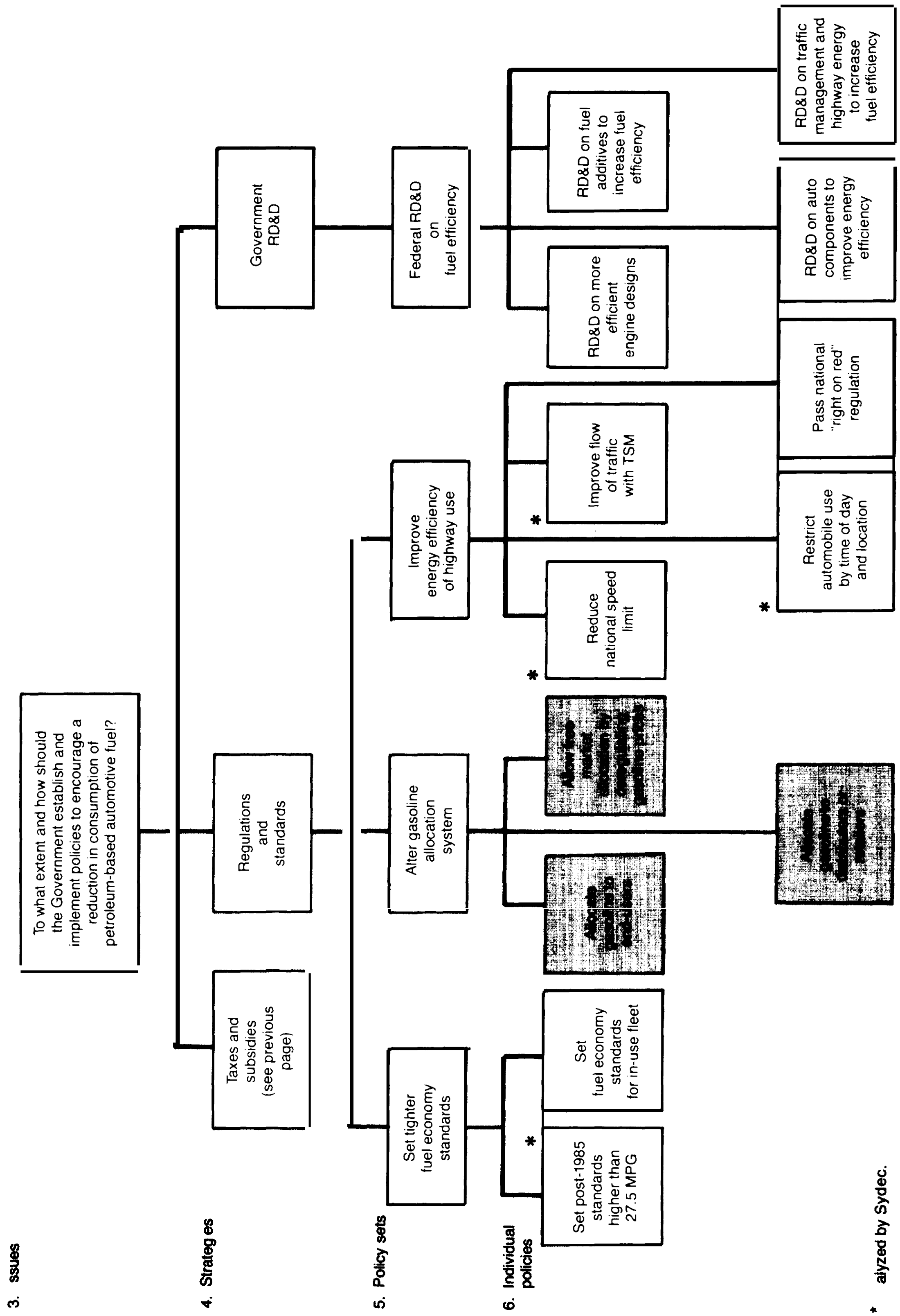
[a] Dashed boxes are outside the scope of the study.

Figure 19.–Relevance Tree for Energy Issues (Continued)



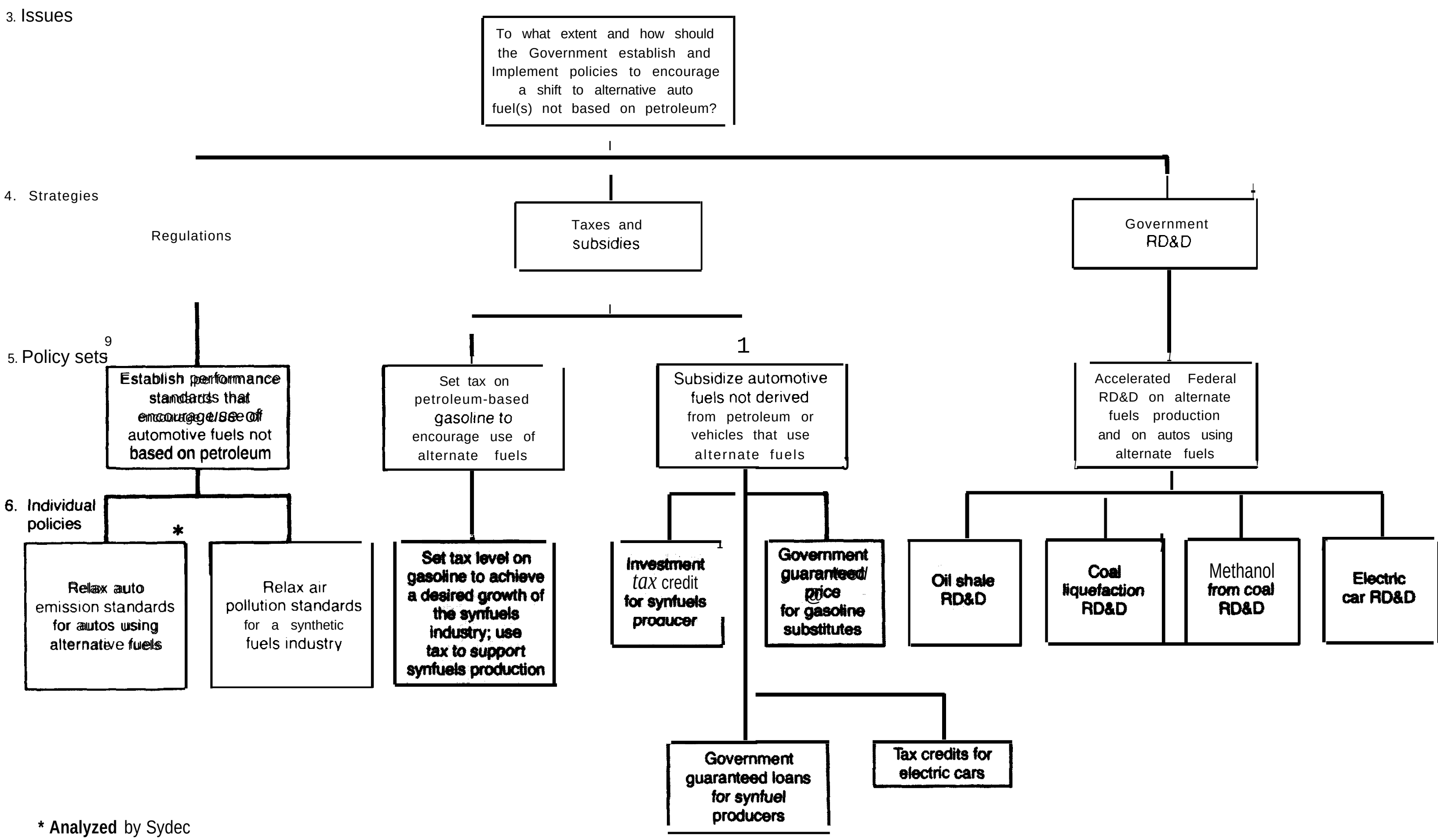
*Analyzed by Sydec.

Figure 19.—Relevance Tree for Energy Issues (Continued)



* Analyzed by Sydec.

Figure 19.—Relevance Tree for Energy Issues (Concluded)



* **Analyzed** by Sydec

Source: Office of Technology Assessment

Figure 20.—Relevance

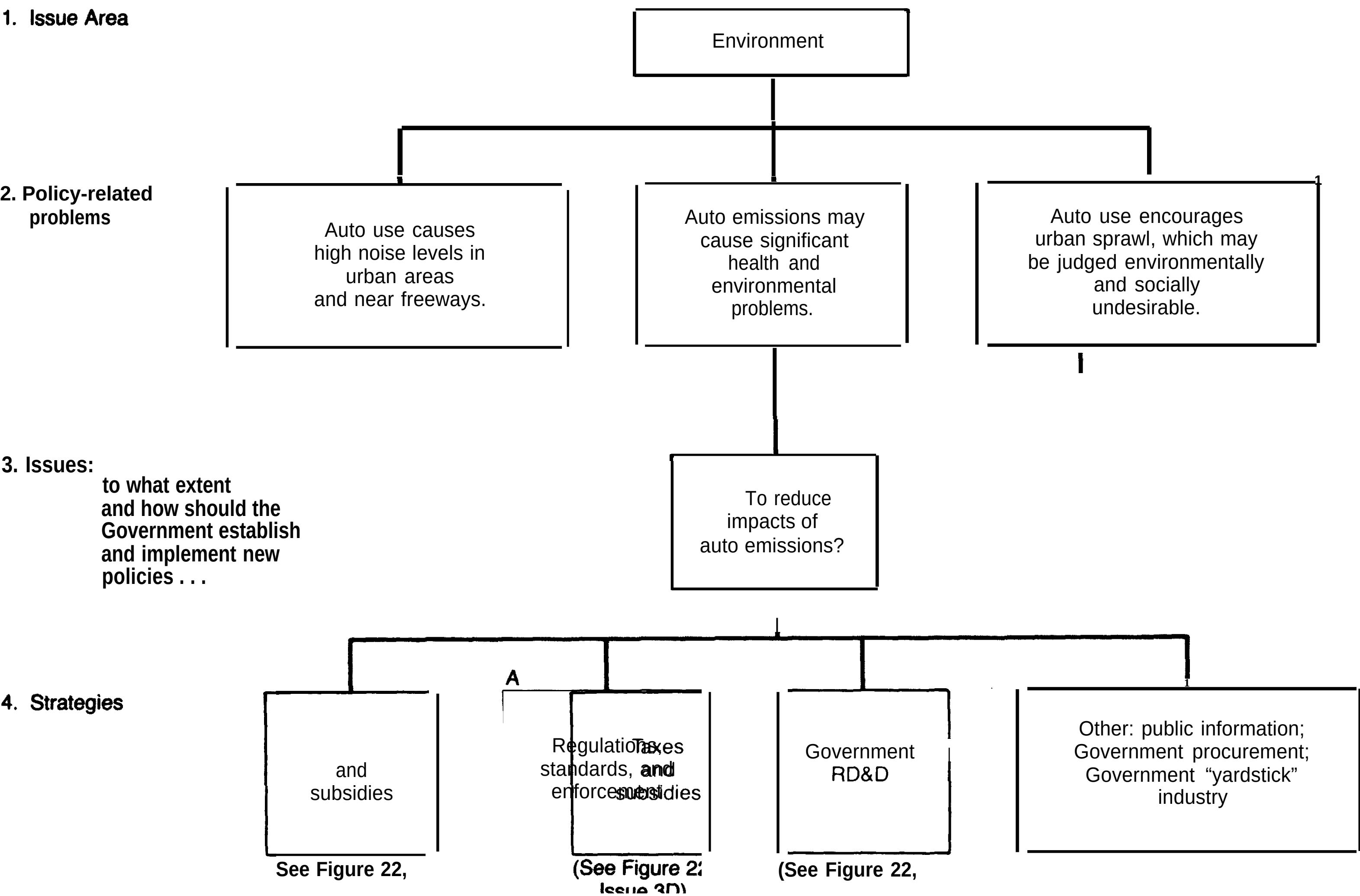
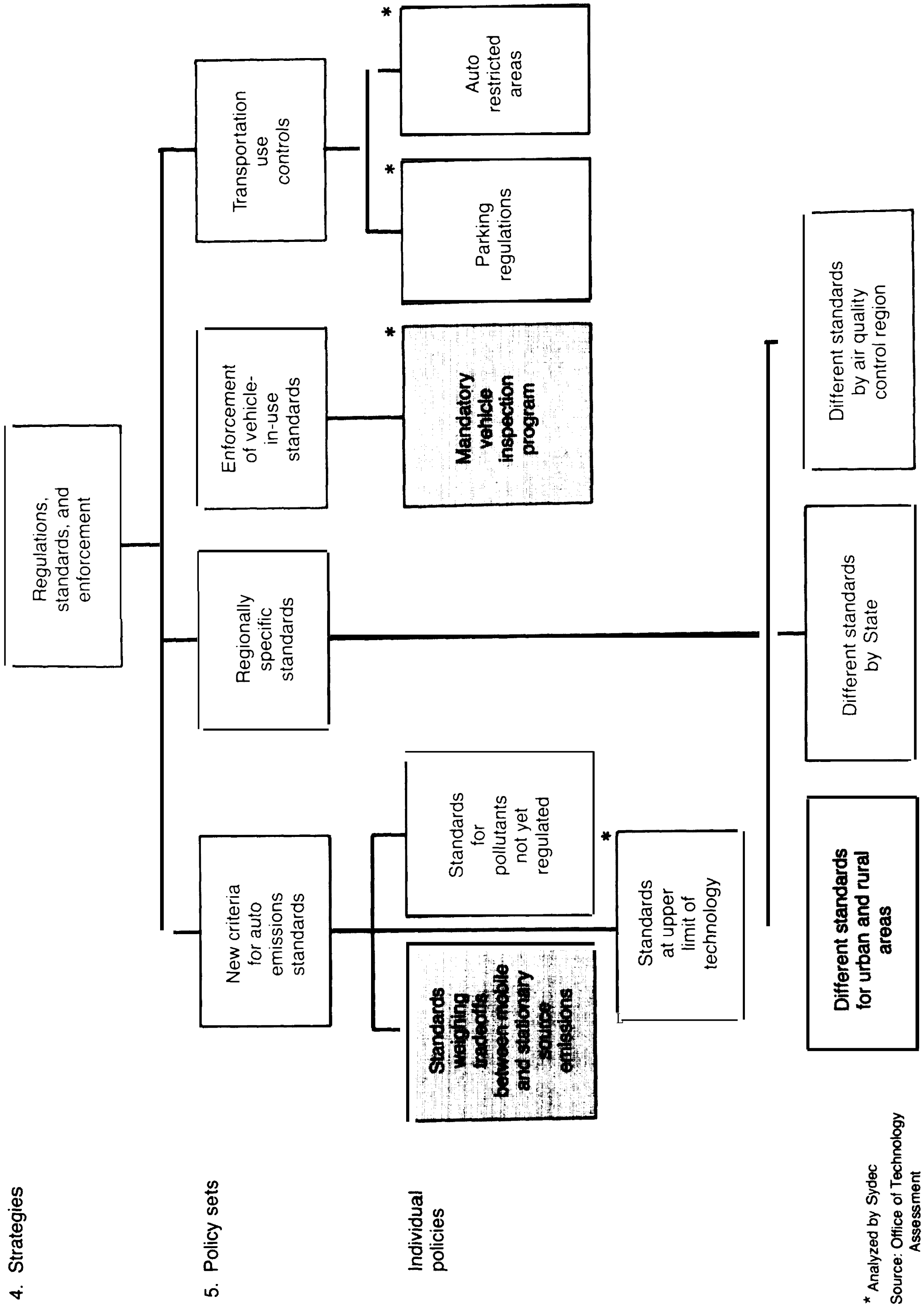


Figure 20
Relevance Tree for Environment Issues Conc uded



* Analyzed by Sydec
Source: Office of Technology Assessment

Figure 21.—Relevance Tree for Safety Issues

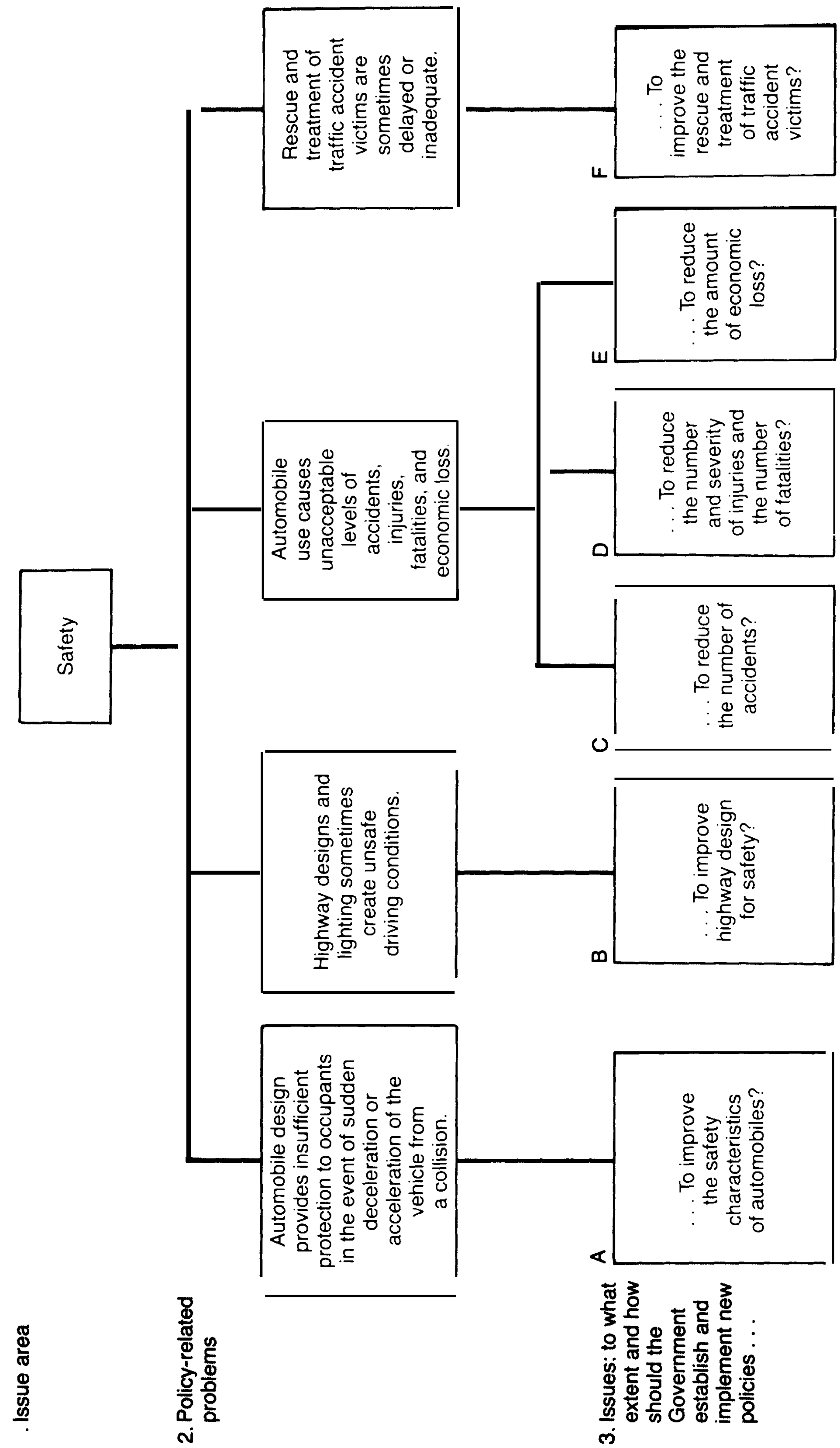
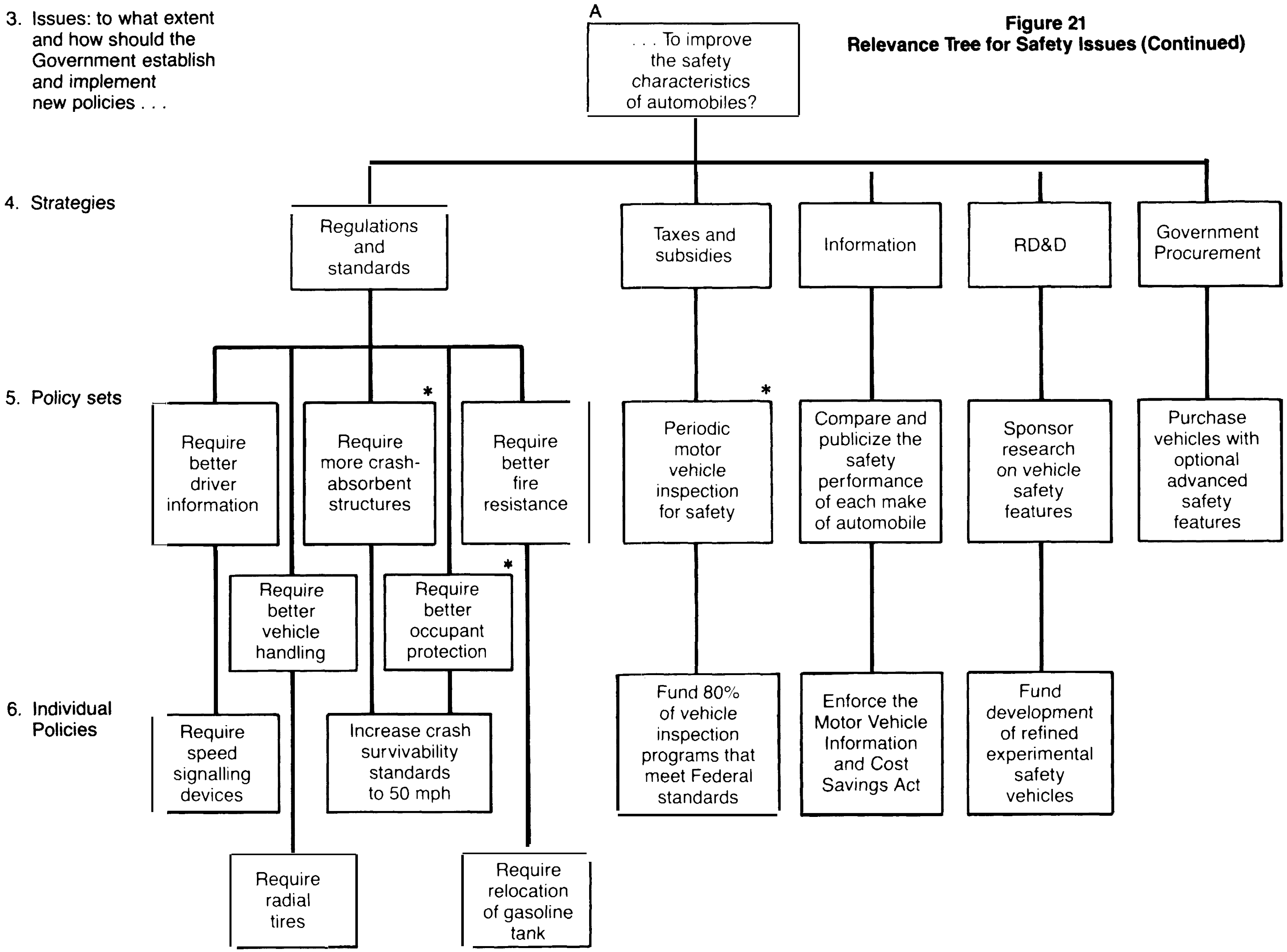


Figure 21
Relevance Tree for Safety Issues (Continued)



Analyzed by Sydec.

Figure 21.–Relevance Tree for Safety Issues (Continued)

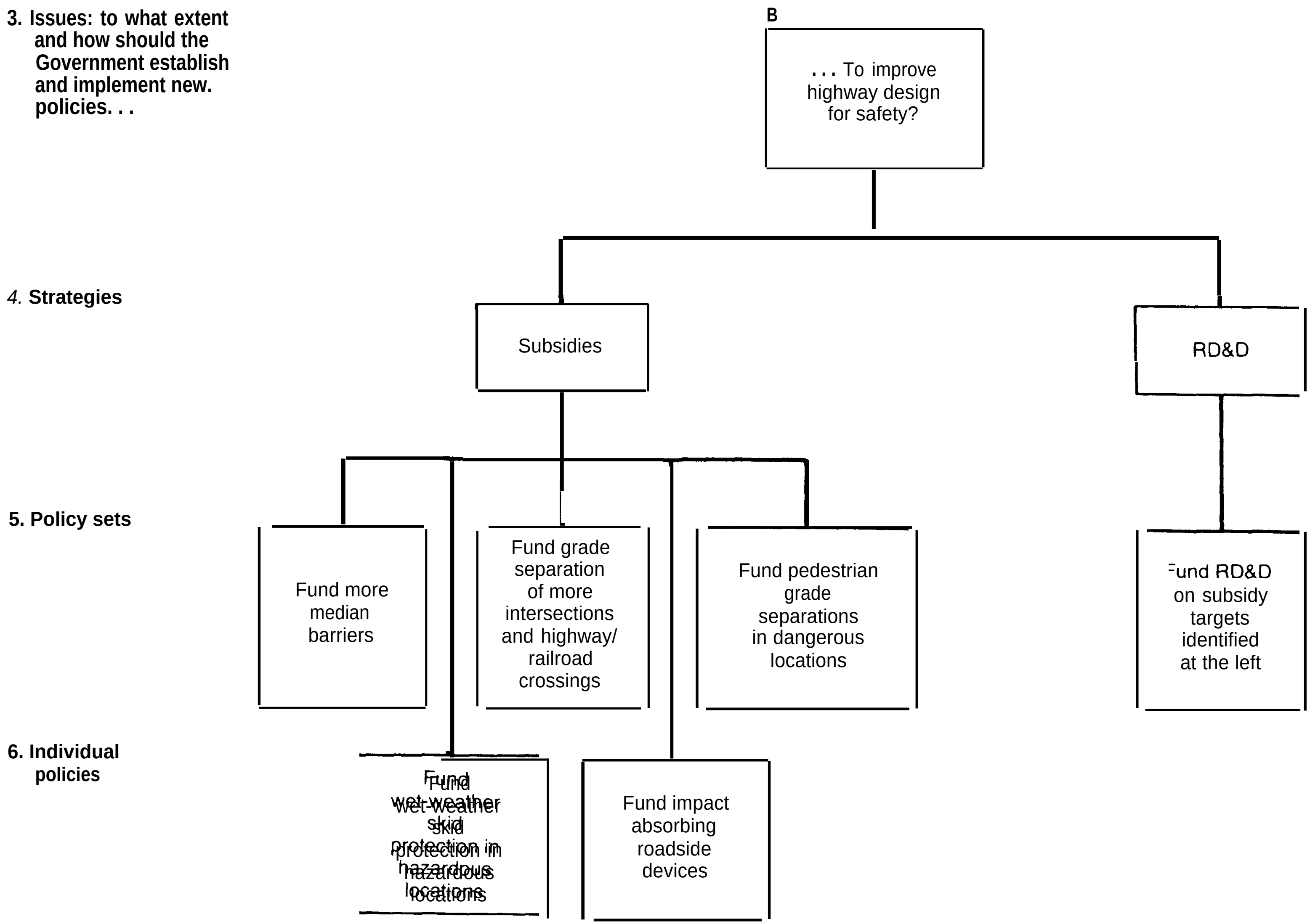


Figure 21.—Relevance Tree for Safety ssues (Continued)

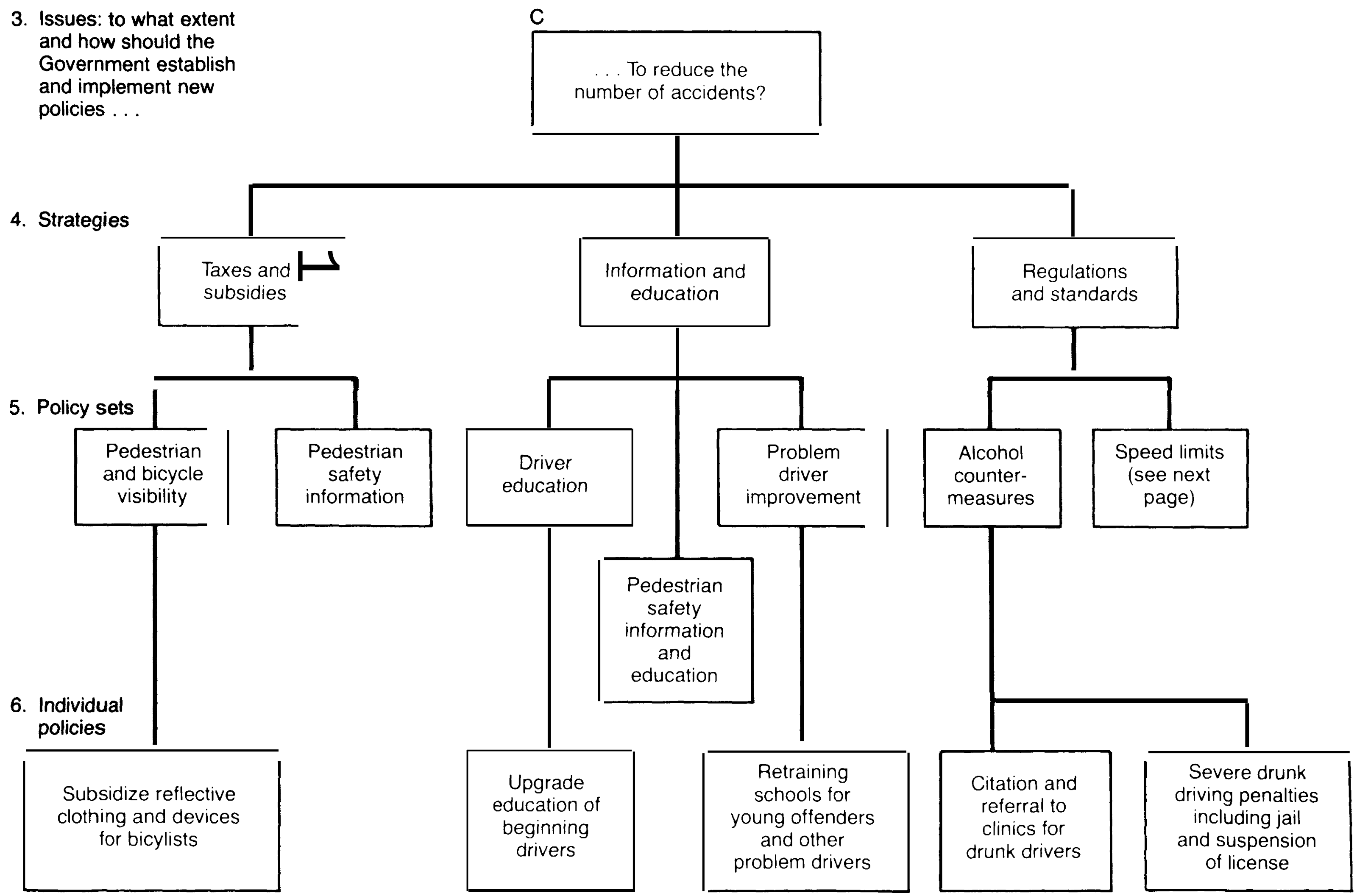
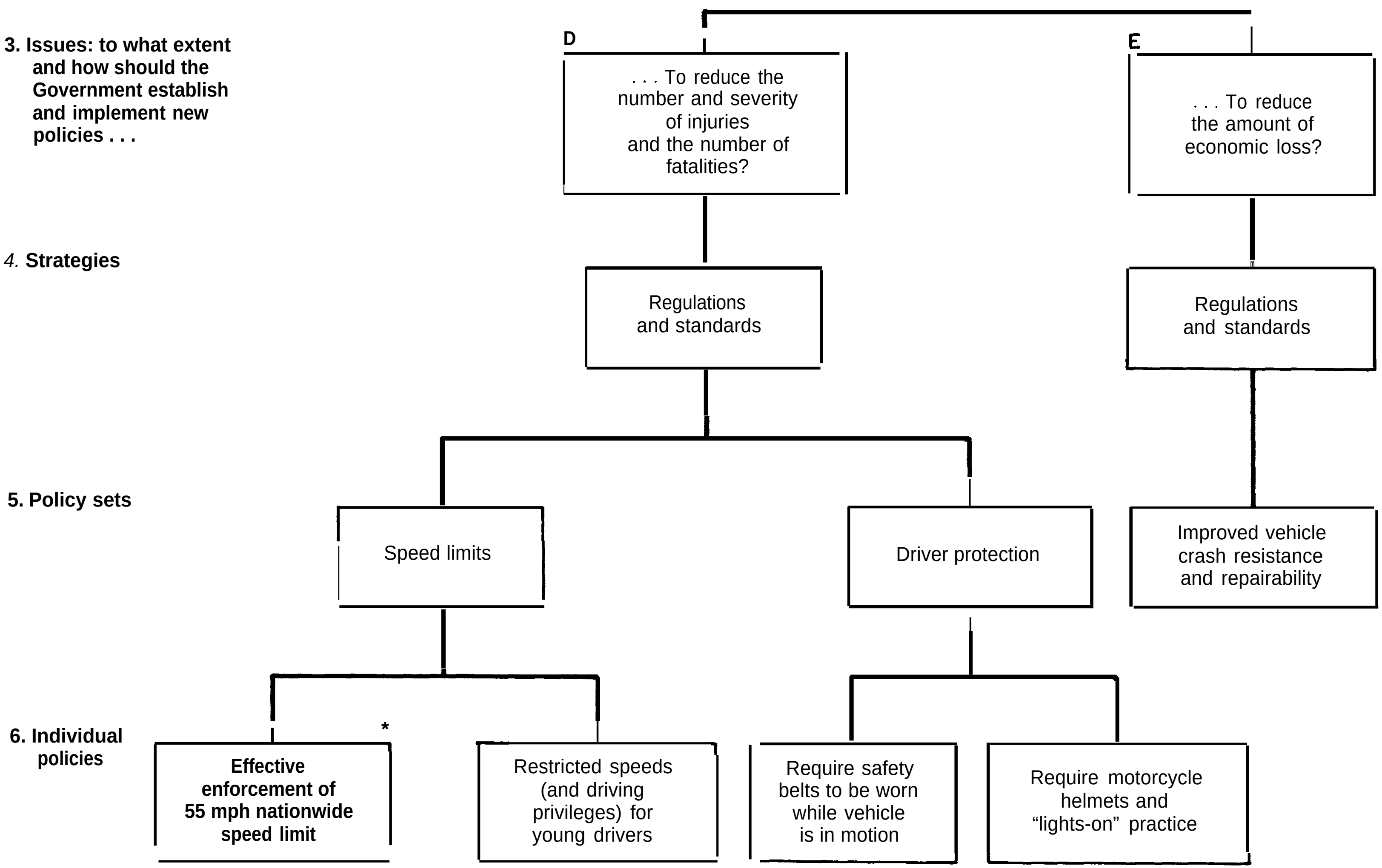
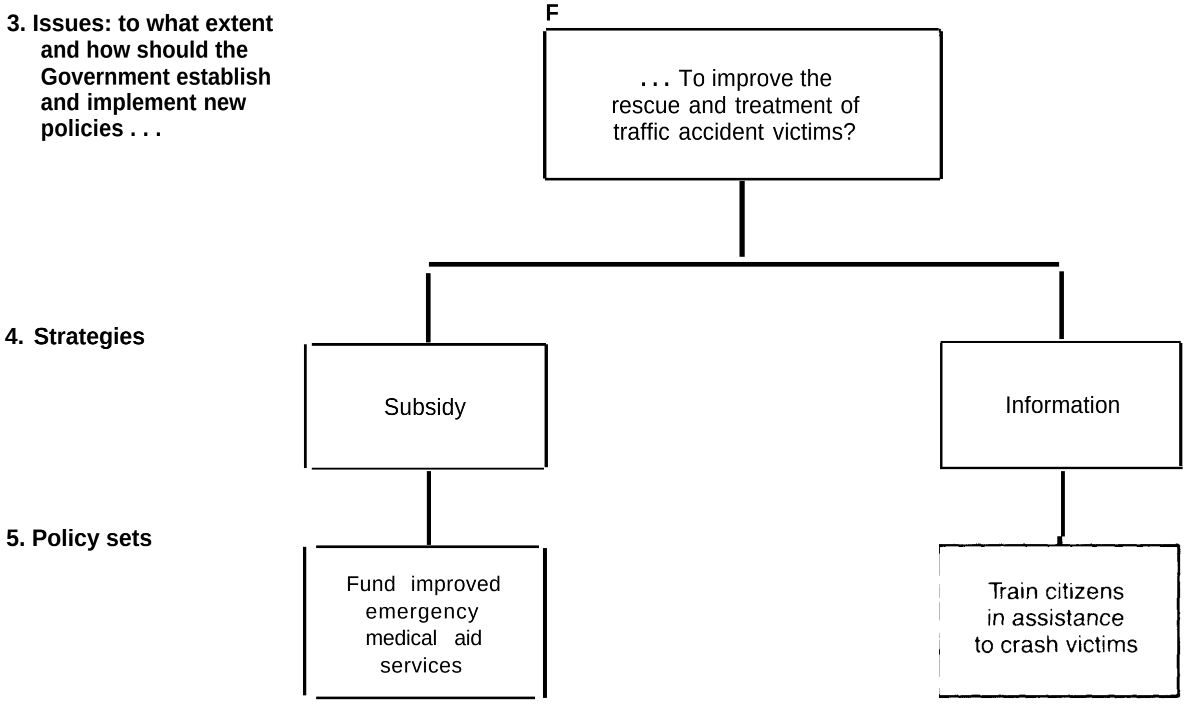


Figure 21.—Relevance Tree for Safety Issues (Continued)



*Analyzed by Sydec

Figure 21.–Relevance Tree for Safety Issues (Concluded)



SOURCE: Office of Technology Assessment.

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Figure 22.—Relevance Tree for Mobility Issues

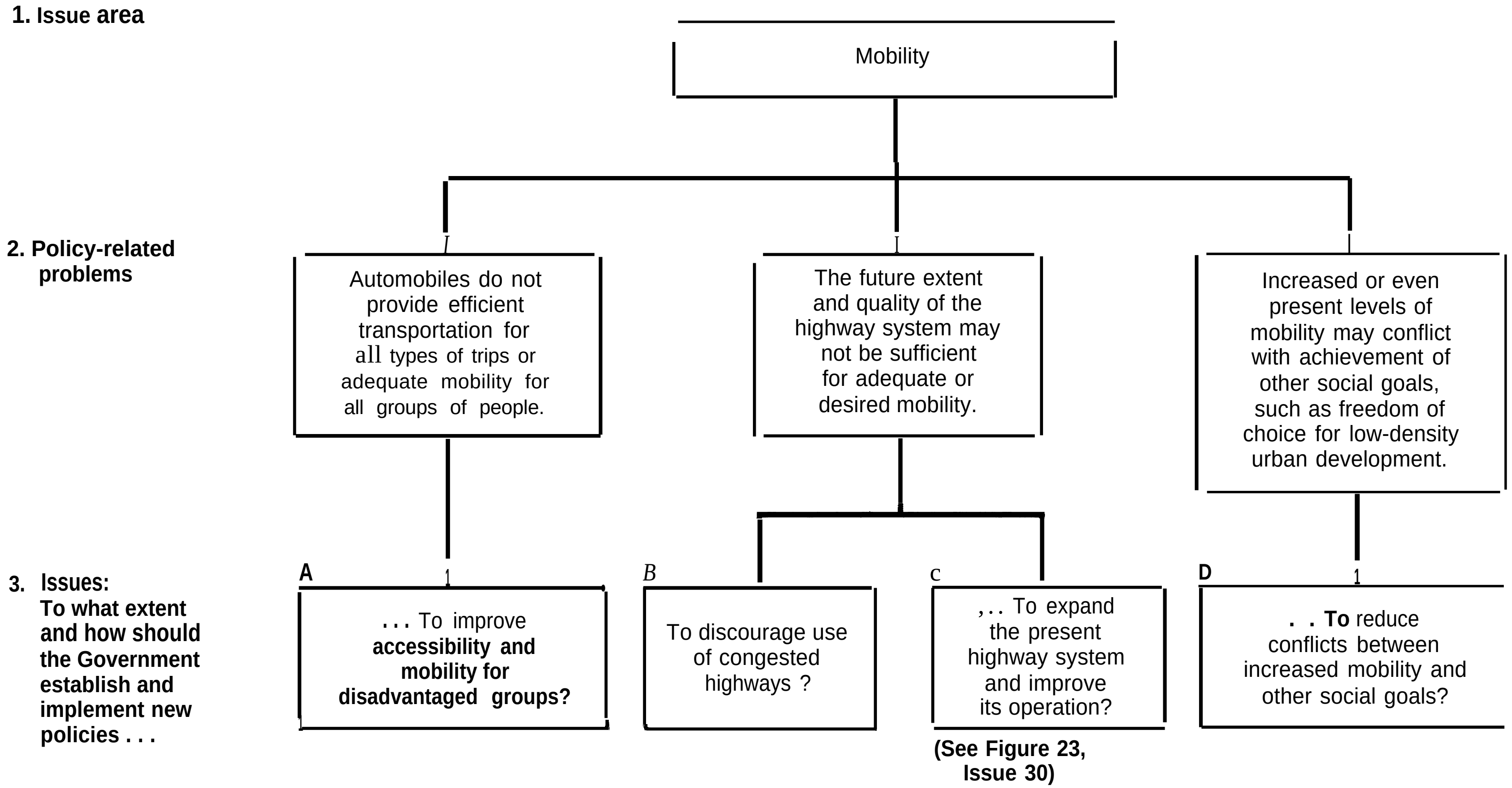
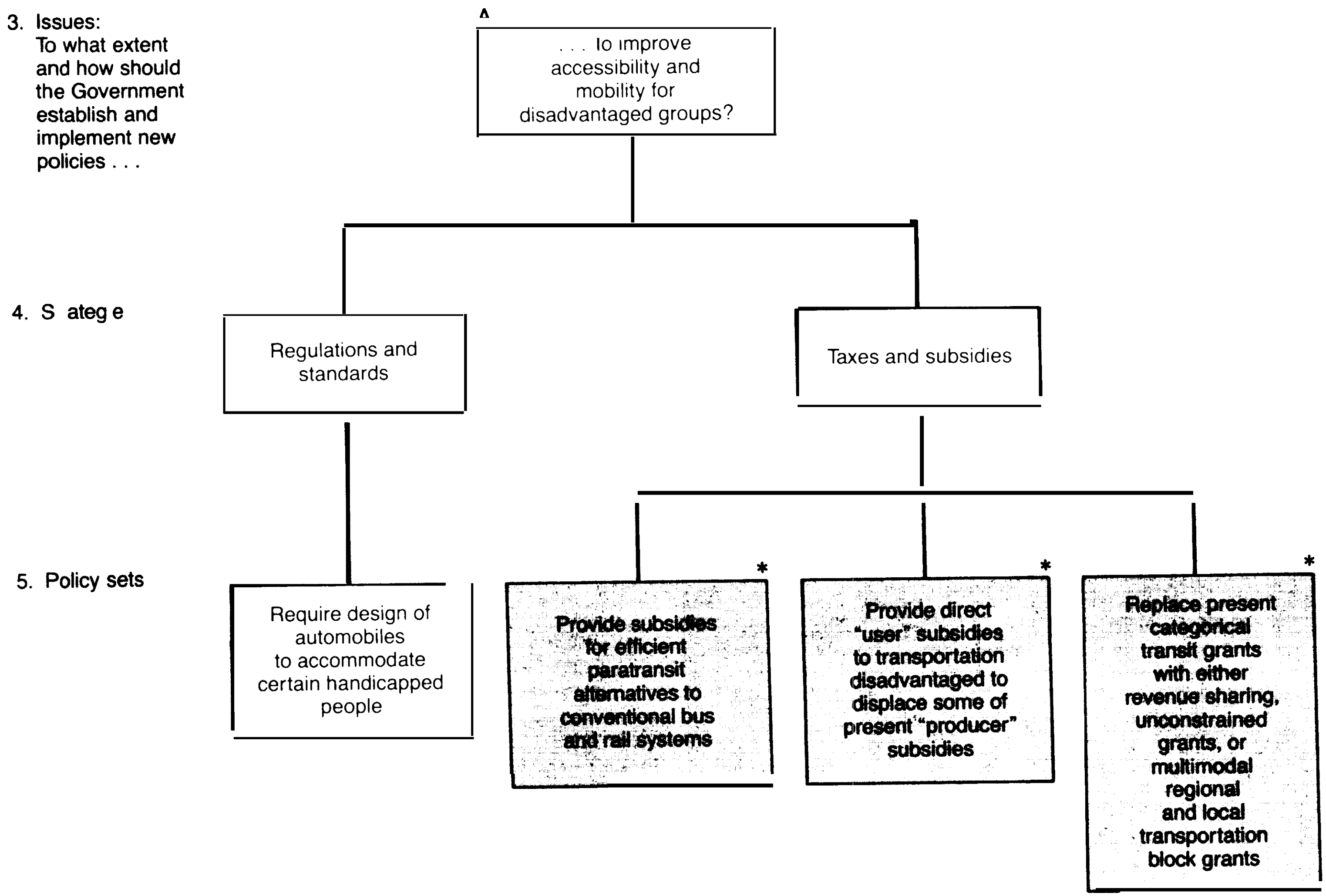


Figure 22.—Relevance Tree for Mobility Issues (Continued)



*Analyzed by

Figure 22.-Relevance Tree for Mobility Issues (Continued)

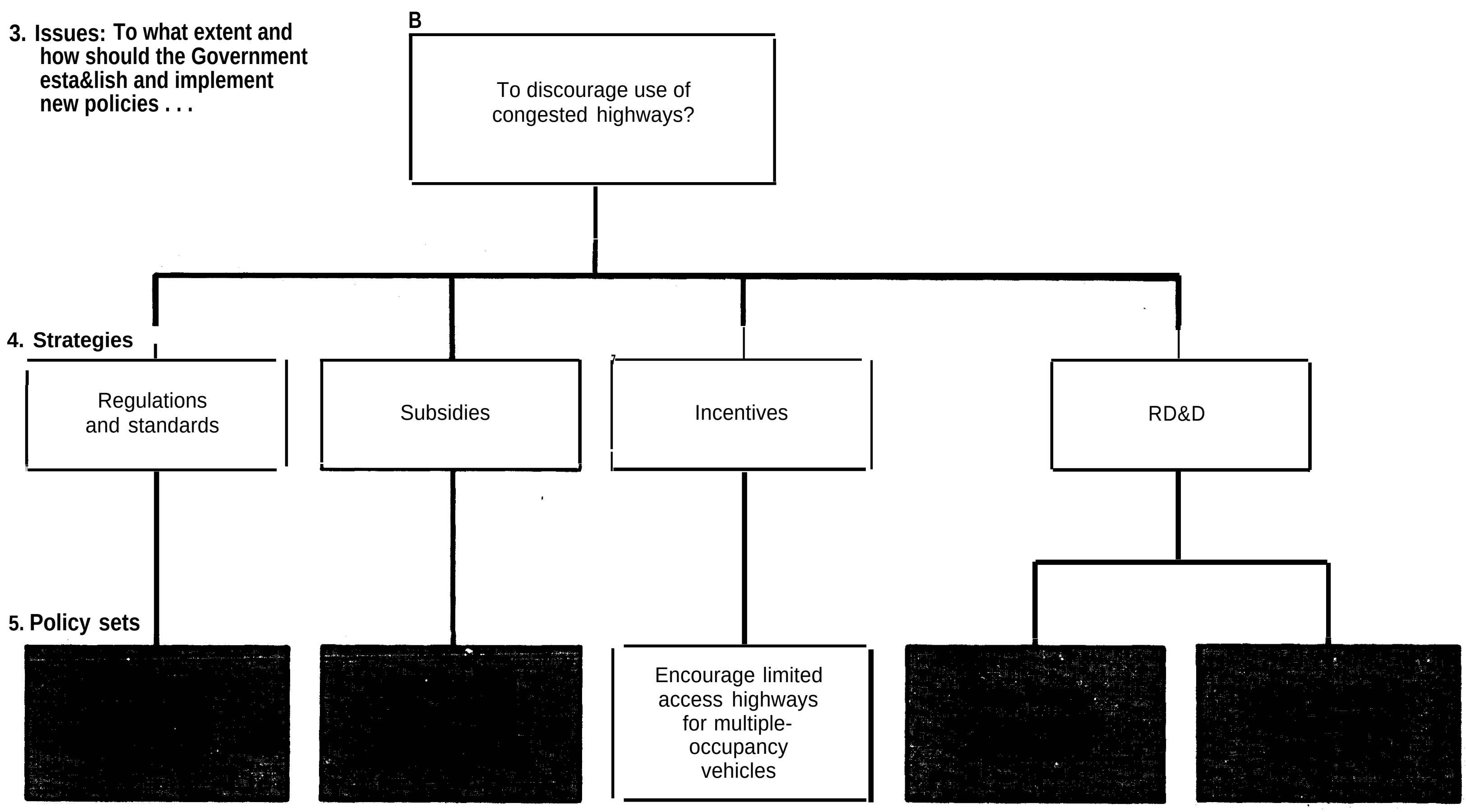
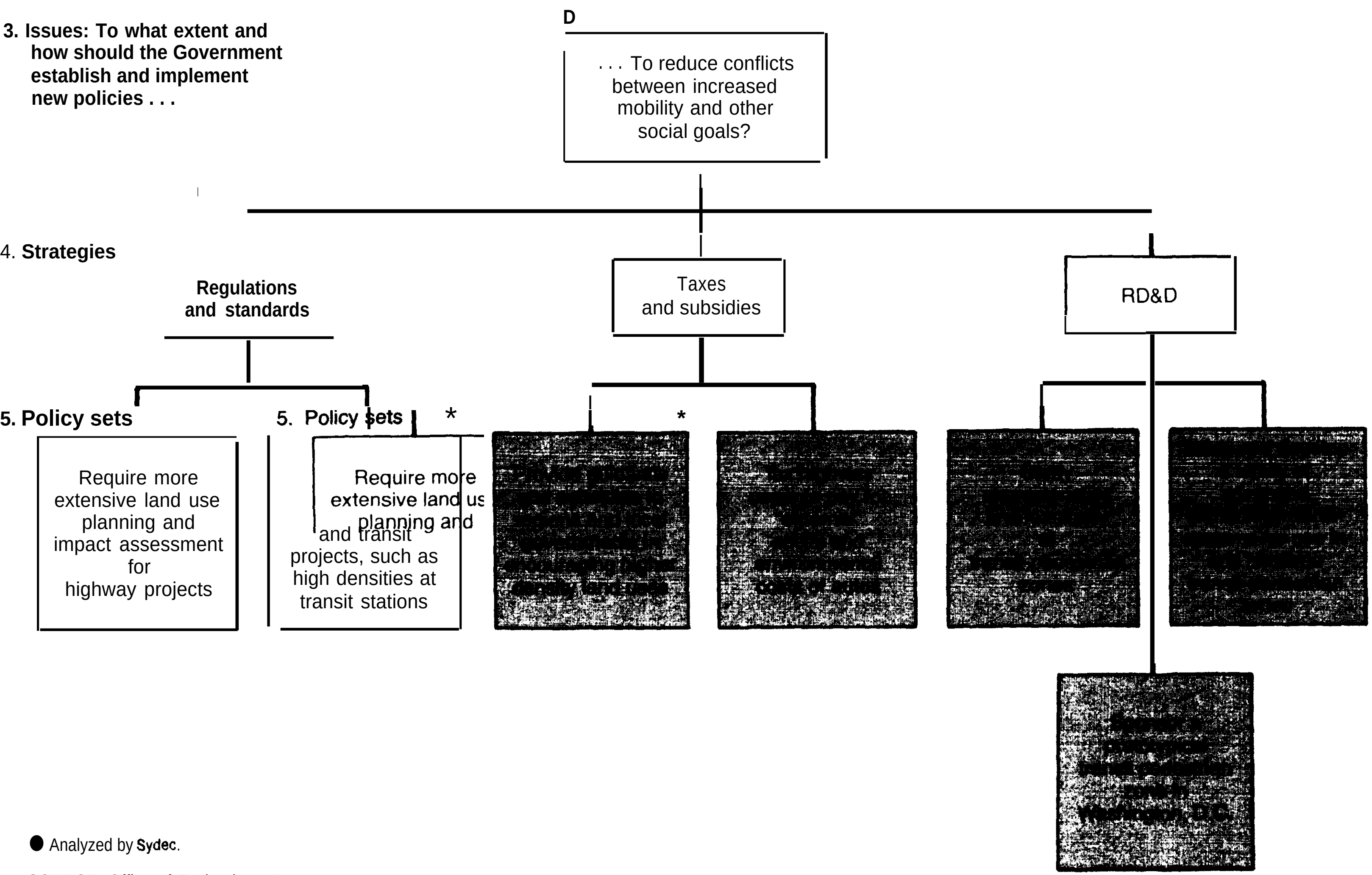


Figure 22.–Relevance Tree for Mobility Issues (Concluded)



● Analyzed by Sydec.

SOURCE: Office of Technology Assessment.

Figure 23.-Relevance Tree- for Cost and Capital Issues

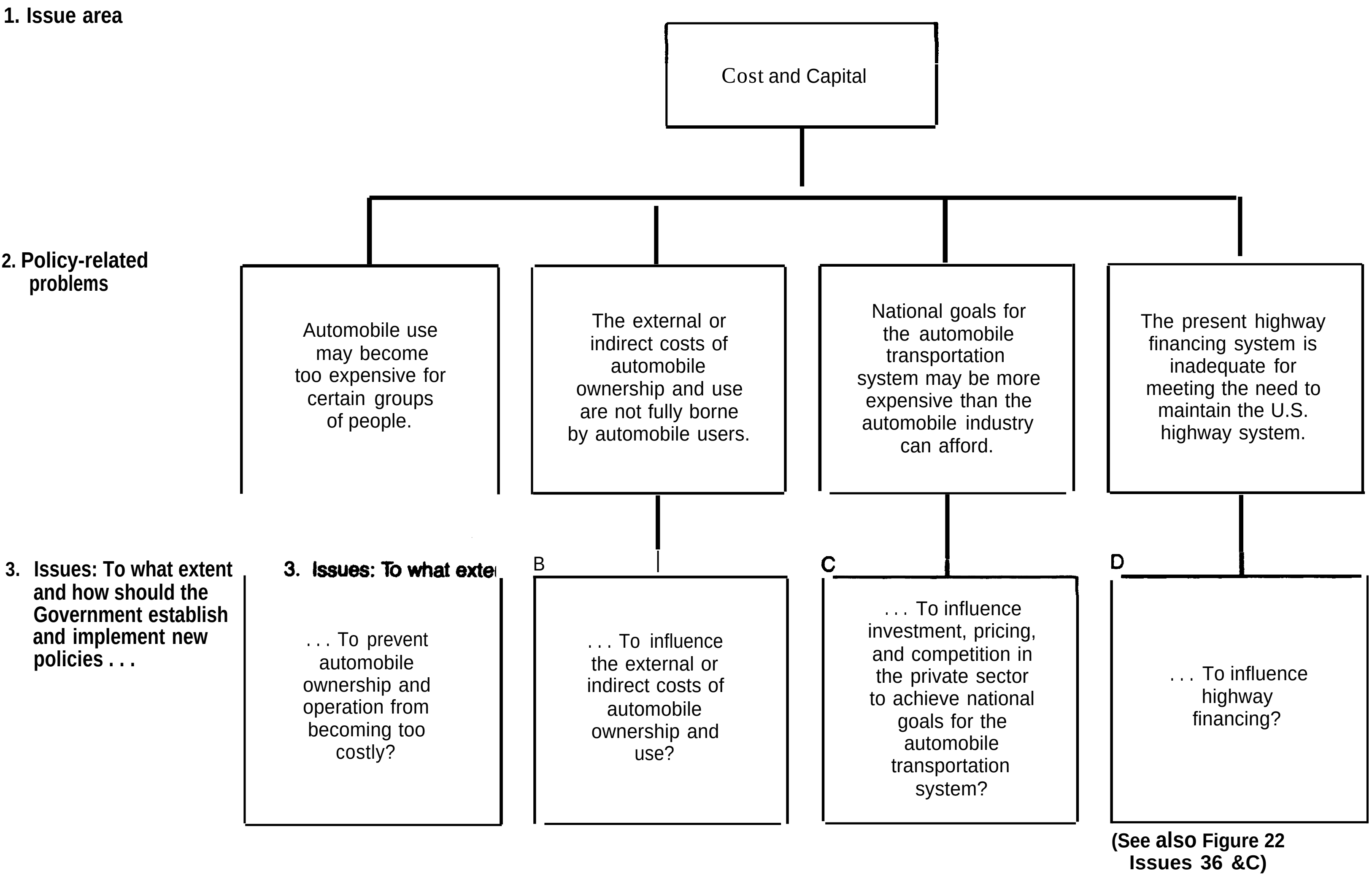
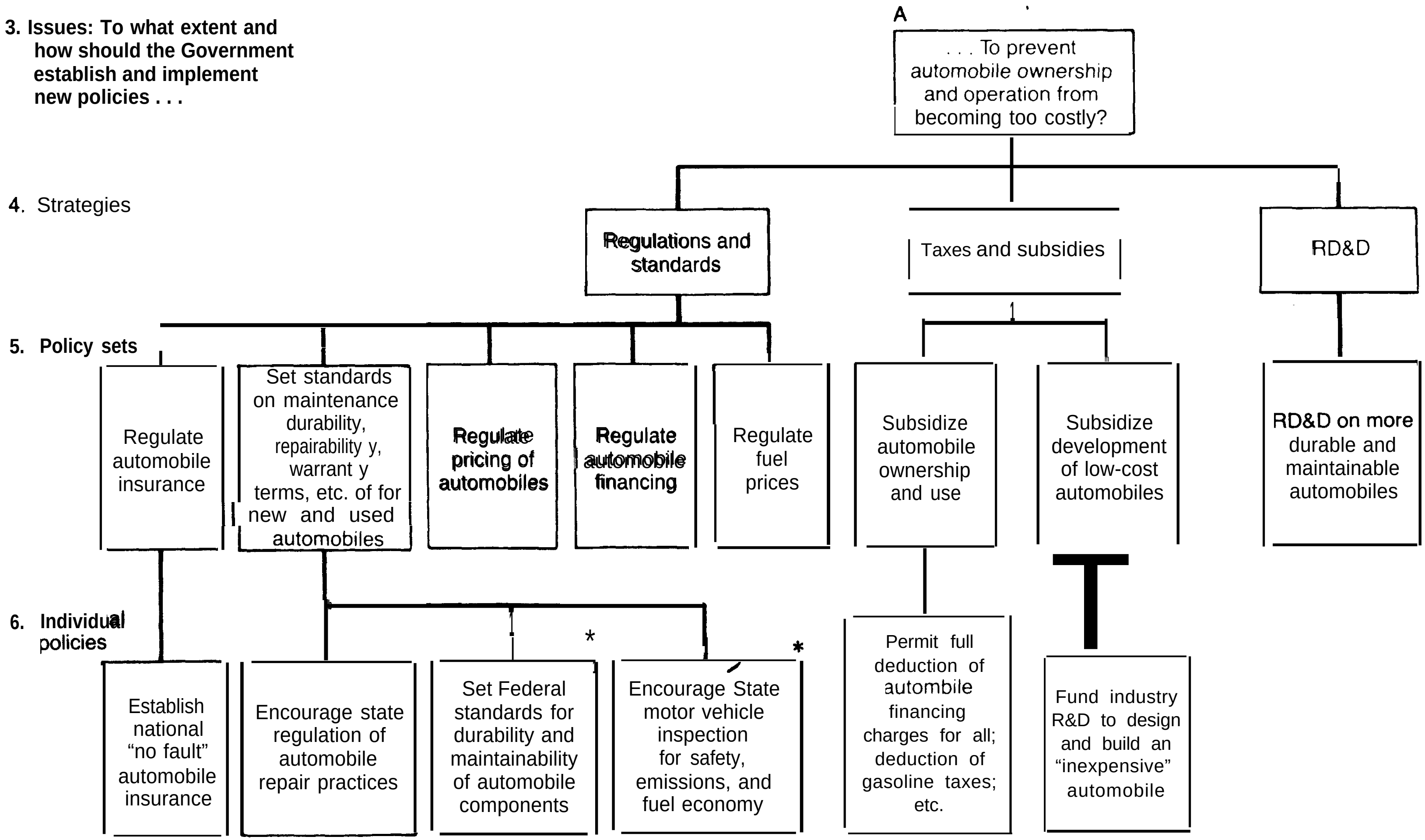
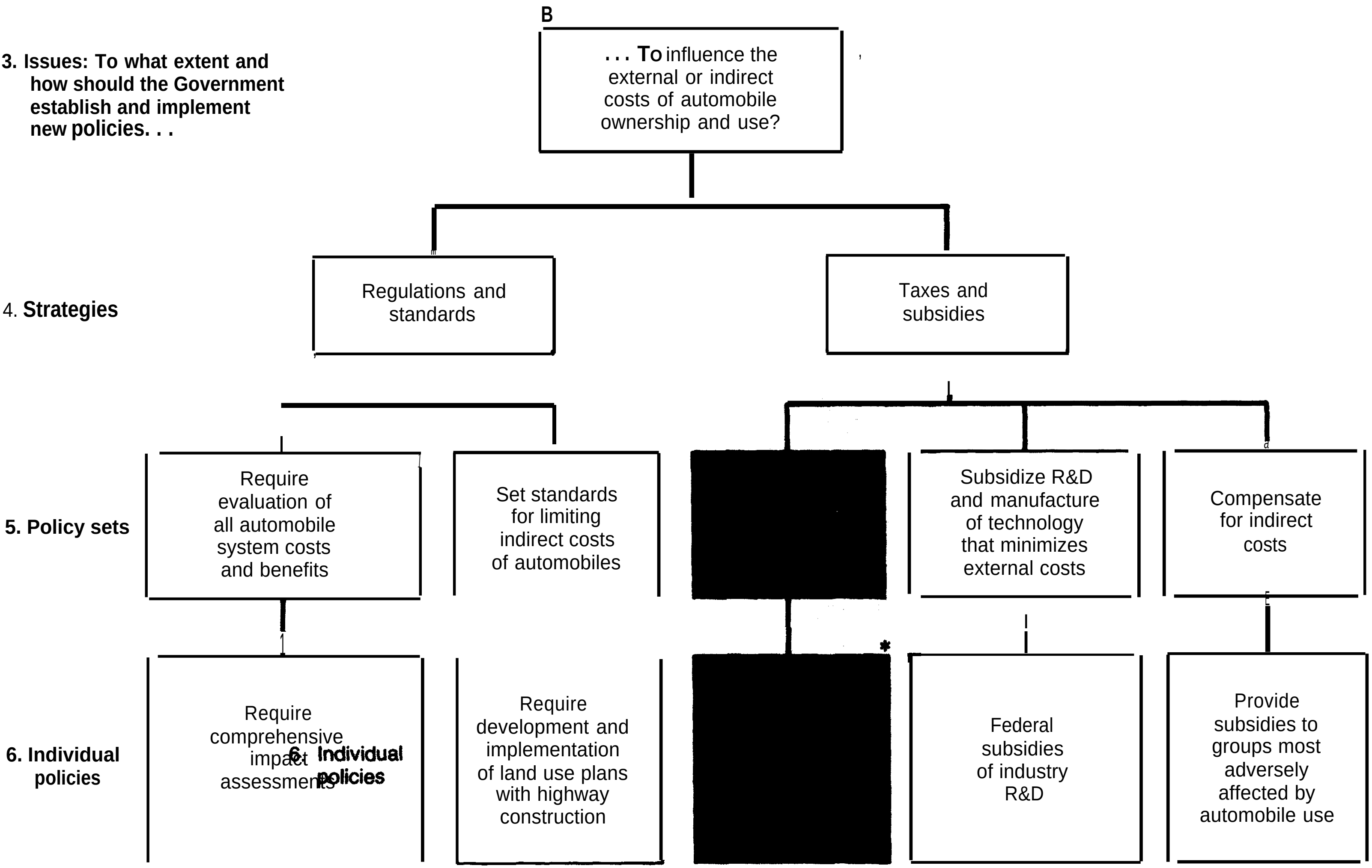


Figure 23.–Relevance Tree for Cost and Capital Issues (Continued)



* Analyzed by Sydec.

Figure 23.-Relevance Tree for Cost and Capital issues (Continued)



● Analyzed by Sydec.

Figure 23.—Relevance Tree for Cost and Capital Issues (Continued)

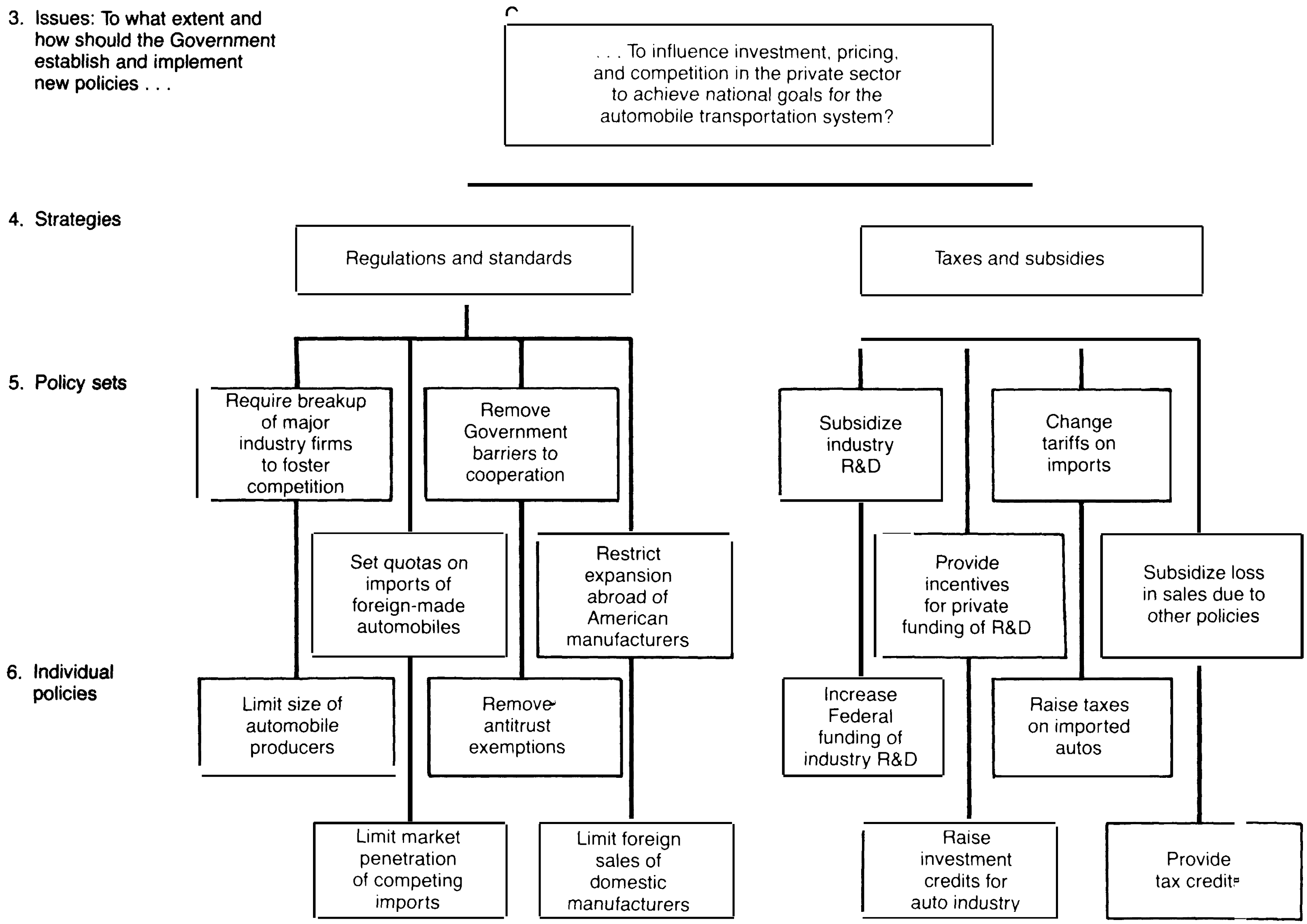
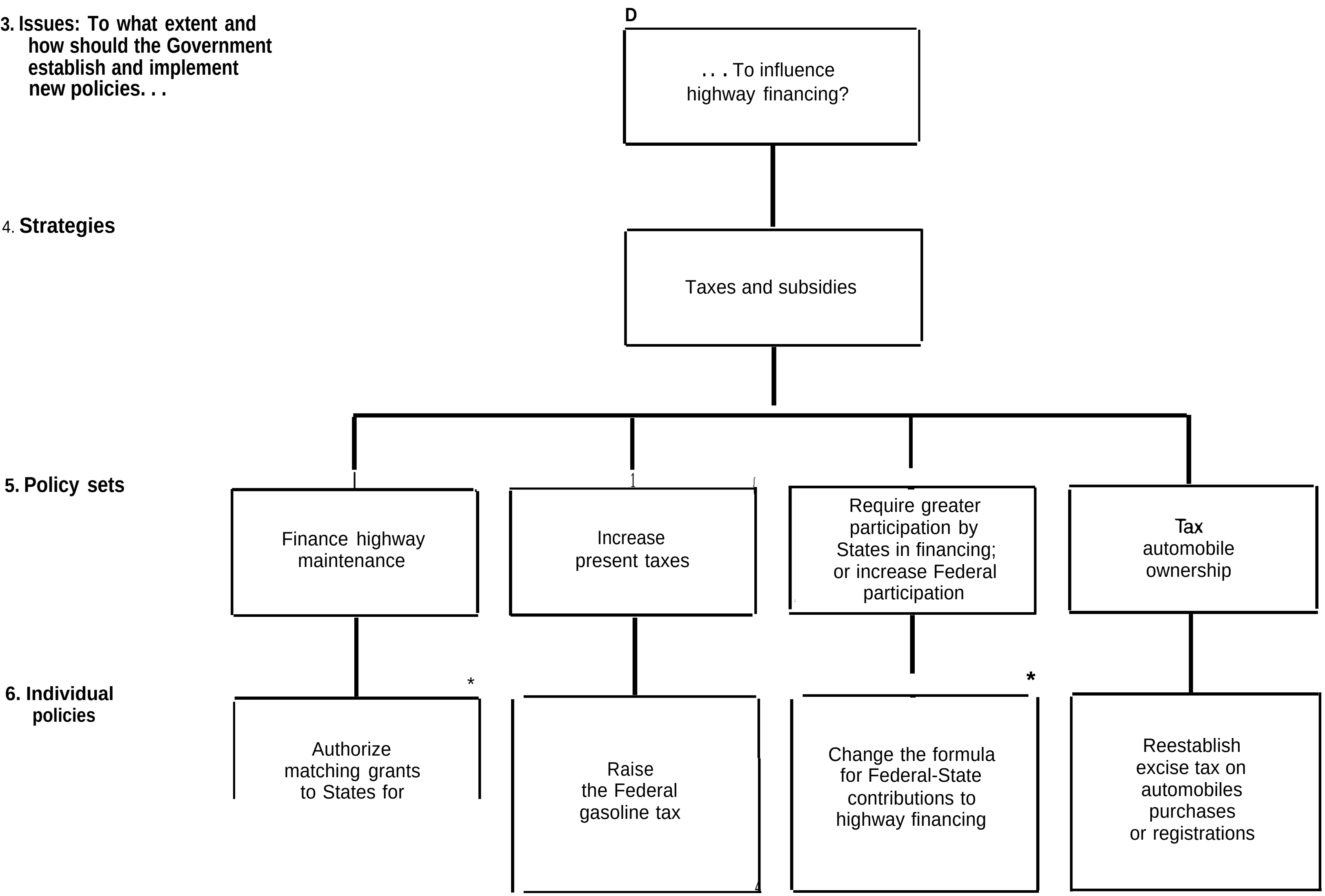


Figure 23.-Relevance Tree for Cost and Capital Issues (Concluded)



● Analyzed by Sydec.

SYDEC POLICY SETS

System Design Concepts was directed to take a somewhat more comprehensive approach to the definition of policy sets. Sydec assembled four "packages" of policies that attempted to address several concerns and issues simultaneously. Each policy had a major direction or thrust, such as energy conservation, but it also included measures addressed to other issues, such as environmental protection, safety, or mobility. The four policy packages formulated by Sydec were:

- Petroleum Conservation
- Improved Environment
- Increased Mobility
- Improved Accessibility

Each policy package was designed to be internally consistent, in that the individual policies were mutually supportive and compatible in terms of their effects. A second important feature of this approach was systematic variation of supportive policies among policy packages. This facilitated the analysis of effects and impacts. Both of these features—internal consistency and systematic variation—can be seen by examining the components of the four policy packages and the Base Case, which are given in table 43.

Table 43.—Sydec Base Case and Policy Alternatives

Policy alternatives	Trend: Base Case	Petroleum Conservation	Improved Environment	Increased Mobility	Improved Accessibility
Highway Total highway expenditures	Increase with inflation (stable in constant dollars).	Increase at 1/2 of inflation (declines 400/o by *2000* in constant dollars).	Same as Base Case.	Increase 47°/0 over Base Case.	Same as Base Case.
Highway construct ion	Decreases from 50% of total highway expenditures to 25%. in *2000.*	Same as Base Case.	Same as Base Case.	Increases to high expenditure level of late 1960's (48% of total in 2000).	Same as Base Case. Emphasis on community cirrculation.
Highway maintenance	Increases from 50%. of total highway expenditures to 75% in 2000.	Same as Base Case.	Same as Base Case.	Same constant dollar level as Base Case (50°/0 of total in 2000).	Same as Base Case.
Transportation system management	Existing policies — no funding program.	Same as Base Case.	Separate funding program: $200 miIlion/year emphasizing high occupancy vehicle movement.	Funded at $1.5 billion per year in real dollars, emphasis on general traffic movement efficiency.	Same as Improved Environment (emphasis on pedestrian and bicycle movement and paratransit services).
Mass transportat ion: capital improvements	Increase current dollar funding 10°/0 per year to 1985. Hold constant in real dollars to ***2000.***	Increase current dollar funding 15 "/0 per year to 1985. Hold constant i n real dollars to 2000.	Same as Petro leum Conservation.	Same as Petroleum Conservation. Emphasis on services for transit dependent groups.	Same as Base Case.
Operations	Increase current dollar funding 10% per year to 1985. Hold constant in real dollars to 2000.	Double funding ini tially. Increase 1 5°/0 per year to 1985. Increase 10"/0 per year 1985-2000 (all current $).	Same as Petro Ieum Conservat ion,	Same as Petroleum Conservation. Emphasis on services for transit dependent groups.	Same as Petroleum Conservation (emphasis on community - oriented transit services).
'Auto performance	EPCA 27.5 mpg through 2000.	33 mpg by 1990,40 mpg by 2000, Mpg minimum on all new autos.	Same as Petroleum Conservation.	Same as Base Case.	Same as Petroleum Conservation.
Highway speed	Moderate enforcement (present average of 62 mph).	Rigid enforcement of 55 mph limit.	Same as Base Case.	Same as Base Case.	Same as Base Case.

Table 43.—Sydec Base Case and Policy Alternatives—Cont.

Policy alternatives	Trend: Base Case	Petroleum Conservation	Improved Environment	Increased Mobility	Improved Accessibility
Taxes	Fuel taxes increased to maintain 1975 revenue levels (12.3$/gal. in 1985; 14.OC/gal. in 2000, constant 1975 dollars).	Increased gas tax to hold constant fleet fuel cost per VMT and to equalize gas and synfuel prices. Gas guzzler tax on new cars.	Increased gas tax to hold constant fleet fuel cost per VMT. Gas guzzler tax on new cars.	Same as Improved Environment.	Same as Improved Environment.
Air pollution					
Vehicle emissions	Attain 1977 Clean Air Act Standards for CO, HC, and NO_x (NO_x waiver for diesels at 1.5 gpm 1981-83.	Same as Base Case.	CO and HC same as Base Case Tighten NO_x, standard to 0.4 gpm. Two-car strategy (electric).	Same as Base Case.	Same as Improved Environment.
Inspection and maintenance	No mandatory program (negligible improvements in deterioration rates).	Same as Base Case.	Mandatory programs nationwide.	Same as Base Case.	Same as Base Case.
Transportation controls	Negligible traffic reduction effect.	Same as Base Case.	Parking management. Vehicle use restraints.	Same as Base Case.	Emphasis on auto-free zones.
Noise					
Vehicle emissions	Emission standards for trucks and buses.	Same as Base Case.	Emission standards for autos and light trucks.	Same as Base Case.	Same as Base Case.
Noise abatement	Continue existing policies.	Same as Base Case.	Continue existing policies and expand funding to include soundproofing.	Same as Base Case.	Same as Base Case.
Occupant restraints	Airbags or t heir equivalent on new vehicles as scheduled.	Mandatory seat belt use only.	Same as Base Case.	Same as Base Case.	Same as Base Case.
Vehicle crashworthiness	Existing standards.	Same as Base Case.	Level 1.	Level Il.	Level I with emphasis on frontend auto design and pedestrian and cyclist safety.
Propulsion	15% diesel by 1985; 40%. diesel by 2000.	25%. diesel by 1985; 600/. diesel by 2000. Electric car introduction by 2000.	Same as Base Case, except diesels phased out after 1990.	Same as Base Case.	Diesel penetration same as improved Environment.
Fuels	5.6% diesel by 1985; 31 .30/0 diesel by 2000.	Increase % of diesel fuel; accelerate transition to synfuels. Potential for gas rationing.	Same as Base Case, except accelerate penetration of electric cars.	Same as Base Case.	Accelerated transitions to electric cars.

SOURCE Sydec/EEA

Petroleum Conservation

Consumption of energy, particularly petroleum products, continues to increase in the United States, despite dwindling domestic supplies of crude oil. Oil imports now represent almost **50** percent of total consumption. A continuation of this trend into the *1980's* could lead to import levels of **60** percent or more, increasing the threat to national security and economic stability. Oil imports are a major factor in the present balance of payments deficit, which is at a record level.

Notwithstanding present efforts in Congress to enact major new energy policies aimed at both conservation and increased energy supplies, it is likely that energy policy will be a continuing concern and an issue for the American people and their elected officials for many years to come.

Energy supplies, and particularly petroleum products, are important to many areas of American society. Attention is focused here on the transportation sector because it accounts for about 50 percent of petroleum consumption. The automobile system alone is responsible for between **25** and 30 percent of petroleum use in the United States.

Policies to promote reduced energy consumption by the automobile system are analyzed in the Petroleum Conservation Case, which contains the following major elements:

- The minimum fuel efficiency level for the auto fleet would gradually increase to 23.5 mpg in 1985, leading to an average fuel efficiency of 30 mpg in **1990** and 35 mpg in 2000.
- The gasoline tax would increase gradually to hold the fuel cost per vehicle mile constant and to stimulate the introduction of synthetic fuels. (The existing Federal and State gasoline taxes—which average 11.65 cents per gallon would be increased by 13 cents in 1985 and 18 cents in 2000, in **1975** constant dollars. This would raise the price of gasoline to 91 cents per gallon in 1985 and $1 .39 per gallon in **2000.)**
- Total expenditures for highways would decrease, primarily in construction funds but with a slight decrease in maintenance funds as well. (Total highway expenditures from all levels of government would decrease from $28.2 billion in 1975 to $22.4 billion in **1985** and $16.8 billion in 2000.)
- Federal funding for mass transit capital improvements (facilities and equipment) would increase from $1.2 billion in 1975 to $2.4 billion in **1985,** and with funding held constant at that level until 2000. (Federal funds for operating subsidies would also be increased from a base of $300 million in **1975** to **$2** billion in **1985** and $4.8 billion in 2000.)

Improved Environment

The Clean Air Act Amendments of 1970 established the objective of a 90-percent reduction in emissions of specified pollutants from automobiles as a primary measure to improve air quality. These reductions have proven difficult to achieve. By both executive and congressional action, auto manufacturers have been granted extensions in meeting emission standards. The delays in meeting standards, as well as questions of whether the full 90-percent reduction is necessary for public health, continue to be matters of intense public debate.

While the objective has not yet been reached, major reductions have been made in the emission levels of new automobiles being produced. Still, most projections indicate that air quality standards will not be met in many places within the next few years and that standards for photochemical oxidants may not be met in some regions even by the year 2000.

A factor that complicates the question of automobile emission standards is that control devices have been shown to deteriorate over the life of the vehicle much more rapidly than expected. It must also be recognized that many automobiles are driven more than the **50,000** miles covered by the manufacturer's warranty for emission control devices. Further, it has been established that emission levels are higher in vehicles that are not adequately maintained. These considerations raise the question of whether programs to control vehicles in use may be necessary.

The potential conflict between reduced emissions and petroleum conservation further complicates the problem and will be a significant factor in propulsion technology for autos of the future. For example, a diesel engine is significantly more fuel efficient than the present spark-ignition engine. The diesel-powered auto can meet established carbon monoxide and hydrocarbon standards but may not be able to meet the nitrogen oxide standard. Electric cars have no known harmful emissions, but the powerplants that produce electricity to charge the batteries may foul the air.

Potential policies to reduce automobile emissions are tested in the Improved Environment Case:

- The standards and implementation schedule for carbon monoxide and hydrocarbon emissions as approved by Congress in the 1977 Clean Air Act Amendments would be maintained. (The nitrogen oxide standard would be reduced from 1.0 to 0.4 gram per mile.)
- Mandatory inspection and maintenance would be imposed for all automobiles and light trucks.
- A program of parking management and auto-free zones would be instituted, primarily in center cities where there is a greater potential for providing alternative transportation through mass transit.
- Federal funding for mass transit capital improvements and operating subsidies would be at the same high levels as in the Petroleum Conservation Case.
- Transportation System Management would be funded at a rate of $200 million per year to provide special expressway and arterial street lanes for transit, carpools, and vanpools. (Special parking privileges would be provided for high-occupancy vehicles.)
- Total national highway expenditures would be held constant at 1975 levels. (Capital expenditures would decrease as maintenance requirements increased.)

Increased Mobility

Throughout the history of the United States, public policy has placed great value on mobility. The transportation of people and goods has been supported by public funds and by measures to regulate the availability and price of transportation services. Sustaining or expanding this transportation network and the personal mobility that it affords will become an increasingly difficult task. The mobility that is now enjoyed may be threatened by energy restrictions, environmental concerns, and the problems of auto system safety.

Thus, there is an important set of issues relating to the extent to which the Federal Government should continue to promote general mobility and the means by which this is to be accomplished. A further issue is whether the Federal Government should attempt to change the distribution of mobility by undertaking policies to aid the transportation disadvantaged.

These issues are addressed by policies which substantially increase the level of Federal funds for highway construction and maintenance and which create a higher level of funding for highway and street improvements under a transportation system management program. In order to provide increased mobility for the transit dependent, increased Federal funding for mass transit also is provided, with a significant amount earmarked for special services for the elderly and handicapped.

The policies and programs in the Increased Mobility Case are:

- Highway expenditures would increase from a total of $28 billion in 1975 to $37 billion in 1985 and to $41 billion in 2000. (This level of funding would provide $20 billion a year for construction between 1985 and 2000, a level about the same or slightly lower than that during the height of the highway program in the late 1960's. Maintenance funds would increase from $14 billion in 1975 to $17 billion in 1985 and $21 billion in 2000.)
- A transportation system management program would be funded at a level of $1.5 billion per year by 1985 and would continue at that level to 2000. (The program would

emphasize removal of congestion points in the highway and street network, safety improvements, and improvements to increase the average speed of traffic flow.)

- Federal funding for mass transit capital improvements and additions would be increased from the level of $1.2 billion in 1975 to $2.4 billion in 1985 and thereafter. (Federal assistance for transit operation would be increased from $300 million in 1975 to $1.6 billion in 1985 and $4.4 billion in 2000.)
- $500 million per year would be allotted to a special program to provide transportation for the elderly and handicapped. (The Federal share would be 80 percent, with State and local funds making up the remainder. The $500 million funding level would be reached in 1985 and continued to 2000.)
- Motor vehicle fuel taxes would increase gradually to keep the average fuel costs per vehicle mile constant for the fleet.

Improved Accessibility

The auto system has contributed to the dispersion of manufacturing and commercial and residential development in patterns that are referred to as urban sprawl. The automobile-highway system has encouraged residential land development in suburban and exurban areas where land is relatively inexpensive and where developers can market housing with more amenities than could be obtained in center cities. Local officials, hard-pressed to provide more public services for growing communities, have willingly provided the infrastructure necessary for this development in order to increase the tax base.

The highly automated processes associated with modern manufacturing and the ready availability of truck transportation have led industry to seek the outlying areas for expansion and replacement of older multistory center city buildings. Commercial enterprises, particularly retail stores and service organizations, have followed the people to the suburbs. In recent years, there has been a substantial movement of commercial offices to the suburbs.

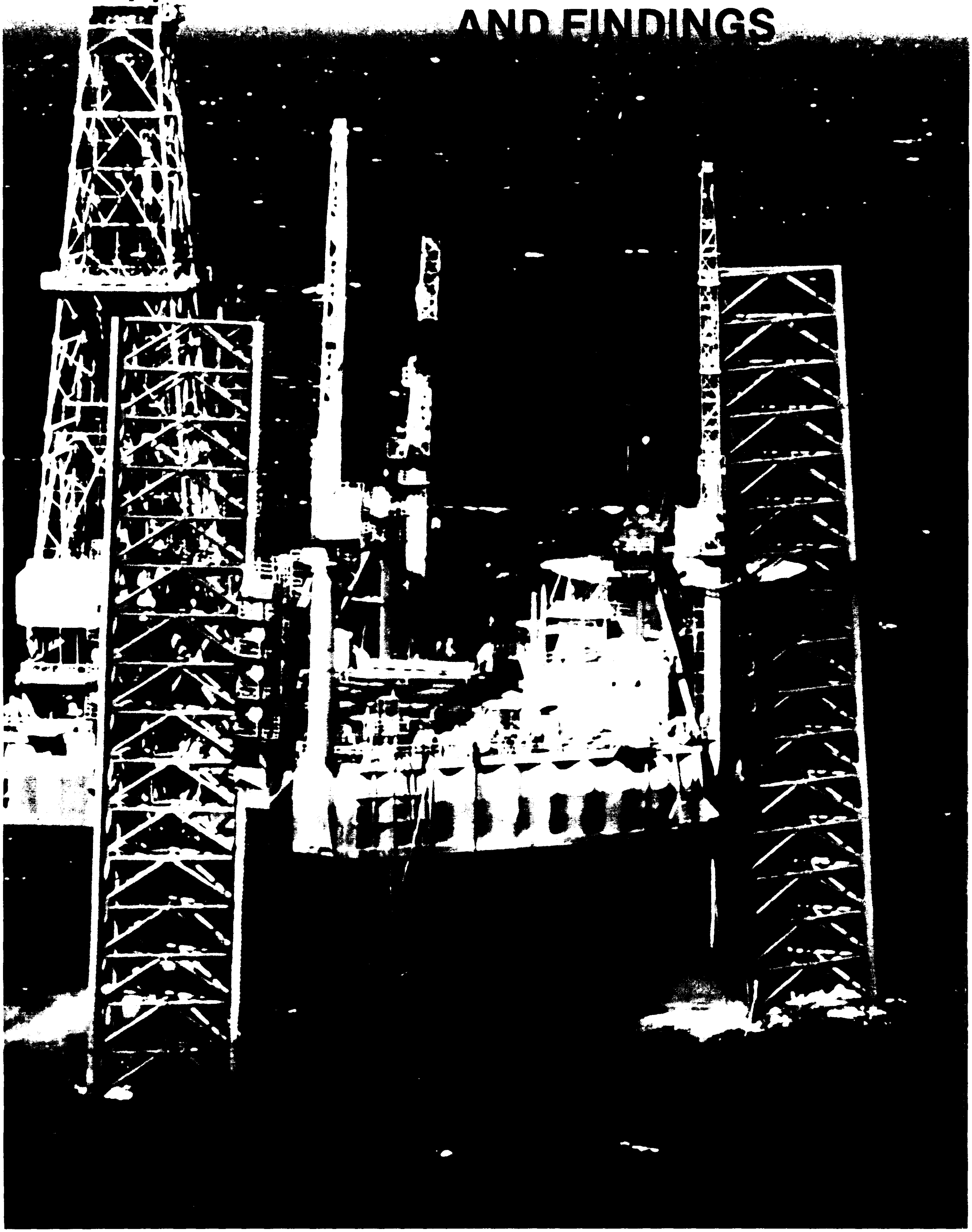
While the phenomenon of urban sprawl is complex, its effect on transportation and particularly the automobile system is well-known and well-documented. Public concern over energy problems, environmental degradation, and other social and economic issues has intensified the debate over land use and the spatial distribution of society's activities.

These problems are addressed in the Improved Accessibility Case, which includes the following policies:

- Quantified and measurable criteria for land use and transportation integration would be established. Meeting the criteria would be a condition for Federal assistance in planning and development.
- The Federal Government would participate directly in development of high-accessibility areas and integrated transportation networks to serve them.
- Highway funding would be held constant at $28.1 billion for the period 1985 to 2000, with a decreasing level of funding for construction and a reorientation to emphasize community circulation. (Capital expenditures would decrease from $14.3 billion in 1975 to $11.2 billion in 1985 and $7 billion in 2000. Highway maintenance would increase from $13.9 billion in 1975 to $17 billion in 1985 and $21.1 billion in 2000.)
- Federal funding for capital improvements of transit would increase from $1.2 billion in 1975 to $1.7 billion in 1985 and after. (Federal assistance for transit operation would be increased from $300 million in 1975 to $2 billion in 1985 and to $4.8 billion in 2000. Funding for operating assistance would emphasize community-oriented transit services.)
- Air quality standards for carbon monoxide and hydrocarbons would be held at the levels approved in 1977, with the standard for nitrogen oxides tightened to 0.4 gram per mile.
- Air quality control plans would emphasize auto-free zones.

Chapter 5

ENERGY ISSUES, POLICIES, AND FINDINGS



Chapter 5.- ENERGY ISSUES, POLICIES, AND FINDINGS

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ENERGY ISSUES, POLICIES, AND FINDINGS

Chapter **5**

SUMMARY

The automobile transportation system now uses over 5 million barrels per day (MMBD) of petroleum, or about **30** percent of total U.S. consumption. More efficient automobile designs and the shift to smaller cars are expected to lead to a decline in petroleum consumption by automobiles under Base Case conditions. By **2000,** it is estimated that automobiles will use between 4.2 and **4.8** MMBD, or about **20** percent of expected U.S. petroleum consumption at that time.

The United States now imports about 50 percent of its petroleum at a cost of over $42 billion per year. Petroleum imports account for a major part of the current $27 billion annual balance-of-payments deficit. In the Base Case, it is estimated that as much as **70** percent of U.S. petroleum supply in the year 2000 would be imported. If so, the cost of imports could rise to over $146 billion per year. (All dollar amounts specified are in 1975 dollars unless noted otherwise.) However, it is doubtful that this level of petroleum imports can be sustained. Several studies have predicted a shortfall by the late 1980's, and the threat of another oil embargo is always present. In addition, most experts predict severe depletion of worldwide petroleum supplies within 50 years.

For these reasons, this study considered changes in present Federal policies and programs, both to achieve greater conservation of petroleum by automobiles and to expedite the development of alternate automotive energy sources.

Among the petroleum conservation policies considered *were:*

- More stringent fuel-economy standards,
- Auto use disincentives and transit promotion,
- Improved transportation system management,
- Auto use controls,
- Increased gasoline taxes, and
- Gasoline rationing.

Although the first four of these policies would have beneficial effects, none is expected to produce petroleum conservation of significant magnitude or to avoid the serious consequences of a petroleum shortfall or embargo. More stringent measures, such as greatly increased gasoline taxes and gasoline rationing, were also considered. These measures could be used to conserve fuels and to control the consequences of an embargo or longrun shortage of petroleum, but they might entail serious economic penalties.

Conservation, however, is not a permanent solution. Sooner or later, the automobile transportation system will have to convert to alternate energy sources. Between 1980 and 2000, it may be possible to start using shale oil, coal liquids, alcohol, gasohol, or electrical energy storage on a large scale. As of now, there is no clear choice **as** to which would be the most technologically and economically feasible. All of the alternatives are more costly and require more total energy than petroleum. None is likely to be available before 1990 unless an active development and investment program is begun immedi-ate] y.

BACKGROUND

Today, more than 80 percent of U.S. households own one or more automobiles, and over **90** percent of personal travel is by automobiles. Under Base Case assumptions, it is estimated that vehicle miles traveled will increase by 75 percent to 1.8 trillion miles per year by 2000. It is expected that new car sales will be about 16 million per year then, compared to 11 million now. The total of automobiles in operation will grow from the present **100** million vehicles to **148** million,

The growth of automobile use in our society has been made possible, in part, by the availability of low-cost petroleum, Government policies, which have kept fuel prices low, have stimulated and helped sustain this growth. Automobiles now use over 5 MMBD of petroleum, or about **30** percent of total U.S. consumption. (See figure **24.**) Under Base Case conditions, the use of petroleum by automobiles in **2000** is projected to be **0.4** MMBD or about 8 percent below the 1975 level. This reduction is more substantial than it may appear because it comes about despite a 75-percent increase in automobile travel by the end of the century.

The future availability of automotive fuel must be set in the context of total U.S. petroleum supply and demand. At present, total demand exceeds domestic supply to the point that about half of the U.S. needs are met with imported oil. Despite current conservation policies and emphasis on increasing domestic production, it is estimated that the need for foreign oil will grow and could reach as high as 70 percent of demand by 2000. The Base Case assumes that U.S. fuel demand would be 22.4 MMBD, of which as much as 15.4 MMBD would have to be obtained abroad or provided by alternative energy sources yet to be developed.

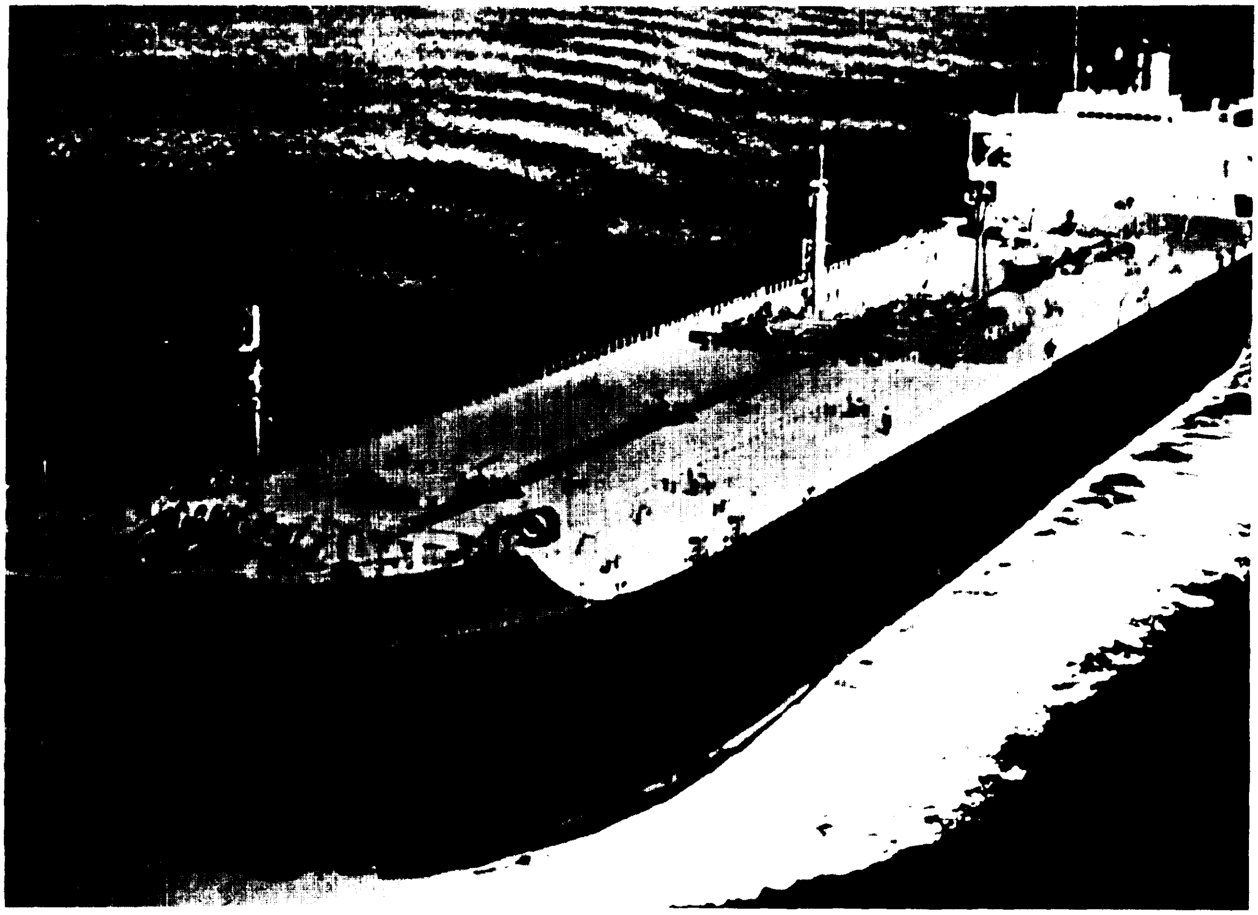
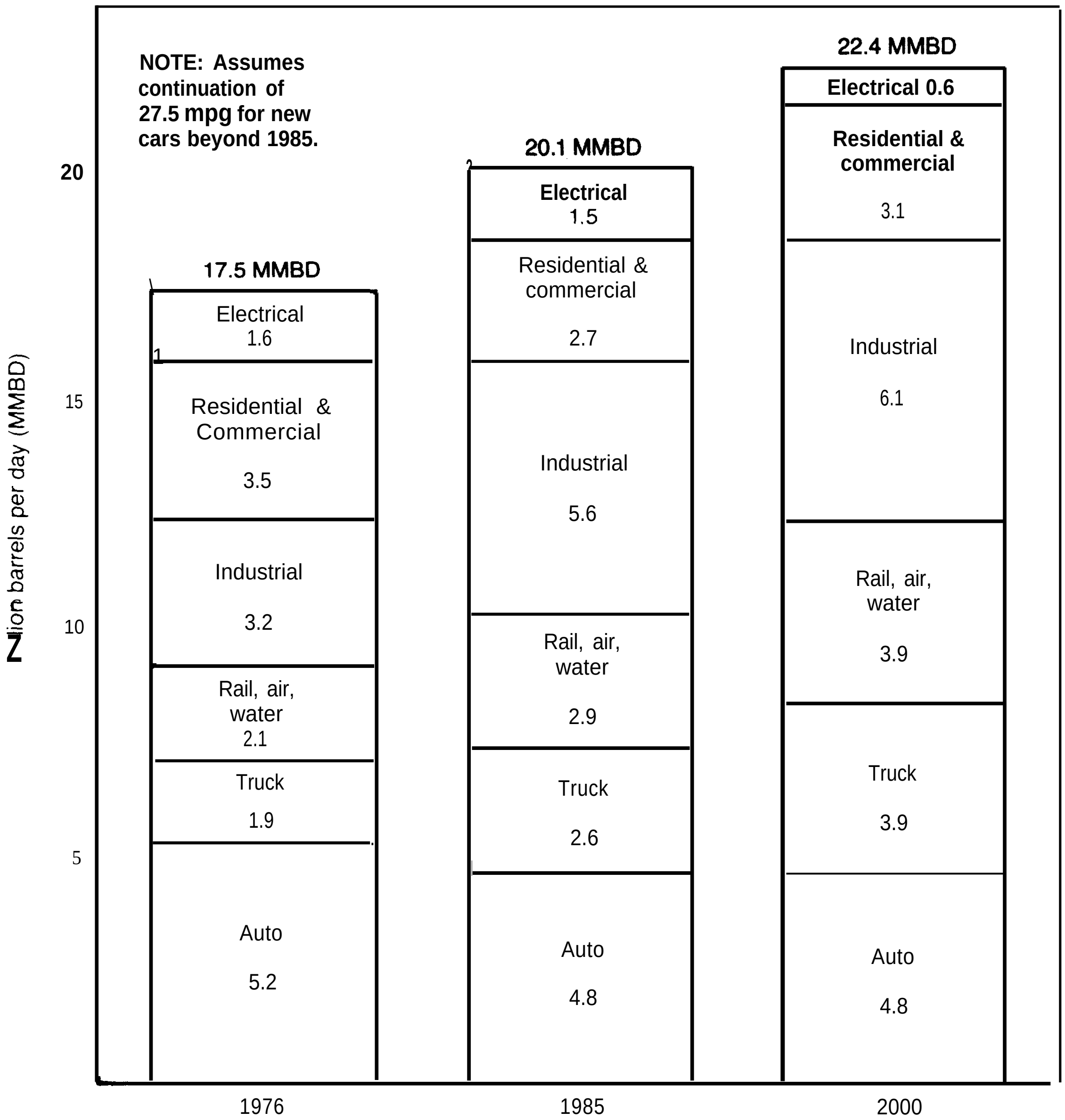


Photo Credit: U.S. Department of Energy

Figure 24.—U.S. Petroleum Demand

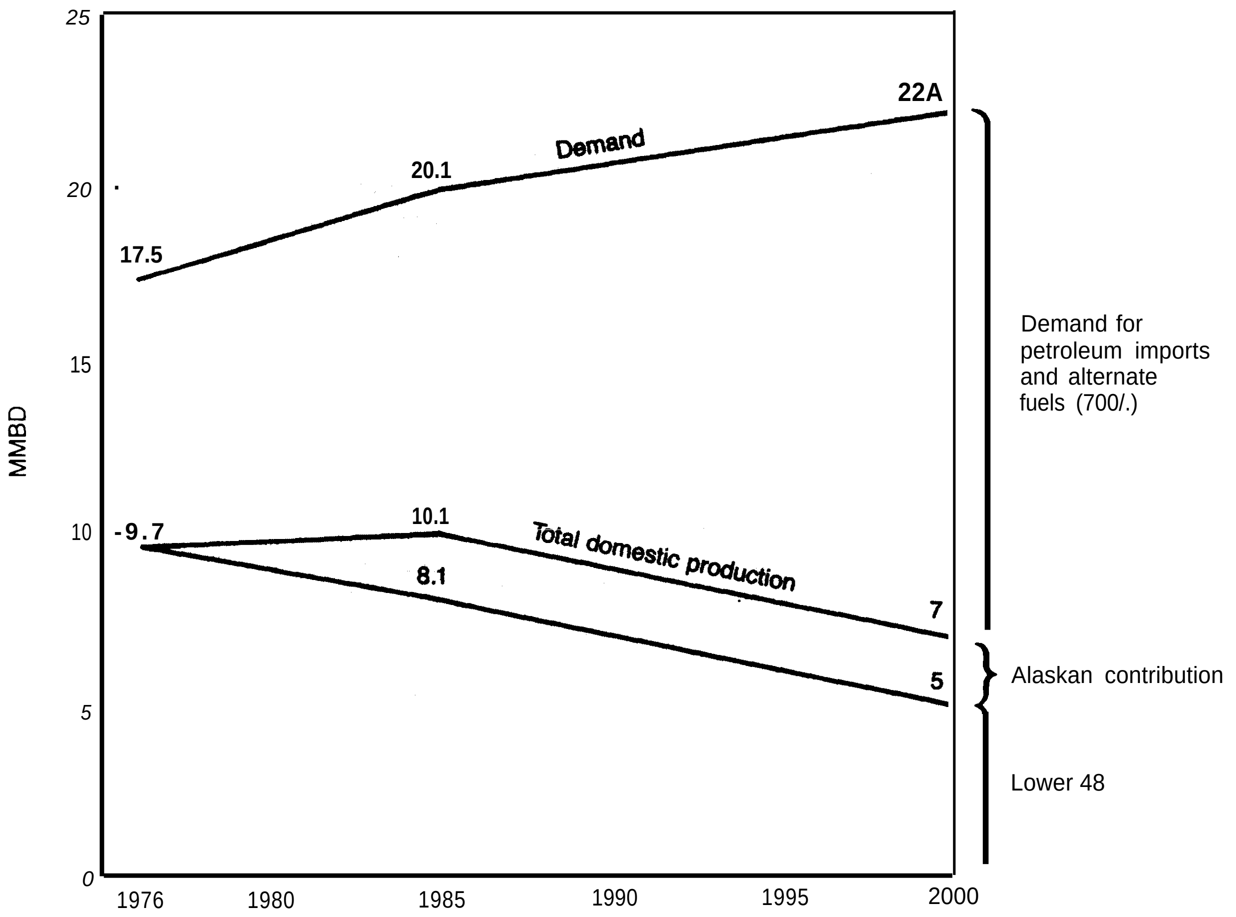


SOURCE: *Sydec/EEA*, p. III-88

The peaking of petroleum production—first in the United States and later throughout the world—has been predicted by several experts, among them M. King Hubbert. Hubbert projected that U.S. production could be expected to peak by the late 1970's, which it has. He has also forecasted that world production will peak sometime between 1985 and 2000.[1] Other ex-

[1] M. King Hubbert, testimony in Hearings before the Subcommittee on the Environment of the Committee on Interior and Insular Affairs, U.S. House of Representatives, 93rd Congress, June-July 1974, Serial No. 93-55, pp. 58-78. Also M. King Hubbert, Chapter XIX in *Project Interdependence: U.S. and World Energy Outlook Through 1990*, Committee Print 95-33, U.S. Government Printing Office, Washington, D.C., November 1977

Figure 25.—U.S. Petroleum Supply and Demand (MMBD)



SOURCE: Adapted from *Sydec EEA,* p III-92

perts disagree with Hubbert's view and estimate that the world production of petroleum from proven reserves will be adequate to meet demand through 2000 and beyond.

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

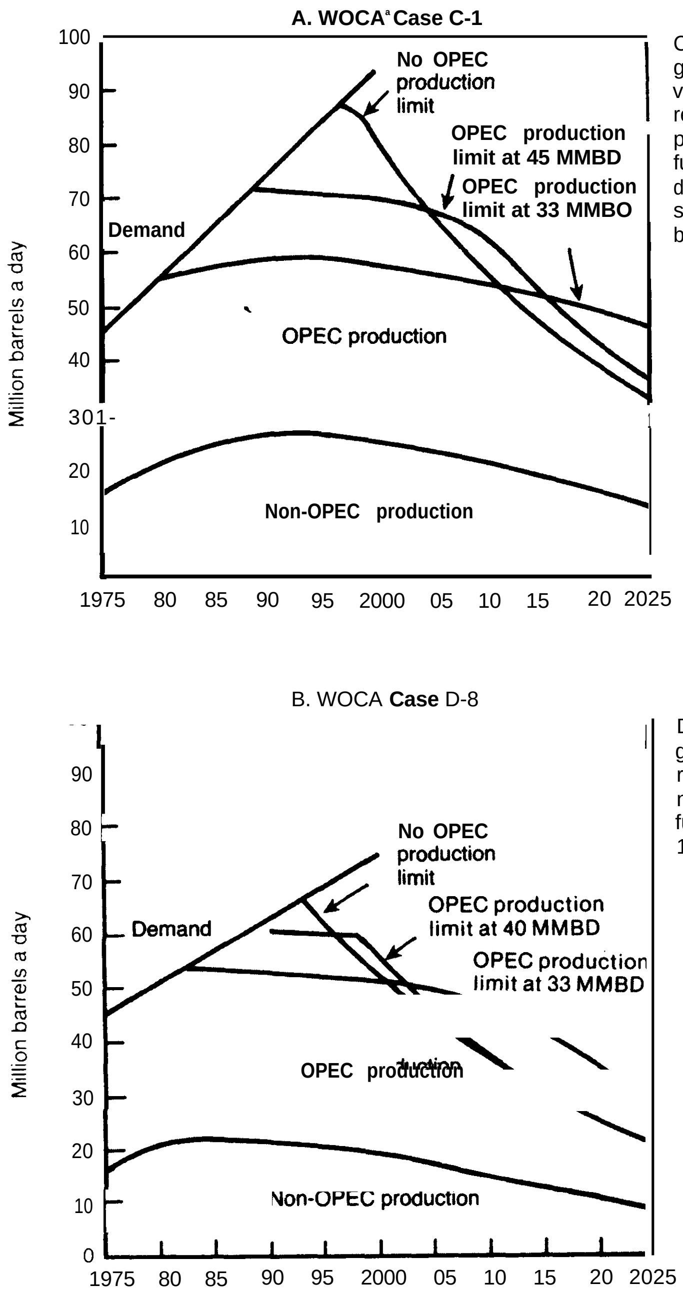
- Growth in world demand for oil,
- Drilling and finding rates for oil,
- Growth of production capacity in the oil-producing nations,
- Production and pricing policy decisions of oil-producing nations, and
- Rates of commercialization of alternative liquid fuels.

It is beyond the scope of the present study to investigate in detail the factors affecting the balance between petroleum supply and demand. Several independent analyses, of which the Workshop on Alternative Energy Strategies (WAES)[2] is probably the most exhaustive, point to the prospect that world demand for oil could outstrip the growth of new oil-producing capacity within the next decade.

The WAES study projects sufficient petroleum supply to meet demand up to 1985. However, after 1985 a gap between supply and unconstrained demand will appear and widen rapidly. (See figure 26.) By 2000, under even the

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

Figure 26.—Estimates of World Oil Production



C-1 Assumptions—high economic growth rate, rislng energy price, vigorous government response, coal as the principal replacement fuel, and gross additions to 011 reserves 20 billion barrels per year

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 billlon barrels per year

‘WOCA—World Outside Communist Area

SOURCE Workshop on Alternate Energy Strategies (WAES)’ *Energy Global Prospects 1985-2000,* p 20

most *optimistic* scenarios, shortfalls of 25 to 35 percent are projected. The WAES study concluded that, to keep supply and demand in balance through 2000 while maintaining economic growth, there would have to be a massive shift to coal and nuclear power, with petroleum reserved almost exclusively for transportation and petrochemical feedstocks. WAES also concluded that, while there is a range of opportunities for closing the petroleum supply and demand gap, they require enormous planning efforts, intensive engineering, and major capital investments with leadtimes usually of 10 or more years. In order to close the gap, development efforts would have to be started immediately for an adequate supply of alternative fuels to be assured by 1985-90.

Actually, the complete exhaustion of oil resources will not occur. 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 employed to produce additional oil or alternatives. As this process continues, the price of oil as an automotive fuel could become prohibitively high. If major improvements in oil recovery techniques were made, they would probably not raise the peak production level. They would be more likely to create a plateau in the production curve or to make decline from the peak less abrupt.

Accompanying the prospect of a long-term decline in petroleum reserves is the short-term threat of a major disruption in supply, such as a repetition of the 1973-74 oil embargo, To deal with temporary disruptions of petroleum supply, the Carter Administration has adopted several policies. The first is to expand the strategic petroleum reserve to 1 billion barrels which, combined with domestic production and emergency conservation measures, would supply essential domestic needs for about 10 months during an embargo.[3] The process of building up the level of petroleum storage was begun in 1977 and will take some years to complete. The second policy is a standby rationing system which, as currently planned, involves "white market" (transferable) coupons.[4]

The control of the price and supply of imports is largely in the hands of the OPEC nations and other foreign oil producers. The price of imported crude oil has risen since the 1973 oil embargo. In the Base Case, it is assumed that the world oil price will increase 3 percent per year, with the result that the price in constant dollars will double by 2000.

Probably the most serious impact of these market conditions, aside from the threat of another oil embargo, is the effect on the balance of payments, the value of the dollar, and employment. In 1977, the cost of imported oil **was $42.1 billion,** making it a major contributor to the $26.7 billion deficit in the balance of payments. In 1985, with the price of petroleum at

[3]Executive Office of the President, Energy Policy and Planning, *The National Energy Plan* Proposal, Apr. 29, 1977,
[4]*Federal Register 43,* (June *28,* 1978, Part II): 2813328168, "Contingency Gasoline Rationing Plan, " Proposed Rules.

Photo Credlf U S Department of Energy

$17 per barrel and imports at 10 MMBD, the annual cost would be $62 billion. If the price of petroleum were to double by 2000, reaching $26 per barrel, the cost of importing oil at the rate of 15.4 MMBD to meet domestic requirements would be $146 billion annually.

The problem of adequate petroleum supply will begin when production peaks and will grow worse with each succeeding year. For perspective, it should be noted that a shortfall of only 10 percent would limit consumption more severely than all of the conservation and curtailment policies normally considered. Thus, there is a clear need to explore a range of policy options to achieve greater conservation of petroleum as an automobile fuel and to hasten the development of alternate energy sources.

PRESENT POLICY

Before turning to an examination of alternatives, it is necessary to look briefly at the major policies now being pursued to see what effects they can be expected to have on petroleum consumption by automobiles.

Energy Policy and Conservation Act

The Energy Policy and Conservation Act (EPCA), enacted in December 1975, seeks to promote energy conservation in a variety of ways, many directly aimed at the automobile transportation system. Prominent among these are the new car fuel-economy standards mandated for model years 1978 through **1985.** Standards for light trucks will also go into effect beginning with the 1979 model year. (See table 44.)

Table 44.— Fuel-Economy Standards Assumed for the Base Case'

Model year	Sales-weighted new car fleet average
1978	18[b]
1979	19[b]
1980	20[b]
1981	22[c]
1982	24[c]
1983	26[c]
1984	27[c]
1985	27.5[b]
1990	27.5/30.0[d]
2000	27.5/35.0[d]

[a]Values shown are those to be achieved on the EPA prototype vehicle dynamometer tests Fuel consumption estimates prepared for this study assume that performance by vehicles in use is 10 to 20 percent less
[b]Mandated by EPCA
[c]Administratively determined by the Secretary of Transportation
[d]Fuel economy assumptions for Case A and Case B, respectively

EPCA provides the Secretary of Transportation with authority to amend the average fuel economy standard for model year 1985, or any subsequent model year. However, any such amendment may not lower the standard beyond 26 mpg without approval of both Houses of Congress. EPCA does not make provision for standards beyond 1985. One policy issue is whether the 1985 standards should be maintained or increased further between 1985 and **2000.**

In addition to mandating automobile fuel-economy characteristics, EPCA also provides for programs to foster energy conservation in automobile use. Among these are:

- Promotion of carpools, vanpools, and public transportation,
- Encouragement to States and municipalities to adopt right-turn-on-red laws, and
- Transportation system management and transportation controls.

Nationwide 55 Mph Speed Limit

The 55 mph speed limit for highway traffic was established in 1974 as a means to save gasoline during the oil embargo. The law was especially effective during its first year or two, when compliance was much higher than it is today. Reduced speed not only saved petroleum but also provided an important extra benefit in lessening highway fatalities and injuries. More recently, the law has been less effective because of declining compliance and unwillingness by some States to enforce the law rigorously. A survey by the Department of Transportation showed that, during the first 6 months of 1977, from 30 to 77 percent of the vehicles on highways in various States exceeded the 55 mph limit.[5] Congress empowered the Secretary of Transportation to cut off highway construction funds to States failing to enforce the 55 mph speed limit, but this sanction has never been invoked. Lack of enforcement remains the major deficiency of this law.

Emergency Petroleum Allocation Act

The Emergency Petroleum Allocation Act, passed in November 1973, provides the Administration with authority to allocate petroleum and to set price controls during an emergency. The responses by the Federal Government to the 1973-74 embargo consisted primarily of the measures authorized under this Act.

The Electric and Hybrid Vehicle Act

The Electric and Hybrid Vehicle Research, Development, and Demonstration Act was passed in September 1976 and amended in 1978. Its aim is to foster the use of electric- and hybrid-vehicles as an alternative to petroleum-fueled automobiles. The intent of this law was to:

- Encourage and support research on, and development of, electric- and hybrid-vehicle technologies,
- Demonstrate the economic and technological practicability of electric and hybrid vehicles for personal and commercial use in urban areas and for personal and agricultural use in rural areas,
- Facilitate, and remove barriers to, the use of electric- and hybrid-vehicles instead of gasoline- and diesel-powered vehicles, and
- Promote the substitution of electric- and hybrid-vehicles for many gasoline- and diesel-powered vehicles now used in routine shorthaul, low-load applications, where such subs itution would be eneficial.

Responsibility for administering the Act was placed on the Energy Research and Development Administration (ERDA), now incorporated into the Department of Energy (DOE). Funding of $37.5 million has been requested by DOE for FY 1979 to handle these responsibilities. Work already completed includes initial studies and analysis of program requirements, review of the state of the art, publication of the first set of performance standards, and plans for a loan guarantee program. In addition, R&D has begun on batteries, components, and vehicles to assist industry in improving product performance, utility, and reliability. A demonstration program has been formulated to place at least 200 electric-vehicles on the road by 1979 and between 7,500 and 10,000 by 1984.[6]

Advanced Automotive Technology and Synthetic Fuels Development

The Department of Energy inherited from the Environmental Protection Agency (EPA) a program to promote development of new technologies for automobile engines, transmissions, and drivetrain components. DOE has entered into a cost-sharing contract with an industry consortium to develop the Stirling engine over an 8-year period. DOE also expects to place contracts for development of gas turbine engines—a continuation of the R&D work performed by the Chrysler Corporation with Federal support since the 1950's.

The Department of Energy also inherited from EPA a program for the development of synthetic fuels. The program originally concentrated on state-of-the-art and feasibility studies. At the present time, small pilot plants are being built to test alternative processes for converting oil shale and coal to synthetic fuel. Emphasis on this program has grown considerably within the past year.

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[5] U.S. Department of Transportation, Office of the Secretary, *Report to the President on Compliance with the 55 MPH Speed Limit*, Oct. 14, 1977, p. 1.

[6] *Electric and Hybrid Vehicle Act, Statutes at Large 90, 1260 (1976), U S Code* vol. *15*, sec. *2501-2514*, vol. *42*, sec. *2451* and *2473*, as amended by the *ERDA Authorization Act of 1978*, P.L. 95-238, 95th Cong., 2d sess., Feb. 25, 1978, S, 1340, Title VI.

ISSUES

The automobile transportation system is confronted with a serious challenge. Abundant low-cost petroleum is no longer assured. Growing petroleum imports, of which automobile fuel demand is a large part, have contributed to a serious negative balance of payments. Efforts to conserve petroleum have so far been slow, difficult, and limited in results. All alternatives to petroleum are more costly and require major investments with high risks. All will take many years to bring to full development and commercialization. Thus, something clearly needs to be done about the way in which automobiles use energy and about assuring a continuing supply of energy for personal transportation. The policy questions facing the Government, the industry, and the public can be summed up in two basic issues:

- Should the Government adopt policies to effect a transition from petroleum to alternate energy sources for automobiles? When should the transition be made? What are the feasible paths?
- Should specific limits or allocations be established for petroleum consumption in the automotive transportation sector? Or, alternatively, should the Government let the market price balance supply and demand?

Concerning the first issue, the Federal Government may have to become involved because the capital requirements are so high and the risks so great that private industry would be unlikely to undertake the needed research and development without strong encouragement and perhaps Federal Government participation. Federal Government involvement might also be necessary to ensure a smooth and expeditious transition and to prevent disruption of supply with resulting hardships on citizens and the economy.

The second issue, limiting petroleum consumption, must be confronted while the longer term transition is taking place. If a petroleum shortfall occurs, there will be a need to consider further measures to reduce fuel consumption in all sectors, including automobile transportation. The issue addressed in this report is how to achieve petroleum conservation by the automobile transportation system through policies that do not have severe negative impacts on consumers, the auto industry, or the economy in general.

POLICY ALTERNATIVES

Policies to deal with the issues outlined above were analyzed in two ways. First, a policy case was constructed to deal with the combined impacts and effects of several policies working together to conserve petroleum. Second, an analysis was carried out of the impacts and effects of individual policies to conserve petroleum or to encourage the transition to alternative sources.

Petroleum Conservation Policy Case

The rationale of the Petroleum Conservation Policy Case was to foster substantial reduction in fuel consumption by automobiles without major adverse impacts in the areas of mobility, environment, safety, and cost. Specific policies within this set include:

- EPCA fuel-economy standards for new cars as now mandated for **1978-85,** with escalation of the standards to 33 mpg in 1990 and 40 mpg in 2000,
- New car fuel-economy standards that establish a minimum of 16 mpg for all cars in the **1980** model year and an increase of 1 mpg each year thereafter until reaching 21 mpg in 1985,
- An excise tax on fuel-inefficient automobiles (“gas guzzlers”) that increases from a maximum of $553 in 1979 to $3,856 in 1985, and

- An increased gasoline tax to keep average fleet fuel cost per mile constant after 1979– the increase amounting to 7 cents per gallon in 1980 and 18 cents per gallon by 2000.

The gasoline tax would be adequate until 1985 to serve also as an incentive to alternative fuel production. Depending on fuel prices and auto fuel efficiencies after 1985, additional taxes might be required to maintain the price advantage of alternate fuels. The assumptions for this set of policies are summarized and compared with the Base Case in table **45.**

As a supplement to the Petroleum Conservation Policy Case, the analysis was extended to consider the consequences of a staged rationing program designed to bring about forced reductions in petroleum consumption for the long term.

In addition to Federal policies that have a direct impact on the cost of driving and on fuel economy, there are other measures that could divert or reduce reliance on conventional automobiles and conventional auto fuels. For example, a gasoline tax or rationing program might be accompanied by Federal subsidies for electric car development and purchase. Stringent fuel-economy standards for new cars could be accompanied by increasing Federal R&D for auto technologies. The negative effects of a gasoline tax on mobility could be somewhat alleviated by subsidies for mass transit and vanpooling. These supporting policies to improve mobility, while clearly important to the success of energy conservation efforts, are not examined in detail in this chapter, but they are considered later in chapter 8.

Individual Policies Analyzed

The range of policy alternatives for effecting automobile petroleum conservation and a transition to alternate sources is extensive. Time and resources did not permit analysis of all the alternatives. The policies selected for study here are those that focus on actions related to the automobile. These policies address what the automobile sector could do to lower demand for petroleum while continuing to meet basic transport needs. For example, policies that would

Table 45.—Assumptions and Conditions for Petroleum Conservation Case

Assumptions	Base Case	Petroleum Conservation
Highway		
Total highway expenditures	Increases with inflation (stable in constant dollars).	Increases at 1/2 inflation rate (declines 40% by 2000 in constant dollars).
Mass transportation		
Capital improvements	Increase current dollar funding 10% per year to 1985. Hold constant in real dollars to 2000.	Increase current dollar funding 15% per year to 1985. Hold constant in real dollars to 2000.
Operations	Same as above.	Double funding initially. Increase 15% per year to 1985. Increase 10°/0 per year 1985-2000 (all current dollars)
Auto feul *economy*	EPCA 27.5 mpg beyond 1985.	33 mpg by 1990; 40 mpg by 2000. Gas-guzzler tax and ban.
Highway speed	Moderate enforcement (present average of 62 mph).	Rigid enforcement of 55 mph limit.
Safety		
Occupant restraints	Airbags or equivalent on new vehicles as scheduled.	Mandatory seat belt use only.
Technology		
Propulsion	**10%** of new cars diesel by **1985; 25°/0 by 2000. Negligible electric vehicles in use.**	25% of new cars diesel by 1985; 60% by 2000.11 million electric vehicles in use by 2000. Neglible use of advanced engine technologies.
Fuels	4.4°/0 diesel by 1985; 17.9°/0 diesel by 2000.	Increase % of diesel fuel; accelerate transition to synfuels. Potential for gas rationing.

SOURCE *Sydec/EEA,* p 1.7

give priority to the auto in the allocation of petroleum were not considered. In assessing the transition policies, no attempt was made to determine how other sectors might make use of the new energy forms.

Petroleum Conservation Policies

Basically, these policies are designed to influence behavior in two ways:

1. To promote the design and sale of fuel- efficient vehicles, and
2. To promote more energy-conscious use of automobiles *or* to provide alternative modes of transportation.

In table 46, several policies have been listed in each of these categories. Four policies from this list are analyzed in this chapter:

- Tighter fuel-economy standards,
- Higher gasoline prices,
- Free-market pricing, and
- Gasoline rationing.

Table 46.—Policy Options for Automobile Fuel Conservation

Vehicle fuel-efficiency policies

- **Tighter fuel** economy standards
- Gas-guzzler ban
- Gas-guzzler tax
- Efficiency incentive tax
- National inspection and maintenance program
- Scrappage of fuel-inefficient cars
- Subsidized industry research and development

Automobile use policies

- Improvements to traffic flow
- Stricter enforcement of 55 mph speed limit
- Deregulation of gasoline and diesel fuel prices
- High gasoline taxes
- Gasoline rationing
- Carpooling and vanpooling promotion and priorities
- Public transit expansion
- Subsidized telecommunications networks
- Public education and appeals
- Auto use controls
- Annual VMT-based tax

Transition to Alternate Sources

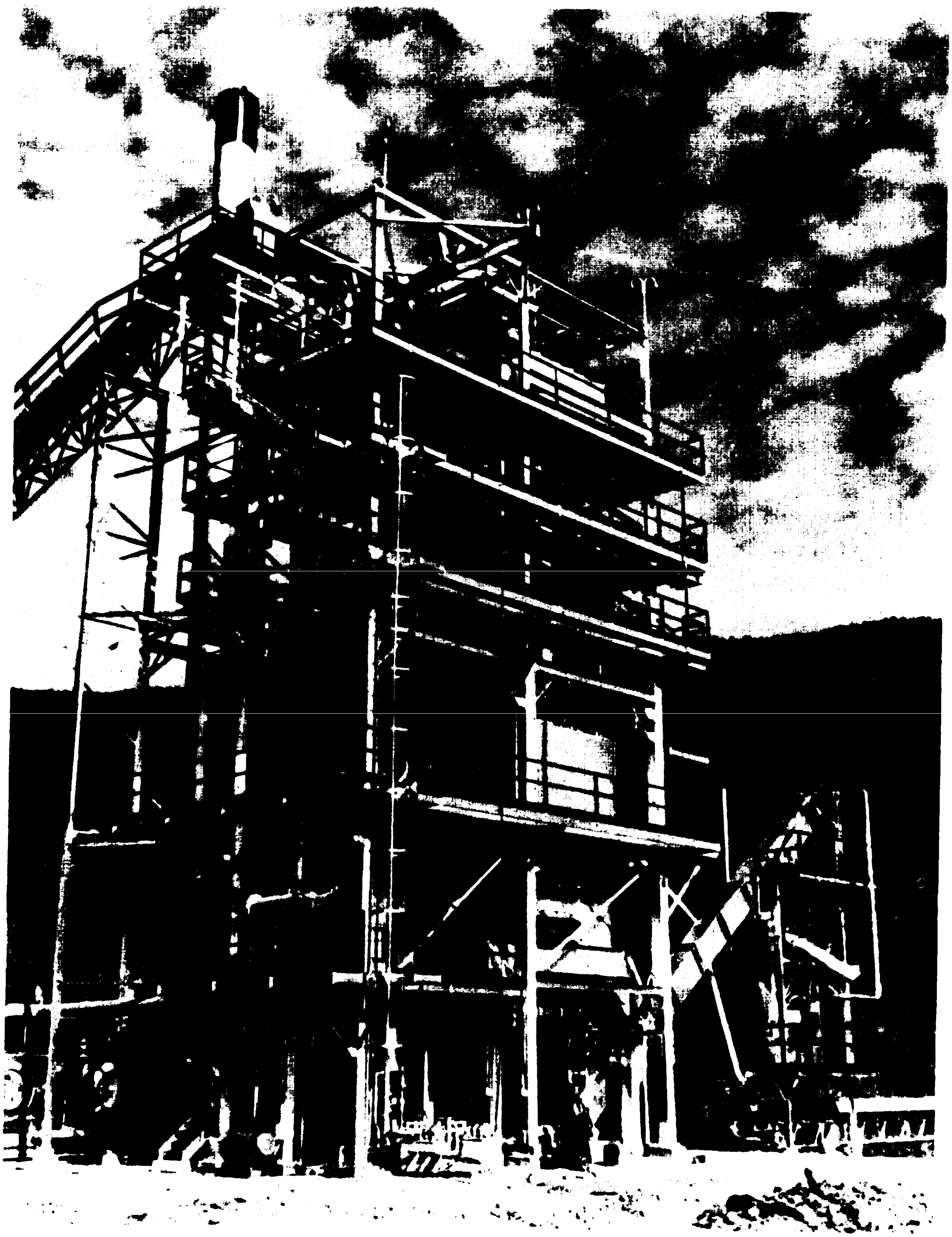
Policies to stimulate transition to alternate energy sources for automobiles were divided into three groups according to the type of energy source promoted: synthetic liquid fuel, alcohol fuels, and electric- or hybrid-vehicles.

Synthetic fuels from coal or shale oil would require the least change in the automobile and energy systems. Although the technologies for producing liquids from coal and shale oil are quite different, the end product from either would be a synthetic crude oil. Such a product could then be refined into gasoline, diesel fuel, or any other suitable liquid through conventional petroleum-refining processes.

Neither coal-based nor shale-based synfuels technology now exists on a commercial scale in the United States. Commercial technologies now employed in other nations (notably South Africa) produce fuel that is substantially more expensive than gasoline derived from petroleum. Uncertainties about the eventual cost of production, about the technology to mitigate environmental damage, and especially about the future price of petroleum-based gasoline are presently the main barriers to development of these alternatives. Policies to encourage the development of synfuels must assure developers that the fuels they eventually produce will be marketable and that they will receive a reasonable rate-of-return on investment. The policies that could be adopted to stimulate development of production facilities and marketing of synfuels are listed in table 47.

A second major alternative to gasoline is a fuel composed of alcohol or a blend of gasoline and alcohol. Several alcohols are under consideration, but the most likely candidate is methanol (methyl alcohol). Several experiments with methanol as an automobile fuel are now underway in the United States and in other countries. Methanol can be derived from coal, from natural gas, from organic wastes, and from biomass.

Methanol may be used as a substitute automobile fuel in two different *ways: as* a mixture or blend, i.e., the “gasohol” alternative, and as a “true” replacement for gasoline. Some proponents suggest that the former strategy could be employed as a precursor to the latter.



Oil Shale Retorting

Photo Credit U S Department of Energy

Table 47.—Policy Options to Promote Synfuels

Strategy	Policy measures
Regulation	• Relax environmental standards for coal mining, shale oil mining, and synfuels processing. • Regulate synfuels industry as a public utility, guaranteeing a reasonable rate of return. • Deregulate prices of oil and remove gasoline price ceilings.
Taxes and subsidies	• Increase investment tax credits for synfuels producers. • Guarantee Government price support for syncrude. • Federal Government purchase and resell sync rude. • Loan guarantees. • Direct loans.
Government RD&D	• Accelerate oil shale and coal liquefaction RD&D with main emphasis on commercialization. • Support research to reduce potential environmental impacts of synfuel processing.
Government commercialization	• Establish Government owned and operated synfuels industry (i.e., similar to TVA).

SOURCE Adapted from SRI p I 20

Because methanol cannot be easily mixed with gasoline in the present fuel distribution system, policies aimed at promoting a methanol distribution and storage system need to be considered as well. Methanol would have to be transported and stored in separate facilities. If gasohol blends were the chosen alternative, the two fuels would be mixed at the pump.

Table 48 shows a range of policy options to encourage the production and use of alcohol-based automobile fuels.

A third alternative, which may be pursued in conjunction with either or both of the previous

Table 48.—Policy Options to Promote Alcohol Fuels

Strategy	Policy measures
Regulation	• Set different emissions and performance standards for automobiles using alcohol or alcohol-gasoline blends. • Require that an increasing proportion of new automobiles be designed to use a alcohol-gasoline blends. • Require automobile fuel distributors and retailers to handle alcohol.
Taxes and subsidies	• Subsidize automobile industry development of alcohol-gasoline or pure alcohol engines. • Subsidize purchase of autos using gasoline-alcohol fuels. • Provide tax credit for retrofitting used cars to make use of blended fuels. • Subsidize development of alcohol fuel conversion, distribution, and storage systems. • Purchase and operate a Government-owned fleet of alcohol or alcohol-gasoline fueled automobiles.
Government RD&D	• Accelerate RD&D on integrating alcohol into existing fuel distribution systems. • Accelerate RD&D on long-term alternative automobile engines.

SOURCE Adapted from SRI p I 22

courses of action, is to encourage a shift to electrically powered automobiles. Assuming that electric cars are a viable and economic alternative to conventionally powered automobiles, electricity itself is readily available from any number of energy-conversion processes.

Electric automobiles (and hybrid-vehicles) have the general advantages of making very efficient use of electricity and, in comparison with conventional autos, they may be more environmentally benign. At present, however, neither battery- nor electric-car technology is sufficiently advanced to produce an electric car that is, on the whole, competitive with conventional automobiles in terms of range, performance, and cost.

The major stakeholders involved in a shift to electric automobiles include automobile users, the automobile manufacturers and after-markets, and, to some extent, the fuel distribution system. Policies to promote electrics must focus on the activities and interactions among these three major groups.

Table 49 summarizes policy options for encouraging the development and use of electric or hybrid automobiles. (In general, hybrids are considered a less well-developed technology than pure electrics. However, most of the same policy options are applicable.) As a second way to promote electric-vehicles, table 49 also lists complementary policies to discourage the use of conventional automobiles.

Table 49.— Policy Options to Promote Electric Automobiles

	Policy measures	
Strategy	**Policies encouraging electric automobiles**	**Policies discouraging use of conventionally powered automobiles**
Regulation	• Require that a proportion of new auto sales be electric automobiles by a certain year. • Change utility pricing to encourage use of off peak times to recharge electric autos. • Relax certain standards for electric automobiles (e. g., safety). • Give electric vehicles credit for being low or non petroleum users in computing corporate average fuel economics.	• Increase restrictions on air emissions of conventionally powered automobiles, especially in urban areas. • Establish restricted zones for conventional automobiles. • Reduce performance on conventional cars • Allocate petroleum.
Taxes and subsidies	• Subsidize automobile industry development of electric automobiles and batteries. • Subsidize parts or all oft he cost of electric automobiles (e. g., insurance, fuel, maintenance, etc.). • Purchase and operate a Government electric-automobile fleet. • Subsidize purchases of electrics for commercial automobile fleets.	• Increase taxes on conventional autos. • Increase cost of access to highways and parking for conventional automobiles. • Increase taxes on conventional automobile fuels.
Government RD&D	• Accelerate Government RD&D on batteries, electric automobiles, and hybrid automobiles.	

SOURCE Adapted from SRI, p 1.23

EFFECTS

The analysis of policy alternatives concentrated on two types of outcomes—effects and impacts. Effects were defined as the primary and intended results of pursuing a policy action, i.e., outcomes directly related to the objectives of the policy. Impacts were defined as secondary or unintended results, falling in areas not directly related to policy objectives.

As an illustration of the distinction between effects and impacts, consider the energy policies discussed in this chapter. The objective of these policies is either to conserve petroleum or to promote the use of alternate energy sources. The effects of these policies, therefore, are the amount of petroleum saved or the degree to which other forms of energy are substituted. The impacts of these policies are the other results that follow in areas such as environmental pollution, safety, mobility, cost, and so on. Effects are, by definition, positive outcomes since every policy can be presumed to attain its objective to a greater or lesser degree. Impacts may be positive or negative. For example, the 55 mph speed limit was implemented to conserve petroleum, but also is credited with significant reductions in highway fatalities (a positive impact). A negative impact of this policy was the increase in trip times.

The overall worth of a policy must, be judged by weighing advantages against disadvantages and striking some suitable balance. During the assessment, this process was carried only part way to completion. An attempt was made to identify effects and impacts and, where possible, to express them in quantitative terms. Where quantitative measurement was not possible, estimates were made of the direction and general magnitude of possible outcomes. However, no attempt was made to balance effects against impacts in an overall evaluation of policies or to analyze the more subtle interactions between effects and impacts.

The effects of the energy policies examined are presented under three headings:

1. Effects of Petroleum Conservation Policy Case,
2. Effects of Conservation Policies, and
3. Effects of Transition to Alternate Sources.

In certain instances, results of the analysis of the Petroleum Conservation Policy Case have been used as supporting material in the discussions of the effects and impacts of individual policies. The findings presented in this section are synopses and highlights of more detailed information in the contractors' reports. Impacts are considered separately in the next section.

Effects of Petroleum Conservation Policy Case

The reduced automobile fuel consumption estimates for this policy case derive from four basic policies:

1. Higher fuel-economy standards (40 mpg by 2000),
2. Fuel-economy minimum (ban on autos with fuel efficiency under 21 mpg after 1985),
3. Excise tax on fuel-inefficient autos (gas-guzzler tax of up to $3,856 after 1985), and
4. Increased gasoline tax (an additional 18 cents per gallon over the Base Case in 2000).

The effects of these policies would be substantial. As shown in table 50, auto fuel consumption in 1985 would be reduced to 4.6 MMBD, about 5 percent less than in the Base Case. By 2000, automobile fuel consumption would be down to 3.4 MMBD or 29 percent below the Base Case. These savings would be achieved without a major reduction in auto VMT—only 3 percent.[7] The fuel-economy of the average car in 2000 would be nearly 2 1/2 times that of its 1975 counterpart.

[7]About 5 percent of the total VMT would be in electric vehicles. This mileage has not been used in computing mpg statistics. See *Sydec/EEA*, pp. IV-54 to IV-58.

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Table 50.—Automobile Energy Demand, Petroleum Conservation Case

	Actual	Base Case[a]		Petroleum Conservation Case		Rationing Case
	1975	1985	2000	1985	2000	2000
Automobile VMT (trillion). .	1.03	1.43	**1.80**	1.42	1.74	**1.53**
Diesel penetration (percent of new car sales)	(b)	10	**25**	25	60	(d)
New car fuel economy (mpg)						
EPA standard@)	None	27.5	27.5	27.5	40.0	(d)
Attained— EPA certification value.	15.6	28.5	29.4	31.5	40.0	(d)
Attained—actual driving	14.0	23.2	25.0	25.6	34.0	(d)
Fleet fuel economy (mpg)						
Attained— EPA certification value.	15.1	24.0	**28.5**	**24.8**	**37.6**	(d)
Attained—actual driving	13.6	19.4	**24.6**	**20.3**	**32.1[e])**	(d)
Annual auto fuel consumption						
Billions of gallons. ... , .	76.0	**73.9**	**73.3**	70.1	51.7	45.8
MMBD equivalent	5.0	**4.8**	**4.8**	4.6	3.4	3.0
Percent of domestic consumption	30.6	**23.9**	**21.4**	23.1	16.2	14.6

[a]Base Case "A" as defined in chapter 3.
[b]Insignificant.
[c]The EPA certification value for a particular car is the weighted average of performance in the EPA urban cycle (55 percent) and rural cycle (45 percent).
[d]Quantitative estimates not available. Presumably new cars would average more than in the Petroleum Conservation Case and more than 60 percent would be diesels
[e]Excludes electric vehicle VMT.
SOURCE: Adapted from *Sydec/EEA*, p. IV-56

Also shown in table **50** are the results of the analysis of long-term, mandatory rationing. This policy, which would be implemented gradually between 1985 and 2000 to control the allocation of auto fuels between diesel and gasoline autos, is discussed later. Compared to the Petroleum Conservation Policy Case, rationing could reduce auto fuel consumption to 3.0 MMBD in **2000,** or **6** gallons per week per car. The table indicates that auto fuel consumption in **2000** might be only 14.6 percent of total domestic consumption; however, if the situation were severe enough to warrant rationing, other sectors would likely be forced to reduce their consumption more than anticipated here.

Additional effects of this policy case relate to the transition to alternate energy sources. It is believed that in 2000, alternate fuel utilization might reach 3.75 MMBD (as opposed to the 2.75 MMBD envisioned for the Base Case). Up to 11.5 million electric vehicles might be on the road; they would account for approximately 5 percent of the VMT. These and other effects are explored further under the separate policy discussions which follow.

Effects of Conservation Policies

This analysis focuses on four individual policies, each designed to promote greater fuel conservation by the automobile system. The four considered are:

1. Higher fuel-economy standards, which represent a strengthening and extension of the present EPCA policy,
2. Increased gasoline taxes to raise the price of gasoline and thereby discourage unnecessary driving,
3. Free-market pricing and deregulation to let petroleum prices rise as supply decreases, thereby providing additional disincentives to automobile use, and
4. Rationing, either as a short-term response to an embargo or as a long-term measure to impose a ceiling on consumption of motor fuel.

Higher Fuel-Economy Standards

Imposition of higher fuel-economy standards for automobiles is an important policy option to counterbalance the projected growth in automobile travel between now and 2000. The automobile fleet traveled about 1.07 trillion vehicle miles in 1976. Base Case projections indicate that by 1985 auto travel will increase to 1.43 trillion vehicle miles and by 2000 to 1.80 trillion vehicle miles. This growth will have important implications on the magnitude of future auto fuel consumption and on the merits of further increases beyond the **1985** EPCA fuel-economy standards.

In **1976,** automobiles consumed **5.2** MMBD of fuel. In 1985, it is expected that consumption will have fallen slightly to 4.8 MMBD, Assuming that the current EPCA new car standard of 27.5 mpg for 1985 remains in effect until 2000, auto fuel consumption would also be 4.8 MMBD. However, if the standard were raised gradually to 35 mpg (as in Base Case B) or to 40 mpg (as in the Petroleum Conservation Case), auto fuel consumption could drop to 4.2 and 3.4 MMBD, respectively, assuming the appropriate supporting policies are also instituted, Each of the higher mpg levels assumes a higher penetration of diesels into the market. The Petroleum Conservation Case assumes higher fuel and excise taxes and an mpg floor; it also assumes that 5 percent of the VMT will be electric cars.

However, the magnitude of the additional savings to be achieved by further raising the EPCA standard tend to have a decreasing value as automobile fuel efficiency improves. For example, for a motorist traveling 10,000 miles annually, shifting from a 12-mpg car to a 27.5-mpg car will save 470 gallons per year. A shift from a 27.5-mpg car to a 40-mpg car saves only 114 gallons. Moreover, the incremental cost of achieving these fuel-economy improvements may increase. However, when consideration is given to the projected growth in fleet auto travel, higher fuel-economy standards can still produce meaningful savings. It is well recognized that there are practical limitations on continuing fuel-economy improvements. It is not known what the maximum auto fuel efficiency could be, but improvements up to 35 mpg and eventually up to 40 mpg by the year **2000,** are thought possible. [8] Several cars listed in EPA's **1978** *Gas Mileage Guide* attain over 35 mpg, and at least three makes could meet a 40-mpg standard. [9]

Under current EPCA standards, the total fuel consumed by automobiles is expected to start declining slowly in a few years, as the fuel economy of the fleet as a whole begins to offset the growth in VMT. Just how soon the peak will be reached and how much motor vehicle fuel consumption will then decline depends, in part, on the fuel-economy standards imposed on light trucks. Light-truck sales, which were 15 percent of auto sales in **1965,** rose to 31 percent of auto sales in 1976. The concern is that many households may be substituting lightweight trucks for automobiles. To the extent that this is the case, fuel-economy gains achieved by shifting to more energy-efficient autos may be offset by the sales of lightweight trucks. Standards for light trucks go into effect for the 1979 model year and have been established for the 1980 and 1981 model years. [10]

Thus, under current EPCA standards, automobile fuel consumption could remain within the range of 4 to 5 MMBD through the year 2000. To bring consumption down further, more stringent fuel-economy standards would be necessary. These higher standards would have the effect of accelerating the present trend toward production and purchase of the smaller compact and subcompact automobiles, some of which can already achieve **40** mpg. However, there are factors that could limit this trend. One is the willingness of automobile owners to switch to smaller cars, which may have less comfort, performance, and utility than vehicles now in use. Another potential limiting factor is the ability of the automobile industry to respond. The capital requirements to accomplish the conversion to smaller, more fuel-efficient cars are large and may pose a threat to the continued viability of one or two domestic manufacturers.

An additional fuel-economy policy would be to ban the sale of any car that did not meet a specified minimum mpg. This would save more

[8] *Sydec EEA*, pp. IV-5, 48, and 54

[9] U.S. Environmental Protection Agency and U.S. Department of Energy, *1978 Gas Mileage Guide*, Second Edition (Washington, D.C.: U.S. Government Printing Office, February 1978).

[10] *Federal Register* 42 (Mar. 14, 1977): 13807; *Federal Register* 43 (Mar. 23, 1978): 11995-12014, "Light Truck Fuel Economy Standarcis, ' Final Rules

fuel than the current EPCA standards alone and would force an earlier shift away from large fuel-inefficient cars. Proponents of the ban argue that the expected increase in gasoline price would not by itself induce new car purchasers to buy more efficient vehicles and that stronger measures are needed. They also contend that the inconvenience of reduced size would be relatively slight. Most vehicles on the road today are oversized, given the low average occupancy. In addition, most trunk and cargo space is normally empty.

Opponents of the mpg floor fear that this measure would abolish the "family-sized" car needed by large families. They argue that the number of cars eliminated is relatively small (depending on where the floor is set), that the fuel savings would not be appreciable, and that persons who today own large, inefficient cars would be encouraged to keep them even longer.

Gasoline Taxes

Since the fuel economy of new cars is already mandated by EPCA, an increase in motor fuel taxes would serve mainly to reduce consumer demand for fuel. Consumers would react by buying more efficient new cars, by scrapping older cars sooner, by driving less, or by carpooling or using transit where available. The effectiveness of additional gasoline taxes depends on how large they are and when they are implemented. The current taxes on gasoline range from 9 to 14 cents, depending upon the State. They are intended as revenue-raisers, rather than gas-savers.

Several factors could limit the effectiveness of a gasoline tax increase. First, even a tax increase as large as the 50 cents originally proposed in the National Energy Plan, if implemented gradually over a 10-year period, would produce only moderate annual increases in real gasoline prices. Small incremental price increases are not seen as serious deterrents to gasoline consumption, particularly in a period in which incomes may be rising as fast as the price of gasoline. Second, doubling the price of fuel would raise the total cost per mile of driving by only about 20 percent. (See figure 27.) Third, over time the increasing fuel efficiency of the average car will compensate for the higher fuel costs, To be effective, a tax increase would have to be large and immediate.[11]

There are disadvantages associated with high gasoline taxes. They constrain mobility. They are inflationary and regressive. They remove large sums of money from the economy. They produce no incentive for producers to expand supplies. To alleviate some of these undesirable impacts, tax rebates have been proposed.

The first major consumer benefit expected of rebates is compensation for the regressiveness of the tax. The success of this would depend upon how the rebates are made and how quickly they are offered. In addition, rebates could put back into the economy the billions of dollars removed by the tax (close to $40 billion could be removed by a 50-cent-per-gallon tax on automobile driving alone). It is also thought that rebates could make the tax more politically acceptable. Finally, it is believed that any increase in driving caused by the refund would be negligible, since the change in total income caused by the rebates would be relatively small.

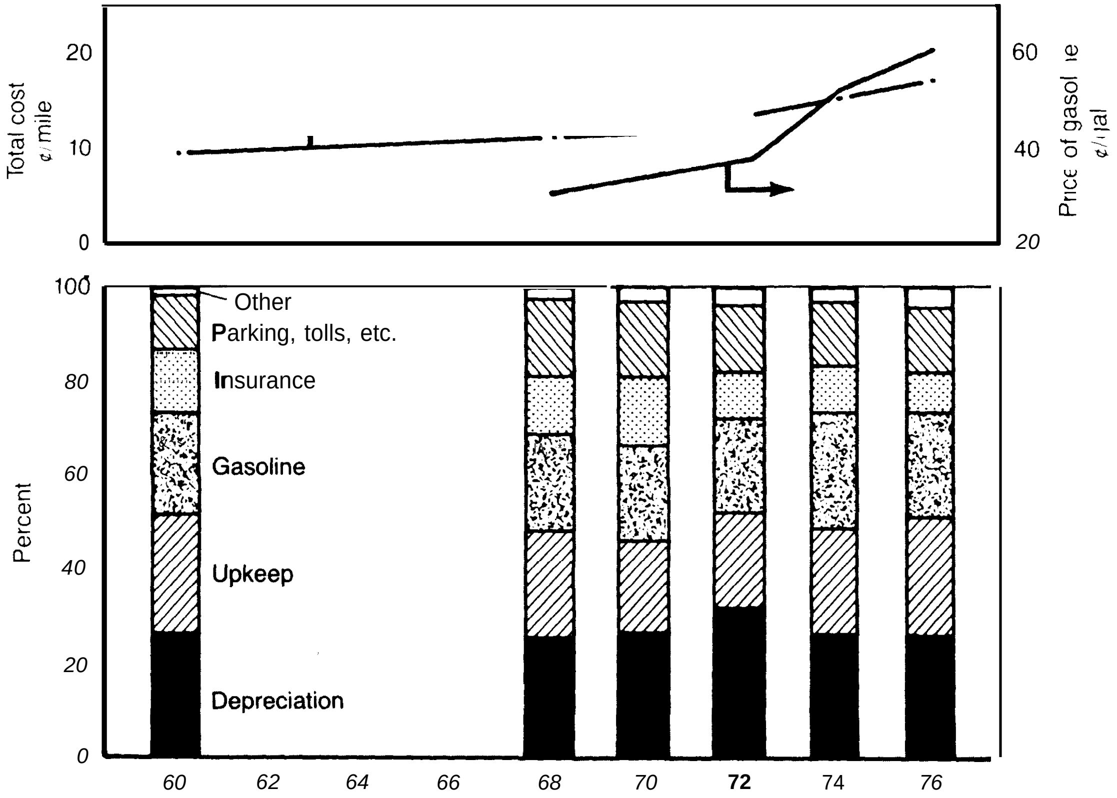
The extent to which aggregate gasoline consumption and automobile travel can be reduced by gasoline price increases is difficult to measure since consumer reaction to higher gas prices has been tested only in a limited range. The data that are available indicate that small increases in the price of gasoline are ineffective in achieving significant reductions in VMT and, therefore, in fuel consumption. The analysis carried out in the Petroleum Conservation Case indicates that the 10-cent gas tax would produce a decline in total VMT of about 3.2 percent from the Base Case. This assumes a price elasticity of – .22, which is an indication that, once discretionary travel is eliminated through increases in gasoline price, further reductions will be more and more difficult to achieve.[12] Table 51 shows three recent assessments of the projected gasoline savings that could be realized from the gasoline tax program proposed in the original National Energy Plan.

The penetration of electric vehicles into the auto fleet by the year 2000 would also serve to reduce liquid fuel consumption. Since it is

[11] U.S. Congress, Office of Technology Assessment, *Analysis of the Proposed National Energy Plan* (Washington, D. C.: U.S. Government Printing Office, August 1977), p. 90.

[12] SRI, p. 1-13.

Figure 27.—Cost of Operating a Suburban-Based Automobile (in current dollars)



SOURCE: U.S. Department of Transportation, Federal Highway Administration, *Cost of Owning and Operating an Automobile, 1976*

Table 51.—Projected Gasoline Savings Under the National Energy Plan Standby Gasoline Tax (thousand barrels per day)

	1980	1985	1990
Administration[a]	200	350	400
Congressional Budget Office			
Partial tax[b]	—	65	200
Full tax[c]	65	150	260
Sweeney			
Without gas-guzzler tax	140	370	450
With gas-guzzler tax	150	490	740

[a]The Administration has estimated that these savings would occur as a result of the imposition of the tax. It has also estimated that a saving of 830,000 barrels per day by 1985 is necessary to avoid triggering the tax.
[b]Assumes a tax schedule of 20 cents in 1985 and 45 cents in 1990.
[c]Assumes the gasoline tax is imposed at the maximum rate—that is, 10 cents in 1980, 35 cents in 1985, and 50 cents in 1990.
SOURCES: Administration, Executive Office of the President, *The National Energy Plan*, April 1977; Congressional Budget Office, *President Carter's Energy Proposals: A Perspective*, Stanford University, James Sweeney, *The Impact of the President's Proposed Gasoline Tax and Gas Guzzler Tax on Gasoline Consumption*, 1977.

assumed that electricity is not taxed under the Petroleum Conservation Case, VMT by gasoline-powered vehicles would be reduced both because of electric-vehicle use and because of the effects of the gasoline tax.

Imposition of a gasoline tax would also spur the production and sale of alternative fuels. In the Base Case, shale oil products (which are assumed to be exempt from taxes) are expected to become competitive with natural crude oil products by 1985. Coal-derived liquids would become competitive in about 1995. The effect of additional gasoline taxes would be to move forward the dates at which shale oil and coal liquids become competitive to 1982 and 1985, respectively. Alcohol and gasohol would become competitive somewhat earlier.

As the after-tax price of gasoline approaches the price of alternative fuels, the reluctance to invest in alternative fuel plants would probably diminish. On the other hand, environmental regulations and water availability will become increasingly important constraints. The net effect of improved price competitiveness created by a gasoline tax could raise total alternate fuel production levels up to 3.75 MMBD by the year 2000, about 35 percent above the Base Case projection of 2,75 MMBD.

Free-Market Pricing

The existing Federal ceilings on the price of gasoline are a few cents above current market prices. Free-market pricing would remove these ceilings. As petroleum demand grows and supplies become scarcer, the price would rise to progressively higher equilibrium points. It is believed that higher prices would reduce consumer demand and provide an incentive for producers to expand supplies by searching for new sources or by continuing to pump oil out of wells as they become less profitable.

Photo Credit U S Department Of Energy

Allowing the gasoline market to seek its own unimpeded price level would mean abandoning the present Federal Government policy of regulating petroleum prices. Under the Emergency Petroleum Allocation Act of 1973, a four-tier price system was established. The lowest prices (first tier) apply to "old oil, " defined as oil from existing wells up to the levels that were produced in the base year of 1975. The next lowest prices (second tier) apply to "new oil, " defined as oil produced from wells drilled since 1975 or oil obtained from existing wells in excess of 1975 production levels. The next higher prices (third tier) apply to oil from stripper wells, which are wells that produce no more than 10 barrels per day. During the fall of 1977, Congress established a fourth price tier to be applied to Alaskan oil. This sets the price of Alaskan oil at the price of imported oil (including the price of entitlements) and makes Alaskan oil the highest priced domestic source.

This pricing scheme for oil was designed with two major objectives in mind: to keep the price of oil down, thereby protecting the consumer from higher prices and limiting profit levels of oil producers, and to encourage exploration for and production of oil from domestic oil sources. The need to protect consumers is based on the recognition that oil prices on the world market are set by the OPEC nations and that these prices are considerably greater than the cost of producing oil from wells that existed before the fourfold price increase of oil in 1974. This is the rationale for the distinction between "old oil" and "new oil" in the existing oil price regulations. It is recognized, however, that keeping prices low encourages consumption.

Deregulation of oil prices would preserve the second objective of present oil-pricing policy, encouragement of domestic exploration. However, it would conflict with the objective of consumer protection and reduction of high profit levels to domestic oil producers who are able to obtain oil at low cost from existing wells.

Opposition to extending the market approach has developed on several grounds. First, the price set by OPEC does not reflect the normal market equilibrium price nor does it have any relation to the cost of production. Second, expert opinion varies widely on whether freeing oil prices from all controls would yield significant additional supply from new and existing sources. Third, there are questions about the extent of economic disruption that might be caused by decontrol. The resulting higher prices would be a heavy economic burden on auto-dependent people with low and moderate incomes.

Rationing

The two approaches to fuel conservation discussed above are based on the premise that drivers will use less fuel because it costs more. Rationing is a mandatory approach that places a limitation on the amount of fuel allocated to a vehicle or a driver. Some rationing approaches would allow high fuel users to be able to purchase additional gasoline, but at significantly greater cost.

The plan proposed by the Ford Administration would have allowed users to purchase up to a specified amount of gasoline at the normal price, A large tax of 50 cents or more would be assessed on additional amounts purchased. Drivers not requiring their full quota of untaxed gas could sell the rights to this gas to other drivers. The plan of the Carter Administration would allow the transfer of ration rights, but would place an absolute ceiling on the total amount of gasoline available to all automobile drivers. Special classes of users and trucks would receive larger quotas. [14]

If a rationing plan limited individual vehicles or drivers to specified quotas, motorists could compensate in several ways. It is believed that the primary response would be a shift to more fuel-efficient automobiles in order to maintain normal travel patterns. Some drivers might also respond in other ways to conserve fuel—by shifting to carpools or by eliminating certain trips, either altogether or by shifting to transit. The exact nature of these responses and any inconvenience to the motoring public would depend upon how the rationing was carried out, the extent to which special exceptions or user classes were permitted, and the rate at which the ceiling was lowered. Ideally, the ceiling would be lowered at a measured rate, designed to give consumers adequate notice to purchase more fuel-efficient cars and avoid the consequences of a fuel limitation.

[13] *Sydec FEA*, p. IV-58.

[14] *Federal Register* 43...28133-28168.

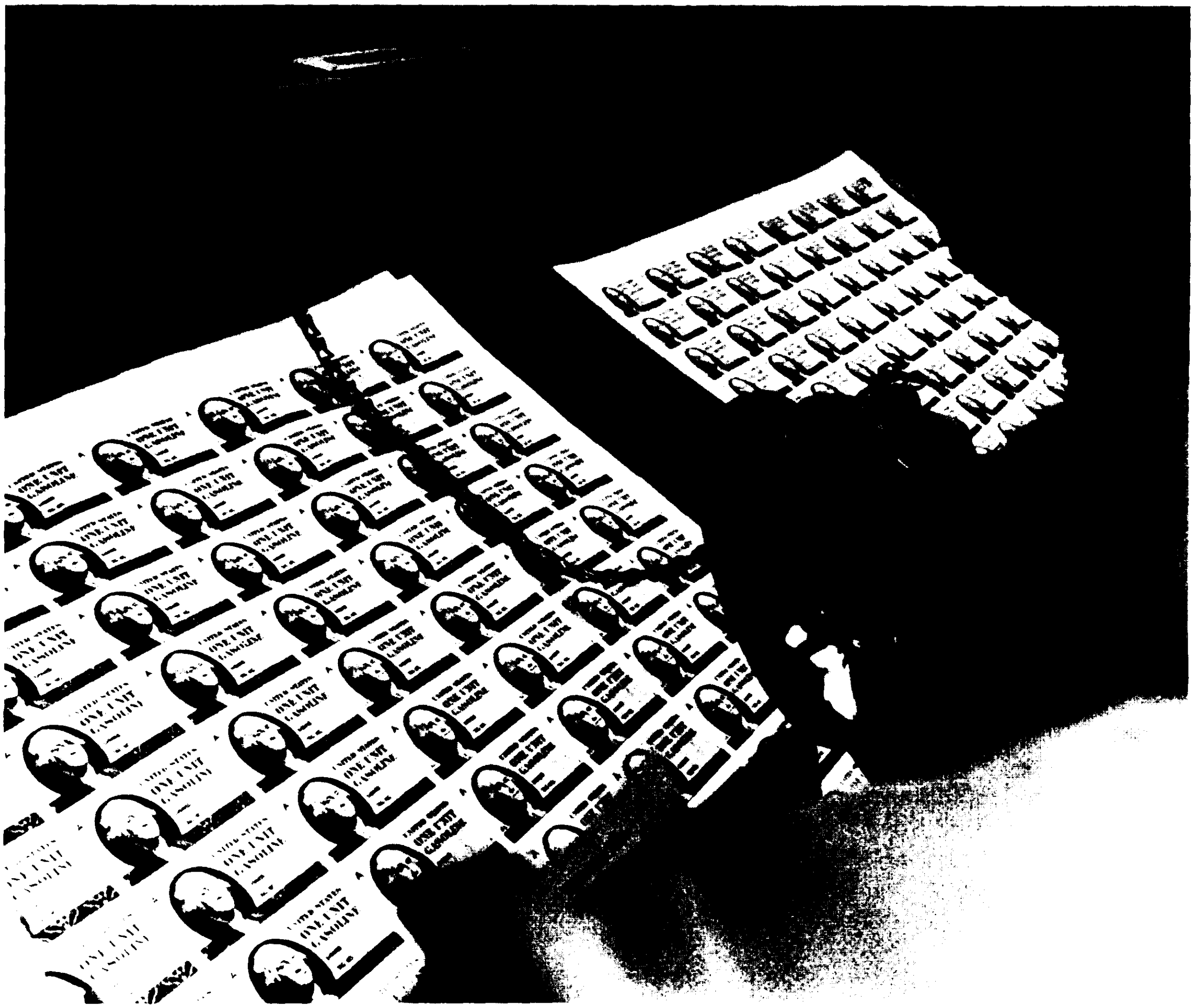


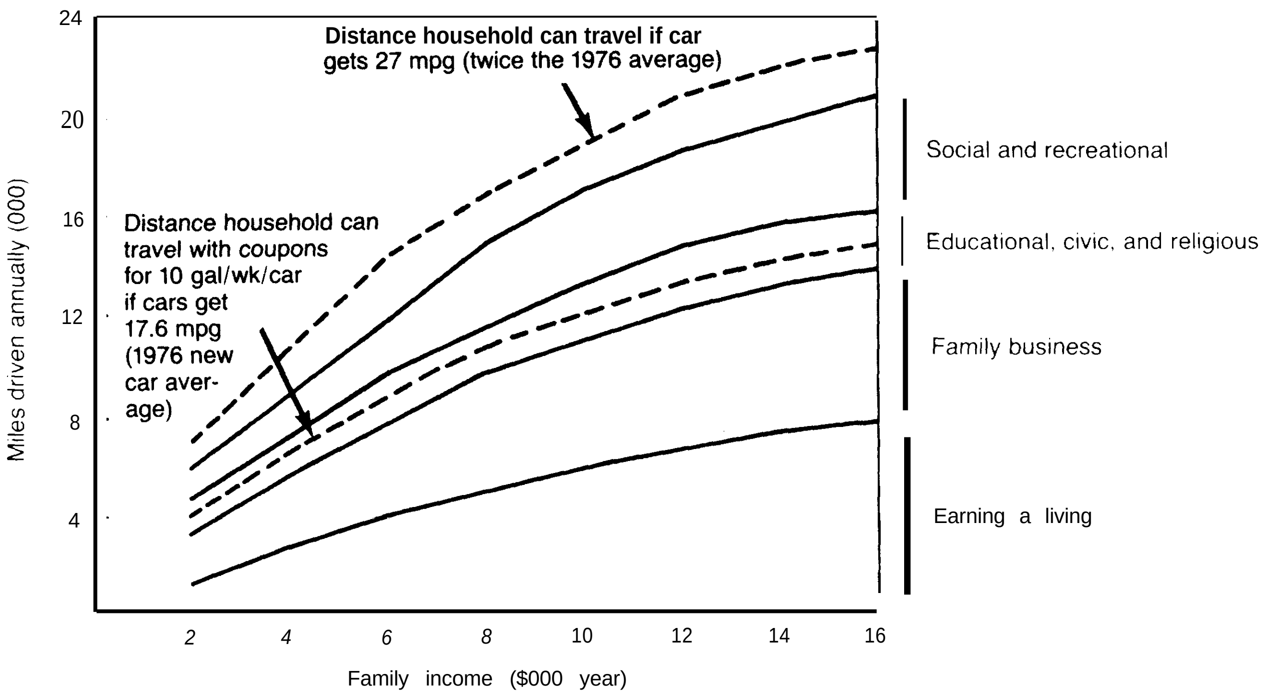
Photo Credit U S Department o/ Energy

A rationing program would have different effects on each segment of the population. For example, rural dwellers typically drive longer distances than urban dwellers. Thus, farmers would probably suffer more than office workers, unless exceptions were built into the administration of the rationing program, Moreover, owners of large, fuel-inefficient cars would be more severely affected than owners of fuel-efficient cars. Figure 28 shows the effect on mobility by trip purpose of a rationing plan that limits households to 10 gallons of gasoline per car per week. If the household were using a 27-mpg car, mobility would not be significantly affected. However, a household using a 17.6-mpg car would have to cut back sharply on trips (probably nonwork trips) or use public transit to get to work.

Under the Base Case assumptions, the unconstrained fuel demand of the Nation as a whole would rise substantially, as would the need for imported petroleum. In 1985, imports would account for 50 percent of domestic consumption. In 2000, imports would amount to 68 percent, assuming that that amount of oil was available on the world market. If, after 1985, imports were restricted by policy to 50 percent[15] of consumption, allowable imports would fall to 7.o MMBD. Maximum consumption would be limited to 14 MMBD, instead of **22.4** MMBD if demand were unconstrained. (See figure **29.)** If the burden of this reduction fell equally on all sectors of the economy, total automobile petroleum consumption would be restricted to 3.0

[15] The 50-percent level is arbitrary and was chosen for illustrative purposes only.

Figure 28.—Miles Driven Annually, by Family Income and Trip Purpose



SOURCE Sydec *EEA* p IV-62

MMBD in 2000. This would amount to an allocation of about 6 gallons per week per car, assuming a fleet of 148 million vehicles. The Base Case assumes the average car would require **9.6** gallons per week in **2000;** current usage is estimated at 15 gallons per week.

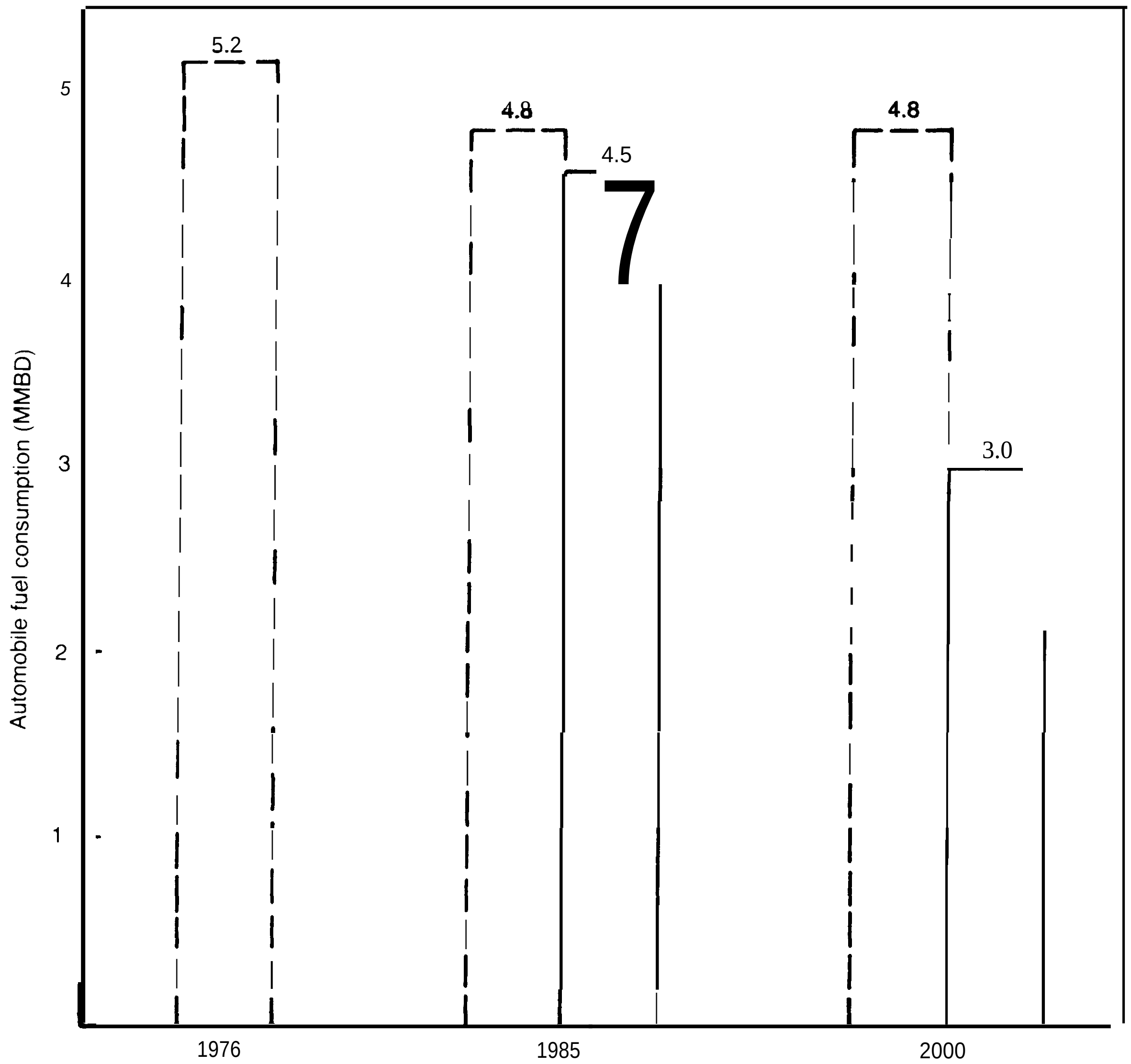
A rationing program implemented gradually over a long period would allow petroleum users to change their automobile ownership and usage patterns to minimize adverse impacts. Most of the responses previously outlined would be adopted in varying degrees by different population segments. This is not to say that mobility would remain unrestricted, since there would not be the freedom of choice that exists today. Overall VMT would drop by about 15 percent from the Base Case to 1.53 trillion miles per year. It is probable that the long-term impacts would be severe for- travel-dependent industries. Businesses such as resorts and drive-in restaurants might survive short-term disruptions but not a long-term erosion of their revenue source.

If the rationing system involved white market (transferable) coupons, the wealthier segments of society would find their mobility less restricted than other groups. Also, with a white market, there would be a transfer of income from high fuel users to low fuel users. Compared to the impacts of deregulation, consumers and not producers would benefit from the higher price. However, without the added income, producers would not have the incentive to expand supplies.

Effects of Transition to Alternate Energy Sources

The need to make a transition from petroleum-based fuels to alternate energy sources for all sectors has become increasingly evident in recent years. The demand for petroleum has grown so great worldwide that what were once thought of as very large *reserves* are now viewed as inadequate to meet demand —possibly as early as the 1980's or 1990's. Other projections (based on the economic viewpoint that the cost of petroleum becomes prohibitively high because of scarcity) conclude that the point

Figure 29.—Effects of Gasoline Rationing on Automobile Fuel Consumption



Assumptions
- Oil imports restricted to 50% of total oil consumption.
- 1985 limit equivalent to 12 gallons per week per car.
- 2000 limit equivalent to 6 gallons per week per car.
- Fuel consumption of light-duty trucks would also be limited in same proportion as cars.

SOURCE: *Sydec/EEA*, p. IV-60

may be reached in 25 to 50 years.[16] During that period, the demand for petroleum by automobiles is expected to be between 4 and 5 MMBD.

Through stringent conservation, it is estimated that automobile petroleum consumption could be reduced by 10 to 15 percent. However, these savings will be difficult to achieve and will require several years to realize. Even if ag-

[16] MIT Workshop on Alternative Energy Strategies (WAES), *Energy: Global Prospects 1985-2000*; Executive Office of the President, *The National Energy Plan*; U.S. Central Intelligence Agency, *The International Energy Situation: Outlook to 1985*, ER 77-102400, April 1977; U.S. Department of Interior, Office of Energy Programs, *Forecast of Likely U.S. Energy Supply/Demand Balances for 1985 and 2000 and Implications for U.S. Energy Policy* (Springfield, Va.: National Technical Information Service, Jan. 20, 1977).

gressive conservation policies were initiated, they would not solve the long-term problem, but simply postpone it a few years. Since transition to alternate energy sources will take even longer to accomplish, efforts to start the transition must be undertaken soon if these resources are to be available when the supply of petroleum eventually begins to decline.

There are a number of different energy resources that can be used to produce fuels similar to gasoline or diesel fuel, and there are a number of other fuels that can potentiality replace gasoline or diesel fuel for- powering automobiles. Roughly, these alternate energy sources fall into four categories:

- Synthetic liquid fueIs (synfuels): These are liquid fuels that are chemically similar to crude petroleum and that can be refined into automobile fuels. They can be derived from either coal or oil shale. Using these would require little or no change in the automobile fuel distribution system or in engine technology.

- Alcohol fuels: Alcohol (primarily ethanol or methanol) can be used in pure form or i n blends of up to 20 percent or more with gasoline. Ethanol is currently widely used as **a** blend **(2o** percent) in Brazil, and is available in scattered Midwestern U.S. locations. Methanol requires large-scale production facilities. Ethanol, which can be produced in smaller scale plants, is most easily obtained from biomass (i. e., plants, grain, or municipal and agricultural wastes). Alcohol fuels currently cost more than gasoline, but have a higher octane rating. Blended fuels require no changes in auto engines, but neat (pure) alcohol would. Alcohol tends to improve engine efficiency (miles per gallon equivalent) and burns cleaner than gasoline. Principal considerations include price and availability, and the need for special storage and distribution facilities to ensure against water contamination which affects the combustion process. (Chapter 10, Technology, contains more background information.)

- Electricity: A number of U.S. and foreign automobile manufacturers are doing research and development on electrics. Major problems with the current state of electric automobiles include poor performance compared to conventionally powered cars, high initial cost, and limited capacity to store energy.

- Longer term alternatives: A number of different automobile fuel systems have been proposed for the longer term (post-2000), including hydrogen-powered cars, [uel-cell-powered automobiles, and the use of blended fuels based on hydrogen, such as hydrazine. Generally, these technologies are still in their infancy.

Estimates of alternative fuel production and sales for 1985 and 2000 are inherently speculative because there are few facilities now in operation on a commercial scale. Table 52 summarizes several recent production estimates for 2000. The Base Case assumed that alternative fuel production would be about **2.75** MMBD under current policies. While there are high rewards from producing synthetic gasolines from coal or shale oil, the price today is far from competitive with conventional gasoline, and the environmental risks are of great concern. Shale-derived liquids would become price competitive by about 1985 and coal-derived fuels around 1995. The Base Case also assumes that alcohol and gasohol would be part of the **2.75** MMBD (or equivalents) of liquid fuels.

The cost, performance, and market acceptance of electric vehicles are highly dependent on the state of battery technology. At present, battery technology is not adequate for large-scale application in electric vehicles. Although the lead-acid system is readily available and is already in actual use, its high weight, low specific power, and low specific energy sharply limit vehicle range between recharges. Improved batteries will be needed to make the electric vehicle competitive with conventional automobiles in performance and cost.

Table 53 presents several projections of the market penetration of electric and hybrid vehicles in 1985 and 2000. The variation in the range of estimates is indicative of the high degree of uncertainty associated with the development and successful commercialization of advanced battery systems. For this study, it is estimated that the size of the electric vehicle fleet will be

Table 52.—Estimates of Synthetic Fuel Production in 2000 (MMBD)

	Coal liquids	Oil shale	Methanol	Total
Stanford Research Institute	2.0	4.0	4.0	10.0
MIT Workshop on Alternate Energy Strategies.	0-1.3	2.0	—	2.0-3.3
Department of Transportation. . .	0.9	3.4	·	4.3
Department of Interior	0.7	2.0	—	2.7
EXXON	—	—	—	0.5
Sydec/EEA.	0.75	2.0	—	2.75

SOURCES: Stanford Research Institute, *Impacts of Synthetic Liquid Fuel Development, Vol. I: Analysis*, prepared for U.S. Energy Research and Development Administration, ERDA 76-129/1; MIT Workshop on Alternative Energy Strategies (WAES), *Energy: Global Prospects 1985-2000;* U.S. Department of Transportation, *Fuels and Materials Resources for Automobiles in the 1980-1990 Decade*, 1976; U.S. Department of the Interior, *Forecast of Likely U.S. Energy Supply/Demand Balances for 1985 and 2000 and Implications for U.S. Energy Policy;* EXXON Corporation, *Energy Outlook 1977-1990*, 1977.

negligible in 1985. By the year 2000, it is projected that, with the incentive of policies such as those in table 49, the size of the electric vehicle fleet could fall midway between the high and low estimates of table 53—or about 11.5 million. Estimates of hybrid-vehicle penetration are speculative. The currently limited Federal support for all-electric vehicles is an indication that projections of hybrid-vehicle penetration may be overly optimistic.

Comparisons of the relative efficiency of conventional automobiles with battery-electric- and hybrid-vehicles are difficult because size and performance differ significantly in current designs. For example, if present conventionally powered autos were designed for reduced performance comparable with currently available electric and hybrid vehicles, their energy consumption in terms of Btu's per mile would be quite similar. However, most of the potential electric- and hybrid-vehicles are somewhat smaller than today's diesel and gasoline cars and hence show better energy utilization. (See table 54,)

Table 53.– Projections of Electric Vehicle Penetration

	1980	1985	1990
Projection of new electric car sales			
ERDA —transportation energy conservation	**22,500**	**500,000**	**2** million
ERDA—market oriented program planning study.	—	10/0	21 0/0
Math-Tech, Inc.	40	4,000	8,800
Projection of electric vehicle fleet			
ERDA—transportat ion energy conservation	22,400	1 million	18 million
ERDA—market oriented program planning study.	—	45,000	5.2 million
Math-Tech, Inc.	40	9,000	66,400
Projection of electric-hybrid vehicle fleet			
Stanford Research Institute.	—	75,000	500,000

SOURCES: U.S. Energy Research and Development Administration, *TEC Electric Vehicle Scenario*, February 1977; Market Oriented Program Planning Study, memo dated June 20, 1977, from Paul J. Brown, Chairman, Transportation Working Group; Math-Tech, Inc., *Draft Final Report: An Analysis of Federal Incentives to Stimulate Consumer Acceptance of Electric Vehicles*, August 1977; Stanford Research Institute, *Technology Assessment of Alternative Transportation Fuels*, Management Report #15, April 1977

Table 54.—Comparison of Fuel Economies

	Vehicle type	Fuel economy[a] kWh/mi	Mpg	Btu/mi
All electric	Lead-acid 2-passenger	0.44	—	1,502
	Lead-acid 4-passenger	0.79	.	2,696
	Nickel-zinc 4-passenger	0.51	—	1,741
	Lithium-sulfur 4-passenger	0.45	—	1,536
Hybrid ICE/electric[b]	Lead-acid 4-passenger	0.625	29	2,786
	Nickel-zinc 4-passenger	0.45	32	2,247
	Sodium-sulfur 4-passenger	0.476	27	2,470
Conventional ICE	Subcompact	—	34.3	3,644
	Compact	—	28.1	4,448
Diesel	Subcompact	—	42.9	3,235
	Compact	—	35.1	3,954

[a]1 kWh = 3,413 Btu
1 gal diesel = 138.8 10^3 Btu
1 gal gas = 125 10^3 Btu

[b]Hybrid fuel economy assumes that 30 percent of the driving is with a gasoline engine and 70 percent with a battery

SOURCE: *Sydec/EEA*, p. IV-39.

IMPACTS

The primary effects of the policies discussed in this chapter will be conservation of petroleum or development of alternate energy sources. The impacts, defined here as secondary consequences not directly related to policy objectives, will fall in the areas of environment, safety, mobility, cost to the consumer, and capital requirements for the automobile and fuel industries. Not all of these impacts are adverse. There are some important secondary benefits from conserving petroleum and making a transition to new energy sources. This section describes the major impacts that could result from pursuing the energy policies discussed above.

Environment

Impacts of Petroleum Conservation

In the aggregate, automobile emissions are influenced by three principal factors: emission standards, engine types, and vehicle miles traveled. Since none of the fuel conservation policies considered here assumes any change in automobile emission standards, the air quality impacts of conservation will result solely from engine characteristics and vehicle miles traveled. Of these, VMT is expected to have the more powerful influence.

Analysis of the Petroleum Conservation Case, which does not include gasoline rationing, shows very little difference from the Base Case in terms of aggregate automobile emissions. With two exceptions, automobile emissions will be reduced in 1985 and 2000, but only slightly. Table 55 shows the expected national aggregates of four automobile emissions in 1985 and 2000, with and without the adoption of Petroleum Conservation Case policies.

Table 56 is an analysis of the factors that will influence automobile emissions in the Petroleum Conservation Case. For the three criteria pollutants (CO, HC, and NO,), there would be reductions of 8 to 10 percent in automobile emissions, compared to the Base Case. Nearly all of these reductions are attributable to the decrease in automobile travel brought about by energy conservation measures.

Policies in the Petroleum Conservation Case are expected to lead to a much higher proportion of diesel automobiles in the fleet, as much as 60 percent of new car sales by 2000 (compared to 25 percent in the Base Case). Because diesel engines emit more particulate matter than gasoline engines, the impact of greater diesel use by 2000 would be higher levels of particulates—about 384,000 tons in 2000 because of the high

Table 55.—Air Quality Impacts of Petroleum Conservation Case (million tons per year)

	1985		2000	
Automobile emissions	Base Case	Petroleum Conservation	Base Case	Petroleum Conservation
Carbon monoxide	32.6	32.3	27.3	25.1
Hydrocarbons	3.5	3.4	2.9	2.7
Nitrogen oxides	2.7	2.7	2.9	2.7
Total suspended particulates[b]	0.077	0.140	0.363	0.384

[a]Assumes no change in currently mandated new car emission standards
[b]Includes lead.
SOURCE: *Sydec/EEA*, pp. III-13, IV-64, and supplementary report.

Table 56.—Factors Influencing Change in Automobile Emissions for the Petroleum Conservation Case

	Automobile emissions in 2000 (million tons)			
	Carbon monoxide	Hydro-carbons	Nitrogen oxides	Particulates[a]
Base Case	27.30	2.94	2.90	0.363
Decreased VMT	– 2.18	– 0.23	– 0.24	—
Increased diesels		– 0.06	—	+ 0.021
Petroleum Conservation Case	25.12	2.65	2.66	0.384
Net difference	– 2.18	– 0.29	– 0.24	+ 0.021
Percent difference	– 8%	– 10%	– 8%	+ 6%

[a]Includes lead.
SOURCE: *Sydec/EEA*, pp. III-113, IV-64, and supplementary report

use of diesels in contrast to 363,000 tons with only moderate diesel use.

In contrast with other petroleum conservation measures, gasoline rationing would have a major beneficial impact on air quality. If gasoline and diesel fuel consumption were restricted to about 6 gallons per car per week by rationing in 2000, VMT would drop nearly 15 percent from Base Case projections. The impact, in terms of automobile emissions, would be corresponding decreases in pollutants from automobile exhaust. This would be at least double, and perhaps triple, the reductions expected from any other combination of petroleum conservation policies.

Impacts of Transition to Alternate Energy Sources

The use of electric vehicles to replace gasoline or diesel vehicles would reduce mobile source emissions but would cause some rise in powerplant emissions within the region. Table 57 shows the per-mile emissions of gasoline and diesel vehicles in the year 2000 and the emissions from a coal- or oil-fired generating plant used to supply power for an electric vehicle for 1 mile of travel. As this table shows, the use of electric vehicles necessitates a trade-off of environmental impacts. Vehicle emissions in downtown areas will be reduced, but emissions of NO_x and SO_2 from powerplants within the region will increase. The benefit of trading off CO and HC for NO_x and SO_2, would have to be assessed on a regional basis, taking into consideration the other emission sources in the region. On the whole, however, it may prove technologically easier and economically sounder to control emissions from one or more stationary sources than thousands of mobile sources,

The two most promising synthetic liquid fuels for automobiles come from oil shale and liquefaction of coal. Extensive development of either of these synfuels poses serious environmental problems in the regions where processing and refining facilities are located. Some of these impacts can be reduced or mitigated by careful control of the processing plants and by judicious site selection.

[17]*Sydec/EEA*, p. IV-62.

Table 57.— Electric Vehicle Emissions Compared to Gasoline Vehicle Emissions in 2000

	Gasoline vehicle emissions (composite vehicle) (gm/mi)	Electric vehicle powerplant emissions' Coal-fired (gm/mi)	Oil-fired (gm/mi)
co.	3.78	0.012-0.021	.0001
HC	0.461	0.004-0.007	.0001
NO_Y [b]	1.139	1.51-2.66	0.649-1.14
SO_2	0.13	2.597-4.57	1.731-3.02

[a]Assumes that powerplant emissions are controlled to EPA New Source Performance Standards
[b]Assumes standard of 1.0 gm per mile from 1981 to 2000.
SOURCE: *Sydec/EEA*, p. IV-66.

The air pollutants produced by a coal liquefaction plant include hydrogen sulfide, ammonia, particulate matter, hydrocarbons, sulfur dioxide, carbon monoxide, and nitrogen dioxide. Other trace materials, such as polycyclic organic matter and heavy metals, may also be present in waste streams. The major sources of these emissions are coal impurities (either offgases or their treatment wastes), fugitive emissions from leaking equipment, airborne particulate from coal handling, and exhaust from combustion of coal.

Large amounts of water are used in the coal liquefaction process for product purification, cooling, steam generation, and sanitary systems. Water demand for a full-scale liquefaction plant is on the order of 50,000 gallons per day. This water, ultimately discharged as waste, requires treatment to remove suspended particulate, ammonia, hydrogen sulfide, trace metals, tars, oils, and phenols.

Two other environmental characteristics of liquefaction are of particular concern: the inherently hazardous nature of organic compounds generated in this process, and the environmental impacts specific to the use of liquefied coal products. Process and waste streams may contain certain organic compounds of a toxic or carcinogenic nature that are hazardous to workers. Plant layout can reduce or eliminate some of these compounds from waste streams. The remaining carcinogenic and toxic organic compounds can be eliminated from gaseous emissions, water effluents, and solid wastes by oxidation and decomposition.

Many of the organic liquids derived from coal are both carcinogenic and toxic (as is natural crude oil), and it is not expected that the products of liquefaction can be rendered wholly inert. Rather, elaborate and rigorous procedures must be developed to ensure that workers and handlers of the liquefaction products are protected from inhalation, skin exposure, or ingestion of these substances. Use of coal-derived fuels and feedstocks may produce new secondary pollution problems during subsequent processing or utilization.

Liquefaction produces a low-ash, low-sulfur fuel that has a high nitrogen content. In fact, liquefaction of coal can actually increase the nitrogen content on a per-Btu basis. To avoid damaging the catalysts in the refinery, some of this nitrogen must be removed before the fuel is refined to gasoline. Unless denitrified, coal-derived liquid gasoline used as a motor fuel can result in higher emissions of nitrogen oxide than gasoline refined from petroleum.

Coal liquids also contain a high proportion of benzene, which has recently been recognized as a carcinogen, Coal-derived gasoline typically contains 5 to 10 percent benzene, in comparison to about 2 percent in gasoline from petroleum. Both EPA and the Occupational Safety and Health Administration (OSHA) are expected to issue regulations pertaining to exposure to benzene in petroleum refining and gasoline handling.

Shale oil can be produced by either of two processes: surface retorting or underground (in situ) processing. Surface processing is characterized by significant land disturbance in mining operations, large volumes of spent shale, relatively high water use, and air and water emissions from retort operations. In situ processing minimizes these impacts but increases the potential for ground water contamination, aquifer disruption, and subsidence or uplifting at the surface.

Gaseous emissions are expected to be greater for surface retorting of oil shale than for underground processing. The primary air pollutants include hydrogen sulfide (which could either be converted to elemental sulfur or the less harmful sulfur oxide), particulate (which can be physically collected or contained), and hydrocarbons (which can be contained or incinerated). Other pollutants include ammonia, nitrogen oxides, carbon monoxide, and toxic trace elements. Control systems are available for these pollutants, but their efficiency and dependability in these specific applications have not been demonstrated.

Many of these emissions do not occur with in situ processing. However, upgrading, refinement, and storage of the product are steps common to both processes and similar impacts will occur. One potential impact specific to in situ processing is the production and release of gaseous pollutants from underground retorting. The effectiveness of techniques to minimize formation of gaseous pollutants and to contain and treat them will not be known until the technology of in situ processing has undergone additional field testing.

The amount of water required in shale processing may constrain the exploitation of major oil shale deposits in arid regions. The principal deposits of oil shale are found in Colorado, Utah, and Wyoming, where water supply is limited. Extensive development of these deposits, using present mining and surface-retorting methods, could cause unacceptable burdens on the water supply and could cause economic hardship for farming and industry in these areas. Comparatively, in situ processing requires less water for shale processing than surface retorting and refining.

Water effluents from shale processing plants are also an environmentaI hazard. With surface retorting, spent shale leachate, runoff, and contaminated retort water can contaminate local water supplies if not properly collected and treated. Retort water, primarily composed of water formed by combustion and pyrolysis but including a small quantity of ground water, generally contains unacceptable concentrations of dissolved solids, ammonia, hydrogen sulfide, and organic compounds.

During in situ processing, backflood water (natural ground water that reenters an in situ retort after its development) becomes contaminated as it contacts the spent, or partially spent, oil shale and newly exposed mineral materials. In a similar way, Ieachate and runoff from surface-processed shale disposal areas occurs if the shale is exposed to rain and snowfall. Laboratory studies of leaching retorted shale indicate that inorganic solids, hydrocarbons, and toxic trace elements may be present.

Site management and land reclamation are important environmental concerns in the commercialization of oil shale. Oil shale mining causes significant disruption of the land, both in excavation and in disposing of the solid wastes produced by shale processing. In surface retorting, these wastes—consisting mainly of spent shale, mining debris, and shale fines—are deposited above ground, where prevention of leaching and contamination of water by organic materials are major problems. With in situ retorting, most of this waste is left underground, but special precautions must be taken to avoid geological disturbance. Hydraulic and explosive fracturing by in situ retorting can cause physical disruption and cracking of strata. There may also be severe disruption of adjacent aquifers and subsidence or uplifting at the surface. Depending upon the proximity and structure of aquifers, drinking supplies from ground water may be contaminated, or there may be changes in the flow and storage characteristics of aquifers. Subsidence at the surface, which may not occur immediately, can damage buildings and roadways or affect options for subsequent land use.

Safety

The energy conservation policies in the Petroleum Conservation Case are expected, on the whole, to have a beneficial impact on safety. The reduction in automobile VMT brought about by Petroleum Conservation Case policies is expected to result in a proportionate reduction in automobile-related death and injury. Thus, while the death and injury toll will continue to rise through the period 1975-2000, the increase is not projected to be as great as it would be under Base Case conditions.

Enforcement of a national 55 mph speed limit, intended primarily as an energy conservation measure, will also result in decreases in automobile accidents—approximately 5 percent in urban areas and **6** percent in rural areas. This projected reduction is consistent with the observed reductions in fatal accident involvements which have been attributed to the 55 mph speed limit since 1974. In the Petroleum Conservation Case, the proportion of small cars in the fleet is expected to grow to **90** percent by 1985, compared to **69** percent in the Base Case. The higher proportion of small, and perhaps less crashworthy, vehicles in the fleet could have an adverse impact on safety.

Mobility

The conservation policies selected for the Petroleum Conservation Case were those that promised to reduce petroleum consumption by automobiles without major adverse impacts on mobility. The analysis supports this expectation. Under the Petroleum Conservation Case, total automobile VMT is projected to drop less than 1 percent from the Base Case level in 1985, due primarily to adjustments in the gasoline tax designed to keep the cost per mile of driving constant. By **2000,** the reduction in automobile VMT is projected to be 3 percent below the Base Case level, again due to increased gasoline taxes. However, this reduction is not expected to be proportionate for all types of driving. There would be significant elimination or shortening of automobile trips for shopping, social, and recreational purposes. There would also be slight VMT reductions as a result of shifting to higher occupancy automobiles or to transit for work trips.

The conditions of travel (e.g., congestion and average travel speed) are expected to be virtually the same under the Base Case and the Petroleum Conservation Case, Travel speeds will be slightly higher than under the Base Case, but they will still be considerably lower than the prevailing 1975 speeds. [19]

Because of the policy of increased transit funding, transit ridership is projected to increase—3 percent higher in 1985 and 8 percent higher in **2000** compared to the Base Case. Some of this increased ridership will be the result of automobile drivers shifting to transit (primarily for work trips), and the remainder will represent new trips by the elderly, poor, and handicapped because of improved transportation service.

Policies to promote the development and use of alternate energy sources will have a generally beneficial impact on mobility, particularly by automobile, since they will contribute to alleviating the severity of the projected petroleum shortfall. In fact, the preservation of automobility is the underlying reason for promoting a transition program. However, the higher projected prices of all fuels will have a slight dampening effect on automobile use.

Cost and Capital

Impacts of Petroleum Conservation

Under the Petroleum Conservation Case, the assumed higher cost of fuel and increased gasoline taxes will combine to raise automobile operating costs slightly over Base Case levels in both **1985** and **2000** for all size classes. The magnitude of these cost increases would differ greatly according to automobile size.

The total price (in 1975 dollars) for gasoline (including taxes) is projected to be **$0.777** per gallon in **1985** for the Base Case and **$0.907** per gallon under Petroleum Conservation policies. This would amount to an average increase of **12** percent in the fuel cost per mile of auto travel This price increase ranges from under $0.03 per mile for subcompacts to over $0.05 for standard and large cars. For the year 2000, the price of gasoline including taxes is projected to be $1.39 per gallon, compared to $1.21 per gallon in the Base Case. This increase of $0.18 per gallon represents a 1.5-percent rise in price and adds $0.04 per mile to the cost of driving a subcompact and up to $0.07 for large cars.

[18] Haus C. Joksch, *Analysis of the Future Effects of the Fuel Shortage and Increased Small Car Usage Upon Traffic Deaths and Injuries*, prepared for Transportation Systems Center, DOT-TSC-OST-75-21A (Hartford, Conn.: Center for the Environment and Man, Inc., January 1976).

[19] *Sydec EEA*, p. IV-42

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The annual auto sales in 1985 are projected to be only slightly lower (1.5 percent) than under the Base Case. However, the mix of new car sales changes dramatically from the present and from 1985 Base Case projections. (See table 58.) Under the Base Case, it is expected that 69 percent of the cars sold would be compacts or subcompacts (including small luxury cars). Under the Petroleum Conservation Case, nearly 90 percent of the cars sold would be in these classes. Cars now classified as standard and intermediate would virtually disappear.

Under the Base Case, it was assumed that 18 percent of new car sales in 1985 would be imports. The Petroleum Conservation policies, however, would create a strong demand for fuel-efficient cars. To maintain 82 percent of the market, U.S. manufacturers would have to shift their product mix much more rapidly than in the Base Case. Domestic small car production would increase from 3.2 million in 1976 to 9.2 million by 1985 if the Petroleum Conservation policies were in force.

While the volume of new car sales would not be appreciably affected in the Petroleum Conservation Case, manufacturer's revenues would be somewhat lower than in the Base Case. Gross revenue from sales in 1985 would be up about $8 billion from 1975–approximately $4.5 billion less than the $12.5 billion increase expected under Base Case conditions for 1985. As a percentage of 1975 sales, manufacturer's gross revenue would be 20 percent higher under Petroleum Conservation policies, compared to 32 percent higher in the Base Case.

The Base Case projects a 10-percent penetration of the new car market by diesel automobiles in 1985. Under Petroleum Conservation policies, manufacturers would be likely to emphasize diesels as a way to meet tighter fuel-economy standards. The fuel economy of diesels would also make them attractive to consumers. These factors could combine to boost diesel sales to 25 percent of the new car market by 1985. Since diesels are assumed to sell at $100 to $200 above gasoline-powered cars, the increase in diesel sales could lead to an additional $100 million to $200 million in manufacturer's revenues, compared with the Base Case.

Along with the projected decline in automobile sales and manufacturers' revenues, the capital requirements of the industry would increase. The Petroleum Conservation Case would require additional capital expenditures for retooling and changes in vehicle production lines and would require writing off investments in some current lines of intermediate and large cars. The combination of increased capital requirements and the change to a less profitable mix would severely strain the industry's ability to generate capital from internal sources. Further difficulty would be added by the introduction of electric vehicles, which would be viewed as an entirely new economic venture that would cut into the sales of gasoline-powered cars. Production of electric vehicles on a large scale would be an essentially new product line for an

Table 58.—1985 New Car Sales Mix for the Petroleum Conservation Case (thousands)

			1985			
	1976		Base Case		Petroleum Conservation	
Model	Number	Percent	Number	Percent	Number	Percent
Subcompact	2,225	22	3,940	30	5,300	41
Compact	1,921	19	3,940	30	4,657	36
Intermediate	2,831	28	2,111	16	798	6
Standard	2,022	20	936	7	0	0
Small luxury	506	5	1,196	9	1,569	12
Large luxury	606	6	935	7	540	4
Total	10,111		13,058		12,891	

NOTE Numbers may not add due to rounding
SOURCE *Sydec/EEA,* p IV.80

industry still engaged in manufacturing gasoline-powered cars, and would add considerably to the industry's capital requirements.

The combination of increased capital requirements, lower revenues and profits, intensified competition in the *lower* size classes, and increased penetration of new engine technology would place stress on the less profitable firms in the industry and increase the likelihood that they might suffer severe financial losses. Further, increasing small-car demand would encourage foreign producers to locate in the United States, perhaps reducing the market share of domestic manufacturers.

Impacts of Transition to Alternate Energy Sources

An estimate was made of the approximate amount of capital required to develop alternative fuel industries capable of supplying 2.75 MMBD by 2000. This analysis was based on the assumption that 2.0 MMBD would be produced from shale oil and 0.75 MMBD from coal. This estimate, however, is highly speculative because of uncertainty about the costs of construction, pollution abatement, and synfuel processing. Furthermore, the ability of the petroleum industry to finance this level of investment will depend on the success of the industry in generating cash flow from its previous investment.

A recent study by Stanford Research Institute[20] estimated the capital costs of synfuel production facilities. Shale oil production of 2 MMBD would require **20** plants, each capable of producing 100,000 barrels per day. These plants are estimated to cost **$823** million each, or a total of **$16.5** billion. Coal synthetic liquid fuel production of **0.75** MMBD would require approximately eight plants capable of producing 100,000 barrels per day. Costs for these plants are estimated to be $1.3 billion each, or a total of **$10.4** billion. Thus, about **$27** billion would have to be invested between **1980** and 1995 to create an industry capable of producing **2.75** MMBD of synthetic fuels by 2000.

To place the **$27** billion in context, it is estimated that $116.5 billion will be invested by the entire energy industry by **1985** and **$207.8** billion will be invested by 1995.[21] Of this, **$36.2** billion by 1985 and $47.4 billion by 2000 will be invested by the petroleum industry for conventional fuel production. In **2000,** energy investments will constitute approximately **32** percent of fixed investment by all U.S. business. The capital requirements for alternative fuels would raise this to 35 percent.

The impact of changes in the mix of gasoline and diesel fuel are important from the standpoint of the refining industry. It is projected that petroleum conservation policies will result in greater use of diesels, which would account for about 10 percent of the motor fuel consumed in 1985 and almost 50 percent by 2000. The most likely impact of this shift in fuel mix would be to create pressures on the relative prices of refinery products and on refinery product demands. The premium price that has been paid for crudes with high gasoline content would no longer apply in a situation where rising diesel fuel consumption drives up the refinery demand for previously low-cost crudes with high kerosene and distillate fuel content. As the proportion of gasoline to diesel fuel decreases, the price of diesel fuel relative to gasoline would rise due to the increased allocation of total refinery costs to diesel production. Also, shifts in relative prices would probably result in shifts in markets for the fuels. For example, lower cost gasoline could become an attractive feedstock for petrochemicals, displacing distillate fuels.

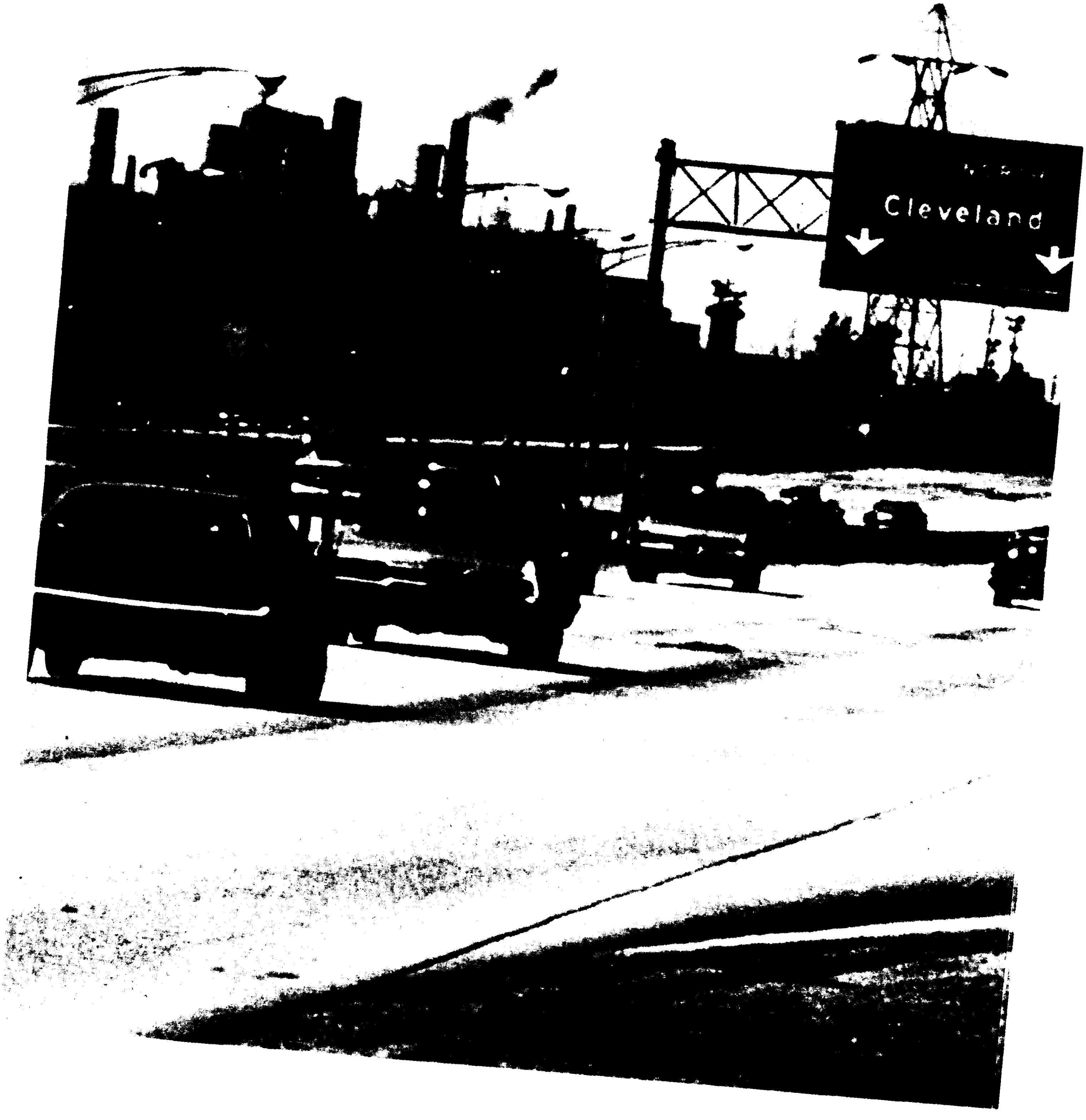
Pressures on prices and on investment and operating costs because of changes in auto fuel mix might be offset by the extent to which the fuel mix shift reduced the total demand by refineries for crude oil. The costs of crude oil inputs may be a much more significant factor in total refinery costs than the annualized capital investment costs. Thus, to the extent that the relatively higher fuel economy of diesels would not result in increased travel demand, the increased proportion of diesels in the fleet would result in reduced crude oil requirements for refiners.

[20] E M Dickson, et al., *Synthetic Liquid Fuels Development Assessment, of Critical Factors* prepared for U.S. Energy Research and Development Administration, ERDA 76-129 2 (Menlo Park, Calif SRI International July 1976

[21] Ibid.

Chapter 6

ENVIRONMENT ISSUES, POLICIES, AND FINDINGS



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Chapter 6.– ENVIRONMENT ISSUES, POLICIES, AND FINDINGS

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ENVIRONMENT ISSUES, POLICIES, AND FINDINGS

CHAPTER

SUMMARY

The environmental problems created by widespread and intensive automobile use include air pollution, noise, disposal of solid wastes, and water contamination. In addition, the impacts of automobiles and highways on communities, rural areas, parklands, and natural preserves are of concern, not only because of possible harm to the physical environment but also because of adverse social and economic consequences.

Until recently, the amount of atmospheric pollutants emitted by automobiles had been growing each year. Emission controls required by the **1970** Clean Air Act and its amendments are helping to reverse this trend. Projections for the year 2000—assuming compliance with the 1977 Clean Air Act amendments, but 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. The reduction in nitrogen oxide emissions will be smaller—about **30** percent. However, these attainments will still leave the country far short of the air quality goals specified in the Clean Air Act.

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. While automobile emissions are expected to represent a declining share of pollutants from all sources between now and **2000,** the impacts of automobile use will remain **a** major problem in urban areas.

Projections of regional air quality in **1985** and **2000** show that violations of the carbon monoxide and oxidant standards, though decreasing in frequency, will still be common occurrences. In 2000, about 10 percent of the 247 Air Quality Control Regions (AQCRs) 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. Since these violations will generally occur in the most populous areas, the number of persons exposed to hazardous concentrations of air pollutants will remain very high—perhaps as many as 136 million persons, or about half the population in **2000.** Since automobiles are particularly heavy contributors to peak concentrations of carbon monoxide and photochemical oxidants, additional measures to control exhaust emissions will be needed to improve air quality in urban areas,

Three policy alternatives to reduce automobile emissions have been considered: further tightening of new car standards (especially for nitrogen oxides), mandatory inspection and maintenance, and restriction of automobile use. Analysis shows that further tightening of new car standards would be only marginally effective and, in the case of nitrogen oxides, could delay or prevent the use of diesels. A nationwide program of inspection and maintenance of vehicles in use could produce major improvements in air quality. Estimates based on Environmental Protection Agency (EPA) data indicate that, within 8 years after implementation, mandatory inspection and maintenance would reduce automobile emissions of carbon monoxide and hydrocarbons by **60** percent and 35 percent, respectively, from what they would be without such a program. Control of automobile use would be effective as a supplementary measure in specific locations, provided that compensating improvements in mass transit are also made, However, as a general measure or as a long-term strategy, automobile use controls appear to be of limited value since they would place limitations on mobility in return for relatively small improvements in air quality.

Projections of other environmental impacts of automobiles and highways—noise, community disruption, intrusion in agricultural, recreational, and wilderness areas, and disposal of scrap vehicles and parts—do not indicate the need for major new policies by the Federal Government to control automobile system characteristics and use. Existing policies, if judiciously and vigorously applied, appear to be adequate to contain or minimize adverse environmental impacts,

The introduction of new technology for automobile propulsion systems and fuels raises the prospects of new or more serious impacts on the environment. The projected increase in the use of diesel engines may call for new measures to control nitrogen oxide emissions (which are particularly high for diesels) or other substances (such as nitrosamines or particulate matter) found in diesel exhaust. More extensive use of electric vehicles may necessitate placing more stringent controls on power-generating plants supplying the electricity for storage batteries. There are major environmental problems associated with the production of synthetic fuels from coal or oil shale. In addition, the high benzene content of coal-derived liquids could cause serious health and safety problems, both during production and distribution and when burned as a motor fuel.

BACKGROUND

Air Pollution

In 1975, the 95 mil lion automobiles in the United States traveled slightly over 1 trillion miles. During the year, these automobiles emitted more than 81 million tons of atmospheric pollutants. As a result of pollution from automobiles, combined with emissions from other forms of transportation and from stationary sources, the National Ambient Air Quality Standards for either carbon monoxide or photochemical oxidants were exceeded in about a third of the AQCRs throughout the country. [1] (See table 59.)

These figures are national aggregates and do not fully reflect 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 those urban areas, where both population and automobile use are the greatest and where air pollution from nonautomotive sources is also the highest, it is estimated that between 125 and 150 million people were potentially exposed at least once during the year to concentrations of carbon monoxide or photochemical oxidants that exceeded established Federal standards. The effects of this exposure on human health cannot be calculated with certainty. Estimates vary both as to the degree of 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.

Recognition of the automobile as a source of air pollution dates back nearly a quarter of a century to the publication of experimental studies by Haagen-Smit, who described the process by which organic substances (such as hydrocarbons) and nitrogen oxides accumulate in the atmosphere and form photochemical oxidants when exposed to the ultraviolet component of sunlight. Haagen-Smit further demonstrated the role played by automobile exhaust, which contains both hydrocarbons and oxides

[1]Currently there are 247 Air Quality Control Regions (AQCRs) in the United States and its territories. The national standard may not be exceeded more than once per year in each AQCR (i.e., a single reading above standard is not considered a violation).

Table 59.—Automobile Emissions and Air Quality–1975

	Automobiles	All sources
Emissions (million tons/year)		
Carbon monoxide.	69.3	119.5
Hydrocarbons	7.9	29.4
Nitrogen Oxides	4.0	22.5

Air quality	Number
Carbon monoxide	
Number of AQCRs[a] exceeding standard[b].	43
Number of AQCRs exceeding 2 x standard	25
Total violations	68
Photochemical oxidants	
Number of AQCRs exceeding standard'	49
Number of AQCRs exceeding 2 x standard.	20
Number of AQCRs exceeding 3 x standard.	8
Number of AQCRs exceeding 4 x standard.	7
Total violations	84

[a]AQCR—Air Quality Control Region. There are 247 AQCRs in the United States and its territories.
[b]The CO standard used here is 10 mg/m³ in an 8-hour period.
[c]The oxidant standard is 160 μg/m³ in a 1-hour period.
SOURCE: Sydec/EEA, from U.S. Environmental Protection Agency, *Monitoring and Air Quality Trends Report, 1974*, February 1976.

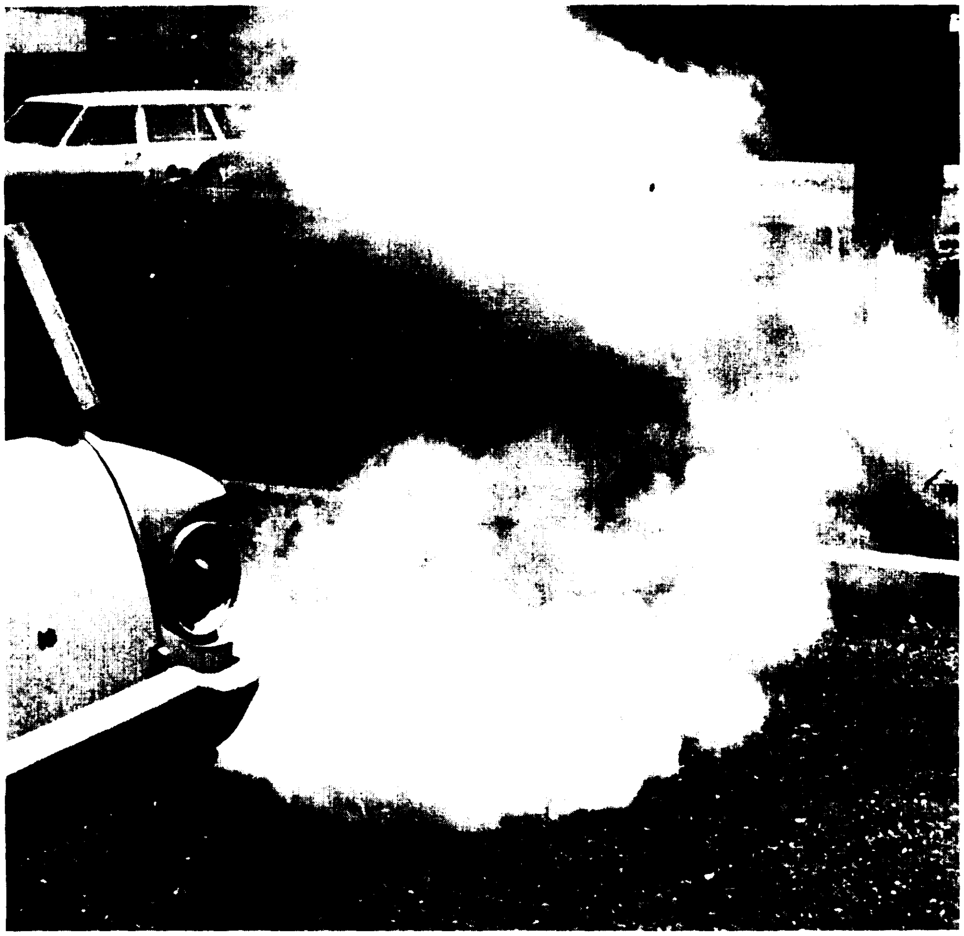

Photo Credit U S Department of Transportation of nitrogen, in the formation of smog.[2] Automobile exhaust also contains carbon monoxide (CO), which results from the incomplete combustion of hydrocarbon fuels. While not involved in the photochemical reaction of hydrocarbons (HC) and nitrogen oxides (NO_x) that produces smog, carbon monoxide is also an atmospheric pollutant because of its toxicity to humans and vegetation. It has been estimated that in 1972, automobiles accounted for about a half of the total CO emissions nationwide and about a quarter of the HC and NO_x emissions.[3]

Carbon monoxide has been linked, either as a causative or contributing factor, to a number of health problems. CO interferes with oxygen transport in the human body by displacing oxygen from hemoglobin and forming carboxyhemoglobin in the bloodstream. Concentrations of carboxyhemoglobin as low as 3 to 5 percent[4] can cause adverse effects both in normal people (decrease of vigilance and shortness of breath) and in those with arteriosclerotic heart disease (inducement of chest pains and reduced heart efficiency).'

Hydrocarbons and nitrogen oxides are the so-called precursor emissions that lead to the production of photochemical oxidants, such as ozone. The health effects of photochemical oxidants range from relatively minor discomforts, such as eye and throat irritation, to aggravation of chronic disorders, such as obstructive pulmonary disease (bronchial asthma, emphysema). It has been estimated that between 3 and 5 percent of the population may be considered to have some degree of obstructive pulmonary disease.[b]

Apart from their role in the formation of oxidants, nitrogen oxides have also been shown to have direct effects on health. Prolonged or repeated exposure to concentrations of NO_x greater than 0.5 parts per million (ppm) appears to be particularly hazardous for persons with asthma, chronic respiratory diseases, and cardiac disease. There are also risks for those suffering from viral and bacterial pulmonary infections (colds, influenza). Some evidence also suggests that the very young have an increased susceptibility to pulmonary damage if exposed to concentrations above 0.5 ppm for prolonged periods. '

The medical evidence on the health effects of CO, HC, and NO_x is far from definitive and complete. Serious questions have been raised about the causal relationships between atmospheric pollutants and health disorders. There is also question about the appropriateness of the present ambient air quality standards.[8,9] The standards and the supporting evidence were reviewed by the Coordinating Committee on Air Quality Standards of the National Academy of Sciences and National Academy of Engineering (NAS/NAE) in 1973. The Committee concluded that:

> Automobile emissions may account for as much as one-quarter of one percent of the total urban health hazard, (representing) as many as 4,000 deaths and 4 million illness-restricted days per year. Four thousand deaths is about an eighth of the deaths from bronchitis, emphysema, and asthma combined, or a twelfth of the deaths from automobile accidents. Four million days of illness is nearly equivalent to a tenth of the total number of days lost from work each year because of respiratory illnesses.[10]

The NAS/NAE report also pointed out the degree of uncertainty surrounding these esti-

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'M. M. Fox and A. J. Haagen-Smit, 'Automobile Exhaust and Ozone Formation," *Vehicle Emissions-Part I* (*New* York: Society of Au torn o t ive Engineers, Inc. , 1964), pp. 1-6, 1 b.

'U.S. Department of Transportation, *The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980* volume 2, Sept. 2, 1976, pp. 10-15.

[4]The percentage of carboxyhemoglobin concentration refers to that portion of the hemoglobin in the blood that is bound with carbon monoxide, and thus unable to transport oxygen.

[5]U.S. Congress, Senate, Committee on Public Works, *Air Quality and Automobile Emission Control* Volume I, Summary Report, A Report by the Coordinating Committee on Air Quality Studies, National Academy of Sciences, National Academy of Engineering, Committee Print, 93d Congress, 2d Session, September 1974, pp. 27-29.

'Ibid., p. 49.

"Ibid., p. 43-44

'The present National Ambient Air Quality Standards specify 9 ppm (10 mg m') in an 8-hour period as the maximum permissible concen t ra tion of CO. The standard for photochemical oxidants is 0,08 ppm (160 μg m') in a 1-hour period. There is no standard for short-term exposure to nitrogen dioxide (NO_2) at this time; the existing standard annual arithmetic average of 0,05 ppm (9.4 mg m') is intended to protect against long-term chronic effects. The 1977 amendments t o the Clean Air Act directed EPA to develop a standard for short-term exposure to NO_2.

'See, for example, Petition of American Petroleum Institute and Member Companies Before the Administrator of the U.S. Environmental Protect ion Agency, Dec. 9, 1976, for a review and critique of the laboratory and epidemiological evidence supporting the current standards.

[10]U.S. Congress, Senate, Committee on Public Works, *Air Quality and Automobile Emission Control*, p. 13.

mates, stating that the total urban health hazard from all forms of air pollution might be as low as 0.01 percent or as high as 10 percent. The range of estimates of the part attributable to automobile emissions was also large—between 1 and **25** percent. If these estimates are combined to produce minimum and maximum approximations of the impact of automobile emissions on urban health, the NAS/NAE findings suggest that automobile emissions may account for something between 0.0001 percent and **0.25** percent of the urban health hazard. Clearly, a definitive assessment of the relationship between automobile emissions and public health cannot be made without further laboratory studies and epidemiological research to narrow the range of uncertainty and to establish firmer causal links.

A more recent study, conducted in 1976 by the Air Quality, Noise, and Health Panel of the Interagency Task Force on Motor Vehicle Goals Beyond **1980,** cataloged a variety of health effects linked to automobile emissions. While the panel did not include a review of medical evidence in its report, the analysis was conducted on the assumption that reduction in CO, HC, and NO_x emissions (from automobiles and other sources) would produce substantial health benefits of the types identified by NAS/NAE.[11]

In addition to CO, HC, and NO_x, automobile exhaust contains other substances that, in sufficient concentrations, may be of concern as atmospheric pollutants.

- Lead—emitted as particulate matter from automobiles burning fuel to which tetra-ethyl lead has been added to increase the octane rating,
- Particulates—contained in diesel exhaust, which have been shown to have strong mutagenic and possibly carcinogenic properties, and
- Nitrosamines—a carcinogenic agent, emitted from the crankcases and fuel systems of diesel engines.

With the exception of lead, which is being phased out as a motor fuel additive under current statutes, the evidence is not conclusive on the health hazards posed by emission of these substances from automobiles at the present levels. Research on both the health effects and the level of permissible concentration is continuing.

Other Environmental Problems

The environmental impacts of the automobile transportation system are not limited to atmospheric pollution. Automobiles and highways have a variety of adverse impacts that should be considered in setting and enforcing policies to protect the general quality of the environment. The noise of vehicles, the disposal of solid wastes (scrap vehicles and major parts, such as tires and batteries), the contamination of water by fuels, lubricants, and road salt, the disruption of communities by highway construction, and the invasion of agricultural lands, natural preserves, and recreation areas by automobiles and highways are problems that also require attention.

The noise of automobiles is of concern both because of its possible health effects and because of its disruption of human activities. Prolonged exposure to high levels of noise can cause hearing damage. Exposure to lower levels has been shown to produce anxiety and distress due to interference with conversation, telephone communication, listening to radio and television, concentration during mental activity, sleep, and relaxation.

The Environmental Protection Agency has defined **70** dB L_{eq}[12] as the noise level below which hearing damage will not occur. Since exposure to urban traffic noise is generally below this level, traffic noise is not regarded as a significant contributor to hearing damage among urban populations as a whole. However, for individuals whose activities place them in a position of regular exposure to high levels of traffic noise (traffic policemen, tollbooth attendants, roadside workers), permanent hearing damage could result. Table 60 shows estimates

[11] U.S. Department of Transportation, Office of the Secretary, *Air Quality, Noise and Health*, Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976.

[12] L_{eq} (24) represents the A-weighted sound energy, measured in decibels (dB), averaged over a 24-hour period. Another measure commonly used for noise effects is L_{dn}, which is L_{eq} with a 10 dB incremental weighting applied to the period 10 p.m. to 7 a.m. to account for the increased sensitivity of people to noise at night.

of the number of people exposed to various levels of traffic noise.

Table 60.—Estimated Number of People Subjected to Traffic Noise

At or above outdoor Ldn	Persons subjected (mill ions)	
	Urban traffic	Freeway traffic
55.	93.4	4.9
60.	59.0	3.1
65.	24.3	, 2.5
70.	6.9	1.9
75.	1.3	0.9

SOURCE: U.S. Department of Transportation, *Air Quality, Noise and Health*, Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976, p. 6-18.

There is no generally accepted standard for evaluating noise as a disruptive or nuisance factor in human activity. The sensitivity to noise varies widely among individuals and for the same individual as a function of age, general health, type of noise, time of day, activity in which engaged, and so forth. Because many of these are subjective factors, there is no reliable way to estimate the extent to which automobile noise has an adverse effect on human activity, personal comfort, and sense of well-being.

The automobile is relatively quiet in comparison with other vehicles that make up the traffic stream. However, because the automobile is the preponderant component of traffic, it must be considered a major contributor to traffic noise, especially in urban areas. (See table 61.) Measures to achieve reduction in traffic noise must therefore give consideration to suppression or elimination of automobile-produced noise.

Table 61 .—Median Noise Levels and Urban Traffic Mix

Source	Median noise level dB(A) at 50 feet[a]	Percent of urban traffic
Heavy-duty trucks . . .	85	1.0
Medium-duty trucks .	77	6.0
Buses	79	0.5
Motorcycles.	82	
Automobiles.	65	91.5:

aThe decibel scale is logarithmic; each Increase of 10 dB repreSentS a doubling of loudness
bAt 27-mph cruising speed, median automobile noise = 60dB(A) During acceleration in urban areas, the median noise level is 72 dB(A)
SOURCE U S Department of Transportation. *Air Quality, Noise* and *Health*. Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976, pp 6-21

The disposal of solid waste produced by the automobile system is also an environmental problem. Each year, about 7 million cars are scrapped—amounting to more than 13 million tons of solid waste, largely steel and iron, but also including aluminum, copper, other metals, rubber, and plastics, About two-thirds of these junk cars are salvaged and processed to recover scrap materials, but the remainder are either disposed of in land fills or left to rust along the roads or in vacant lots. In addition to the vehicles themselves, about 150 million tires and 50 million batteries are discarded each year.[13] Only a fraction of these items is reclaimed through salvage; the rest (amounting to perhaps as much as 5 million tons) is added to municipal refuse. Overall, it is estimated that automobile solid wastes make up about 7 percent of the total commercial, residential, and municipal waste in the United States each year.[14] This figure does not include the additional millions of tons of litter deposited along streets and roads by motorists. While disposal of waste is largely a municipal concern, Federal policy may play a role in determining the composition (and hence recoverability) of automobile scrap or in promoting more productive use of scrap vehicles and parts.

Automobiles and highways also have important impacts on water quality. Highway construction leads to stream pollution by erosion and sedimentation from excavations or by contaminating runoff water with chemicals or other materials used in roadbuilding. Road salt and other chemicals used to clear streets and highways of snow and ice are carried away by runoff water and pollute streams or destroy vegetation in the path of the runoff. Automobiles deposit a variety of materials on the road surface. These are subsequently either dissolved or borne away by runoff water into nearby streams. Automobile deposits include exhaust components, lubricants, coolants, hydraulic fluids, and tire materials. In addition to the materials deposited on the road, the automobile system produces millions of gallons of waste fluids (crankcase oil, hydraulic fluids, battery acid, and spilled fuel) that may make their way into soil and water. Even if measures are taken

[13] Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures '77* (Detroit: Motor Vehicle Manufacturers Association, 1977).
[14] *Sydec/EEA*, p. 111-127.

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to prevent their drainage into the surrounding soil and water, the disposal of these liquid wastes (chiefly used crankcase oil, coolants, and battery acid) poses an important environmental problem. As with solid waste, the treatment and disposal of liquid wastes and effluents are largely local matters. However, Federal policy may have an influence, either through requiring control of water quality impacts (for example, as a precondition for Federal funding of highways) or through promoting environmentally sound methods of treatment, disposal, or reclamation,

The environmental impacts of the automobile and highway system reach far beyond the physical effects on the atmosphere, water, and soil enumerated thus far. There is also a class of impacts that are variously designated as social impacts, community impacts, or quality-of-life impacts. These include a number of undesirable consequences of highway building and automobile use—among which are displacement of homes and businesses, denial of accustomed access to facilities and services, disruption of community cohesion, alteration of land values (and property taxes), removal of land from agricultural production, endangerment of terrestrial ecosystems, invasion of natural preserves and pristine areas, and infringement on sites of historical, archaeological, natural, or aesthetic importance. The need to protect specifically affected individuals (and society in general) from these impacts of automobiles and highways, while assuring all the wider benefits of mobility, is one of the most controversial and keenly debated questions of national environmental policy. Part of the controversy stems from the lack of an objective method to quantify these impacts and to assess costs and benefits, many of which may be intangible. The question is also controversial because it tends to pit the values and desires of the automobile-using public at large against the values of a relatively small group of affected or interested parties (residents of a particular neighborhood, those who want to preserve a certain natural site, or those who want a community of a special character). Environmental considerations of this sort tend to raise profound questions of social and economic equity.

PRESENT POLICY

The present policy of the Federal Government on environmental matters is set forth in a variety of documents—Federal Statutes and the U.S. Code, Presidential Executive Orders, the Code of Federal Regulations, Department of Transportation (DOT) Orders, and administrative rulings by DOT, the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and EPA. However, the essential features of this policy are embodied in the eight major legislative acts described below. Table 62, is a classification of this legislation according to the type of environmental impact dealt with.

It will be noted that much of the legislation is of recent origin. Most of these laws were enacted within the past decade, and half since 1970. Most of the legislation deals with a specific environmental problem (e.g., emissions, noise, social impacts of highways), with air quality being the predominant concern. Also, much of the present policy is regulatory in nature and directed toward particular automobile performance characteristics.

The Clean Air Act of 1963 (Public Law 88-206) provided for interstate conferences on abatement of air pollution and authorized the Federal Government, in some cases, to initiate suits to force reduction of emissions. The Act also designated three major areas of air pollution research: control of motor vehicle emissions, removal of sulfur from fuels, and development of air quality criteria. An amendment to the Act (Title 11), passed in 1965, authorized the Department of Health, Education, and Welfare (HEW) to set emission standards for automobiles beginning in the 1968 model year.

The Department of Transportation Act of **1966** (Public Law 89-670) stated that it was the national policy to make a special effort to preserve "the naturaI beauty of the countryside and public parks and recreational lands, wildlife and water-fowl refuges, and historic sites. " The Act provided that transportation programs and projects involving the use of public land be approved only if it was demonstrated that there was "no feasible and prudent alternative to the use of such land" and that such programs include "all possible planning to minimize harm" to natural, recreational, and historic sites.

The Air Quality Act of **1967** (Public Law 90-148) attempted to remedy some of the deficiencies of the 1963 Clean Air Act by preempting States from setting emissions standards for new motor vehicles unless they had done so before March 30, 1966. California was the only State to have imposed emissions standards by this deadline. The Act, in effect, indicated the intent of the Federal Government to assume the lead in setting automobile emissions standards.

The National Environmental Policy Act of **1969** (Public Law 91-190) established a broad policy for environmental protection. NEPA set policies and goals concerning all aspects of the environment and required that specific Federal policies, regulations, and programs be administered in accordance with these policies and goals. NEPA also provided for the creation of the Council on Environmental Quality (CEQ) and the adoption of an interdisciplinary approach in planning federally assisted highway projects. To do this, NEPA established provisions for environmental impact statements, public hearings on environmental impacts, and preparation of environmental action plans.

The Highway Act of **1970 (23 U.S.C. 109)** directed the Secretary of Transportation, in consultation with EPA, to develop and put into effect guidelines to assure consistency of highways with approved plans for implementation of ambient air quality standards. The Act also provided for DOT to develop and promulgate standards for highway noise levels compatible with different land uses and to withhold approval of highway projects that do not include adequate measures to comply with noise standards.

The Clean Air Act of 1970 (Public Law 91-614), technically amendments to the 1963 Clean Air Act, set standards for emissions of CO, HC, and NO_x from new light-duty vehicles at a level 90 percent below that of 1970 vehicles. The CO and HC standards (later determined administratively to be 3.4 grams per mile for CO and 0.41 gram per mile for HC) were to be met

Table 62.—Selected Laws Relating to Environmental Impacts of Automobiles and Highways

Statute	System component affected		Type of impact controlled						
			Physical						
	Vehicles	Highways	Air quality	Noise	Historic & aesthetic	Land ecosystems	Water ecosystems	Economic[a]	Social[b]
Clean Air Act of 1963	●		●						
Department of Transportation Act of 1966		●			●			●	●
Air Quality Act of 1967	●		●						
National Environmental Policy Act of 1969	●	●	●	●	●	●	●	●	●
Highway Act of 1970		●	●	●					
Clean Air Act of 1970	●	●	●					o	
Noise Control Act of 1972	●	●		●					
Clean Air Act of 1977	●		●						

[a]Economic impacts include those on employment business activity residences, prOperty taxe S. regional & community growth and resources
[b]Social impacts include those on community *cohesion* accessibility to facilities and Services and displacement of people

by 1975. The NO_x standard, to be met by 1976, was 0.4 gram per mile. The Act required that these standards be met over the useful life of the motor vehicle, defined as the first **50,000** miles or 5 years, whichever comes first. The Act authorized EPA to establish National Ambient Air Quality Standards (NAAQS)[15] and AQCRs. The Act required States to submit plans for attaining NAAQS and authorized the imposition of transportation control plans, if necessary, to attain air quality standards for particular AQCRs by the specified deadline. Title 11 of the Act provided for a fine of $10,000 per vehicle to be levied against manufacturers marketing vehicles not certified as meeting standards.

The Noise Control Act of **1972** (Public Law 92-754) provided EPA with authority to set comprehensive standards and regulations for abatement and control of noise, including that from automotive sources. While recognizing the primary responsibility of State and local governments in noise control, the Act affirmed that Federal Government action is essential to assure national uniformity in dealing with major noise sources. States and localities retain rights and authorities to determine the levels of noise permitted in their environments and to establish and enforce controls on noise through licensing, regulation, or restriction of noise sources. The Act, however, authorizes EPA to establish noise emission standards for products distributed in interstate commerce and to set deadlines based on the application of best available technology. The Act also foresees the need for Federal assistance to State and local governments in enforcement and research.

The Clean Air Act of 1977 (Public Law 95-95), the most recent of a series of amendments to the 1970 Clean Air Act, established automobile emission standards to be met in successive steps through 1981:

	1977-79	*1980*	*1981*
HC	1.5 gm / mi	0.41 gm/mi	0.41 gm/mi
co	15.0 gm/mi	7.0 gm / mi	3.4 gm/ mi
NO_x	2.0 gm / mi	2.0 gm / mi	1.0 gm / mi

The 1977 amendments also allowed a 2-year waiver of the 1981 CO and NO_x standards under certain conditions and postponed imposition of the 0.4-gram-per-mile standard for NO_x until further research is conducted. The 1977 Act contained some provisions that indicate a shift from the policy of the **1970** Clean Air Act, such as permitting States to adopt the more stringent California standards if they desire, granting States explicit authority to adopt indirect source control programs, requiring promulgation of an air quality standard for short-term exposure to nitrogen dioxide, requesting EPA to report to Congress on the advantages and disadvantages of a system of penalties for NO_x emissions, and requiring EPA to set emissions standards for trucks, buses, and other vehicles over 6,000-pound gross weight manufactured for use on public roads and streets.

From the foregoing summaries, it can be seen that present environmental policy with respect to the automobile transportation system is of two basic types—statements of goals, principles, and guidelines (such as in NEPA), and specific regulatory standards (as in the case of automobile emissions and noise). The regulatory policies have four basic features:

- They are predicated on objective and quantified measures that are directly related to public health.
- They call for progressive attainment of goals by a series of deadlines.
- They embody the concept of "technology forcing."
- The sanctions for noncompliance are set so as to remove any economic incentive for not meeting the standards (i.e., the fine for not complying is at least as great as the cost of complying).

The present environmental protection policies, especially automobile emissions standards, have met with several criticisms. The adequacy of the research on health effects and the benefits ascribed to specific reductions in pollution levels have been challenged.[16] The goals and deadlines for achieving air quality standards have been

[15] NAAQS have been established for five pollutants: particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and photochemical oxidants.

[16] See, for example, American Petroleum Institute (footnote 9); and F. P. Grad, et al., *The Automobile and the Regulation of Its Impact on the Environment* (Norman, Okla.: University of Oklahoma Press, 1975), pp. 31-66.

called unrealistic and economically unsound. 1[7] It has been argued that the strategy of technology forcing removes the Federal Government too much from the field of research and places the burden of innovation almost exclusively on manufacturers without any assurance that they will be able to meet the challenge. [18] It has been asserted that the deadlines accompanying the standards have the effect of pushing manufacturers toward short-term, remedial techniques (such as catalytic converters) at the expense of encouraging efforts to find more fundamental, long-term solutions. '9 Questions as to the appropriateness of a single standard for all automobiles in all parts of the country under all conditions of use have led to suggested alternative approaches, such as regional standards or the so-called two-car strategy .20 There is doubt about the ability to enforce standards, the strict application of which might do grave harm to one or more manufacturers or to the economy as a whole. " There has been strong resistance to transportation use controls as a means to reduce air pollution on the grounds that they represent intrusion by the Federal Government into traditionally local decisions on transportation and land use policy .22 It has been suggested that the present approach is too rigidly concerned with automobile emissions and should be replaced with a more flexible policy that treats mobile and stationary source emissions as a whole and permits tradeoffs.[23] Finally, the basic strategy of regulation has been attacked on economic grounds as more costly and less efficient than an approach based on taxation or market incentives.[2q]

No attempt will be made at this point to deal in detail with the arguments for and against the present environmental protection policy of the Federal Government. However, the questions raised above should be kept in mind during the discussion of policy alternatives, where ways of changing the Federal role in environmental protection are considered. Also, some of these criticisms will be examined specifically in the analysis of effects and impacts that may ensue from these policy options.

ISSUES

Several issues of public policy surround the general problem of how to prevent harm to the environment by the automobile transportation system. These issues involve the need to protect the health and well-being of the populace from the adverse effects of automotive technology, while assuring the continued benefits of a personal transportation mode that is vital to the economic and social structure of the country. Some of the issues arise from the way in which present environmental protection policies are formulated and applied. Others stem from the characteristics of automotive technology, both now and as it may evolve in the future. Some confront us now; others are expected to emerge or intensify later as the number and concentration of automobiles in use increase over the rest of this century.

The environmental issues addressed in the automobile assessment are:

- How should the Federal Government set environmental standards relating to the characteristics and use of the automobile system, and how should they be enforced?
- Should Federal environmental standards be extended to control of passenger vehicles in use?

I-A, V. Kneese and C. L. Schultze, *Pollution, Prices and Public Policy* (Washington, D. C.: The Brookings Institution, **1975)**.

[1*]H. S. Jacoby and J. D. Steinbruner, *Clearing the Air* (Cambridge, Mass.: Ballinger Publishing Co., **1973)**.

[1] *U.S. Congress, Senate, Committee on Public Works, *Air Quality and Automobile* Emission *Control*, Volume 3.

[20]Kneese and Schultze, op. cit.

[2']D. Harrison, Jr., *Who Pays for Clean Air—The Cost and Benefit Distribution of Federal Automobile Emission Controls* (Cambridge, Mass.:Ballinger Publishing Co., 1975),

[22]J. E. Blodgett, *Environmental Protection*, Issues in Public Policy Series, IPP *76-19 (Washington*, D. C.: The Library of Congress, Congressional Research Service, Nov. 5, 1976).

[2']U.S. Department of Transportation, *The Report by the Federal Task Fore-c on Motor Vehicle Goals Beyond 1980* pp.10-1 to 10-19.

[24] Harrison, Jr., *Who Pays for Clean Air.*, Kneese and Schultze, *Pollution, Prices and Public Policy*, E. S. Mills and L. J. White, "Auto Emissions: Why Regulation Hasn't Worked, " *Technology Review* March April *1978*, pp. *55-63*.

- To what extent should transportation use controls be applied to reduce the environmental impacts of the automobile?
- What criteria should be used to judge the value of environmental policies and programs related to the automobile?
- To what extent should factors other than public health (e.g., community impacts, quality of life, and aesthetics) be considered in setting environmental standards?
- What environmental problems should be considered in the evolution of new automotive technologies and at what point in the development process should research on environmental effects be started?

These issues have been examined in the automobile assessment and used both to identify potential impacts and to guide the formulation of policy alternatives relating to environmental protection.[25] The issues also provide a framework for evaluation of the policy alternatives that are discussed later in this chapter.

POLICY ALTERNATIVES

The range of policy alternatives for dealing with the environmental effects of automobiles is shown on the relevance trees in chapter 4. These policies include new or more stringent standards for new vehicles, control of automobile use, alternatives to regulation, and encouragement of other more environmentally benign modes of personal transportation. Because the range of policy options is broad, not all could be examined during the automobile assessment. Some selectivity was therefore required.

The two contractors supporting OTA were directed to take different approaches to policy selection. SRI performed separate analyses of three individual policies. Sydec/EEA examined a group of policies, which had the collective intent of achieving major improvement in environmental quality beyond that projected for the Base Case. Thus, neither contractor attempted a comprehensive treatment of all possible environmental policies. SRI concentrated on air quality as the most important concern, and examined three different approaches to supplement present policy on automobile emissions. Sydec/EEA formulated a coordinated set of policies aimed at general environmental improvement, but consistent with other concerns such as safety, mobility, energy, and cost.

The policies studied by SRI were:

- Mobile-Stationary Source Tradeoffs.—Consideration of tradeoffs between automobile emission standards and stationary source controls as a more cost-effective appreach to meeting air quality objectives;
- Regionally Specific Standards.—Differentiation between the air pollution problems of cities and rural areas by setting standards for automobiles based on the air quality in the region where the vehicle is owned and operated (i.e., the two-car strategy);
- Mandatory Inspection and Maintenance.—Adoption, at the State level, of a program for periodic inspection and required maintenance of vehicles in use to ensure that they continue to meet emission standards for new cars.

It should be noted that these policies are not mutually exclusive, nor are they inconsistent with the present policy governing the emissions characteristics of new cars. Any or all could be combined with the current provisions of the Clean Air Act or with either tighter or more relaxed versions of these standards.

The Sydec/EEA policy set (called the Improved Environment Case) is made up of several measures, which are of two types: major policy actions to reduce the negative environmental effects of automobiles, and supporting measures

[25] Fuller discussion of the issues is contained in a series of working papers prepared by the OTA staff, issues *Involved in the Study of Potential Changes in the Characteristics and Use of the Automobile Transportation System,* OTA, Oct. 21, 1977.

to increase the effectiveness of the major policy actions. (See table 63.)

Table 63.—Policies for Improved Environment Case

Major Policies

- Mandatory inspection and maintenance of vehicles in use.
- More stringent NO_x *standard for new cars,*
- *Motor fuel tax to keep the cost of driving constant.*
- *Parking management (including zoning and restraints on use of land for parking lots).*
- *Restraints on automobile use in urban areas (except e/ectric vehicles).*
- *Improved transit.*

Supporting Policies

- Carpool and van pool incentives.
- Transit incentives.
- Incentives for use of electric vehicles in commercial applications.
- Bicycle incentives.
- Other transportation system management projects.

The major policies assumed for the Improved Environment Case are:

- Mandatory Inspection and Maintenance. — A program of annual or semiannual inspection of all cars on the road would be 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 a program, with sufficient facilities and trained mechanics to inspect all vehicles semiannually and to deal with an expected 30-percent failure rate, would be implemented.

- More Stringent NO_x Standard.—A NO_x emission standard of **0.4** gram per mile would be imposed on all new vehicles (including light trucks, vans, and diesels) in **1990.** If diesels were unable to meet this standard, they could not be sold as passenger or light-duty vehicles,

- Motor Fuel Tax. —To offset the decline in real fuel cost per mile as the result of fuel economy improvements, Federal motor fuel taxes would be increased periodically to hold the cost per mile constant at the 1975 level. This would tend to discourage increased auto use and the attendant growth in emissions.

- Parking Management.—Local and regional authorities would be encouraged (or in extreme cases, required) to restrict or eliminate parking in congested areas by means of such measures as parking surcharges, elimination of on-street parking, bans on parking for nonresidents, and limits on construction of new parking lots.

- Restraints on Automobile Use.—Local and regional authorities would be encouraged to limit the use of automobiles in congested areas. Possible restrictions that might be imposed 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 carpools and vanpools. Electric vehicles would be exempt from these conditions.

- Improved Transit.—To provide a useful alternative means of personal transportation and to compensate for the restrictions on automobile use, public transit facilities would have to be expanded or improved. It is assumed that Federal Government funding of capital improvements would increase 15 percent per year from 1975 to 1985 (in constant 1975 dollars) and that the 1985 level of funding (also in constant dollars) would be maintained through 2000. Federal subsidy of mass transit operations would also be increased. In the first year, funding would double. Thereafter, it would increase at 15 percent annually through 1985 and then remain at the 1985 level until 2000 (all in constant 1975 dollars).

- Noise Standards.—It is assumed that noise standards for all new motor vehicles (medium and heavy trucks, buses, and motorcycles as well as passenger cars, vans, and light-duty trucks) will be in force by 1985. In areas of particularly high or objectionable noise, additional measures would be imposed either to control motor vehicle use or to provide sound insulation for unusually sensitive buildings (e. g., hospitals or schools) or for severely affected areas.

- Supporting Policies.—In addition to the major policies above, certain supporting measures would be required. It is assumed that the Federal Government would adopt policies to provide incentives for carpools, vanpools, mass transit, and bicycle use as alternatives to the single-occupancy automobile. Incentives would also be offered for commercial and personal use of electric vehicles, principally in congested areas.

The rationale of this policy set is to foster a substantial improvement in environmental quality, but without major adverse impacts in the areas of energy, safety, mobility, and cost. Accordingly, certain additional assumptions and conditions were made in constructing the Improved Environment Case. These assumptions and conditions are summarized in table **64 and** described briefly below.

- Total expenditures for highways are assumed to remain constant in real dollars at the 1975 level. The distribution of Federal highway funding is assumed to change so that capital expenditures decrease at the rate of 1 percent per year, while maintenance expenditures increase at a corresponding rate. (This is the same assumption as in the Base Case.)

- It is assumed that a separate transportation system management program is established and funded at the level of $200 million per year (in constant 1975 dollars). The emphasis of this program would be on projects designed to serve high-occupancy vehicles, thereby reducing emissions per passenger mile.

- Level I crashworthiness standards and mandatory installation of air bags (or their equivalent) are assumed to be in effect by 1980. The mandatory inspection and maintenance program for emissions control would include inspection of critical safety-related equipment as -well.

- It is assumed that the technology to meet automobile emissions and noise standards is available, or will be at the time the standards go into force. Specifically:

  —NO_x emission levels of 0.4 gram per mile will be attainable for spark-ignition engines by 1990.

  —Diesels will be able to meet the standard of 1.0 gram per mile for NO_x by 1981. They may not be able to meet the 1990 standard of 0.4 gram per mile. (The influence of NO_x standards on diesel penetration is discussed later in the analysis of effects and impacts.)

  —Automobile noise levels can be reduced to 65 dB(A) during acceleration and 60 dB(A) for cruise.

EFFECTS

The primary objective of the policies studied in the Improved Environment Case is to bring about an improvement in air quality through reduction of automobile emissions. Other environmental concerns—such as noise and community disruption by highways—are also addressed, but only as secondary objectives. The heavy emphasis on policies to control auto emissions stemmed from analysis of Base Case projections. These showed that the dominant adverse impact of automobile characteristics and use in 1985 and 2000 would be on air quality, particularly in urban areas where automobile use is concentrated.

Air Quality

The Improved Environment Case contains three kinds of policies to reduce automobile emissions:

1. Policies to reduce auto travel,
2. A stricter NO_x emission standard for new cars, and
3. Mandatory inspection and maintenance of automobiles in use.

Figure 30 shows the combined effect of these policies on automobile emissions of CO, HC,

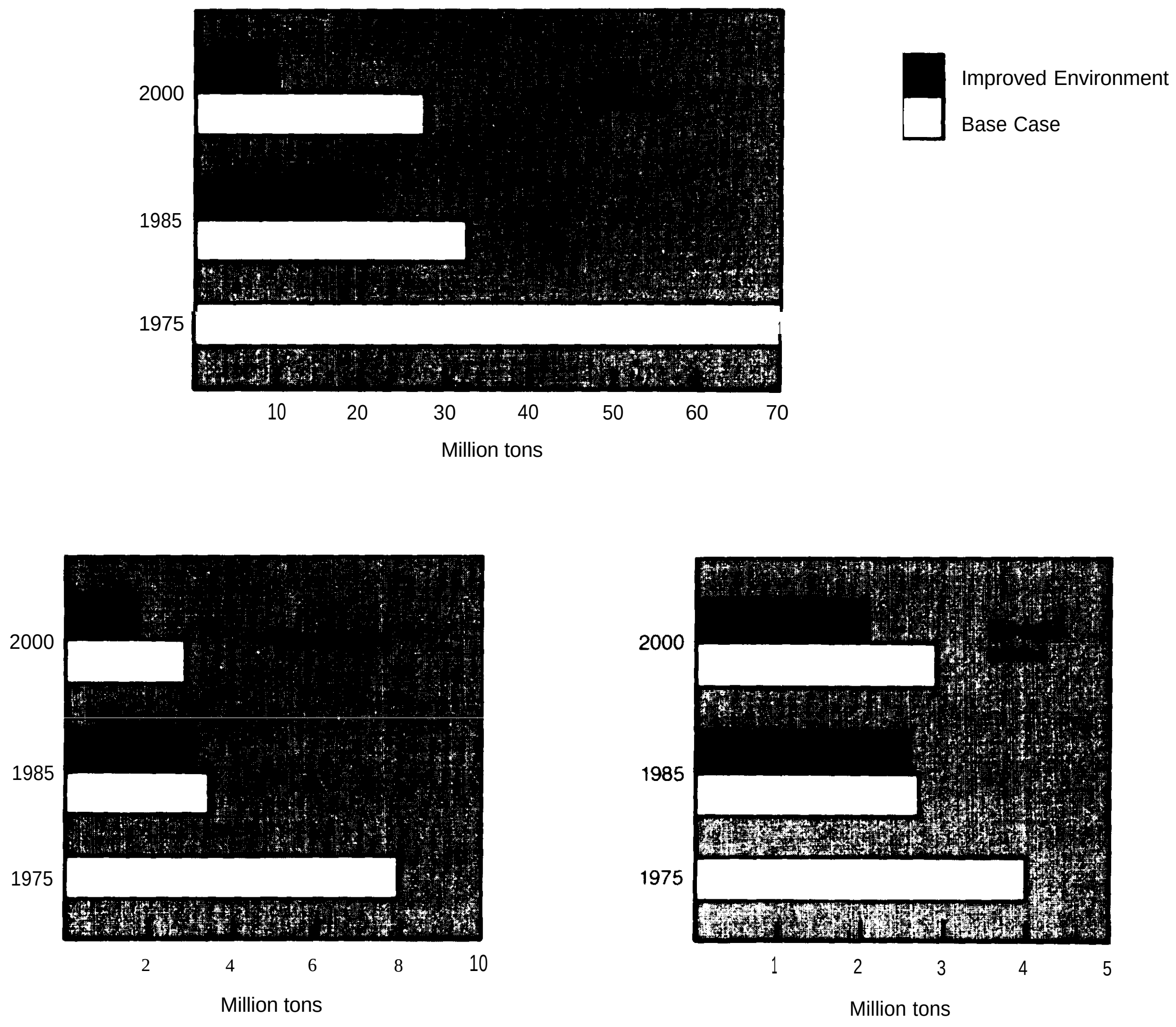
Table 64.—Assumptions and Conditions for Improved Environment Case

Assumptions	Base Case	Improved Environment
Transportation system		
Highway		
Total expenditures	Stable at 1975 level (in constant dollars).	Same as Base Case
Construction	Decreases from 50°/0 of total highway expenditures in 1975 to 25°A in **2000.**	Same as Base Case.
Maintenance	**Increases from 50°/0 of total highway expenditures in 1975 to 75°/0 in 2000.**	Same as Base Case.
Transportation system management	**Existing policies, no special funding.**	Separate program, funded at $200 million per year.
Mass transportation		
Capital improvements	Funding increased 10% per year (constant dollars) through 1985 and maintained at 1985 level through 2000.	Funding increased 15% per year (constant dollars, through 1985 and maintained at 1985 level through 2000.
Operations	Funding increased 10%A per year (constant dollars) through 1985 and maintained at 1985 level through 2000.	Funding doubled initially and then increased at 15% per year (constant dollars) through 1985 and maintained at 1985 level through 2000.
Environment		
Air quality		
Vehicle emissions	1977 Clean Air Act standards met, waiver for diesel NO, at 1.5 gpm for 1981-83.	CO and HC same as Base Case, Nonstandard tightened to 0.4 gpm, no diesel waiver, two-car strategy (electric cars).
Inspection and maintenance	No mandatory program.	Mandatory program by 1985.
Transportation controls	Negligible.	Parking and auto use restraints.
Noise		
Vehicles	Noise standards for trucks, buses, and motorcycles.	Noise standards for all vehicles.
Noise abatement	Continuation of existing policies.	Continuation of existing policies. plus funding for soundproof ing buildings.
Energy		
Fuel economy	**Case A: 27.5 mpg.** **Case B: 30 mpg by 1990,35 mpg by 2000.**	**Same as Base Case.**
Highway speed	Moderate Enforcement (present averaqe of 62 mph).	Same as Base Case.
Safety		
Occupant restraint	Airbags or equivalent on new vehicles as now scheduled.	Same as Base Case.
Crashworthiness	Existing standards.	Level I.
Taxes		
Fuel taxes	Fuel taxes increased to maintain revenue at 1975 level.	Fuel taxes adjusted to hold cost per mile constant.
Vehicle taxes	No new taxes.	Gas-guzzler tax on new cars.
Technology		
Propulsion	**Case A: 100/~ diesels by 1985, 250/o by 2000.** **Case B: 15°/0 diesels by 1985,** 40% by 2000.	**Same as Base Case A, except diesels phased out after 1990** unless 0.4 gpm NO_x standard can be met.
Diesel fuel consumption (percent of all motor fuel)	Case A: 4% by 1985, 18% by 2000. Case B: 6% by 1985, 29% by 2000.	Same as Base Case A, except accelerated penetration of electric vehicles.

and NO_x in 1985 and 2000. The greatest benefit is reduction of CO emissions which, by 2000, are expected to decline to about one-third of what they would be under Base Case conditions. The reductions of HC and NO_x emissions, while not as great as CO, are also significant.

A more detailed picture of the effects is presented in table 65, which shows quantitative estimates of automobile emissions in comparison with 1975 levels and projected Base Case levels in 1985 and 2000. Compared to 1975, all automobile emissions in 2000 would be greatly reduced. The national aggregate of CO emissions from automobiles is expected to fall to 9.7 million tons in 2000 (14 percent of the 1975 level). Hydrocarbons are projected to decline to 1.8 million tons (23 percent of 1975). The corresponding reductions for other pollutants are: NO_x, 52 percent of 1975; and particulate, 12 percent. The projected effects of present policies (the Base Case) are also given in table 65. By comparison, the package of improved environment policies would be considerably more effective in reducing air pollution from automobiles.

Figure 30.—Comparison of Automobile Emissions, Base Case vs. Improved Environment Case



SOURCE: *Sydec/EEA,* p V-33 and Supplementary Report

Table 65.—Projected Automobile Emissions for the Improved Environment Case (million tons per year)

Pollutant	1975	1985 Base Case	1985 Improved Environment	1985 Percent change	2000 Base Case	2000 Improved Environment	2000 Percent change
Carbon monoxide	69.3	32.6	21.4	–34	27.3	9.7	–64
Hydrocarbons	7.9	3.5	3.1	– 11	2.9	1.8	– 40
Nitrogen oxides	4.0	2.7	2.6	– 4	2.9	2.1	–28
Total suspended particulates[b]	0.377	0.077	0.094	+ 22	0.250	0.044	–82

[a]Includes crankcase emissions and evaporative losses. [b]Incl les lead. SOURCE: *Sydec/EEA*, p. V-33

Effects of Individual Policies

Table 66 shows the contributions of individual policies to the overall decrease in CO, HC, and NO_x emissions. Policies to reduce automobile travel—increased gasoline taxes, automobile disincentives, and transit improvements—are expected to have small, but beneficial, effects for all types of pollutants. The assumed tax on gasoline, designed to keep the fuel cost per mile constant through **2000,** is expected to reduce auto VMT by 0.8 percent from 1985 Base Case VMT and 0.4 percent from 2000 Base Case VMT, Auto disincentives and transit improvements would create further VMT reductions of 1 percent in 1985 and 3 percent in 2000. Unlike the gasoline tax, which would affect rural and urban travel equally, the effects of auto disincentives and transit improvements would be concentrated in urban areas, primarily for journey-to-work trips. As a result, urban VMT under these policies would be down 2 percent from the Base Case in 1985 and 6 percent in 2000. As a whole, the effects of policies to reduce VMT will account for between 5 and 20 percent of the total decrease in CO, HC, and NO_x expected from Improved Environment policies.

The second major feature of the Improved Environment Case is lowering the NO_x standard for new automobiles from 1.0 to **0.4** gram per mile beginning in the 1990 model year. The need for tightening the automobile NO_x standard stems from two considerations. First, projections of atmospheric pollution under Base Case conditions show that NO_x emissions will be the major air quality problem in coming years. Unless more stringent measures are adopted to control NO_x emissions from all sources, air quality in many urban areas in 1985 and 2000 may be worse than today. Second, the most serious aspect of the NO_x problem is likely to be how to control peak concentrations, which often coincide with rush-hour automobile traffic. Thus, a more stringent standard for NO_x in automobile exhaust becomes a particularly important control strategy.

From table 66 it can be seen that lowering the new car emission standard for NO_x to 0.4 gram per mile has the potential of reducing the national aggregate of NO_x emissions by 690,000 tons per year by 2000. This represents nearly 80 percent of the total reduction of NO_x from automobiles projected under Improved Environment policies.

Table 66.—Analysis of Effects of Improved Environment Policies

Contributing factor	Change from Base Case year 2000 (million tons): Carbon monoxide	Hydro-carbons	Nitrogen oxides	Particulate
Decreased auto travel	- 0.840	-0.164	-0.190	**– 0.007**
Stricter NO, standard	—	+ 0.098	– 0.690	– 0.199
Inspection and maintenance	– 16.730	– 1.040	—	—
Net	– 17.570	– 1.106	– 0.880	– 0.206

SOURCE *Sydec/EEA,* supplementary report

However, this potential benefit would entail certain penalties. First, the lower 0.4-gram-per-mile standard probably could not be met by 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. For the Improved Environment Case, no such breakthrough in diesel technology has been assumed. As a result, the immediate consequence of a 0.4-gram-per-mile NO_x standard would be preclusion of diesels from the new car market after 1990.

This, in turn, would 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 and lead per mile than diesels. The projections shown in table 66 indicate that the tightening of the NO_x standard for new cars could result in a nationwide increase of about 98,000 tons per year of hydrocarbons, in comparison with the level of this pollutant expected under Base Case conditions. The consequences are not so important since the increase stemming from the lower NO_x standard is far outweighed by reductions in HC emissions brought about by other Improved Environment policies.

The new policy which has the greatest net air quality benefits in the Improved Environment **Case** is the nationwide program of mandatory inspection and maintenance for all automobiles in use. The analysis of this policy assumes that, starting in 1985, all States implement programs requiring annual or semiannual inspection of all registered automobiles. Owners whose vehicles failed inspection would be obliged to have the necessary repairs or adjustments made before being allowed to continue operating the vehicle, which is similar to a provision now employed in motor vehicle safety inspection programs in many States.

The program could be administered and implemented either by State-run inspection centers or by licensing private service stations and garages as inspection facilities. Inspection standards could be set either nationwide through administrative action by EPA or by the States individually in accordance with Federal guidelines. It has been assumed that standards would be set for each model year and that they would vary with the age of the vehicle. Generally, the standards would be set at levels such that approximately 30 percent of the vehicles in each model year would fail and be required to have maintenance performed. For further discussion of the administration of a mandatory inspection and maintenance program, see the final section of this chapter.

The inspection procedure itself would be limited to tests of CO and HC exhaust emissions. At present, there are no test procedures for NO_x emissions and evaporative HC losses in general use. While some benefits in terms of reduced NO_x and evaporative HC emissions might reasonably be expected from the adjustments and tuneups required under this program, none have been assumed in the analysis of this policy. Therefore, the projected effects of the inspection and maintenance program include only the potential reductions in CO and HC from automobile exhaust.

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 amounts to 95 percent of the total reduction of CO from automobiles expected under Improved Environment policies. The reduction of HC is equally substantial—slightly over 1 million tons per year in 2000, or almost 95 percent of the total reduction projected for all Improved Environment policies combined. (See table 66.)

Mandatory inspection and maintenance thus appears to have great potential as a means to reduce automobile emissions. However, a word of caution is needed about the magnitude of the projected effects. The benefits of inspection and maintenance depend heavily on estimates 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 EPA during the period 1975-77 indicated that the performance of emission control devices was relatively stable over time and that they would retain about half their initial effectiveness throughout 10 years of use on the road. [26]

Data from more recent tests by EPA indicate that emission control devices have much more rapid rates of deterioration 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 from automobiles after **10** years on the road without maintenance or repair of the emission control system .[27]

Thus, the benefits of inspection and maintenance are proportional to the assumed deterioration rates of emission control devices. The more rapid the deterioration rate, the greater the benefits of periodic adjustment and repair. The analysis presented here is based upon the most recent 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.

Overall Air Quality

To appreciate the effects of policies to reduce automobile emissions, it is necessary to consider the future magnitude of air pollution from all sources. Figure 31 shows estimates of the national aggregates of emissions from all sources in 1985 and **2000,** divided into three classes: automobiles, other mobile sources, and stationary sources.

On the whole, atmospheric pollution is expected to remain high. The levels of CO and HC will be down somewhat from 1975, but NO_x emissions are expected to continue rising. In all cases, however, the levels of emissions are projected to be lower than in the Base Case because of measures to control automobile emissions. The most substantial improvement is in CO emissions, which by 2000 will be down **27** percent because of a 64-percent reduction in automobile emissions. The effects of policies to control HC and NO_x in automotive exhaust will have a relatively smaller payoff since the automobile is expected to be only a minor source of HC and NO, in comparison with stationary sources.

While automobile exhaust will make up a declining share of total emissions, the importance of continuing efforts to control automotive sources of pollution can be seen by examining the projections of urban air quality for 1985 and 2000. Table 67 shows that a significant decline in violations of the carbon monoxide standard can be expected in both 1985 and 2000 as a result of auto emission controls. In 2000, for instance, the total number of CO standard violations would fall from **24** under Base Case policies to 7 under Improved Environment policies. On the other hand, violations of the oxidant standard would remain high, largely because of stationary source emissions. Measures to control automobile HC and NO_x emissions would have a relatively minor effect on the production of photochemical oxidants.

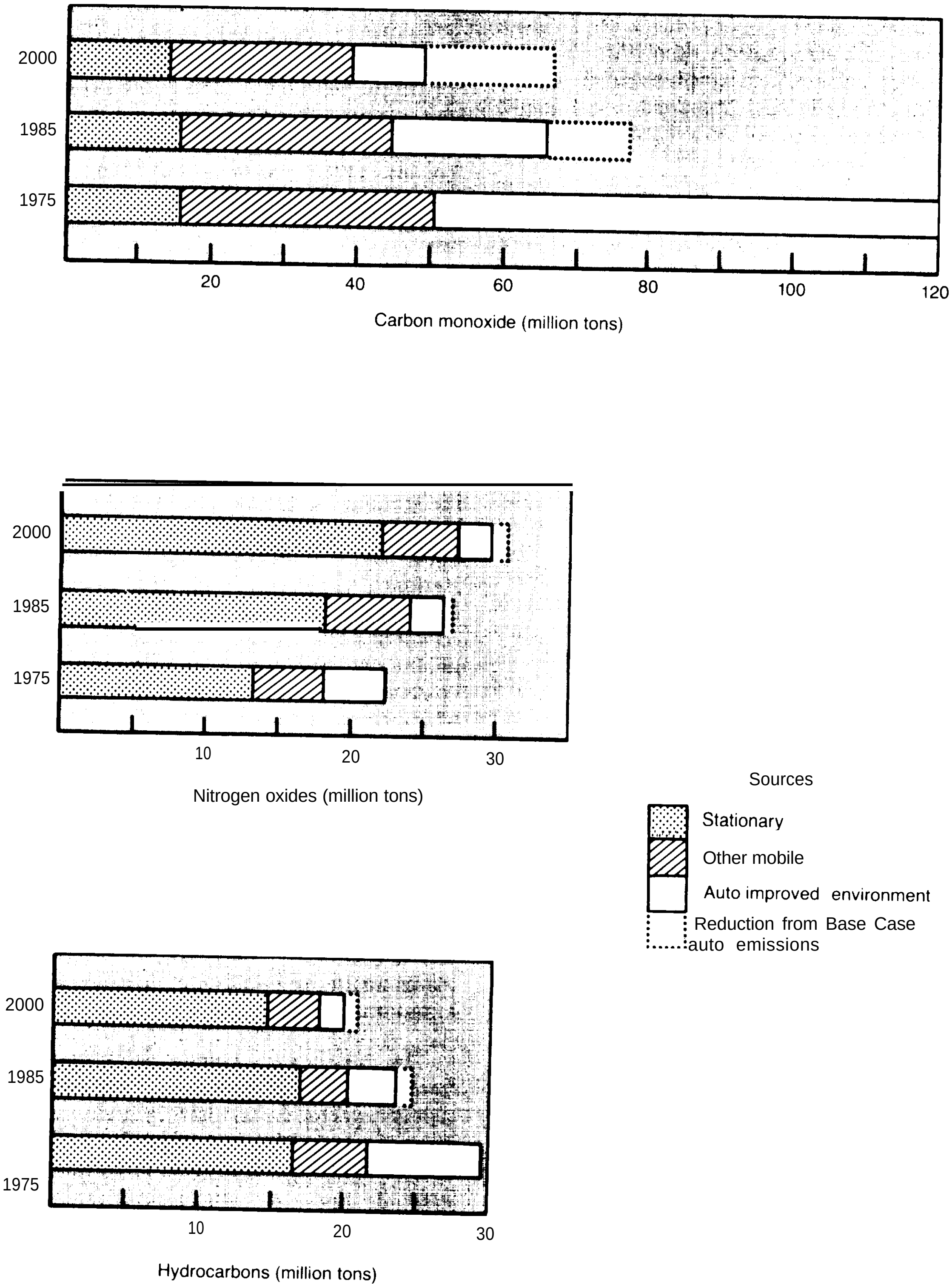
Figure 32 translates the 1985 and 2000 air quality projections into estimates of the population exposed to hazardous concentrations of criteria pollutants, The difference between the Base Case-and Improved Environment policies for CO is quite large, especially by 2000, and illustrates again the-value of controlling automobile emissions of CO.

The number of people exposed to oxidant concentrations higher than the national standard is expected to be essentially the same for the Base Case and Improved Environment policies in 1985. By 2000, however, small improvements are expected as a result of automobile *emissions* controls. The total number of people exposed to oxidant standard violations will remain about the same, but the number exposed to extreme violations (greater than 320 micrograms in a 1-hour period, i.e., twice the national standard)

[26] U S. Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors*, Part A,

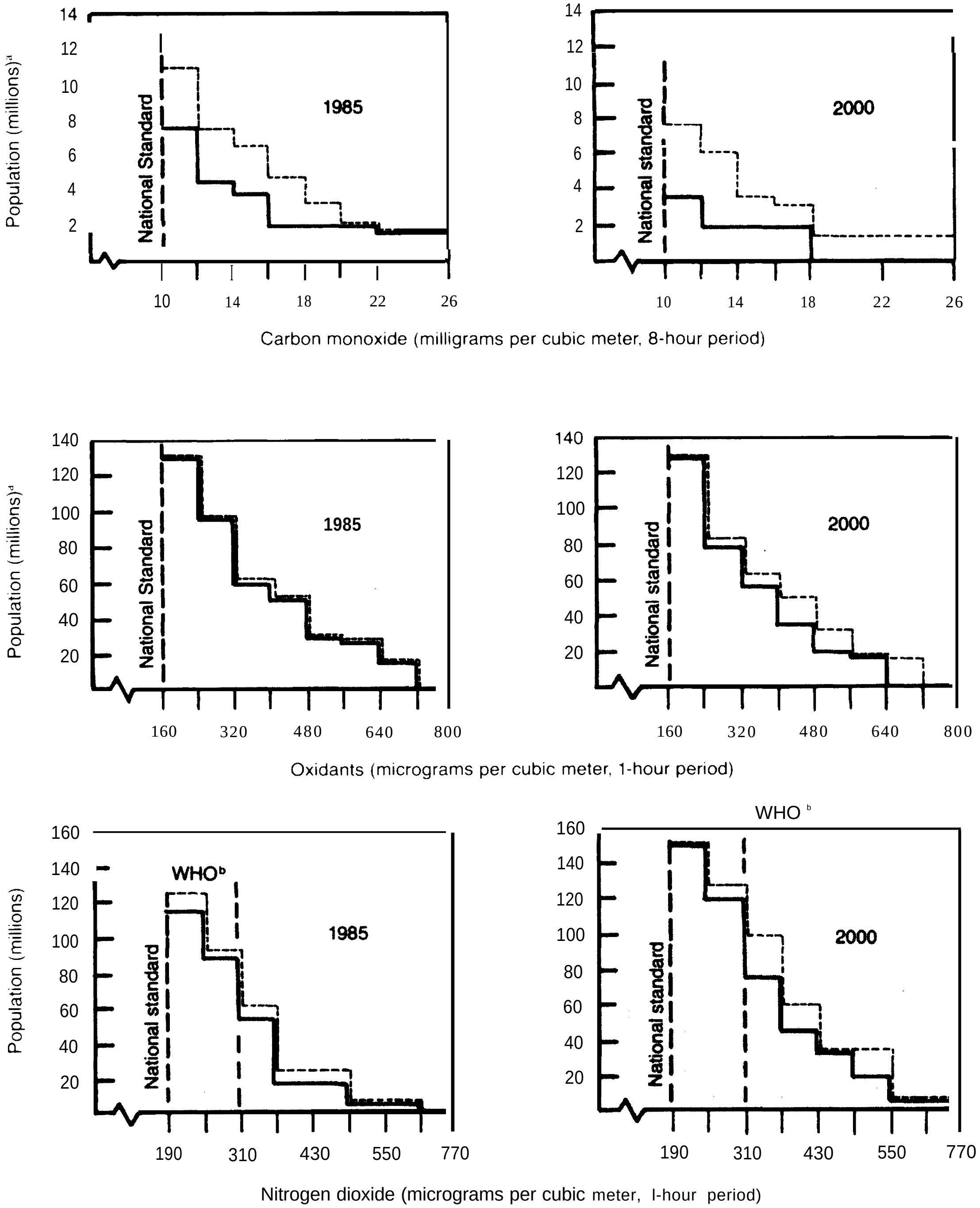
[27] EPA memorandum on revised mobile source emission factors, dated January *1978*, incorporated in the revised edition of *Compilation of Air Pollutant Emission Factors*, AP-42.

Figure 31.—Projected Emissions from All Sources, 197 S-2000 Improved Environment Policies



SOURCE: .*Sydec/EEA,* p, V-33 and Supplementary Report

Figure 32.—Population Exposed to A.ir Pollution, Improved Environment Case



[a]Population in Air Quality Control Regions exposed to above-standard levels of air pollutants. For CO, populations of AQCRs were divided by 10 to account for localized effects

—— Improved Env.
Base Case

[b]One-hour standard advised by World Health Organization, *Environmental Health Criteria for Nitrogen*, February 1977

SOURCE Sydec *EEA*, pp V-36-38

Table 67.—Projected Violations of Air Quality Standards, Improved Environment Case

Pollutant	1975	1985 Base Case	1985 Improved Environment	2000 Base Case	2000 Improved Environment
Carbon monoxide					
Number of AQCRs[a] exceeding standard[b]	43	34	22	22	7
Number of AQCRs exceeding 2X standard	25	3	2	2	0
Total violations	68	37	24	24	7
Oxidants					
Number of AQCRs exceeding standard[c]	49	46	45	41	40
Number of AQCRs exceeding 2X standard	20	11	10	8	8
Number of AQCRs exceeding 3X standard	8	2	2	3	2
Number of AQCRs exceeding 4X standard	7	3	3	2	1
Total violations	84	62	60	54	51

[a]AQCR—Air Quality Control Region. [b]The CO standard is 10 mg/m³ in an 8-hour period [c]The oxidant standard is 160 μg/m³ in a 1-hour period
SOURCE Sydec/EEA, p V.40.

will be lower under Improved Environment policies. Thus, policies to control automobile emissions, while having only a slight effect on the national aggregate of HC and NO_x, can be expected to have an important benefit in populous areas, where automobile use is concentrated.

Figure **32 also shows estimates** of exposure to nitrogen dioxide in relation to two standards that have been suggested for maximum l-hour concentrations by the World Health Organization. The picture for nitrogen dioxide is similar to that for photochemical oxidants. The small overall reductions in NO_x emissions due to automobile emission controls would have disproportionately large benefits in urban areas. The general effect of measures to reduce automobile emissions is to help lessen both the magnitude and frequency of peak concentrations.

A major finding from these projections is that attainment of air quality standards nationwide will require more than automobile controls. Emissions from other mobile sources and stationary sources also must be reduced. Even so, the concentration of automobiles, trucks, and industry may remain so high that, even with the maximum possible controls, violations will persist, Realistically, some cities may never be able to meet the National Ambient Air Quality Standards.

Other Environmental Effects

The set of policies examined in the Improved Environment Case included measures aimed at lessening the adverse effects of the automobile on other aspects of the environment—noise, solid waste disposal, water quality, and community disruption. Quantitative projections of these effects were not made. What follows, therefore, are general estimates of the nature and direction of environmental effects expected under these policies.

Noise

Automobile noise is expected to be somewhat less in the Improved Environment Case than in the Base Case because of reduced auto VMT and, in 2000, because of fewer diesels on the road. Greater reduction would be possible if noise standards were imposed for new cars or if there were vehicle-in-use noise standards requiring every automobile to have a properly main-

Photo Credit: U.S. Department of Transportation

tained muffler. It is not foreseen that automobile noise will become so great as to warrant such measures, except perhaps on a selective, local basis.

Reduction of highway noise could be achieved by improved roadway and tire design, although there would be some safety penalty in the form of reduced skid resistance. Highway noise could also be reduced by erection of sound barriers to screen residences, businesses, and institutions from highways. However, since trucks and buses will continue to be the noisier elements of the traffic stream, exclusion of trucks and buses from noise-sensitive areas may be the more effective noise reduction measure.

Solid Waste

The amount of solid waste from automobiles is a function of the vehicle retirement rate, scrappage and materials recycling practices, and the amount of component replacement during the lifetime of the vehicle. Greater durability of new cars and a requirement that some percentage of every new vehicle be easily recoverable could greatly decrease present levels of waste from automobiles.

Methods to increase vehicle durability include design for longer overall vehicle life, use of less corrosive and more durable materials, and emphasis on repair rather than replacement of components. A vehicle with an engine life expectancy of 200,000 miles would be of little use if the body were designed to last only 50,000 miles. Conversely, a very durable body would have very little benefit if the expected engine life were only 50,000 miles. A long-life body and engine would also be useless in a vehicle that would require intricate and costly repairs or replacements to keep the durable components operating properly. Thus, the essential for increasing average fleet life is a combination of a body built of durable, corrosion-resistant material, a long-lasting engine, and vehicle systems and components that can be repaired easily.

A second way to reduce automobile waste would be to encourage recycling of components and materials. Batteries and tires are both commonly recovered from scrapped vehicles. Many auto hulls are processed for their scrap metal value. However, much of the plastic and interior materials is discarded. Present techniques for recovery of metals use large shredders and separators, which can operate economically only in urban areas where there is a large volume of junk cars from which to recover metals and components. Vehicles retired in less populous areas are often not processed for scrap since the cost of delivering them to a metal recovery plant exceeds their salvage value.

At present, there are no Federal policies directed at promoting recycling of automobile materials. Among the policies that could be adopted are a requirement that new cars be designed such that some percentage of the component materials can be recovered at a reasonable cost or a policy adding a deposit to the cost of a new car that can be returned only if the vehicle is recycled.

Water Quality

Water quality impacts of highway construction and use will be approximately the same under Improved Environment policies as in the Base Case since both have identical assumptions about the level of Federal funding for highways and the allocation of funds between construction and maintenance.

Community Disruption

Because capital expenditures for highways assumed for the Improved Environment Case are the same as for the Base Case, the projected number of highway-related displacements is identical. It is expected that the average annual number of displacements will be about half those experienced in the 1971-75 period, totaling about **7,700** in **1985 and 6,200** in 2000.

As in the Base Case, it is projected that highway construction will be concentrated in the outlying suburban and rural communities where the potential for disruption of community cohesion is somewhat less than in the central cities. Therefore, these social effects are expected to decline over the remainder of the century.

IMPACTS

Energy

The chief energy impact of Improved Environment policies would be a reduction in automobile fuel consumption, amounting to 4 percent less than the Base Case level in 1985 and 10 percent less in 2000. These reductions would be brought about primarily by the expected reductions in auto VMT and, in 2000, by the growing use of electric vehicles. Table 68 summarizes automobile fuel consumption impacts projected under Improved Environment policies.

The projected decline in automobile VMT is partially the result of the motor fuel tax designed to make fuel cost per mile constant through 2000 and partially the result of urban traffic restrictions imposed for environmental reasons. The combined impact of these policies would be to lower the annual consumption of motor fuels by slightly more than 6 billion gallons (0.4 MMBD) by 2000—a reduction of about 10 percent from Base Case levels.

Because of the 0.4-gram-per-mile NO_x standard, diesel sales will be restricted after 1990, and the diesel fuel consumption by the auto fleet as a whole would begin to decline sharply. By 2000, diesel fuel consumption is expected to be only 2 percent of that forecast under Base Case conditions. Sales of gasoline-powered automobiles are assumed to expand after 1990 to satisfy the additional demand created by the phase: out of diesels. Accordingly, gasoline consumption is expected to be 27 percent higher than Base Case levels in 2000. Another impact of this shift back to gasoline-powered automobiles is expected to be increased pressure on the automobile industry to improve the fuel-economy of conventionally powered vehicles as a compensation for the phase-out of the more energy-efficient diesels.

The growing use of electric vehicles by 2000

Table 68.—Automobile Energy Demand, Improved Environment Case

	Actual	Base Case[a]		Improved Environment	
	1975	1985	**2000**	1985	**2000**
Automobile VMT (trillions)	1.03	1.43	1.80	1.40	**1.74**[b]
Diesel penetration (percent of new car sales)	(c)	10	25	10	(c)
New car fuel economy (mpg)					
Regulation— EPA certification value	None	27.5	27.5	27.5	**40.0**
Attained— EPA certification value	15.6	28.5	29.4	30.4	**40.0**
Attained—actual driving	14.0	23.2	25.0	24.6	**34.0**
Fleet fuel economy (mpg)					
Attained— EPA certification value	15.1	24.0	28.5	24.3	**33.4**
Attained—actual driving	13.6	19.4	24.6	19.8	**28.3**
Annual fleet fuel consumption					
Billions of gallons	76.0	73.9	73.3	70.7	**58.3**
MMBD	5.0	4.8	4.8	4.6	**3.8**
Percent of domestic consumption	30.6	23.9	21.4	23.1	**17.8**

[a]Base Case "A," as defined in chapter 3. [b]Includes 85 billion electric vehicle VMT. [c] significant
SOURCE Svdecl EEA

would improve fleet fuel economy and help offset some of the adverse impacts of phasing out diesels. By the end of the century, it is estimated that electric vehicles will travel about **85** billion miles annually, resulting in net fuel savings of about 0.2 MMBD. Since electric vehicle use is expected to be concentrated in urban areas, there could also be secondary benefits in the form of small decreases in CO, HC, and NO_x emissions,

Safety

There is little safety benefit expected from Improved Environment policies per se, except for the minor decrease in automobile crashes brought about by the reduction in VMT. The decreases in death, injury, and property damage that are forecast for the Improved Environment Case ensue from other, safety-specific policies that have been incorporated into this policy set. Chief among these are Level I crashworthiness, passive restraints, and mandatory periodic safety inspections carried out in conjunction with the nationwide program of inspection and maintenance of emission control equipment.

The introduction of passive restraints and Level I crashworthiness is expected to reduce fatalities and injuries by about 11 percent from Base Case levels in 1985, when about one-quarter of the fleet will be so equipped. In **2000,** vehicle occupant fatalities and injuries would be about **20** percent below projected Base Case levels.

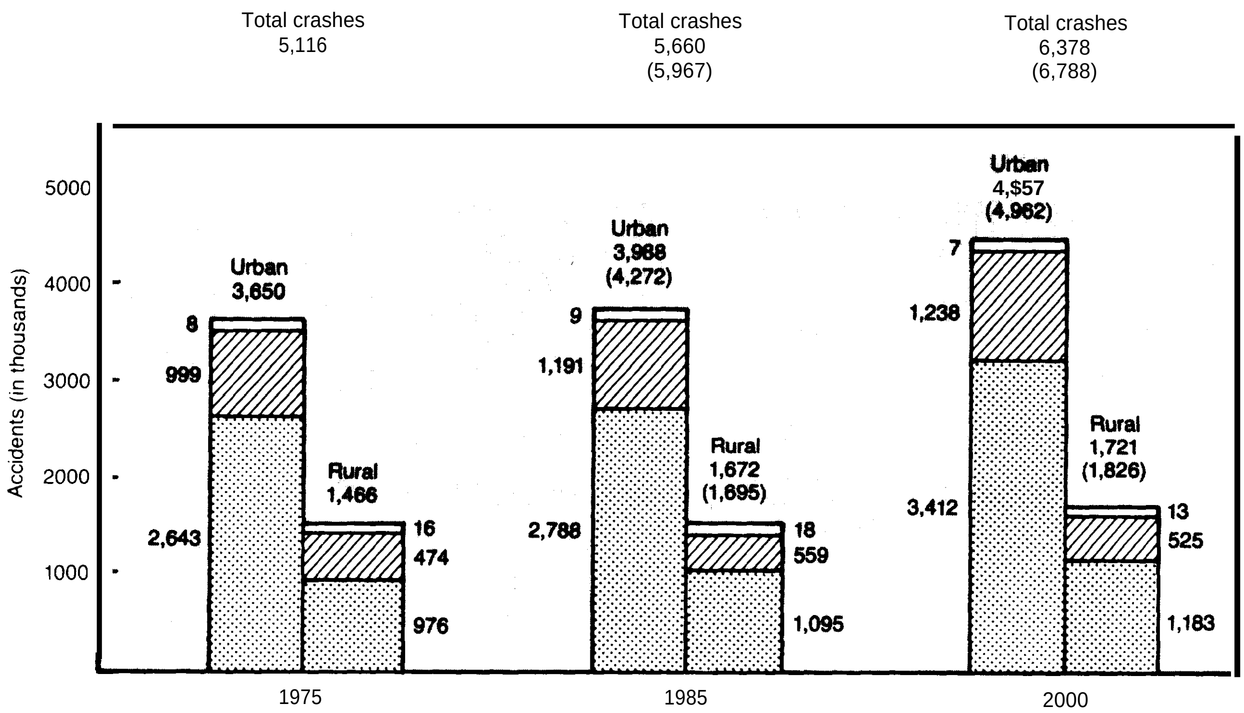
The inspection of safety features that is assumed to accompany the periodic check of emission control devices is projected to bring about a reduction of 4 to 5 percent in traffic crashes by 2000. The reduction of death and injury may be somewhat greater because the crashes that occur because of failure of safety equipment tend to be more severe than crashes produced by other causes.

Figure 33 shows the expected safety benefits that result from the combination of Level I crashworthiness and periodic safety inspections.

Mobility

A major emphasis of the Improved Environment policies is reduction in automobile use for

Figure 33.—Auto Occupant Fatal and Injury Crashes and Auto Property Damage Crashes, Improved Environment Case[a] (thousands)



‘For comparison, Base Case projections are shown in parentheses.

Auto occupant fatal crashes

n Auto occupant nonfatal injury crashes

Auto property damage only crashes

SOURCE: Sydec *EEA,* p V-57

work travel in major urban areas as a means to improve air quality. Specifically, the following target levels were established for SMSAs with populations over 1 million:

- For those large SMSAs with relatively good transit service, automobile VMT by commuters would be reduced by 10 percent by 1985 and 25 percent by 2000.
- For those large SMSAs with relatively poor transit service, automobile VMT by commuters would be reduced 10 percent by **2000.**

If these targets were attained, the nationwide reduction in VMT would be 57 billion miles per year by 2000, or **6** percent of the total urban VMT in the Base Case.

A pure transit incentive strategy, a strategy of improving transit services and decreasing transit fares without pricing or regulatory actions directed against auto use, would not achieve the target reductions of automobile VMT. The problem in using transit incentives by themselves to attempt to bring about large reductions in automobile VMT is that, even in large SMSAs with relatively good transit service, the proportion of home-to-work trips that can be made conveniently by conventional transit is less than 50 percent. Even in large SMSAs, more than half the jobs are located in areas where conventional transit service is relatively poor, such that less than 1 employee in 10 currently uses mass transit to get to work. Thus, carpooling, vanpooling, paratransit, and transportation system management strategies would have to play a major role in achieving large decreases in automobile VMT.

Given that transit incentives alone will not produce the desired decreases in auto commuting, it will be necessary to apply other actions to increase the cost of "drive alone" commuting relative to other modes.

A study of travel changes that could be brought about by various policies applied in the Washington, D. C., metropolitan area concluded that the areawide application of a $3-per-day parking surcharge would produce an 11-percent decrease in auto trips to work. ” This price increase would bring about roughly half the decrease in VMT in large urban areas sought by the Improved Environment policies.

Approximately half of the desired decrease in "drive alone" commuting could also be achieved by imposing a $6-per-day charge for all long-term parking in downtown areas of large SMSAs. However, a potentially serious long-run impact of such severe parking fees is that many businesses would relocate to areas not affected. This could have longrun counter-productive effects on transit and on the environmental goal of VMT reduction.

Alternatively, reductions in automobile VMT could be achieved by actions that decrease the travel time by carpooling or transit relative to that required for "drive alone" commuting. Such decreases could be provided through the institution of exclusive or priority lanes, traffic signalization, and transportation system management procedures that give special priorities to buses and carpools. If transit or carpool travel times were reduced by an average of 4 minutes per one-way trip compared to "drive alone" commuting, it is estimated that "drive alone" auto commuting would be reduced by about 5 percent.

Opportunities exist in most large metropolitan areas for providing priority lanes without causing large decreases in speed on parallel lanes. However, to achieve the carpool or transit time reduction of 4 minutes per one-way trip for the metropolitan area as a whole, it would be necessary to reduce the nonpriority capacity on many already congested streets and highways. In such circumstances, most of the relative travel time gain for carpools and transit would come about through increased congestion for auto commuters. Aside from causing strong resentment among auto commuters, this effect would also be counterproductive from an environmental point of view. Idling automobiles emit more pollutants per hour of operation—and in more densely concentrated pockets—than automobiles in smoothly flowing traffic.

Additional disincentives for "drive alone" commuting could be achieved by providing premium parking locations for carpools. Time spent walking to or from an automobile is considerably more onerous than in-vehicle travel time, such that drivers would spend an additional 3 to 5 minutes of in-vehicle travel time to reduce their walk time by 1 minute. If premium parking locations were provided for carpools, such that an average metropolitan areawide reduction of 1 minute in walking time would result, an additional 5-percent reduction in "drive alone" commuting might be expected.

The three actions discussed above—increasing the cost of "drive alone" commuting, reducing carpool and vanpool travel time by an average of **4 minutes, and** providing preferential parking for carpools—could produce the target reductions in VMT sought in the Improved Environment Case.

One possible consequence of such transit and ridesharing promotion programs that has not been adequately evaluated is that additional trips might be made by other household members in the car left at home. To some extent, these trips might defeat the purpose of measures to discourage "drive alone" commuting by merely substituting one automobile trip for another. However, such trips would probably not be to congested downtown areas during rush hours. It is the use of automobiles in heavily traveled corridors at peak periods that creates

[28] U.S. Department of Transportation, Federal Highway Administration, *Applications for New Travel Demand Forecasting Techniques to Transportation Planning*, March 1977.

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much of the air pollution problem; transit and ridesharing incentives seek to reduce these types of trips. Presumably, much of the travel induced by the availability of automobiles that would otherwise be used for commuting would occur at times and places that would not contribute significantly to air pollution.

The Washington, D. C., mode split model was used to estimate the impacts of decreased commuting by auto on transit ridership. About 30 percent of the decrease in auto commuting would occur through diversion to transit while the remaining 70 percent would occur through transportation system management actions to increase carpooling and paratransit usage. The effect of this diversion to transit, together with the effect of increasing transit vehicle miles, would be to increase total transit ridership from 5.6 billion revenue passengers in 1975 to 7.1 billion in 1985 and 8.7 billion in 2000. Transit ridership under Improved Environment policies would thus be 35 percent higher in 2000 than under the Base Case.

Cost and Capital

Under Improved Environment policies, gasoline prices (including tax) would be 89.9 cents per gallon in 1985 and 123.5 cents per gallon in 2000. This represents increases of 12.2 cents and 1.7 cents per gallon, respectively, over Base Case prices. On a per-mile basis, this amounts to increased fuel costs of 0.3 to 0.5 cent compared to the Base Case in 1985. For 2000, the difference between fuel cost per mile for the two cases is negligible.

In addition to increasing fuel costs, Improved Environment policies would also cause automobile maintenance costs to rise. It is estimated that mandatory inspection and maintenance of emission control equipment would add between 0.4 and 0.5 cent per mile to the cost of owning and operating an automobile in 2000, compared to the Base Case.

The total increase in operating costs per mile for the Improved Environment policies ranges from 0.7 to 1.0 cents per mile in 1985 compared with the Base Case, an increment of about 5 percent. In 2000, the cost increases would be 0.4 to 0.5 cent per mile, or about 3 percent higher than the Base Case.

One measure to reduce air pollution in the Improved Environment Case is the application of strong cost disincentives for commuting to work by automobile. Adding $3 per round trip to the cost of "drive alone" commuting would amount to $34 billion per year. Assuming 20 miles as the length of the average round trip to work, this would constitute an increase of 15 cents per vehicle mile, or a doubling of the average operating cost for work trips. If there were no other penalty charges applied to automobile travel, the increase would average 2 cents per vehicle mile for all travel.

Auto sales and size class distribution under Improved Environment policies are projected to be about the same as those under the petroleum conservation policies discussed in chapter 5. Improved Environment policies are expected to have little or no impact on auto prices through 1985. However, after 1990, when the 0.4-gram-per-mile NO_x standard goes into effect, the cost of the improved emission control equipment would add between $5o and $2oo to the price of a new car.

ANALYSIS OF INDIVIDUAL POLICIES

These policies are frequently suggested to deal with the problem of automobile emissions:

1. Regional standards (the so-called two-car strategy),
2. Tradeoff between control of mobile and stationary sources, and
3. Mandatory inspection and maintenance of vehicles in use.

None of these policies is proposed as a replacement for the present new car emission standards. Rather, they would serve as supplementary measures to enhance the effect of new car standards or as a way to deal with aspects of the automobile emissions problem not adequately addressed by new car standards.

The following' analysis is intended to shed light on the applicability and effectiveness of these measures in reducing air pollution from automotive sources in the period 1985-2000.

Regional Standards

Present Federal policy on automobile emissions is, in effect, a regional or two-car strategy. The 1977 Clean Air Act amendments allow the States to adopt either the Federal emission standards for new cars or the somewhat stricter standards now in force in California. It has been suggested that the present strategy be modified to allow two different standards to be set within each State—a strict standard in areas of high air pollution (primarily large metropolitan areas), and a somewhat relaxed standard for less populous parts of the State where air pollution is not a problem. Such a policy would allow automobile manufacturers to produce two rather different types of vehicles —''city cars" very much like those designed to meet the present 1981 Federal standards, and "country cars" whose emissions would be somewhat higher (perhaps on the order of 15 grams per mile CO, 1.5 grams per mile HC, and 2 grams per mile NO_x).

The logic behind this modified two-car strategy is that air pollution is basically a localized urban problem that does not correspond to State boundaries. Many States have severe air pollution problems in one or more metropolitan areas, but virtually no problem in the remainder of the State, covering perhaps as much as 80 or 90 percent of the land area and including up to half of the State's population. By applying automobile emission standards selectively, States could avoid the inequity of penalizing some owners by making them have emission control equipment they do not need in order to reduce air pollution in other areas where automobile use is concentrated.

A quantitative analysis of regional standards was not made in this assessment. The comments that follow are offered to suggest the major policy questions raised by establishing such a two-car standard and to indicate the avenue of inquiry that should be taken.

The major advantage of the regional two-car strategy is its purported efficiency. Measures to control automobile emissions would be applied only where they are needed, Residents of unaffected areas would be spared the unnecessary expense of pollution control equipment. Thus, the efficiency of this policy is both technical (reduced auto emission in cities) and economic (the costs are borne chiefly by those whose use of automobiles creates the problem). Regional standards may also be more cost-effective than other nationally applied emission control policies, although this point has not been firmly established.

The disadvantages of a regional two-car strategy lie primarily in implementation. For the standards to be effective, it would be necessary to obtain the cooperation and support of **50** State governments and hundreds of local jurisdictions. Since many metropolitan areas span State boundaries, it wouId also be necessary for some states to reach bilateral or trilateral agreements to coordinate standards and enforce compliance. Registration of vehicles and determination of which standard each vehicle in the State should meet could be a cumbersome process, both at the time of initial sale and subsequent resale. Since standards would probably be applied on a county-by-county basis, the burden on the administrative apparatus of county governments could be enormous.

Automobile manufacturers are likely to oppose regional standards. The higher cost of cars equipped to meet urban standards might reduce sales, without any prospect of recouping these losses through increased sales of less expensive cars in rural areas. Because of economies of scale in manufacturing, the present single standard might yield 1ower new car prices than a regional two-car standard, which would call for two somewhat different product lines. A detailed analysis of the comparative costs needs to be made both to determine the impacts on consumers and to assess the consequences for industry profitability and production.

Mobile-Stationary Source Tradeoff

The projections of air quality for 1985 and 2000 under Base Case and Improved Environment policies indicate that, for HC and NO_x, automobile emissions will constitute a small and diminishing fraction of the total of these pollutants from all sources. By 2000, automobile-emitted hydrocarbons will make up about 10 percent of the national aggregate, and automobiles and other mobile sources combined are expected to account for only one-quarter of all hydrocarbon emissions. The picture for NO_x is similar. Automobiles are projected to emit less than 10 percent of all NO_x in 2000, and other mobile sources will emit an additional 18 percent. Thus, the major share of these pollutants (70 to 75 percent) will come from stationary sources.

These figures are national aggregates and do not necessarily reflect the situation that is expected to exist in many urban areas where, because of concentrated vehicular traffic, automobiles and trucks may continue to be large (if not major) sources of pollution. Still, it appears that consideration should be given to tradeoffs between mobile and stationary source standards. These tradeoffs might be applied either as an alternative to setting new and stricter standards for automobiles after 1985 or as a way of relaxing existing standards for one *or* n-tore automobile-emitted pollutants in the interest of reducing cost or improving fuel economy.

An illustration of how this tradeoff policy might be applied can be seen in the question of whether to tighten the NO_x standard for new cars from 1.0 gram per mile to 0.4 gram per mile after 1985. The cost-effectiveness of various control measures for mobile and stationary sources was analyzed by the Federal Task Force on Motor Vehicle Goals Beyond 1980.[29] The results of this analysis, shown in table 69 and figure 34, indicate that—in terms of cost-effectiveness—several strategies aimed at stationary sources are superior to a stricter NO_x standard for automobiles.

In all, nine measures to control mobile or stationary source NO_x emissions were considered in the analysis. The cumulative effect of the six that ranked highest on the criterion of cost-effectiveness (four measures to control stationary sources, one for trucks, and a I. O-gram-per-mile standard for automobiles) was an annual reduction of 14 million tons of NO_x at a cost of $4 billion per year.[30] By adopting the remaining three measures on the list, an additional 8 million tons of NO_x could be removed from the atmosphere per year, but at a further cost of $9 billion per year.

The cost-effectiveness of automobile NO_x standards of 1.0 gram per mile and 0.4 gram per mile can be compared to that of various stationary source controls by examining figure 34. The I .()-gram-per-mile standard has a cost-effectiveness rate of $450 per ton of NO_x removed and ranks sixth among all measures. The 0.4-gram-per-mile standard has a cost-effectiveness rate of $2,300 per ton—the 1east cost-effective of the nine measures considered.

Analysis such as this indicates that control of stationary sources would be the more effective expenditure of funds to achieve an overall reduction in NO_x emissions. Further, lowering the automobile NO_x standard from 1.0 gram per mile to 0.4 gram per mile appears to yield rather small benefits in terms of the cost incurred. Changing the standard from 2.0 to 1.0 gram per mile would remove 1.91 million tons of NO_x from the atmosphere per year, at a cost of $45o per ton. Reducing the standard from 1.0 to 0.4 gram per mile would remove an additional 1.15 million tons of NO_x per year and cost $2,300 per ton. In other words, 60 percent more benefit but at a cost 5 times greater.

Cost, however, is but one criterion for making tradeoffs. Consideration must also be given to other criteria, such as the relative importance of each type of emission source in the overall pattern of air pollution. For example, there is some evidence from a recent study of smog formation in the Los Angeles Air Basin[31] that emissions from automobiles figure more prominently than stationary source emissions in severe smog episodes. If this interpretation of the data is confirmed and similar results are found in

‘W, S. Department of Transportation, *The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980,* pp. 10-1 to 10-5.

[30]The projected emission reductions cited here should not be confused with those given elsewhere in this report. The figures here are from the Federal Task Force report and are based on a different forecasting methodology from that used by OTA. The projections by the Federal Task Force and OTA, while in general agreement, cannot be compared point by point.

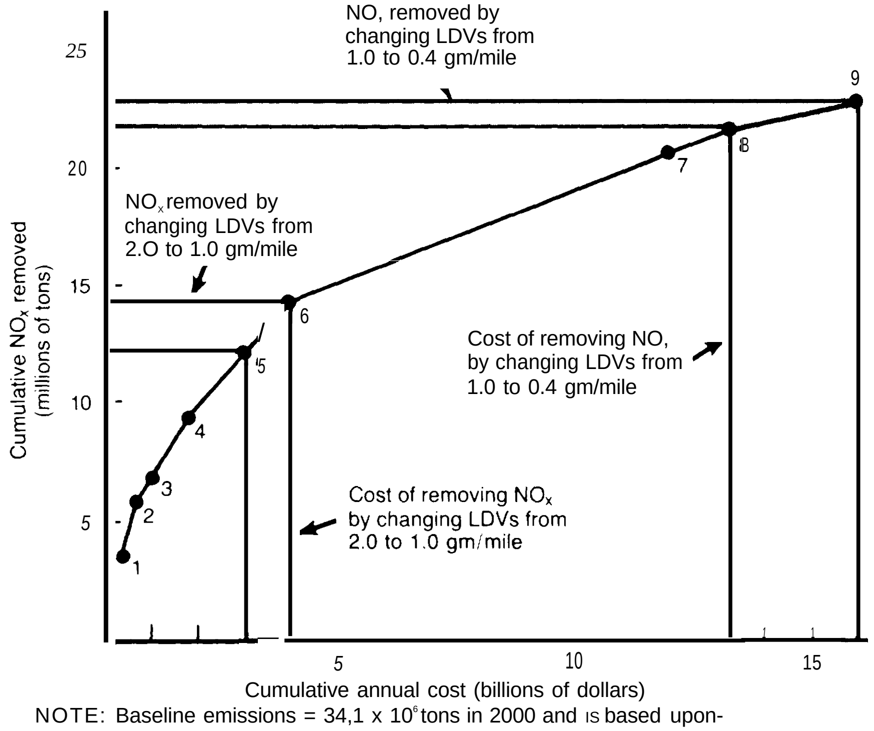
“A. Eschenroeder, *Applications of the Los Angeles Reactive Pollutant Program (LARPP) to the Assessment of Proposed California Emission Controls,* presented to the California Air Resources Board Workshop, Jan. 5-6, 1977.

Table 69.—Cost Effectiveness of Control Strategies for NO_x Emission in 2000

Control strategy	NO_x removed (10^6 tons)	0/0 of baseline emissions removed[a]	Cumulative 0/0 of baseline removed	cost effective-ness ($/ton)	Annual cost of strategy (billions $)	Cumulative annual cost (billions $)	Cumulative NO, removed (10^6 tons)
1 New utility boilers from 25% to 50% control	3.52	11	11	100	0.35	0.35	3.5
2 Industrial boilers from 25°/0 to 65°/0 control	2.46	7	18	150	0.37	0.72	6.0
3 Existing utility boilers from 25% to 50% control	0.62	2	20	225	0.14	0.86	6.6
4 Stationary internal combustion engines from 25% to 50% control[b].	2.87	**9**	29	340	**0.98**	1.84	**9.5**
5 Other mobile from 10 gm/ mile to 80°/0 control	2.9	**9**	38	450	**1.3**	3.14	**12.4**
6 Lightweight vehicles from 2.0 to 1.0 gin/mile	1.91	**6**	44	450	**0.86**	4.0	**14.31**
7 Utility boilers from 50% to 90°/0 control	6.62	**20**	64	1,200	**7.94**	11.94	**20.93**
8 Stationary internal combustion engines from 75% to 90°/0 control.	0.86	**3**	67	1,700	1.46	13.43	21.79
9. Light utility vehicles from 1.0 to 0.4 gin/mile	1.15	3	70	2,300	2.65	16.08	22.94

[a] Internal combustion engine control does not include small engines.
[b] Baseline emissions = 34.1 × 10^6 tons in 2000 and is based upon light-utility vehicle standard, 2.0 gm/mile. Other mobile, 10 gm/mile, 25% control of all stationary source emissions.
SOURCE: *SRI*, p. G-24

Figure 34.—Cost-Effectiveness of NO_x Control Strategies



NO, control strategies

1. New utility boilers from 25% to 50% control
2. Industrial boilers from 25% to 65%. control
3. Existing utility boilers from 25% to 50% control
4. Internal combustion engines from 25% to 75°. control
5. Other mobile from 10 gm/mile to 800/0 control
6. "Light-duty vehicles" from 2,0 to 1.0 gm/mile
7. Utility boilers from 50% to 90% control
8. Internal combustion engines from 75% to 900/o control
9. LDV from 1.0 to 0.4 gin/mile

NOTE: Baseline emissions = 34,1 x 10^6 tons in 2000 and is based upon LDV standard 2.0 gin/mile, other mobile 10 gin/mile, 25%. control of all stationary source emissions

SOURCE U S Department of Transportation, *The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980,* p 10-3

Photo Credit: U.S. Department of Energy

other cities, a much stronger argument can be made for a stricter automobile NO_x standard despite its relatively high cost.

A second, somewhat different example of the need for a policy that permits tradeoffs can be found in the comparison between emissions from gasoline-powered vehicles and those from powerplants producing electricity for battery-powered vehicles. In this case, the tradeoff to be made is not between alternative measures to control a single pollutant but between different types of pollutants. The results of one such analysis are shown in table **70.**

This analysis indicates that the use of electric vehicles would result in the virtual elimination of carbon monoxide and hydrocarbon emissions, even if the powerplants were fired by coal. Nitrogen oxides and sulfur dioxide, however, would be emitted in much greater quantities. The emission of NO_x, in terms of the equivalent per vehicle mile, would be 3 to 4 times higher for electric vehicles. Sulfur dioxide emissions would be 20 to **30** times higher. Thus, the potential use of electric vehicles forces a tradeoff that must take into consideration not only the quantities of each type of pollutant, but also the comparative cost and technical feasibility of mobile and stationary source controls.

Regardless of the importance attached to these two examples of mobile-stationary source tradeoffs, one point emerges clearly. No single pollution control measure—whether it is directed at automobiles or other sources—is uniformly superior in all situations and for all pollutants. A mixture of controls (some for mobile sources, others for stationary sources) will be required. Further, this mixture will almost certainly have to be varied from site to site. What is optimum for one city may be inadequate for another.

Substantiation of this point can be found in the analysis of present and future air quality problems performed for three U.S. cities during this assessment. The cities studied were Washington, D. C., Houston, Tex., and Chicago, Ill.,—each representative of a certain urban situation. Washington is a city with very little industry and a high dependence on automobile transportation. Houston is also a city with a heavy degree of automobile use, but it has a much greater amount of industry, notably petroleum refining. Automobile use in Chicago is also high, but Chicago has an extensive and well-developed transit system. The industrialization of the Chicago area is intense.

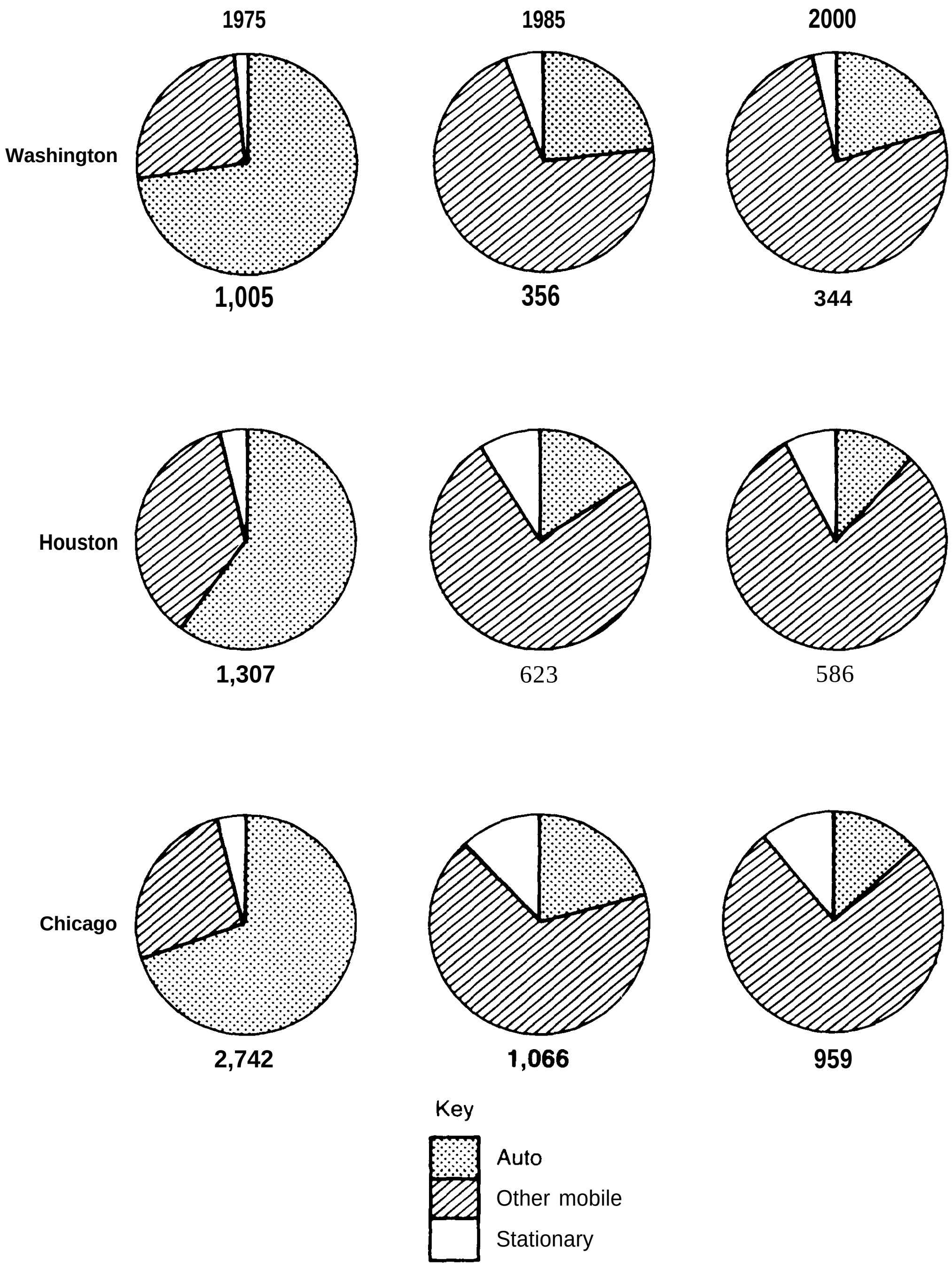
Figures 35, **36,** and **37** show the actual and projected levels of CO, HC, and NO_x emissions in these three cities for **1975, 1985,** and **2000.** More significant than the absolute quantities of pollutants is the **way** in which the distribution by source changes over time and from city to city. No attempt is made here to draw detailed conclusions about the relative effectiveness of different control measures. The figures speak for themselves and illustrate the basic point that future air poIlution control strategies must be both flexible and selectively applied.

Table 70.— Electric-Vehicle Emisisons Compared to Gasoline-Vehicle Emissions, 2000

Type of emission	Gasoline vehicle (composite) (gm/mi)	Electric-vehicle powerplant emissions’ Coal fired (gm/mi)	Oil fired (gm/mi)
Carbon monoxide . . .	3.78	0.012-0.021	0.0001
Hydrocarbons	0.461	0.004-0.007	0.0001
Nitrogen oxides[b]	0.588	1.51-2.66	0.649-1.14
Sulfur dioxide’.	0.13	2.597-4.57	1.731-3.02

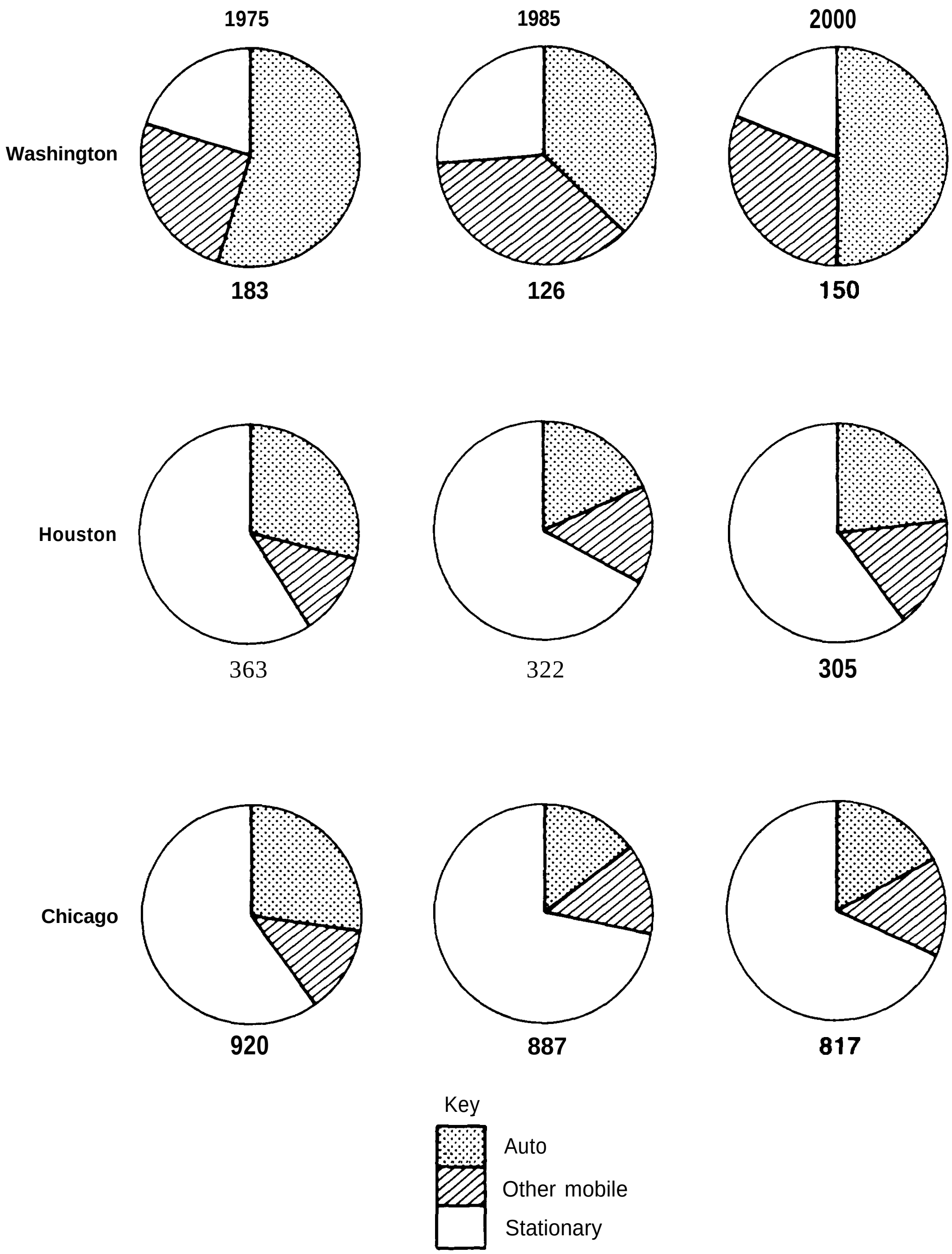
[a]Powerplant emissions are controlled to New Source Performance Standards levels, when applicable, assumed 35 percent efficiency. These standards are being revised at present to lower the allowable emissions, and further reductions by 2000 could occur.
[b]Assumes automobile standard of 1.0 gm/mile from 1981 to 1990.
[c]Based on EPA data from *Compilation of Air Pollutant Emission Factors*, AP-42, Supplement 5, December 1975.
SOURCE: *Sydec/EEA*, p. V-44.

Figure 35.— Projected Carbon Monoxide Emissions for Washington, Houston, and Chicago (thousands of tons)



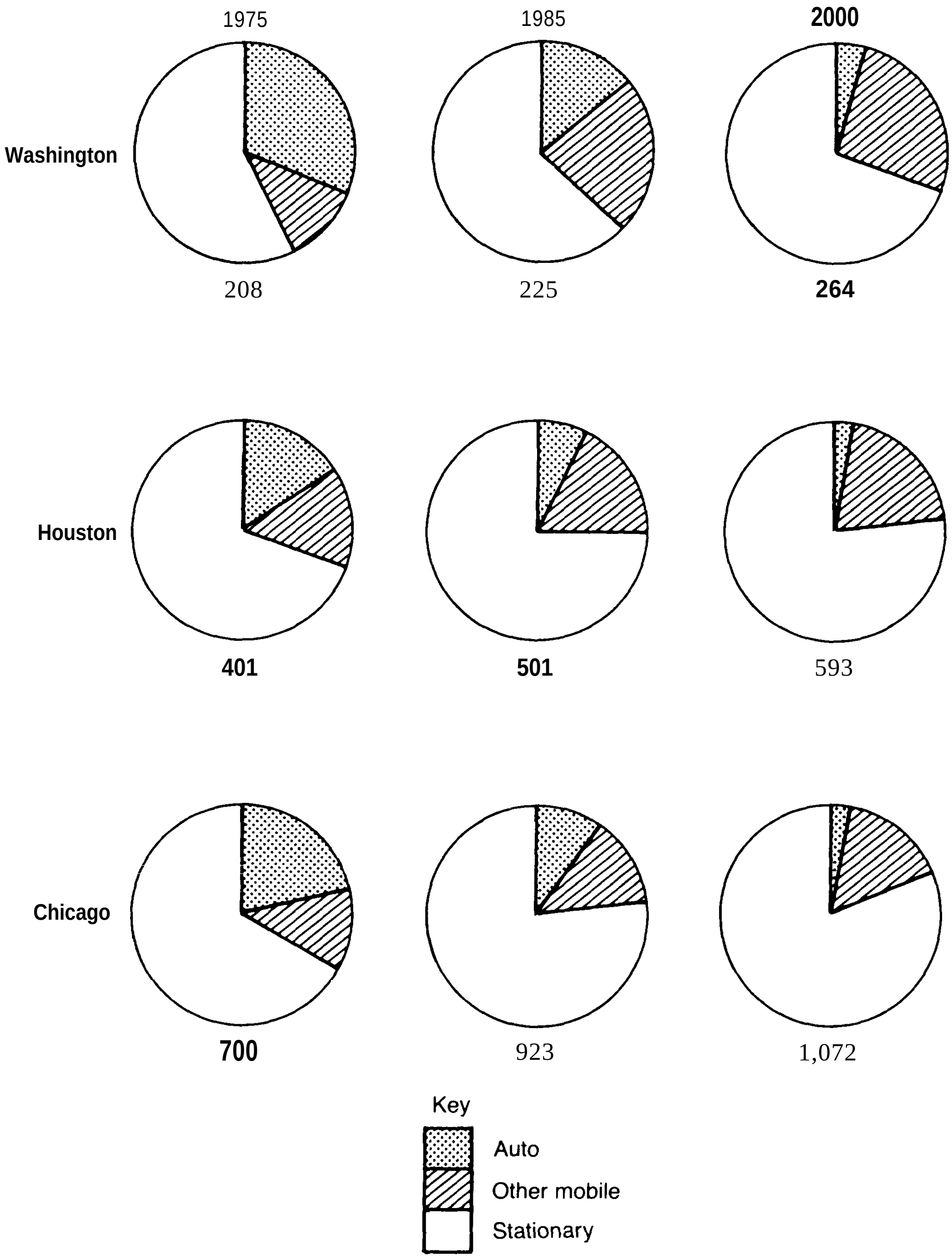
SOURCE: *Sydec/EEA*, pp. V-48, V-50 and V-53.

Figure 36.— Projected Hydrocarbon Emissions for Washington, Houston, and Chicago (thousands of tons)



SOURCE Sydec *EEA,* pp V-48, V-50 and V-53

Figure 37.— Projected Nitrogen Oxide Emissions for Washington, Houston, and Chicago (thousands of tons)



SOURCE: *SydeclEEA,* pp. V-48, V-50 and V-53

Mandatory Inspection and Maintenance

The projected effects of a program of inspection and maintenance of vehicles in use were presented earlier in this chapter. It was found that inspection and maintenance could yield substantial benefits—the largest of any environmental measure considered—if adopted nationwide and consistently enforced. The purpose of the discussion offered here is to examine some of the factors that would influence the implementation of the program and its potential cost to the public.

To implement the program would require that inspection stations be set up in all localities, either in private service stations and garages or in State-operated facilities, to measure the amounts of CO and HC in automobile exhaust. At present, there is no rapid and practical test for NO_x or evaporative HC, and no inspection procedure for these emissions is assumed for this discussion. Based on empirical data on emissions from vehicles of various ages, the controlling Government agency would establish emission standards. Some percentage of the vehicles in each age group would fail the inspection, and owners would be required to effect the necessary adjustments, repairs, or replacements and submit to reinspection.

An inspection and maintenance program could be administered and implemented in several ways. Two of the most likely methods would be State-run inspection centers or certification of private service stations as inspection stations. The former would give the State or local government a direct role in the inspection process, whereas the latter would delegate a large portion of the responsibility for the program to private service station operators. Both programs would require special equipment to analyze emissions. Costs can range from $2,000 per analyzer for an idle mode test to $12,000 per analyzer for a test that simulates the various driving modes.

Both programs would require employment and training of personnel. The State-run inspection would need personnel to run the facility and to perform the inspections. Maintenance would be carried out at a private station or garage of the owner's choice. The privately run program would require State personnel to train the service station employees in the use of the equipment and to certify and to check on their proficiency. In either case, it would be necessary for the agency responsible for the program to have legislative authority to inspect private vehicles and require maintenance if emissions exceeded a specified level.

An appreciation of the complexities of establishing a nationwide system of inspection can be gained by looking at the efforts of DOT to establish the Periodic Motor Vehicle Inspection (PMVI) program for safety features. In 1966, DOT encouraged States to establish inspection programs to assure the safety of vehicles on the road. Twenty-three States voluntarily established PMVI programs. In 1967, 10 more States passed laws in response to the Highway Safety Act that provided for withholding Federal highway funds from States without PMVI programs. Table 71 shows the results of DOT's effort to encourage State inspection programs over the 6- year period between 1969 and 1974. Aside from the original 32, no State adopted a true periodic inspection program during this period, but three States adopted programs of inspection of vehicles at the time of title transfer or on the spot or on a random basis. The inability of DOT to expand the concept after the initial flurry has been attributed to several factors:

- The cost of establishing a thorough national program,
- Disagreement on appropriate levels of standards and testing,
- Inability to demonstrate the benefits of the program, and
- Adverse public reaction to inefficient or unethical testing practices and subsequent repair costs.

This experience suggests that an inspection program is likely to be successful only if the following conditions are met:

- There is a simple uniform testing procedure that is easily implemented and audited.
- The costs of the program are kept within acceptable limits.
- The benefits of the program are projected before the program starts and updated with

Table 71.—State Motor Vehicle Inspection Programs

Type of inspection	1969 No. of States[a]	1969 Registered vehicles (millions) Total	1969 Registered vehicles (millions) Inspected	1974 No. of States[a]	1974 Registered vehicles (millions) Total	1974 Registered vehicles (millions) Inspected
No inspection	**10**	**23**	0	7	25	0
Spot/title transfer	9	25	3	12	35	8
Annual inspection	25	45	45	25	57	57
Semiannual inspection	7	12	12	7	14	14
Total	51	105	60	51	131	79
Percent of registered vehicles inspected	—	57%	—	—	61‘A	—

[a]Including the District of Columbia
SOURCE: *SRI*, p. G-29.

actual results after the program is in operation.

These three areas of concern—testing procedures, cost, and benefits—are closely tied.

Currently, there are a variety of testing procedures that could be used. They can be grouped in two categories:

1. Direct examination of specific maladjustments and malfunctions using conventional or more sophisticated garage-type equipment, and
2. Indirect diagnosis of engine maladjustments and malfunctions using measurements of exhaust emission levels under different engine loadings.[32]

No single procedure is ideally suited to all situations. However, in the interests of uniformity and ease of administration on a nationwide basis, it may be desirable to adopt a common procedure. If so, the procedure should meet the following minimum criteria:

- All cars should be inspected on a periodic basis, either annually or semiannually, on a schedule that coincides with vehicle registration.
- The inspection costs should be low so as not to impose economic hardship.[33]
- The inspection program must provide for mandatory maintenance and repair.[34]

The question of payment for maintenance and repair or replacement is particularly troublesome. One method is to include the cost of repair or maintenance in the inspection fee. The cost of repair could be averaged for all vehicles inspected. Another method would be to increase the initial cost of the emissions control devices to include warranty coverage for necessary maintenance and repairs. If automobile or equipment manufacturers were obligated to provide this insurance, as they presently do in warranties on other parts of the automobile, an additional benefit gained from the program would be an incentive for the manufacturer to produce reliable and durable emission control systems that are easy and inexpensive to repair or maintain.

It would probably be necessary for the Federal Government to assume financial responsibility for the development of a uniform testing program and for disseminating information to State personnel. Once the program is in opera-

[32]O. P. Hall, Jr., and N. A. Richardson, The *Economic Effectiveness of Vehicle Inspection Maintenance as a Means for Reducing Exhaust Emissions A Quantitative Appraisal* Society of Automotive Engineers, Automotive Engineering Congress (Detroit: Feb. 15-Mar. 1, 1974).

[33]The State of Arizona provides an inspection program that costs $5 per vehicle, which is entirely covered by increased registration fees. The State of New York has estimated that emissions testing would cost ***$3.72*** per vehicle inspected if the program were State-administered. Both of these States were costing programs to test vehicles under both idle and loaded conditions.

[34]O.P. Hall, Jr., and N.A. Richardson.

tion, the Federal Government would have to fund the monitoring of the program on a national level. The States would have to fund initial expenses of establishing the programs, unless the Federal Government were to provide grants to cover these costs, Federal funds might also be necessary either to operate the program or to monitor privately operated test facilities. However, these expenses might be recovered through inspection fees, as in the State of Arizona. The consumer would probably have to pay the inspection fee and the cost of maintenance either by means of the inspection fee or by increased cost of emissions control devices if a warranty system for emission control equipment could be devised. Automobile manufacturers would incur higher expenses in covering the emission control equipment under warranty, but this cost would almost certainly be passed along to the owner.

The political impacts of the program would also be important. From DOT's experience in trying to implement the PMVI program, it is obvious that Federal standards for testing and the threat of withholding Federal funds from States are not sufficient to guarantee adoption of an inspection and maintenance program. In order to achieve uniform testing in all States, it would probably require some form of Federal legislation—either a mandate or a strong system of incentives. States, in turn, would have to pass enabling legislation to modify portions of their legal codes–a process that would be lengthy and fraught with political difficulties.

Table **72** is a summary of the impacts that a mandatory inspection and maintenance program could have on Federal and State governments, consumers, and the automobile industry.

Table 72.—impacts of Mandatory Testing and Maintenance of Emissions Control Devices

	Cost impacts	Political impacts	Other impacts
Federal	Funding for development of uniform test procedure. Funding for initial program development. Funding for national monitoring.	Legislation requiring State participation.	Additional personnel for program development and monitoring.
State	Funding for establishing program. Funding for either operating or monitoring testing and repair procedures. Funding for data collection and processing.	Changes of vehicle registration procedures or new procedures to require testing of vehicles. Decreased State independence in solving emissions problems.	Additional personnel for system operation and monitoring.
Consumer	Increased cost of either vehicle registration or emissions control devices.		Inconvenience and time required for inspection and maintenance Independent automobile repair. Shift of some personnel to testing and repair programs.
Automobile maintenance	Increased cost and inconvenience of insuring emissions control devices.		Increased incentive for reliable, maintenance-free emissions control devices.

SOURCE Sff/ p G 35

Chapter 7

SAFETY ISSUES, POLICIES, AND FINDINGS

Chapter 7.—SAFETY ISSUES, POLICIES, AND FINDINGS

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SAFETY ISSUES, POLICIES, AND FINDINGS

CHAPTER 7

SUMMARY

The current annual toll of motor vehicle crashes is almost 48,000 deaths and over 4 million injuries. The estimated monetary cost to society is approximately $44 billion, Despite existing Federal policies, regulations, and programs dealing with automobile and highway safety, and despite the introduction of new safety features, such as passive restraints, the annual toll is expected to keep rising, By 2000, there could be as many as 64,000 deaths and over 5 million injuries annually.

The major aspects of the system that need to be addressed to improve safety are vehicle and highway design and driver behavior. All have been the subject of Federal highway and traffic safety policies and programs, and it appears that these efforts by the Federal Government have had a beneficial effect. The rate of fatalities per vehicle mile has been reduced nearly 40 percent in the past decade. In absolute numbers, however, the annual toll remains high and is expected to rise steadily in the coming years as the result of more cars on the road, more drivers, and more miles of travel, Additional policies and programs to stem the trend of increasing death and injury should be considered.

In the near term, safety benefits could be realized rapidly from policies to promote increased use of seat belts (passive restraints will not be in widespread use for many years) and to enforce adherence to the 55 mph speed limit. Potentially great benefits could also be achieved by measures to reduce the use of alcohol associated with driving.

In the long term, increased crashworthiness and improved occupant restraint systems are two aspects of vehicle design that could produce significant reductions in death and injury. For highways, the greatest benefits could be achieved by a general program to eliminate roadside hazards or to provide crash attenuation.

As a long-term strategy, the Federal Government may also wish to consider the policy of establishing a comprehensive set of specific and quantitative safety goals. This policy, analogous to those which established national goals for clean air and fuel economy, could provide the basis for planning, implementing, and evaluating individual safety measures. Safety goals could also provide for more effective coordination of Federal, State, and local programs and could help in determining the appropriate allocation of resources.

BACKGROUND

The safety of the automobile transportation system is a severe and long-standing problem. For many years, highway deaths have accounted for over 90 percent of all the transportation-related deaths in the country. In 1977, the toll on streets and highways amounted to 47,715 deaths and over 4.3 million injuries. The costs to society are estimated to be $44 billion annually. (See table 73.)

In this century, approximately 2 million persons have died and nearly 100 million have been injured through the use of motor vehicles—a total that is more than 3 times the combat losses

Table 73.—1977 Crash Data

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

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

suffered by the United States in all wars.[1] The Nation's vehicles and highways claim more American lives each year than were lost in either the Korean or Southeast Asia Wars. On the average, a highway fatality occurs every 11 minutes and an injury every 9 seconds.

In 1975, motor vehicle crashes accounted for 2.4 percent of total reported deaths in the United States and ranked as the sixth leading cause of death. (See table 74.) Accidents of all kinds accounted for 103,000 deaths and 10.7 million injuries in 1975, and motor vehicle crashes represented approximately 45 percent of the total accidental deaths and 37 percent of the injuries. Measured in terms of working life lost, traffic deaths represent a social problem comparable to heart disease and cancer. (See figure 38.)

Table 74.—Leading Causes of Deaths for 1975

Causes	Number	Percent of Total
Diseases of the heart	716,215	37.8
Malignant neoplasms	365,693	19.3
Cerebrovascular disease	194,038	10.3
Other accidents	57,177	3.0
Pneumonia	51,387	2.7
Motor vehicle crashes	45,853	2.4

[a]If the category of "Other Accidents" were disaggregated, motor vehicle crashes would be the fifth-ranking cause of deaths and the leading cause of accidental death.

SOURCE: U.S. Department of Health, Education, and Welfare, National Center for Health Statistics, *Monthly Vital Statistics Report.*

Motor vehicle crashes are the leading cause of death in the 15 to 34 age group. About half of the yearly death toll consists of persons in that age bracket. As shown in figure 39, the proportion of young adults that die in traffic crashes far exceeds the relative size of this age group in the population as a whole.

Over the years, the general trend has been a continuing increase in the number of traffic fatalities. A high point of 56,000 deaths was reached in 1973. A sharp drop to 46,000 deaths occurred in 1974, due in part to the 55 mph speed limit and the temporary reduction in auto travel brought about by the gasoline shortage. Since then, the number of fatalities has risen again but still remains below the peak of 1973.

While the number of traffic deaths has grown over the years, the fatality rate (deaths per 100 million miles of vehicle travel) has steadily declined—from 18 per 100 million miles in 1925 to 3.25 per 100 million miles in 1977. Thus, while the death rate is decreasing, the steady rise in the number of autos and miles of travel has resulted in a growing number of traffic deaths. (See figure 40.)

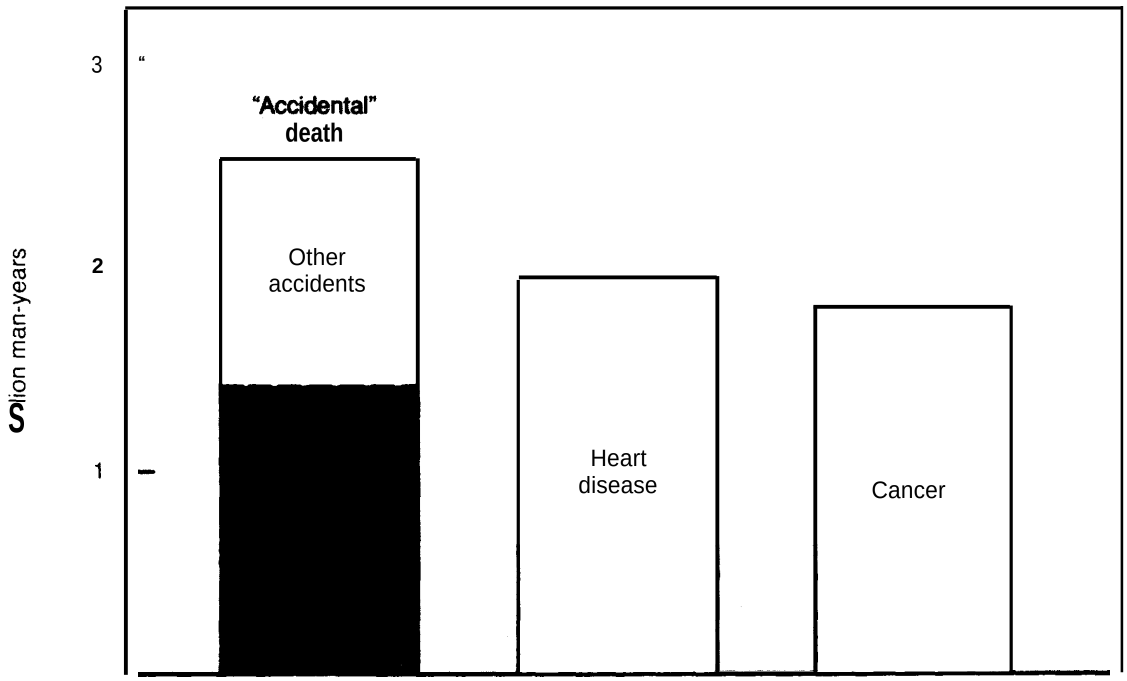
Traffic mortality on a population basis increased in the years 1960 to 1973, but declined in 1974, consistent with the sharp drop in fatalities. (See figure 41.) The traffic death rate per hundred thousand population has ranged from about 20 to 30 over the last five decades.

While the death rate per vehicle mile traveled is relatively low in this country, the death rate per 100,000 population is on the high side compared with other nations. Industrialized countries in general rank high in transportation mortality rates—with some exceptions, notably Japan, Great Britain, Sweden, and East Germany. (See table 75.)

When stated in terms of passenger miles of travel, as shown in table 76, the death rate for automobiles is among the highest of all modes of transportation. Automobile travel is considerably more dangerous than bus, rail, and airline travel, but a much safer form of transport than motorcycle and general aviation.

[1]National Safety Council, *Accident Facts, 1977* Edition,

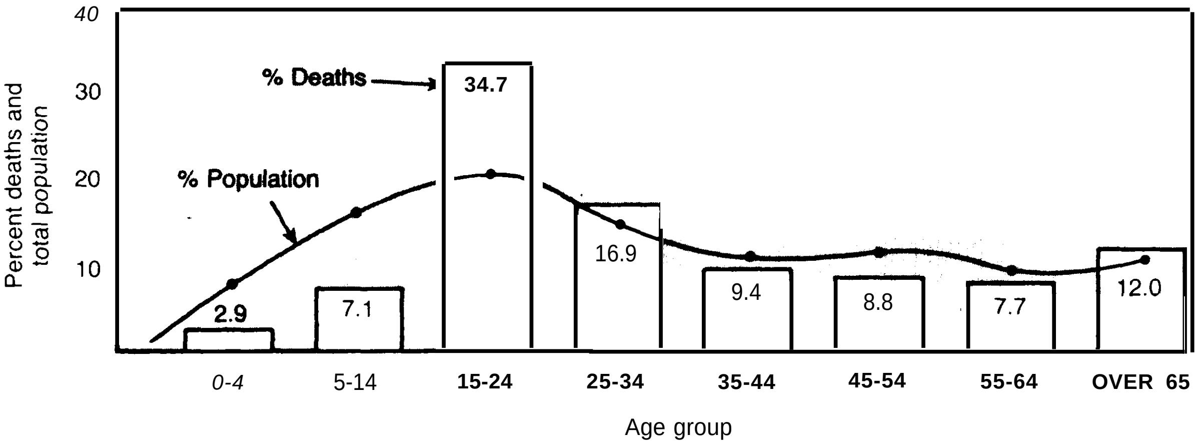
Figure 38.—1975 Loss of Working Life—Annual Man-Years[a]



SOURCE: Computed by the OTA from 1975 data from the National Center for Health Statistics.

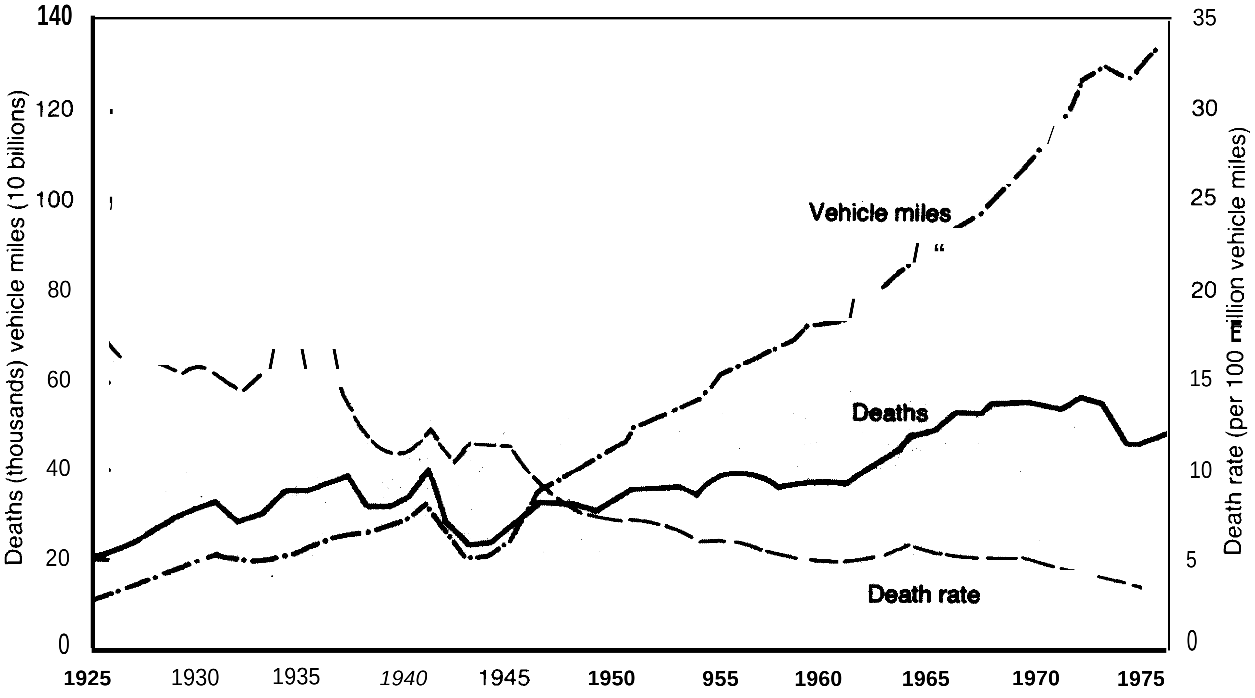
[a] Loss of working life is defined as the working years between the ages of 18 and 65 that are lost due to death before age 65

Figure 39.—Traffic Deaths by Age Groups



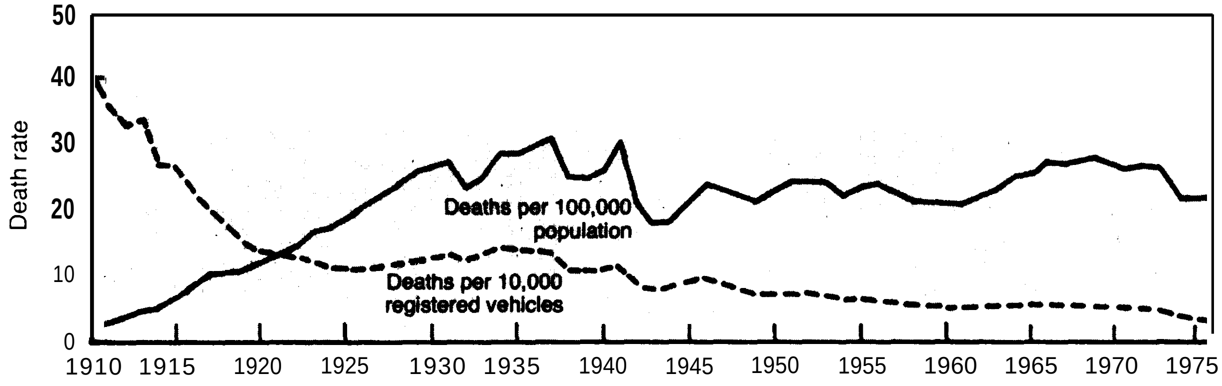
SOURCES: U.S. Department of Health, Education, and Welfare, National Center for Health Statistics, *Monthly Vital Statistics Report;* U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1976*, 97th Edition

Figure 40.—Motor-Vehicle Travel, Deaths, and Death Rates



SOURCE: National Safety Council, *Accident Facts*, 1978

Figure 41 .—Trends in Death Rates



SOURCE: National Safety Council, *Accident Facts*, 1977

Table 75.—Motor Vehicle Deaths By Nations[a]

Nat ion	Year	Deaths	Deaths per 100,000 population
, Chile	1974	1,115	11.1
Japan, ...	1975	14,206	12.8
England-Wales.	1974	6,372	13.0
Norway	1974	549	13.8
Greece.	1974	1,297	14.5
Sweden	1975	1,236	15.1
East Germany.	1975	2,578	15.3
Mexico	1974	8,887[b]	15.3
Denmark	1975	849	16.8
Ireland.	1974	562	18.2
Switzerland.	1975	1,237	19.5
Israel	1974	563	19.8
Czechoslovakia	1973	2,958	20.3
United States	1974	46,402[b]	22.0
France.	1974	11,786'	22.5
West Germany	1974	14,242	23.0
Canada	1974	6,325[b]	28.1
Australia.	1974	3,816	28.6
Austria.	1975	2,483	33.0
Portugal.	1975	3,299	34.9

[a] In general, the data presented include deaths that occur within 30 days of the traffic crash. Other time periods are noted as follows: [b] One year (the total deaths are about 2 percent greater than if 30 days is used). [c] Three days (reduces the total number of deaths compared with 30 days).
SOURCE: National Safety Council, *Accident Facts*.

Table76.— Estimates of Death Rate for Transportation Modes in the United States

Type of travel	Deaths per 100 million passenger miles"
Commercial aviation.	0.1
Passenger train	0.1
Rail rapid transit	0.1
Bus	0.2
Automobile.	1.4
Motorcycle.	13.0
General aviation.	13.0

[a] Includes only persons traveling by this means of transportation. Data sources range in the period 1974-76.
SOURCE: William Haddon, Jr., and Susan P. Baker, *Injury Control*, Insurance Institute for Highway Safety, March 1978.

TRAFFIC CRASH DATA

Traffic crash data are collected by the States (through police accident reporting), insurance companies, the U.S. Public Health Service, the U.S. Department of Transportation (DOT), and various research organizations. The U, S. DOT Fatal Accident Reporting System is currently considered the most reliable source of data on traffic fatalities. For injuries and property damage, national estimates are not based on actual totals but on reports from individual States. The National Accident Sampling System (NASS), a program recently begun at DOT, should greatly improve the accuracy of injury and property damage data in the years ahead.

The following sections summarize the data available on traffic crashes, deaths, and injuries.

Crashes

The National Safety Council (NSC) estimated that in 1976 there were 16,800,000 motor vehicle crashes involving 28,400,000 motor vehicles. (OTA estimates for **1977,** based on the 1976 figures, are 17,600,000 crashes involving 29,800,000 vehicles.) About 93 percent of those crashes were relatively minor, involving property damage and nondisabling injury. [2] Table 77 shows a breakdown, by vehicle type, of vehicles involved in these crashes. The data indicate that one out of every five vehicles was involved in some type of collision in 1976.

Deaths

Data from the DOT Fatal Accident Reporting System are shown in table 78 for the years 1975 to 1977.

The majority (73 percent) of the 47,715 persons killed in traffic crashes in 1977 were vehicle occupants—27,353 in automobiles and 5,222 in pickups or vans. From 1975 to 1977, the largest increases in fatalities were from crashes involving heavy trucks (33.1 percent), motorcycles (28 percent), and pickups/vans (20.5 percent). There was a 4.1-percent increase in automobile fatalities and a 7.2-percent increase in total highway fatalities. Pedestrian and cyclist deaths averaged over 8,000 annually for these 3 years.

Other statistics that indicate the nature and distribution of fatal traffic crashes are:

- Males constitute 54 percent of the drivers but account for 70 percent of the driving, over 70 percent of all fatalities, and 82 percent of all drivers involved in fatal crashes.
- On Friday, Saturday, and Sunday between the hours of 4 p.m. and 4 a.m., the frequency of fatal crashes is the highest. The period from 4 a.m. to 8 a.m. accounts for the fewest fatalities throughout the week.
- Over half of vehicle occupant fatalities are the result of frontal impacts. (See figure 42.)
- For single-vehicle crashes, collision with a fixed object is most prevalent.
- The ratio of fatalities to occupants in multivehicle crashes is 2 times higher in small cars than in large cars. For single-vehicle crashes, the ratio is the same for all vehicle sizes.
- Approximately 35 percent of the fatalities occur in urban areas and **65** percent in rural areas.
- About 37 percent of urban fatalities are pedestrians, compared to 8 percent in rural areas.
- Half of the pedestrian and bicycle deaths are persons under 14 or over **65.**

[2] A disabling injury is one which causes permanent or temporary disability for longer than 24 hours. All other injuries are classified as nondisabling.

Table 77.—Crash Data by Vehicle Type, 1976

Type of vehicle	Vehicles in all crashes: Number	Vehicles in all crashes: Percent	Percent of vehicle registrations	Percent of registered vehicles in crashes[a]
Total	28,400,000	100.0	100.0	19.9
Automobile[b]	23,280,000	81.9	77,1	21.2
Motorcycle[c]	402,000	1.5	3.6	7.8
Buses	235,000	0.8	0.3	55.0
Trucks	4,100,000	14.5	19.0	15.2
Other[d]	383,000	1.3	(e)	(e)

[a] Computations based on the NSC figure of 142,400,000 vehicle registrations in 1976
[b] Includes taxicabs.
[c] Includes motorscooters and motorbikes.
[d] Includes farm equipment, fire equipment, ambulances, and other.
[e] This category not included in vehicle registrations.
SOURCE: National Safety Council, *Accidental Facts*.

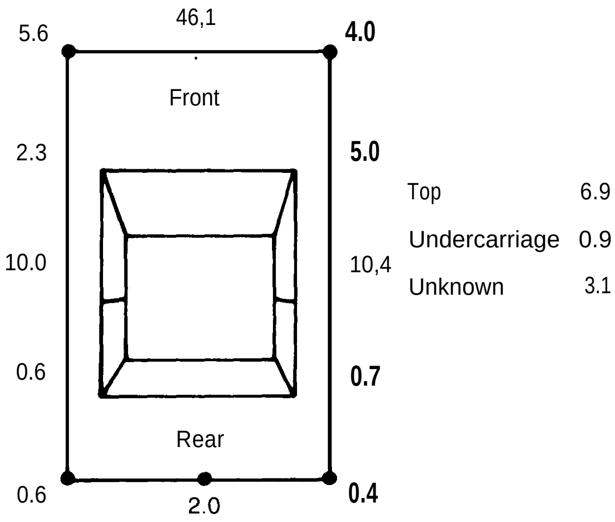
Table 78.—Fatal Crashes 1975-77 Number of Persons, Crashes, Vehicles, and Fatalities by Vehicle Type

	Persons				Crashes			
	1975	1976	1977	% Change '75-'77	1975	1976	1977	% Change '75-'77
Total	05,149	105,870	111,043	5.6	39,160	39,747	42,064	7.4
Automobile	69,292	68,442	70,772	2.1	30,122	29,967	'31 .285	3.9
Motorcycle	4.040	4,168	5,147	27,4	3,148	3,245	4,011	27.4
Buses	1,043	1,126	1,149	10.2	323	318	318	(1 .5)
Pickup/van	13,211	14,372	15,360	16.3	7,335	7,966	8,658	18,0
Heavy trucks	3,545	4,162	4,590	29.5	2,858	3,380	3,774	32.0
Other trucks	2,018	1,716	1,960	(2.9)	1,406	1,252	1,460	3.8
Other	2,447	2,504	2,421	(1 .1)	1,357	1,334	1,362	0.4
Pedestrian	8,253	8,135	8,476	2.7	7,420	7,343	7,592	2.3
Pedal cyclist	1,058	979	998	(5.7)	993	902	916	(7.8)
Other nonoccupant	242	266	220	(9.1)	155	139	135	(1 2.9)

	Vehicles				Fatalities			
	1975	1976	1977	% Change '75-'77	1975	1976	1977	% Change '75-'77
Total	55,535-	56,084	60,302	8.6	44,524	45,523	47,715	7.2
Automobile	38,330-	37,795	39,781	3.8	26,268	26,647	27,353	4.1
Motorcycle	3,265	3,343	4,143	26.9	3,189	3,312	4,083	28.0
Buses	327	319	318	(2.8)	53	73	41	(22,6)
Pickup/van	7,692	8,370	9,125	18.6	4,332	4,893	5,222	20.5
Heavy trucks	3,042	3.566	3,998	31.4	717	862	954	33.1
Other trucks	1,447	1,273	1,487	2.8	428	378	444	3.7
Other	1,432	1,418	1,450	1.3	937	937	926	(1 .2)
Pedestrian	—	—	—	—	7,516	7,427	7,705	2.0
Pedal cyclist	—	—	—	—	1,003	914	916	(8,7)
Other nonoccupant	—	—	—	—	81	80	71	(1 2,3)

SOURCE Fatal Accident Reporting System data, U S Department of Transportation, National Highway Traffic Safety Administration. Office of Statistics and Analysis

Figure 42.—Percent Distribution of Fatalities by Principal Impact Point



SOURCE Derived from U S Department of Transportation, National Highway Safety Administration, *Fatal Accident Reporting System 7976 Annual Report* November 1977

- Heavy trucks represent less than 1 percent of the vehicle fleet, but they are involved in 9 percent of the fatal crashes.[3]
- In collisions between cars and large trucks, the occupants of the car are 14 times more likely to be killed than the truck occupants.[4]

Injury

Motor vehicle injury data are not as reliable as the information on fatalities. There are several sources of injury data, each using somewhat different classifications for injury. The National Safety Council defines an injury as that which results in some degree of impairment or renders a person unable to perform regular duties or activities for a full day beyond the day of the injury (a disabling injury). The National Health Survey of the U.S. Public Health Service classifies injuries in the following categories:

- Medically Attended. —A physician was consulted (in person or by telephone) for treatment or advice within 2 weeks of the injury.
- Activity Restriction.—Causes a person to cut down on usual activities for 1 full day (does not require complete inactivity).
- Bed Disabling. —Confines a person to bed for more than one-half of the daylight hours on the day of the injury or some following day.

In 1971, the American Medical Association's Committee on Medical Aspects of Automotive Safety published the Abbreviated Injury Scale (AIS), which provides a detailed identification of the severity of injuries. The general AIS classification is:

Code	*Category*
0	No Injury
1	Minor
2	Moderate
3	Severe (Not Life-Threatening)
4	Serious (Life-Threatening, Survival Probable)
5	Critical (Survival Uncertain)
6	Maximum (Currently Untreatable)
9	Unknown

A more detailed description of the Code 3 injuries is shown in table 79 for illustrative purposes.

The 1975 injury data from the U.S. Public Health Service, the National Safety Council, and the Department of Transportation are compared in table 80. The data indicate that in 1975 about 4,000,000 persons were injured in motor vehicle crashes, and that as many as 150,000 were left with permanent physical impairment.

The U.S. Public Health Service estimated there were 5,033,000 motor vehicle injuries in 1977, 4,392,000 of which were traffic-related. (See table 81.) The National Safety Council estimates there were 1,900,000 traffic-related disabling injuries in 1977.[5]

cost

A traffic crash results in loss both to the individuals involved and to society **at large. Sev**eral efforts have been made to quantify these monetary losses. No attempt has been made to

[3]Robert Sherrill, "Raising Hell on the Highways," *New York Times Magazine*, Nov. 27, 1977, pp. 38-102.
[4]Ibid.

[5]National Safety Council, Accident Facts, 1978 preliminary condensed edition, February 1978.

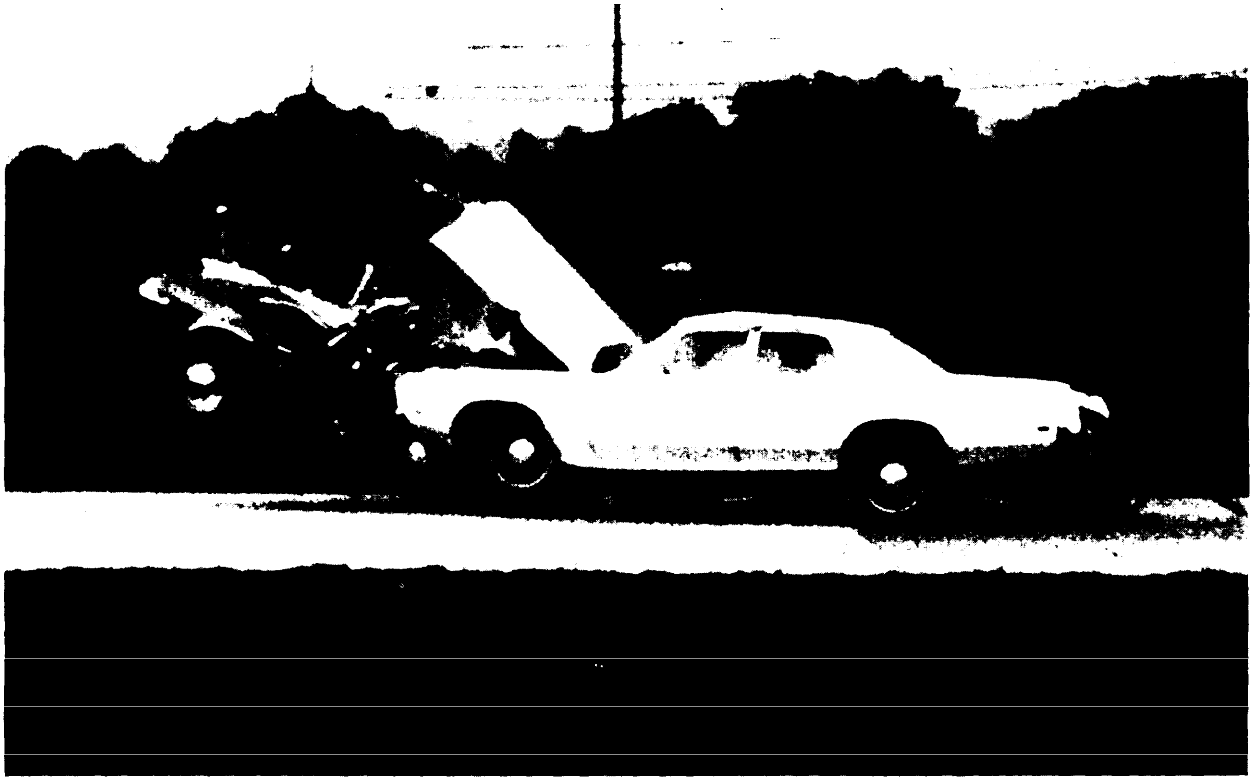


Photo Credit. Insurance Institute for Highway Safety

Table 79.—Abbreviated Injury Scale Severity Code 3: Severe (Not Life-Threatening)

General external	Head & Neck	Chest & thoracic spine	Abdomen & lumbar spine	Extremity and/or pelvic girdle
Laceration Involving major nerves and/or vessels 2" or30 burns (21 % - 30% body surface)	Cerebral concussion with or without skull fracture, unconsciousness more than 15 minutes, no other neurological signs. Cerebral concussion with displaced or depressed skull fracture, unconsciousness less than 15 minutes, no other neurological signs. Avulsion of eye or optic nerve Open and/or displaced facial bone fracture or fracture with antral or orbital Involvement. Cervical spine fracture and/or dislocation (C-4 or below) without cord damage	Thoracic cavity Injury with unilateral hemothorax or pneumothorax. Lung contusion. Thoracic spine fracture without neurological Involvement (excluding minor compression fracture). Multiple rib (2 or more) fracture with - out flail chest,	Abdominal organ contusion. Extraperitoneal bladder rupture. Diaphragm rupture, Stomach, mesentary, or urethra superficial laceration Ureter avulsion. Lumbar spine fracture without neurological Involvement (excluding minor compress ion fracture).	Displaced, comrnlnuted and/ or open fracture of long bone, hand, or foot. Displaced pelvic fracture with or without dislocation, Major joint dislocation

SOURCE American Associatlon of Automotive Medicine The *Abbreviated Injury Scale (AIS)* 1976 *revlslon*

Table 80.—Motor Vehicle Injuries, 1975

National Safety Council		U.S. Public Health Service		U.S. Department of Transportation	
Category	Number	Category	Number	Category (A IS Code)	Number
Permanent disabling	150,000	Without activity restriction	1,448,000		
Temporary disabling	1,650,000	With activity restriction	1,364,000	1	3,400,000
				2	492,000
		Bed disabling	1,647,000	3 : : : : : : : : : : : : : :	80,000
				4	20,000
				5	4,000
Total disabling injuries.	1,800,000	Total . . . . injuries	4,459,000	Total . . . . injuries	3,996,000

SOURCES: National Safety Council data *Accident Facts*, 1976 Edition; U.S. Public Health Service data from National Safety Council, *Accident Facts*, 1977 Edition, for the "Motor Vehicle (Moving)" category; U.S. Department of Transportation data, National Highway Traffic Safety Administration, *1975 Societal Costs of Motor Vehicle Accidents*, DOT HS 802119, December 1976.

Table 81 .—Injuries in the United States, 1977

Total injury	73,927,000
Motor vehicle (moving)	5,033,000
Traffic ., ...	4,392,000
Work.	11,414,000
Home.	29,588,000
Other	31,435,000

SOURCE U S Department of Health, Education, and Welfare, Public Health Service, National Center for Health Statistics

quantify the human suffering, pain, loss of relationships, and other psychological factors associated with traffic crashes. The Department of Transportation has estimated traffic crash losses in terms of: 1) resources consumed in treating personal injury and repairing vehicular damage that otherwise could be shifted in the long run to welfare-producing activities, and 2) losses in production and the ability to produce.

Table 82 shows these costs and their estimated value (in 1977 dollars). Multiplying these cost components by the number of injuries in the AIS code levels shown in table 79 and the 1977 total deaths results in an estimated cost of $43.9 billion, which includes the property damage associated with traffic crashes. (See table 82.)

The National Safety Council estimates of the costs of traffic crashes for 1976 are shown in table 83. There is considerable difference between the NSC and DOT estimates, both in the cost categories included in the totals and in the costs within similar categories.

Table 82.—Estimated Cost of Traffic Crashes in 1977 (1977 dollars)

Cost component	Injury severity (AIS) 6	5	4	3	2	1	PDO[a]	Totals $ Billions
Production/consumption								
Market	$244,480[b]	$146,180[b]	$64,115[b]	$,900	$1,000	$75	—	$14.43
Home, family, and community	73,345[b]	43,855[b]	19,230[b]	490	355	25	—	4.36
Medical:								
Hospital	340	7,130	2,790	1,360	560	55	—	0.67
Physician and other	195	6,710	2,625	640	200	65	—	0.46
Coroner-medical examiner	155			—	—	—	—	0.01
Rehabilitation	—	7,295	3,650	—	—	—	—	0.10
Funeral	1,000[b]	—	—	—	—	—	—	0.05
Legal and court	2,490	1,870	1,240	875	170	160	8	1.02
Insurance administration	425	425	410	345	320	75	45	1.46
Accident investigation	90	90	80	50	40	30	7	0.29
Losses to others	4,255	4,825	2,110	300	150	35	—	0.48
Vehicle damage	4,600	4,600	4,365	3,365	2,150	1,840	360	15.79
Traffic delay	90	70	70	185	185	185	185	4.79
Total	$331,465	$223,050	$100,885	$9,510	$5,130	$2,545	$605	
Number of occurrences[c]	47,715	4,000	20,000	80,000	492,000	3,400,000	21,900,000	
Total cost in billions of dollars	$15.82	$0.89	$2.02	$0.76	$2.52	$8.65	$13.25	$43.91

[a]Property damage only.
[b]7-percent discount rate.
[c]1977 fatality figure report from DOT, FARS data. Injury and property damage figures from original source material.
SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *1975 Societal Costs of Motor Vehicle Accidents*, DOT HS 802119, December 1976 and updated data.

Table 83.—National Safety Council Summary of Motor Vehicle Accident Costs in 1976

	Billions of dollars
Wage loss	$ 7.6
Medical expenses	2.1
Insurance administration	6.1
Property damage	8.9
Total	$24.7

SOURCE: National Safety Council, *Accident Facts*.

PRESENT POLICY

The earliest Federal Government response to the highway safety problem was in 1924, when Secretary of Commerce Herbert Hoover brought together a group of experts at the First National Conference on Street and Highway Safety. The conference addressed such matters as traffic control, construction and engineering, education, and motor vehicle design. Five additional conferences were held in the years through 1950, but no specific role for the Federal Government evolved from these efforts.

In the years following 1950, however, a more intense interest in highway safety was displayed by Congress and the executive branch. In 1954, President Eisenhower convened a White House Conference on Highway Safety and created a President's Committee for Highway Safety. The Federal Aid Highway Act of 1956 authorized the Secretary of Commerce to investigate thoroughly the Federal role in highway safety. A report of that investigation, submitted in 1959, became the basis for significant change in the Federal Government's involvement in highway safety.

Noting the increasing fatalities and injuries on the Nation's highways, President Johnson stated in his March 2, 1966, transportation message to Congress that:

> Neither private industry nor government officials concerned with automotive transportation have made safety first among their priorities. Yet we know that expensive freeways, powerful engines, and smooth exteriors will not stop the massacre on our roads.[6]

The first major Federal effort in highway safety began with the passage of the National Traffic and Motor Vehicle Safety Act of 1966 (Public Law 89-563) and the Highway Safety Act of 1966 (Public Law 89-564). This legislation called for Federal involvement in three major areas:

1. Federal safety standards for new vehicles,
2. Safety defect recall campaigns, and
3. State and local highway safety programs.

These laws directly affected the automobile industry, State and local governments, and highway users.

Motor Vehicle Safety Standards

The most important and controversial feature of Federal involvement in highway safety is the Federal Motor Vehicle Safety Standards (FMVSS). Under this program (summarized in table 84), new vehicles and vehicle components must comply with certain performance requirements before they can be sold to the public. These standards have been shown to have made a contribution to the reduction in fatality and injury rates on highways since 1966. A recent General Accounting Office study estimated that the standards might have saved as many as 28,000 lives between 1966 and 1974.[7]

In addition to about 50 Federal safety standards now in force for passenger cars, the National Highway Traffic Safety Administration (NHTSA) has indicated its intention to extend certain standards to include light trucks and to upgrade existing standards or issue new ones for passenger cars. These proposed new and revised standards are listed in table 85.

Safety Defect Recall Campaigns

NHTSA has an aggressive vehicle defect and recall program. In the period 1966 to 1975, 52.4 million vehicles were recalled. This amounted to 43 percent of the vehicles produced during that time.[8]

The effectiveness of this massive recall effort in improving vehicle safety has not been determined. For example, it is unknown at this time how many of the 52.4 million vehicles recalled were actually brought in for repair or replacement of defective components.

[6] U.S. Congress, Senate, *Highway Safety Act of 1966*, Senate Report 1302, 89th Cong., 2d sess., June 23, 1966, p. 2743.

[7] *Effectiveness, Benefits, and Costs of Federal Safety Standards for Protection of Passenger Car Occupants*, Report to the Committee on Commerce, U.S. Senate, by the Comptroller General of the United States, CED-76-121, July 7, 1976.

[8] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety '76*, DOT HS-802 427.

Table 84.—Chronology of Federal Motor Vehicle Safety Standards and Regulations

Date Issued		Standard
January 31, 1967.	Standard No 101–	Control Location. Identification, and Illumination
	Standard No, 102	Transmission Shift Lever Sequence, Starter Interlock, Transmission Braking Effect
	Standard No. 103	Windshield Defrosting and Defogging
	Standard No 104	Windshield Wiping and Washing Systems
	Standard No 105	Hydraulic Brake Systems
	Standard No. 106	Brake Hoses
	Standard No 107	Reflecting Surfaces (Chrome Trim)
	Standard No. 108	Lamps, Reflective Devices, and Associated Equipment
	Standard No. 111	Rearview Mirrors
	Standard No, 201	Occupant Protection In Interior Impact
	Standard No 203	Impact Protection for the Driver from the Steering Control System
	Standard No, 204	Steering Control Rearward Displacement
	Standard No. 205	Glazing Materials (Automobile Windshield Glass)
	Standard No 206	Door Locks and Door Retention Components
	Standard No. 207	Seating Systems
	Standard No 208	Occupant Crash Protection
	Standard No 209	Seat Belt Assembles
	Standard No 210	Seat Belt Assembly Anchorages
	Standard No 211	Wheel Nuts, Wheel Discs, and Hub Caps
	Standard No. 301	Fuel System Integrity
November 8, 1967.	Standard No 109	New Pneumatic Tires
	Standard No. 110	Tire Select ton and Rims
February 12, 1968.	Standard No 202	l-lead Restraints
April 24, 1968 .,	Standard No, 112	Headlamp Concealment Devices
	Standard No 113	Hood Latch Systems
	Standard No. 114	Theft Protection
July 3,1968	Standard No. 115	Vehicle Identification Numbers
August 13, 1968”	Standard No. 212	Windshield Mounting
December 24, 1968.	Standard No. 116	Motor Vehicle Brake Fluids
January 17, 1969	Part No. 567	Certification Regulation
	Part No. 569	Regrooved Tires
March 23, 1970 ., .,	Standard No, 213	Child Seating Systems
July 17.1970	Standard No. 118	Power-Operated Window Systems
October 22, 1970.	Standard No 214	Side Door Strength
November 5, 1970. ,	Part No 574	Tire Identification and Record keeping
December 31, 1970.	Standard No 302	Flammability of Interior Materials
February 10, 1971	Part 573	Defect Reports
February 19, 1971	Standard No. 121	Air Brake Systems
April 9, 1971.	Standard No 215	Exterior Protect Ion (Bumpers)
April 14, 1971.	Standard No. 117	Retreaded Pneumatic Tires
December 3, 1971’	Standard No. 216	Roof Crush Resistance
March 1, 1972.	Standard No 122	Motorcycle Brake Systems
	Standard No, 125	Warning Devices
March 31, 1972	Standard No 124	Accelerator Control Systems
April 4, 1972.	Standard No, 123	Motorcycle Controls and Displays
May 3.1972	Standard No 217	Bus Window Retention and Release
August 3, 1972	Standard No.126	Truck-Camper Loading
January 17, 1973	Part No. 577	Defect Notifications
January 22, 1973	Part No 555	Temporary Exemptions from Federal Motor Vehicle Safety Standards
January 31, 1973. .	Part No. 580	Odometer Disclosure Requirements
July 26, 1973 .,	Part No. 572	Anthropomorphic Test Dummy
August 9, 1973	Standard No. 218	Motorcycle Helmets
November 5, 1973	Standard No 119	New Pneumatic Tires
May 20, 1975	Part No 575	Consumer Information—Uniform Tire Quality Grading
June 9, 1975.	Standard No 219	Windshield Zone Intrusion
September, 1975	Part No 552	Petitions for rulemaking, Defect and Noncompliance Orders
	Part No 570	Vehicles in Use Inspect Ion Standards
January 19, 1976	Standard No, 120	Tire Selection and Rims for Vehicles Other Than Passenger Cars
January 22, 1976.	Standard 220	School Bus Rollover Protection
	Standard No. 221	School Bus Body Joint Strength
	Standard No. 222	School Bus Seating and Crash Protection
February 27, 1976	Part 581	Bumper Standard (Incorporates Standard 215)

SOURCE U S Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety '76*

Table 85.—Federal Motor Vehicle Safety Standards, Near-Term Improvements Under Consideration for Passenger Vehicles

Current standards	Inclusion of light trucks[a]	Upgrading of standards
FMVSS No. 201 —Occupant Protection in Interior Impact	XX	
FMVSS No. 203—impact Protection for the Driver from the Steering Control Systems	XX	X
FMVSS No. 204—Steering Control Rearward Displacement	XX	X
FMVSS No. 208—Occupant Crash Protection	X X	X[b]
FMVSS No. 213—Child Restraint Systems		X
FMVSS No. 214—Side Door Strength	XX	X
FMVSS No. 101 —Control Location, Identification, and illumination	XX	X
FMVSS No. 105—Hydraulic Service Brake, Emergency Brake, and Parking Brake Systems	XX[c]	
FMVSS No. 108—Lamps, Reflective Devices, and Associated Equipment	XX’	X
FMVSS No. 109— New Pneumatic Tires	(d)	**X**
FMVSS No. 11 1—Rearview Mirrors	X	X
FMVSS No. 114—Theft Protection	XX	X
FMVSS No. 115—Vehicle Identification		X
New **Proposed Standards’**		
Exterior Protrusions (minimize)		
Truck Rear Underride Guard (heavy trucks)		
Low Tire Pressure Warning		
Direct Fields of View		
Handling and Stability Performance Requirements		
Brake System Inspectability		
Speedometers/Odometers (limit speed indication)		

[a]Items marked X already apply; marked XX are intended to apply
[b]Upgrading quality of active seat belts prior to passive restraint requirement
[c]Will be extended to all motor vehicles (except motorcycles)
[d]For passenger car tires, many of which are used on light trucks
[e]Vehicle applicability not always specified
SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, "Five Year Plan for Motor Vehicle Safety and Fuel Economy Rulemaking and Invitation for Applications for Financial Assistance" Federal Register 43: 11100-11107, Docket No. 78-07; Notice 1, Jan. 14, 1978

State and Local Highway Safety Programs

Federal involvement in highway safety at State and local levels before 1966 was limited. States were permitted to spend some Federal-Aid Highway funds for safety projects related to highway and traffic engineering, but not for driver safety programs or other safety features of the system.

The Highway Safety Act of 1966 mandated that the Secretary of Transportation issue safety standards to be implemented by the States. The law also provided for Federal matching grants to assist States in implementing the standards and provided for withholding of Federal-Aid Highway funds (up to 10 percent) if a State failed to comply with a standard.

The Department of Transportation issued 18 standards under this act. (See table 86.) Compliance by the States has varied; in some cases, noncompliance has persisted for long periods. When DOT decided to impose sanctions, Congress, in the Highway Safety Act of 1976, placed a moratorium on sanctions and directed the Secretary to study the "adequacy and appropriateness of the standards" and report the findings by July 1, 1977.

The DOT report prepared pursuant to this direction by Congress stated that "Federal standards are generally adequate, in that they incorporate countermeasures which are believed to ultimately reduce accidents. "[9] DOT recommended "that mandatory compliance with each of the present 18 standards no longer be required. " In certain critical areas, however, DOT stated that national conformity should still be required and that the pertinent standards should be maintained.

Legislation to this effect was proposed by the Carter Administration, but was rejected by Congress. However, the Highway Safety Act of 1978 does grant limited waivers regarding the 18 standards for States with approved alternate highway safety programs.

[9]U.S. Department of Transportation, National Highway Traffic Safety Administration, *An Evaluation of the Highway Safety Program. A Report to the Congress from the Secretary of Transportation*, July 1, 1977.

[10]U.S. House of Representatives, 95th Congress, *Surface Transportation Assistance Act of 1978*, Conference Report No. 95-1797, Oct. 14, 1978.

Table 86.— Federal Highway Safety Program Standards

Standard No. l—Periodic Motor Vehicle Inspection (NHTSA): To increase the likelihood that every vehicle operated on the public highways is properly equipped and is being maintained in safe operating order.

Standard No. 2—Motor Vehicle Registration (NHTSA): To provide a means of identifying the owner and the type, weight, size, and carrying capacity of all vehicles licensed to operate in the State.

Standard No. 3—Motorcycle Safety (NHTSA): To ensure that motorcycles, motorcyclists, and their passengers meet standards that contribute to safe operation and protection from injuries.

Standard No. 4—Driver Education (NHTSA): To ensure that every eligible high school student has the opportunity to enroll in a course of instruction designed to train him to drive skillfully and as safely as possible, under all traffic and roadway conditions.

Standard No. 5—Driver Licensing (NHTSA): To improve the quality of driving by requiring more effective and uniform licensing procedures.

Standard No. 6—Codes and Laws (NHTSA): To eliminate all major variations in traffic codes, laws, and ordinances on given aspects of highway safety, among political subdivisions in a State, and to further the adoption of appropriate sections of the Uniform Vehicle Code.

Standard No. 7— Traffic Courts (NHTSA): To provide prompt, impartial adjudication of proceedings involving motor vehicle and traffic laws.

Standard No. 8—Alcohol in Relation to Highway Safety (NHTSA): To broaden the scope and number of activities directed toward reducing traffic accidents arising in whole or in part from persons driving under the influence of alcohol.

Standard No. 9—identification and Surveillance of Accident Locations (FHWA): To identify specific highway locations which have high or potentially high accident experience, as a basis for establishing priorities for improvements to eliminate or reduce the hazards.

Standard No. 10—Traffic Records (NHTSA): To improve the quality of traffic records systems, to include and have readily available all data necessary to the operating agencies responsible for highway safety.

Standard No. 1 l—Emergency Medical Services (NHTSA): To provide an emergency care system for quick identification and response to accident injuries, to sustain life through first aid, and to coordinate the transportation and communications necessary to bring together the injured and definitive medical care in the shortest possible time.

Standard No. 12—Highway Design, Construction, and Maintenance (FHWA): To maintain existing streets in a condition to promote safety, to modernize or build new roads to meet safety standards, and to protect motorists from accidents at construction sites.

Standard No. 13—Traffic Engineering Services (formerly Traffic Control Devices) (FHWA): To assure application of modern traffic engineering principles and uniform standards for traffic control.

Standard No. 14—Pedestrian Safety (NHTSA and FHWA); To emphasize the recognition of pedestrian and pedal cyclist safety as an integral, constant, and important element in community planning, and to ensure continuing programs to improve such safety.

Standard No. 15—Police Traffic Services (NHTSA): To improve police traffic services in all aspects of accident prevention. and to bring errant drivers to justice.

Standard No. 16—Debris Hazard Control and C/can-up (NHTSA): To provide for the planning, training, coordination, and communication needed to assure prompt correction of conditions that constitute potential traffic dangers.

Standard No. 17—Pupil Transportation Safety (NHTSA): To reduce the danger of death or injury to school children being transported to and from school, by setting requirements for safe equipment and its maintenance, and for training and supervision of drivers and maintenance personnel.

Standard No. 18—Accident Investigation and Reporting (NHTSA): To establish a uniform, comprehensible, accident investigation program to gather information on traffic accidents and enter it into the traffic records system for use in furthering highway safety.

SOURCE U S Department of Transportation National Highway Traffic Safety Adminitration, Traffic Safety 76

Other Related Policies

Under the Motor Vehicle Information and Cost Savings Act of 1972 (Public Law 92-513), NHTSA was directed to determine crash susceptibility, crashworthiness, associated insurance costs, and ease of diagnosis and repair of mechanical and electrical problems for automobiles. The information must be made known to the public for each make and model of car. Also included under this legislation is the "bumper standard" (Part 581 of the Act). The "no-damage" requirement is intended primarily to save consumers monetary loss associated with low-speed collisions, but there may also be marginal safety benefits that accrue. Except for Part 581, the provisions of this Act have not yet been implemented by NHTSA.

There are also safety benefits associated with other policies not specifically directed at safety. Prominent among these are:

- New highway construction and reconstruction under the Federal-Aid Highway Act and the growing use of the Interstate System during the past 10 years. These roads are built to very high safety standards and have fatality rates significantly lower than local roads built to lower standards.
- The 55 mph national speed limit, originally enacted as an energy conservation measure, appears to have brought safety benefits as well. Retention and enforcement of the 55 mph speed limit is now justified by many experts on both safety and energy conservation grounds.

PROJECTIONS

While the rate of fatal crashes per vehicle mile has steadily decreased over the past 50 years, the number of crashes—and the resulting death and injury—has been growing just as steadily, largely because there have been more drivers, more vehicles, and more miles traveled. Projections of highway fatalities and injuries to 2000 are influenced by several factors that may increase the severity and magnitude of the future traffic safety problem:

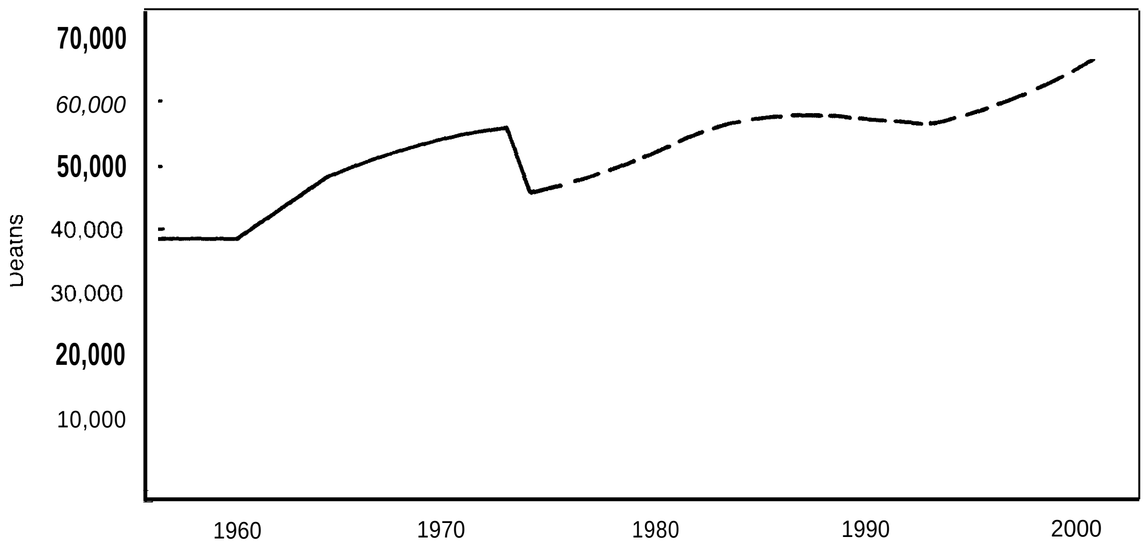
- VMT are expected to keep rising, as will the number of vehicles and drivers.
- The average size and weight of the automobile fleet are expected to decline.
- The percentage of trucks in the fleet and truck VMT are expected to increase.
- Highways are deteriorating at a rate faster than they are being maintained. Unless maintenance is emphasized, the condition of roads could contribute to an increase in crashes.

Other factors are expected to have a countervailing effect:

- The use of passive restraints will reduce vehicle occupant deaths and injuries.
- Changes in the age distribution of drivers—fewer younger drivers and more female drivers—may tend to lower the fatal crash rate. On the other hand, more drivers over the age of 65 may adversely affect the fatal crash rate.
- The proportion of vehicles equipped to meet present safety standards will increase.

Estimates based on these factors indicate that crashes, injuries, and fatalities will increase in the years to come. By 2000, it is projected that there will be approximately 64,000 deaths and over 5 million injuries annually. The total traffic deaths from 1977 to 2000 will exceed 1 million and injuries could reach as high as 130 million. (See figure 43.)

Figure 43.—Motor Vehicle Deaths, 1955 to 2000



SOURCE OTA propctlon using Base Case VMT adjusted for total vehicle travel

ISSUES AND POLICIES

In the last century technology has changed radically the way people live and the way they die. Infectious disease as a cause of death has virtually been eliminated. A child born in the United States today can look forward to a life untroubled by common diseases such as smallpox, scarlet fever, diphtheria, tuberculosis, typhoid fever, and polio, which were major causes of death a few generations ago.[11] Today, however, that same child is confronted with the prospect that from age 1 to 39, he or she is more likely to die in a motor vehicle crash than in any other manner.

Traffic safety is a modern sociotechnical problem, created by the interaction of humans, highways, and motor vehicles. Improvements in traffic safety will depend on adjustments or changes in the vehicles, in highways, and in the way people use them. The issues and policies considered in this study revolve around these changes.

Issues

In the course of this assessment, eight safety issues were identified and examined. These issues address the level of Federal involvement in safety, the priorities and allocation of safety activities, the application of safety technology, the methodologies used to select and evaluate safety strategies, and the distribution of safety costs. The issues are presented in table 87.[13] They have been developed to guide the formulation and evaluation of policy alternatives, and the identification of potential policy impacts.

The issues that address the role of the Federal Government in traffic safety, the level of involvement, and the questions of establishing priorities for safety strategies have been the subject of intense debate over the years, and this debate is unlikely to subside. Many considerations bear on these issues:

- the severity of the problem,

[11]John Cairns, "The Cancer Problem," *Scientific American* Volume 233, November 1975, pp. 64-72.

[12]Computed from data from the National Center for Health Statistics.

[13]A discussion of the issues is contained in a working paper prepared by the OTA staff, *Issues Involved in the Study of the Potential Changes in the Characteristics and Use of the Automobile Transportation System* OTA, Oct. 21, 1977.

Table 87. Safety Issues

Goals. —By what process should the Federal Government set safety goals for the automobile transportation system, and in what forms should these goals be expressed—quantitative, qualitative?

Involvement.—To what extent and how does the achievement of safety goals require Federal Government involvement with the automobile transportation industry, State, and local governments? Private institutions and the general public/individuals? What should be the roles of each of these groups?

Methodologies. —To what extent should the Federal Government use benefit-cost, cost effectiveness, or other methodologies to assess automobile safety strategies and improvements?

Requirements. —Should the Federal Government set minimum safety requirements for each class of vehicle, highway, and user? If so, how should those requirements and associated risk management activities be set pertaining to safety at entry, in operation, and at reentry?

Priorities and Allocation.—How should the Federal Government set priorities for achieving safety goals among strategies dealing with vehicles, highways, and system users?

Technology .—What should the Federal Government do to decrease the time to attain general usage of proven safety advances?

Involvement. —Should the Federal Government impose upon the automobile transportation system safety measures beyond those which individuals, governments, and industry perceive as necessary to control risk? What steps should the Federal Government take to improve the understanding of individuals, governments, and industry of the nature of risk and benefits of managing risks?

Costs.— How should the Federal Government determine how the cost of safety is allocated? Who should pay? How much? When? By what means?

- the responsibility of the Federal Government in matters affecting the public health,
- the resources available,
- questions of individual freedom and choice,
- public and private sector interests, and
- public attitudes and opinions.

There is general agreement that the traffic safety problem is severe and worthy of serious attention, but there is debate over what to do about the problem, No single stakeholder group in the automobile transportation system is wholly responsible for traffic crashes, and no single stakeholder could effectively or completely solve the safety problem. Likewise, there is no unanimous “public opinion” on the technical and political feasibility of solutions.

Although there is no one solution and no single party responsible for action, there are many technical features of the automobile transportation system and many behavioral aspects of highway users which, if altered, could make partial contributions to a reduction in highway losses. The marketplace has not provided sufficient incentive to bring about these changes. Thus, Federal initiative and Federal involvement appear to be appropriate.

For many years highway crashes were generally considered “accidents” caused by individuals, and hence an individual problem. Although this view is still held by some, there is growing awareness that traffic crashes, and the resulting death and injury, are a community problem not borne solely by the individuals involved. This view leads to a broad, and more objective framework for assessing traffic safety problems, developing countermeasures, and establishing priorities among them.

There is little debate over the cause of crashes. The majority of traffic crashes are caused by the vehicle drivers, although roadway and vehicle features may contribute to the cause of about one-third of all crashes. (See table 88.) The issue of establishing priorities centers on whether safety strategies should focus on crash prevention or crash severity reduction. Crash prevention strategies apply countermeasures to eliminate the cause of crashes, thus their occurrence. Crash severity reduction strategies seek to prevent or minimize injury when a crash occurs.

Table 88.—Traffic Crash Causation

Element	Estimated percentage of crash causation
Vehicle.	4-12
Highway	10-30
Driver.	70-90
Violation	20-30
Decision	20-30
Attention.	40-60

SOURCE U S Department of Transportation, National Highway Traffic Safety Administration, *Tri-Level Study of the Causes of Traffic Accidents Final Report.* Vol. I: Causal Factor Tabulations and Assessments, prepared by the Institute of Research in Public Safety, Mar. 31, 1977; National Safety Council, *Accident Facts*

It is difficult to find effective countermeasures for the driver-related crash causation categories shown in table 88. The effectiveness of traffic laws in preventing improper driver behavior appears to be limited, and the magnitude and extent of law enforcement is subject to public approval. Various forms of driver education and training might reduce the rate of decision errors, but the degree of improvement attainable by such measures has not been demonstrated.

The largest factor of crash causation, driver inattention, **also** does not lend itself to practical countermeasures. Driving, especially in the United States, is a relatively simple, repetitive task requiring a low level of conscious decision-making. Highways and vehicles have been designed to make the driving task easier and more comfortable. It is likely that human error will continue to be a major cause of traffic crashes, unless ways are found to augment the performance of the driver with automatic control systems.

The vehicle factors that are the primary causes of crashes are defects in brakes, wheels, and tires. The leading highway features that cause or contribute to crashes are obstructed view and slick roads.

The mechanisms that cause injury and death, and the types of bodily damage incurred in crashes, are well known. The chief mechanism is abrupt decelerative dissipation of kinetic energy in crashes. Vehicle occupants sustain injury when striking the interior of the vehicle during a crash, Passengers ejected from vehicles in collisions suffer injury from impact with the vehicle and the ground, highway, or other structures. Pedestrians and cyclists are injured by striking, or being struck by, the vehicle and by the subsequent impact with the roadway or ground. The method to reduce injury is to spread the impact forces over a greater surface area and a longer time, thus reducing the severity of the contact.[14] Crash severity reduction strategies can be effective, and reasonably amenable to evaluation. Highway design features, if properly maintained, would remain throughout the life of the highway. Safety design criteria for motor vehicles, once established, would also be long-lasting.

[14]W. Haddon, Jr., and Susan P. Baker, *Injury Control, Insurance Institute for Highway Safety*, March 1978.

Photo Credit: U.S. Department of Transportation

In summary, for long-range determination of safety priorities, an analytical framework that embraces all loss-reduction strategies is appropriate. Each safety strategy must be evaluated for its potential effects, impacts, and feasibility of implementation. Thus, a comprehensive analysis of strategies is required to determine priorities among them.

Policy Framework

Figure 44 shows a policy framework based on a functional subdivision of the automobile transportation system. This framework helps identify policies and related issues applicable to safety countermeasures. The framework specifies a programmatic approach to each component of the system. Issues are related to programs in hierarchical levels. An abbreviated listing of policy areas is shown under the boxes representing system elements in figure **44.** A policy analysis flow diagram is depicted in figure **45.**

Highway Design

Highway design and condition can contribute to both the frequency and severity of traffic crashes. The *National Highway Safety Needs Report*[15] (hereafter referred to as the "Needs" report), identified 37 safety countermeasures, including 19 related to highway design features. Tables 89, 90, and 91 list these countermeasures, and rank them by cost-effectiveness, cost to implement, and potential to forestall death and injury. Table 92 shows the 19 highway design-related countermeasures.

The "Needs" report estimated that these 19 highway improvements could save about **34,000** lives and a million injury-producing accidents over a 10-year period. The actual benefits of these countermeasures could be even greater because most would be maintained well over 10 years and would continue to accrue the benefits of reduced death and injury.

[15] U.S. Department of Transportation, Office of the Secretary, *National Highway Safety Needs Report*, April 1976.

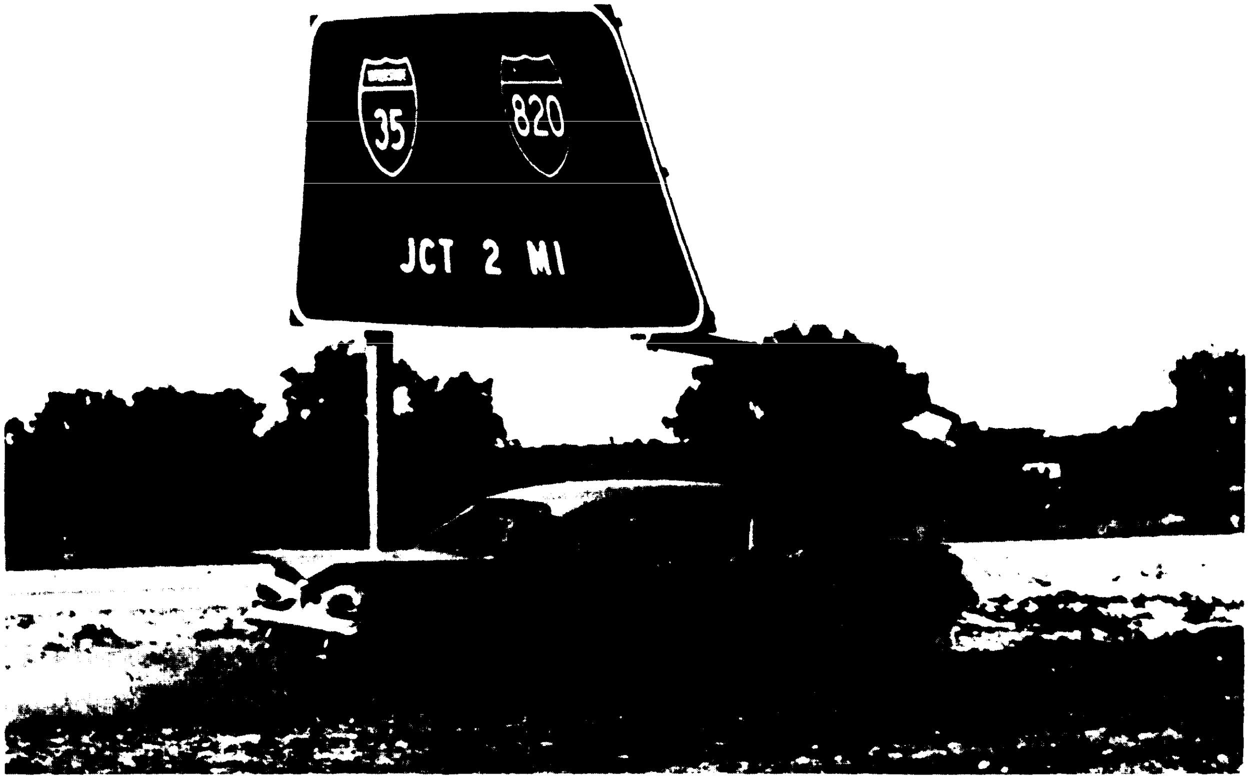


Photo Credii U S Department of 7ransportation

Figure 44.—issues, Policies, and Strategies for Traffic Safety

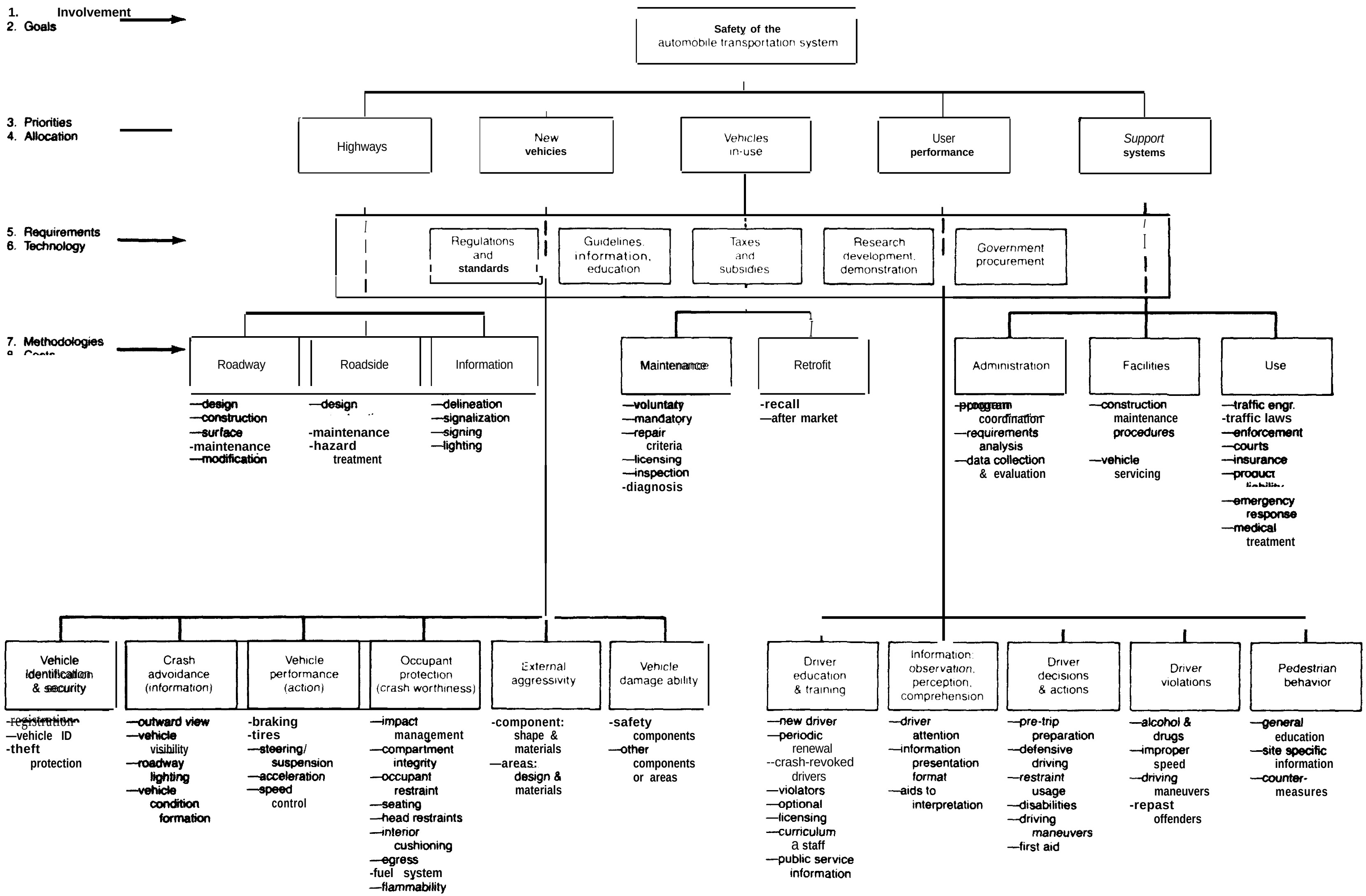


Figure 45.—Policy Analysis Flow Diagram

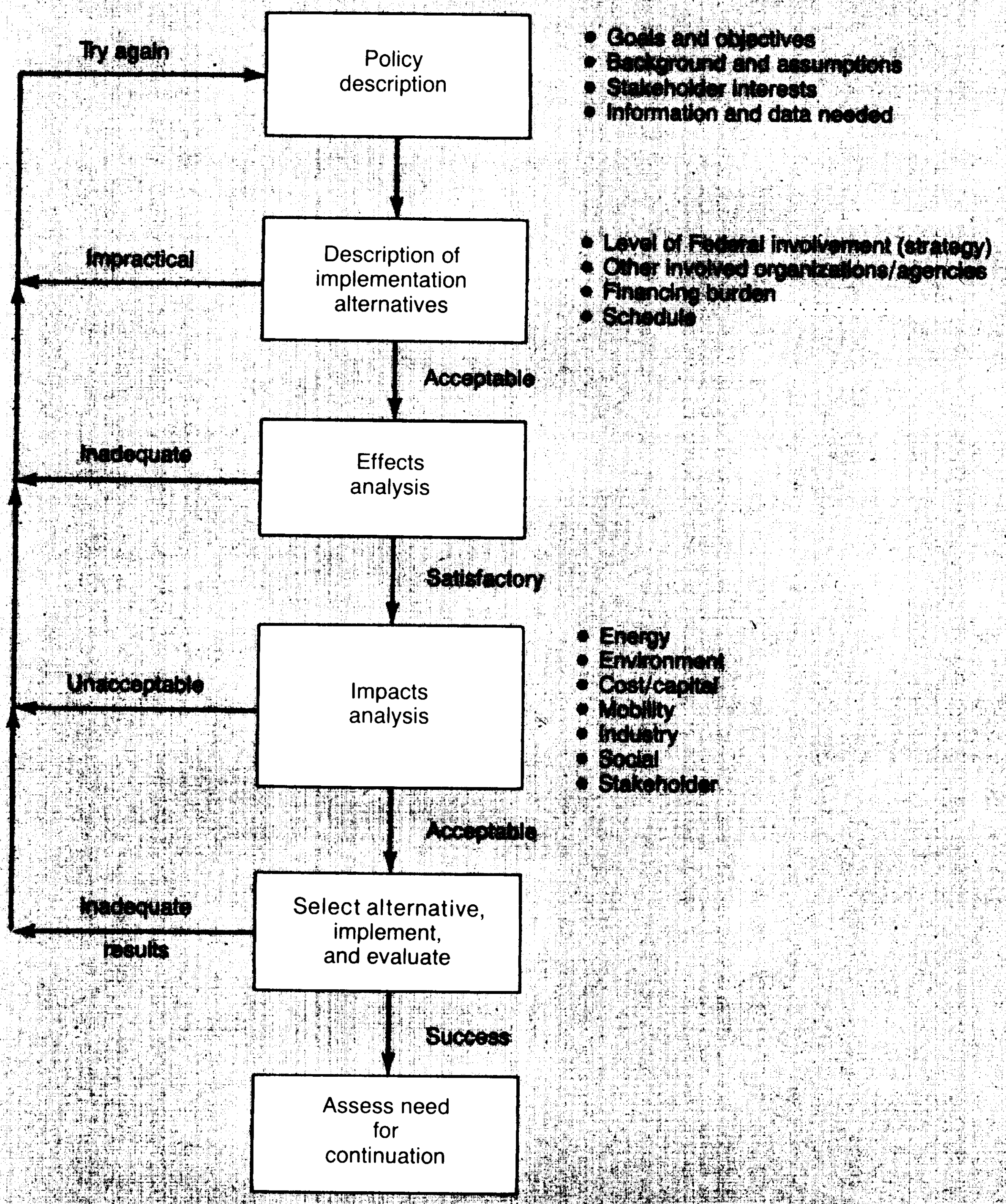


Table 89.—Ranking of Countermeasures by Decreasing Cost-Effectiveness in Present Value Dollars Per Total Fatalities Forestalled— 10-Year Total

Countermeasure	Fatal i ties forestalled (A)	cost ($ millions) (B)	Dollars per fatality forestalled (c)
1. Mandatory safety belt usage	**89,000**	$ 45.0	**$ 506**
2. Highway construction and maintenance practices	**459**	9.2	**20,000**
3. Upgrade bicycle and pedestrian safety curriculum offerings	**649**	13.2	**20,400**
4. Nationwide 55 mph speed limit.	**31,900**	676.0	**21,200**
5. Driver improvement schools	**2,470**	53.0	**21,400**
6. Regulatory and warning signs.	**3,670**	125.0	**34,000**
7. Guardrail	**3,160**	108.0	**34,100**
8 Pedestrian safety information and education	**490**	18.0	**36,800**
9 Skid resistance	**3,740**	158.0	**42,200**
10 Bridge rails and parapets	**1,520**	69.8	**46,000**
11 Wrong-way entry avoidance techniques	**779**	38.5	**49,400**
12 Driver improvement schools for young offenders	**692**	36.3	**52,500**
13 Motorcycle rider safety helmets	**1,150**	61.2	**53,300**
14. Motorcycle lights-on practice.	**65**	5.2	**80,600**
15. Impact-absorbing roadside safety devices	**6,780**	735.0	**108,000**
16. Breakaway sign and lighting supports	**3,250**	379.0	**116,000**
17. Selective traffic enforcement	**7,560**	1,010.0	**133,000**
18. Combined alcohol safety action countermeasures	**13,000**	2,130.0	**164,000**
19. Citizen assistance of crash victims	**3,750**	784.0	**209,000**
20. Median barriers	**529**	121.0	**228,000**
21. Pedestrian and bicycle visibility enhancement.	**1,440**	332.0	**230,000**
22. Tire and braking system safety critical inspection—selective	**4,591**	1,150.0	**251,000**
23. Warning letters to problem drivers	**192**	50.5	**263,000**
24. Clear roadside recovery area	**533**	151.0	**284,000**
25. Upgrade education and training for beginning drivers	**3,050**	1,170.0	**385,000**
26. Intersection sight distance	**468**	196.0	**420,000**
27. Combined emergency medical countermeasures	**8,000**	4,300.0	**538,000**
28. Upgrade traffic signals and systems	**3,400**	2,080.0	**610,000**
29. Roadway lighting	**759**	710.0	**936,000**
30. Traffic channelization.	**645**	1,080.0	**1,680,000**
31. Periodic motor vehicle inspection—current practice.	**1,840**	3,890.0	**2,120,000**
32. Pavement markings and delineators.	**237**	639.0	**2,700,000**
33. Selective access control for safety	**1,300**	3,780.0	**2,910,000**
34. Bridge widening	**1,330**	4,600.0	**3,460,000**
35. Railroad-highway grade-crossing protection (automatic gates(excluded)	**276**	974.0	**3,530,000**
36. Paved or stabilized shoulders	**928**	5,380.0	**5,800,000**
37. Roadway alinement and gradient	**590**	4,530.0	**7,680,000**

SOURCE US Department of Transportation Office of the Secretary, National *Highway Safety Needs Report, April 1976*

Table 90.—Ranking of Countermeasures by Increasing Costs of Implementation in Present Value Dollars—10-Year Total

Countermeasure	cost ($ million)
1. Motorcycle lights-on practice	$ 5.2
2. Highway construction and maintenance practices,	9.2
3. Upgrade bicycle and pedestrian safety curriculum offerings.	13.2
4. Pedestrian safety information and education	18.0
5. Driver improvement schools for young offenders	36.0
6. Wrong-way entry avoidance techniques.	38.5
7. Mandatory safety belt usage	45.0
8. Warning letters to problem drivers	50.5
9. Driver improvement schools	53.0
10. Motorcycle rider safety helmets	61.2
11. Bridge rails and parapets	69.8
12. Guardrail	108.0
13, Median barriers	121.0
14. Regulatory and warning signs	125.0
15. Clear roadside recovery area	151.0
16. Skid resistance	158.0
17. Intersection sight distance	196.0
18. Pedestrian and bicycle visibility enhancement	332.0
19. Breakaway sign and lighting supports	379.0
20. Pavement markings and delineators.	639.0
21. Nationwide 55 mph speed limit	676.0
22, Roadway lighting.	710.0
23. Impact-absorbing roadside safety devices.	735.0
24. Citizen assistance of crash victims.	784.0
25, Railroad-highway grade-crossing protection (automatic gates excluded)	974.0
26. Selective traffic enforcement	1,010.0
27, Traffic channelization.	1,080.0
28. Tire and braking system safety critical inspection—selective.	1,150.0
29. Upgrade education and training for beginning drivers.	1,170.0
30. Upgrade traffic signals and systems.	2,080.0
31. Combined alcohol safety action countermeasures.	2,130.0
32. Selective access control for safety	**3,780.0**
33. Periodic motor vehicle inspection—current practice.	**3,890.0**
34. Combined emergency medical countermeasures	**4,300.0**
35. Roadway alinement and gradient	**4,530.0**
36. Bridge widening	**4,600.0**
37. Paved or stabilized shoulders	**5,380.0**
Total	$41,600.0

SOURCE: U.S. Department of Transportation, Office of the Secretary, *National Highway Safety Needs Report*, April 1976.

Table 91 .—Ranking of Countermeasures by Decreasing Potential To Forestall Fatalities and Injury Accidents— 10-Year Total

Countermeasure	Fatalities forestal led (A)	Injury accidents forestalled (B)
1. Mandatory safety belt usage . . .	89,000	3,220,000
2. Nationwide 55 mph speed limit .	31,900	415,000
3. Combined alcohol safety action countermeasures	13,000	153,000
4. Combined emergency medical countermeasures	8,000	146,000
5. Selective traffic enforcement . .	7,560	296,000
6. Impact-absorbing roadside safety devices	6,780	158,000
7. Tire and braking system safety critical inspection—selective . .	4,590	80,000
8 Citizen assistance of crash victims	3,750	
9 Skid resistance	3,740	95,000
10 Regulatory and warning signs . .	3,670	43,000
11 Upgrade traffic signals and systems	3,400	33,000
12 Breakaway sign and lighting supports.	3,250	27,000
13 Guardrail.	3,160	52,800
14 Upgrade education and training for beginning drivers.	3,050	31,000
15 Driver improvement schools . . .	2,470	13,000
16 Periodic motor vehicle inspection—current practice	1,840	71,900
17 Bridge rails and parapets	1,520	15,300
18 Pedestrian and bicycle visibility enhancement.	1,440	24,200
19 Bridge widening.	1,330	51,000
20 Selective access control for safety	1,300	50,300
21. Motorcycle rider safety helmets	1,150	14,400
22. Paved or stabilized shoulders . .	928	35,800
23. Wrong-way entry avoidance techniques , ...	779	3,290
24. Roadway lighting.	759	29,600
25. Driver improvement schools for young offenders	692	27,000
26. Upgrade bicycle and pedestrian safety curriculum offerings	649	11,200
27. Traffic channelization	645	31,500
28. Roadway alinement and gradient	590	23,000
29. Clear roadside recovery area . . .	533	20,700
30. Median barriers	529	2,740
31. Pedestrian safety information and education	490	19,200
32. Intersection sight distance	468	18,300
33. Highway construction and maintenance practices.	459	18,000
34. Railroad-highway grade-cross-*protection* (automatic gates excluded)	276	1,080
35. Pavement markings and delineators.	237	9,210
36. Warning letters to problem drivers.	192	3,760
37. Motorcycle lights-on practice . .	65	1,680

SOURCE: U.S. Department of Transportation, Office of the Secretary, *National Highway Safety Needs Report*, April 1976.

Table 92.—Countermeasures Related to Highway Design—10 Year Total (dollars in millions of 1977 constant dollars)

	Estimated deaths forestalled, cumulative	Estimated injuries forestalled, cumulative	Estimated societal costs forestalled, cumulative	Estimated cost of countermeasure cumulative
1. Regulatory and warning signs	3,670	371,800	$ 2,633	$ 250
2. Guardrail	6,830	509,100	4,204	466
3. Skid resistance	10,570	1,016,100	7,375	782
4. Bridge rails and parapets	12,090	1,055,900	8,031	922
5. Wrong-way entry avoidance techniques	12,869	1,064,500	8,322	999
6. Impact-absorbing roadside safety devices	19,649	1,457,300	12,135	2,469
7. Breakaway sign and lighting supports	22,899	1,805,500	14,470	3,227
8. Median barriers	23,428	1,876,700	14,917	3,469
9. Clear roadside recovery area	23,961	1,930,500	15,299	3,771
10. Intersection sight distance	24,429	1,978,100	15,636	4,163
11. Upgrade traffic signals and systems	27,829	2,323,900	18,081	8,323
12. Roadway lighting	28,588	2,400,900	18,626	9,743
13. Traffic channelization	29,233	2,482,800	19,152	11,903
14. Pavement marking and delineators	29,470	2,506,700	19,322	13,181
15. Selective access control for safety	30,770	2,637,500	20,251	20,741
16. Railroad-highway grade-crossing protection	31,046	2,640,300	20,353	22,689
17. Bridge widening	32,376	2,772,900	21,299	31,889
18. Shoulders	33,304	2,866,000	21,961	42,649
19. Roadway alinement and gradient	33,894	2,925,800	22,384	51,709

SOURCE OTA, using U S Department of Transportation, Off Ice of the Secretary, *National Highway Safety Needs Report,* April 1976.

There would be a sizable savings associated with forestalled death and injury. For the 10-year period, using the cost data in table **82,** the social costs forestalled would be $ll.2 billion for **34,000** deaths. Assuming **2.6** injuries per injury-producing crash that is forestalled and an average injury cost of $3,809, the total injury costs forestalled would be $11.1 billion. The total societal costs forestalled would be **$22.3** billion in 1977 constant dollars and 1977 costs. (See table 92.)

The total cost of implementing these 19 highway design features is estimated in the

Photo Credit Department of *Transportation*

"Needs" report to be $26 billion over 10 years in present value dollars (from 1974 estimates). This cost estimate converted to 1977 constant dollars is $49 billion over 10 years. If this cost were spent evenly over a 10-year period, there would be approximately 15-percent additional burden on the highway-financing structure (about 4 mills, or four-tenths of a cent, for every 100 vehicle miles traveled). The principal beneficiaries of this transfer of funds would be the State and local highway departments and the highway design and construction industry, which would receive increased employment and revenues.

Cost-benefit comparison is hampered by inadequacy of data and by uncertainty about their interpretation. For example, the cost of an injury forestalled may not equal the average cost of an injury, but instead might be the net cost of replacing a severe injury with a minor injury plus the cost of a minor injury forestalled, However, the available data can be organized to show how the cost-benefit analysis might apply to program development. Table 92 contains the 19 highway design features ranked in order of decreasing cost-effectiveness. The cumulative expenditures are tabulated, along with the cumulative societal costs forestalled. A hypothetical, economic-oriented, cost-benefit ratio of 1:1 occurs at about item 15 on the Iist of 19 items.

The energy impacts of these highway improvements would be primarily in the use of additional construction energy. Mobility would be enhanced by safer highways, but highway capacity, speed, etc., would not change much as a result of these features. Environmental impacts would result from the use of wider rights-of-way, and the clearance of trees, rock outcropping, etc. Landowners of adjacent properties also would be impacted in some cases. Roadside right-of-way regulations now permit the installation of utility poles, which would have to be moved. Alternatively, the utility lines could be put underground.

Vehicle Design Features

The current Federal Motor Vehicle Safety Standards and proposed additions or amendments were presented earlier, in tables 84 and 85. There is some evidence that these safety standards are saving lives and reducing injuries and that benefits exceed costs.[16] The passive restraint standard, effective for all cars by the 1984 model year, has also been shown to be cost-effective.[17] When the fleet is fully equipped with passive restraints in the 1990's, DOT estimates that about 9,ooo lives will be saved annually in addition to the estimated 3,oOO lives saved annually through the use of seat belts. (See table 93.) Further evaluation of other Federal Motor Vehicle Safety Standards is in progress, and some modifications are expected by the early 1980's, in accordance with a 5-year plan recently released by DOT. (See table 85.)

The long-range objective in vehicle safety is to have on the market an affordable automobile that offers high levels of safety, damage resistance in low-speed collisions, and protective features to mitigate pedestrian and cyclist injury. The Research Safety Vehicle (RSV) program of DOT is demonstrating that such a goal is achievable within the state of current technology,[18] Figure 46 shows two versions of vehicles designed under this program.

Table 94 shows requirements for three levels of crashworthiness. Research Safety Vehicles, such as those illustrated in figure 46, are exceeding Level II and approaching Level III crashworthiness specifications. The results of the RSV program to date indicate that a four- or five-passenger vehicle, approaching Level 111 requirements and meeting fuel-economy and emission standards, can be manufactured for about $800 more than a similar vehicle meeting today's safety standards.[19] Further work in the program is aimed at reducing that cost to, perhaps, as low as $4oo.

Accurately determining the necessary level of vehicle crashworthiness, occupant protection, and crash avoidance features for the vehicle

[16] *Effectiveness, Benefits, and Costs of Federal Safety Standards for Protection of Passenger Car Occupants.*

[17] Allstate Insurance Company, *Automotive Occupant Protective Safety Air Cushion Expenditure/Benefit Study,* prepared by the John Z. DeLorean Corporation, August 1975.

[18] Ronald L. Braun, "Toward Safer Motor Vehicles," *IEEE Spectrum,* November 1977, pp. 80-86.

[19] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Research Safety Vehicle Program* (Phase II), Final Report, Volumes I-III, prepared by Calspan Corporation, Report Nos. 802250, 8022.51, 802252, February 1977.

Table 93

Part A.—Occupant Crash Protection System Effectiveness Estimates'

A IS injury level	Lap belt	Lap and shoulder belt	Air cushion	Air cushion and lap belt	Passive belt and knee bolster	Knee bolster
1	0.15	0.30	0	0.15	0.20	0.06
2	.22	.57	.22	.33	.40	.10
3	.30	.59	.30	.45	.45	.15
4-6 :	.40	.60	.40	.66	.50	.15

[a]Effectiveness shown as fraction of persons not injured in specified injury category who otherwise would be without the use of a restraint system

Part B.— Effectiveness of Occupant Crash Protection Systems[b]

	Fatalities prevented per year	Injuries prevented per year (A IS 2-5)
Lap and shoulder (15 percent) and lap (5 percent) belts (nominal projection). . .	3,000	39,000
Lap and shoulder (35 percent) and lap (5 percent) belts (optimistic projection).	6,300	86,000
Lap and shoulder belt (70 percent usage).	11,500	162,000
Lap and shoulder belt (100 percent usage).	16,300	231,000
Lap belt (100 percent usage).	10,900	96,000
Driver-on I y air cushion:[c]		
Nominal projection	**9,600**	86,000
Optimistic projection	11,500	107,000
Full-front air cushion:		
Nominal projectional	12,100	104,000
Optimistic projection.	13,500	115,000
Passive belts:		
Nominal projection.	9,800	117,000
Optimistic projecting	10,700	129,000

[b]These estimates assume the car population and occupant fatality rates to be that of 1975 (approximately 100,000,000 cars and 27,200 people, respectively), 10,000,000 cars to be manufactured annually, and the distribution of injuries by severity to be the same as in 1975.
[c]Belt use for this mixed active and passive system is assumed to be the same as for the active belts for the passenger and the same as the air cushion system for the driver. These estimates assume 72.56 percent of front seat occupants are drivers.
[d]Assumes 20 percent lap belt usage by all front seat occupants.
[e]Assumes 40 percent lap belt usage by all front seat occupants.
[f]Assumes 60 percent passive belt usage, i.e., 40 percent of people defeat the system.
[g]Assumes 70 percent passive belt usage, i.e., 30 percent of people defeat the system.
SOURCE: Brock Adams, Secretary of Transportation, U.S. Department of Transportation, *Motor Vehicle Occupant Crash Protection*, House Document No. 95-177, June 30, 1977

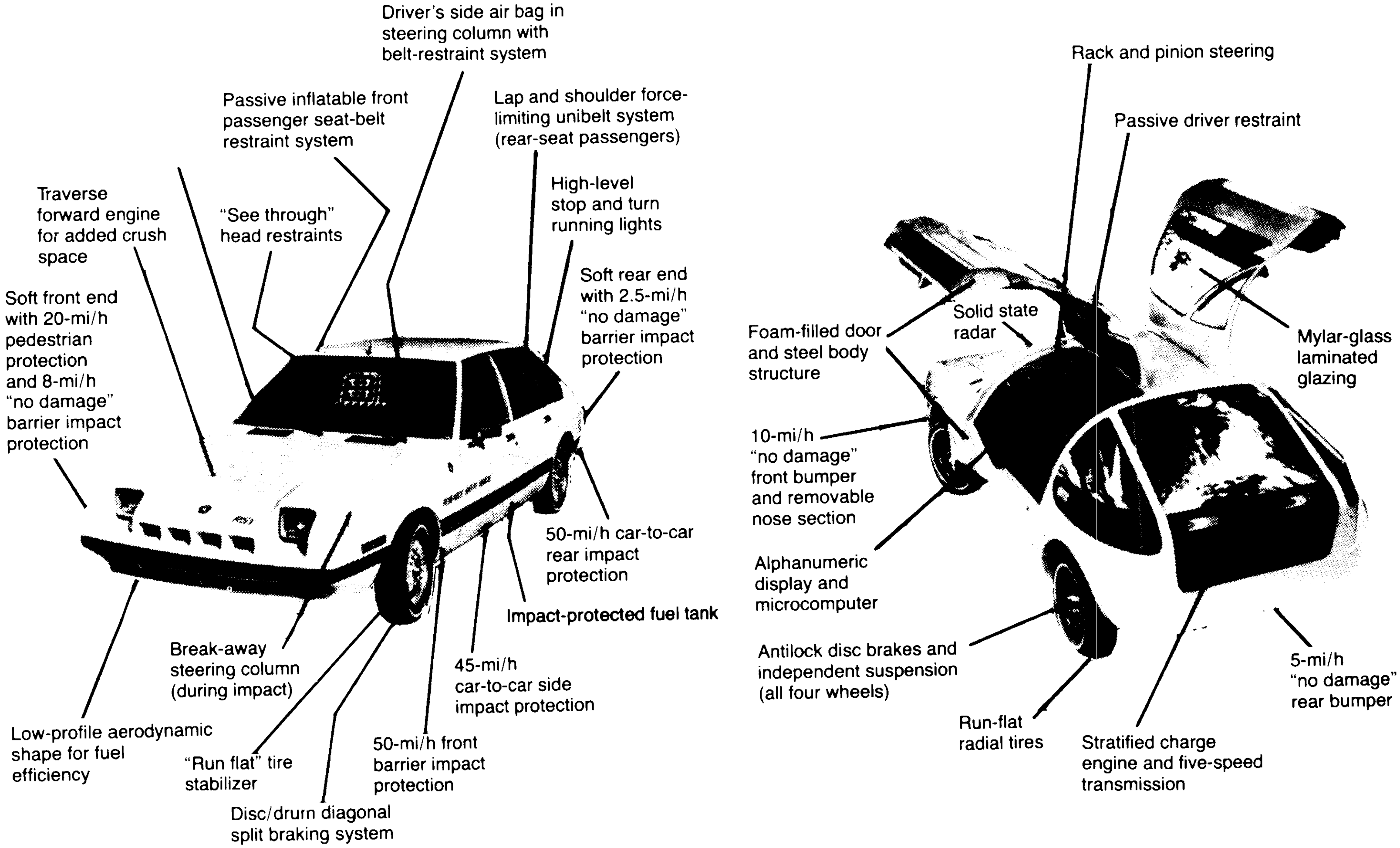
fleet is still a research question. The attainment of Level II requirements by the mid-1980's is a reasonable expectation from a technical standpoint and has been suggested in the recent report by the Federal Task Force on Motor Vehicle Goals Beyond 1980.[20] Whether to pursue crashworthiness beyond Level II is a question that requires more study. Developing a fleet of "socially responsible" vehicles could be accomplished under the current legislative authority of the National Traffic and Motor Vehicle Safety Act of 1977 through Federal Motor Vehicle Safety Standards.

[20]U.S. Department of Tranpsortation, *The Report by the Federal Task Force on Motor Vehicle Goals Beyond 1980*, Volumes I-II, September 1976.

Achieving high levels of vehicle occupant protection could reduce the deaths and injuries of vehicle occupants beyond the projections of the lifesaving potential of passive restraints. It has been estimated that the addition of Level II crashworthiness would increase the effectiveness of the Air Cushion Restraint System by **30** to **40** percent. (See table 95.) The ability to'mitigate pedestrian and pedacycle death and injury through front-end design modifications still requires technical examination.

The impacts of the evolution of much safer cars would be reflected primarily in the price of new cars to the consumer. Over the last decade, vehicle safety improvements have added an estimated **$250** to the retail price of a 1978

Figure 46.—Two Research Safety Vehicles



The Calspan/Chrysler Research Safety Vehicle developed for the National Highway Traffic Safety Administration (NHTSA) started with a Simca 1308 that was modified to provide front barrier and rear car-to-car protection at speeds up to 80.5 km/h (50 mi/h).

The Eagle II RSV, developed by Minicars, Inc., Goleta, Calif., was designed "from the ground up" to accommodate safety, energy, environmental, and economic factors, as well as full-scale mass-production technologies.

SOURCE: Ronald L. Braun, "Toward Safer Motor Vehicles," *IEEE Spectrum*, November 1977.

Table 94.—Vehicle Crashworthiness and Damageability Levels[a]

	Crashworthiness	Crash avoidance	Damageability
Level 1	All FMVSSs[b] pertaining to crashworthiness which are effective for MY 1975 cars **and** those which will become effective during the 1976-80 period (protection for front, rear side, rollover, fire), 30 mph frontal performance.	All FM VSSS[c] pertaining to crash avoidance which are effective for MY 1975 cars **and** those which will become effective during the 1976-80 period (braking performance, lighting, field of view, and other).	Both Levels I & II correspond to existing standards (Part 581 requiring that front and rear bumper sustain 5 mph impacts without damage to vehicle except for m i nor dents on bumpers).
Level II	Same as Level I plus 40 mph passive frontal protection, **20** mph passive side protect ion and egress.	**Same as** Level I plus all weather brake performance (anti lock brakes).	
Level Ill	Same as Level I plus passive protection for— Impacts: • 50 mph flat barrier frontal (O-45) angle • 50 mph narrow barrier • 100 mph car to car al ined • 100 mph car to car offset • 45 mph car to car side • 30 mph rollover • 50 mph car to car rear • Egress, all test conditions • No fuel leakage, all test conditions	Same as Level II plus run f l at tires.	Same as Level I for impact speeds up to 10 mph.

[a]Level I and Level II specifications from "Goals" study by DOT. Level III specifications were developed from the RSV program of DOT
[b]Federal Motor Vehicle Safety Standards

Table 95.—Effectiveness of Level II Crashworthiness With Air Cushion Restraint Systems

	Fatality reduction (percent)[a]	Injury reduction (percent)
Air cushion	43	20
Air cushion and lap belt	50	24
Level II and air cushion	59	23
Level Il, air cushion, and lap belt	65	27

[a]Percent reduction in number of unrestrained fatalities and injuries for front, side, and rear crash modes (rollovers not included)
SOURCE: U.S. Department of Transportation, *Interagency Task Force on Motor Vehicle Goals Beyond 1980*, 1976

automobile[21] with no observable negative effect on vehicle sales. The average new car buyer now spends $750 to $1,000 on comfort and convenience options.[22] This indicates that additional vehicle safety, costing perhaps $400 to $800, may be within acceptable limits.

Vehicles in Use

The primary policy consideration for vehicles in use is mandatory periodic motor vehicle inspections. Vehicle-in-use safety inspection programs were in effect in many States even before enactment of the Highway Safety Act of 1966. It

[21]U.S. Department of Transportation, National Highway Traffic Safety Administration, *The Contributions of Automobile Regulation*, Preliminary Report, June 1978.
[22]Ibid

has been shown that bad tires and bad brakes contribute to crashes (up to 5 percent of total crashes).[23] The actual number of cars on the road operating with inadequately maintained brakes and worn tires may be much higher.[24] The impetus for uniform inspection programs may come from efforts to meet emissions goals since including a safety inspection in such a procedure is logical.

The effect of current inspection programs in reducing crashes, injury, and death has not been clearly demonstrated. Any upgrading or broadening of such programs would not have the support of reliable effectiveness data. The primary impact is cost to the consumer for repair and and replacement of parts, particularly in addition to repairs to meet fuel-economy and emissions requirements.

User Performance

In the *Highway Safety Needs Report*, the three strategies with the highest lifesaving potential are related to driver behavior. They are increased seatbelt usage, the 55 mph speed limit, and alcohol countermeasures.

Seat belts have been required in all passenger cars since 1964. However, the current usage rate is only about 20 percent (15 percent lap and torso, 5 percent lap only). Even at this low degree of use, it is estimated that about 3,000 lives are saved annually by the use of belts. It is also estimated that an increase to a 70-percent lap and shoulder belt usage rate would save an additional 8,500 lives per year and prevent 162,000 injuries of severity 2 to 5 on the AIS code. (See table 93.)

With passive restraints entering the fleet in the 1980's, seat belts and seat belt laws may not be as important in the long run. However, passive restraints will not be widespread in the vehicle fleet until the 1990's. Also, 25 percent of the vehicle fleet is composed of light trucks, a percentage that is expected to rise. Currently there is no requirement for passive restraints in vehicles other than passenger cars, although such a regulation for light trucks is under consideration by DOT.

Two types of passive restraint systems are being considered to meet the Federal standard: the air cushion restraint system (ACRS, or air bag) and the passive seat belt. The ACRS used with a lap belt is considered to offer the best overall protection, although the passive belt system is also quite effective. The passive seat belt is a "coercive" system, in that the user must agree to leave the belt in place. The passive belts can be easily disconnected.

There are several approaches that may raise the level of seat belt usage: educational or promotional campaigns, economic incentives, and mandated belt *use.*

Promotional campaigns, the approach now used by the Federal Government, do not appear to have much potential. Incentives such as insurance credits, or other economic rewards, have not been tried in this country. Mandatory belt-use laws are in effect in 16 foreign countries, 2 Canadian provinces, and Puerto Rico. The success of these laws varies, primarily depending on social acceptance and the level of enforcement. (See table 96.)

One of the best examples of mandatory belt use laws is that of the State of Victoria, Australia. In 1970, surveys showed safety belt use rates in Australia to be comparable to those in the United States—about 20 percent. After the law became effective in January 1971, the usage rate rose to about 50 percent immediately, despite an amnesty on prosecution against offenders. When enforcement and prosecution were implemented, the use rate rose to an average of 75 percent in the metropolitan area of Victoria.[25] By early 1972, following the reported success in reducing injuries and deaths in Victoria, all of the other Australian states had enacted similar laws. The reported results are mixed but favorable. Table 96 shows a 25-percent reduction in deaths and a 20-percent reduction in injuries in Australia from 1972 to 1974.

[23] U. S. Department of Transportation, National Highway Traffic Safety Administration, *Tri-Level Study of the Causes of Traffic Accidents Final Report,* Volume I: Causal Factor Tabulations and Assessments, prepared by Institute for Research in Public Safety, Indiana University, Report No. DOT-HS-034-3-535-77-TAC, Mar. 31,1977,

[24] Joseph I. Innes, Viability of the Motor Vehicle Diagnostic Inspection Concept Demonstrated by NHTSA, *Fifth International Congress on Automotive Safety — Proceedings* (Washington, D.C.: U. S. Department of Transportation").

[25] R. Ungers, "The Introduction of Compulsory Seat Belt Wearing Laws in Australia and Their Effect, " *Proceedings of the Scientific Conference on Traffic Safety* (Ottawa, Canada: 1974).

Table 96.—Effect of Safety Belt Usage Laws Around the World—2/1/77

Country	Effective date of law:	Penalty for noncompliance	Enforcement[a]	Public information program	Belt usage before law effective	Belt usage after law effective	Occupant fatality reduction	Occupant injury reduction
Czechoslovakia	1-1-69	Max $10						
Japan	12-1-71	None	0	None		Aug 1975 8%		
Australia (all states)	1-1-72	Max $20	1	Yes	1971—25%	1972-75 68-85%	1972-74 25%	1972-74 20%
New Zealand	6-1-72	Max $200	1		May 1972 30%	1972-1975 62-83%		
France	7-1-73[b]	$10-$20	1	Yes	March 1973 26%	March 1974: 64% 1975—85% (Outside cities) In city: daytime 15% nightime 30%	1975—22%	1975—32%
Puerto Rico	1-1-74	$10	0-1	Yes	July 1973 30/0	July 1976 25%		
Sweden	1-1-75	Max $100 Usual $10	1	Yes	360/0	March 1976 79%		
Spain	10-3-74[c]	$15				July 1975 92%	June-Sept 1975—39%	June-Sept 1975—24%
Belgium	6-1-75	$1.50-$15.00						
Luxembourg	6-1-75	$5-$12.50						
Netherlands	6-1-75	$0.20-$120			Oct 1974 Rural: 28% Urban: 15%	June 1975 Rural: 72% Urban: 58%		
Finland	7-1-75	None	3	Yes	June 1975 9-40%	Dec 1975 53-71%		
Norway	9-1-75	None	0	Yes	Sept '73-'75 Rural: 37% Urban: 15%	June 1975 Rural: 61% Urban: 32%		
Israel	7-1-75	Max $110	3	Yes	June 1975 8%	Aug 1975 80% July 1976 80%		
Switerland	1-1-76	$8	1-2	Yes	May 1975 35-500/0	May 1976 87-95%		
West Germany	1-1-76	None	1	Yes		Jan 1976 70-77%		
Canada—Ontario	1-1-76	**$20-100**	1	Yes	Oct 1975 17%	Mar 1976 77% June 1976 64%	Jan-July 1976—17%	Jan-July 1976—15%
USSR	1-1-76	**$1.50**	1	None				
Canada—Quebec	8-15-76	**$10-$20**	0-1	None	190/o			

[a]0-Essentially none
1-When motorist stopped for another purpose
2-Strict (when observed not wearing belt)
3-Only requested to "buckle up" by officer
[b]On roads outside city limits. As of 1-1-75 usage was also required on city roads between 10 p.m. and 6 a.m.
[c]Usage not required in cities.
[d]Urban roads exempt.
NOTE: Blanks indicate no information available.
Data Prepared by: Office of Driver and Pedestrian Research NHTSA.
SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety '76*.

Other examples of foreign experience with seat belt laws are not as encouraging. In Puerto Rico, the usage rate rose from 3 percent to only 25 percent between 1973 and 1976. In Japan, the laws are not enforced and the usage rate is reported to be 8 percent. On the other hand, Norway, with no enforcement, has usage rates of 61 percent in rural areas and 32 percent in urban areas. In Sweden, the mandatory seat belt usage law was put into effect in 1975 and met with a high degree of public acceptance, resulting in high usage rates. Approximately 80 percent of front seat occupants in Sweden were observed to wear seat belts.

Foreign experience indicates that mandatory seat belt use laws can be an effective safety measure. However, foreign experiences tells little about their probable success in this country.

Photo Credit U S Department of Transportation

It is clear that the use of seat belts saves lives and reduces injury, and mandatory seat belt laws with reasonable levels of enforcement would probably increase the usage rate somewhat. However, no State in the United States has enacted legislation requiring seat belt use. Public opinion seems to be against such a law, which is regarded as an undue infringement of individual freedom.

Speed

The national 55 mph speed limit went into effect in early 1974. There were **9,000** fewer traffic deaths in 1974 compared with 1973, a 17-percent reduction. The average speed on rural interstate highways before **1974** was above **65** mph. In 1974 and 1975, the average rural interstate speed dropped to below **58** mph,

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Many studies have examined the relationship between the drop in fatalities and the speed limit, and various conclusions have been reached. The evidence seems to indicate that reduced highway speeds contributed to the reduction in traffic deaths, but the magnitude of this contribution is subject to debate. Many researchers believe that about 50 percent of the reduction in deaths in 1974 was due to the 55 mph speed limit.[26] DOT data show that the most significant drop in fatality rates occurred on highway systems most affected by the reduced speed limit—the Interstate System and rural primary roads. However, other factors could be involved, as evidenced by the fact that urban pedestrian deaths also dropped about 17 percent from 1973 to 1974. It is unlikely that urban pedestrian fatalities were affected by the speed limit change.

DOT data indicate that in 1976 and 1977 the average speed on the highways, and the percentage of drivers operating their vehicles above the posted speed limit, increased steadily over the 1974 and 1975 figures.[27] The speed limit is actually a State law, and enforcement of the law is a matter for the States. There is lack of support for strict enforcement in many State legislatures, and enforcement places an increased imposition on enforcement agencies. DOT claims the public has indicated support for the speed limit.[28] However, the public's most convincing expression on the matter is how fast they drive. One apparent factor in noncompliance is that the original intent of the law—to save gasoline—is not perceived as necessary.

In October 1977, the Secretary of Transportation recommended that the President seek from Congress dedicated funding assistance for State speed limit enforcement, and the authority to establish compliance standards.[29] In the recently signed Highway Safety Act of 1978, Congress authorized $50 million for the States for each fiscal year from 1979 through 1982 along with a compliance schedule, penalties, and incentives for enforcement of the speed limit.

The debate on speed limits and safety is not over. The equilibrium of the reduced speed limit has not been reached, and most conclusions on the subject can be considered only tentative. Educational and promotional campaigns to convince people to drive slower for safety and fuel economy have suffered, and will probably continue to suffer, from credibility problems. Increased enforcement levels may produce a public backlash.

The safety aspects of the 55 mph speed limit need to be addressed from a broader base of experience. Speed is relevant to safety primarily in the context of a crash. The data regarding speeds at which crashes occur are inadequate. The DOT Crash Recorder Program, designed to collect this data, was initiated many years ago and has consistently failed to gain congressional support. Speeding in the context of "reckless driving" can also contribute to the cause of a crash. Trying to enforce speed limits in general does not readily address this problem.

There is also the question of why motor vehicles need to have the capacity for high speed. Data on traffic behavior under constrained top-speed conditions is limited, although many vehicles on the road essentially have a limited top speed of 60 to 70 mph. Vehicle engine sizes are becoming smaller as the country moves into the "economy" era. Still, top-speed limitation would be considered by many to be an infringement on personal (and technological) freedoms, and would inhibit manufacturers from using "power" and "speed" as a common part of sales campaigns. These arguments, however, overlook the consideration that drivers of the next generation may feel differently about automobiles and driving.

Interestingly, top speed for electric vehicles is a primary constraint and is traded-off with vehicle range. If electric vehicles became widely used, top-speed limitation would be an inherent feature of the automobile transportation system.

[26] U.S. Department of Transportation, Federal Highway Administration, *Safety Aspects of the National 55 MPH Speed Limit*, November 1976.
[27] U.S. Department of Transportation, *Report to the President on Compliance With the 55 MPH Speed Limit*, Oct. 14, 1977, and personal communication with the Office of Statistics and Analysis, U.S. DOT.
[28] Ibid.
[29] Ibid.

Alcohol Use

Alcohol consumption per capita has risen 50 percent in the United States since 1960. This high rate of increase is not expected to continue, but alcohol will probably continue to be the customary social intoxicant, [30] Alcohol use is a far-reaching social phenomenon. The data suggest that alcohol is a factor present in as much as **50** percent of crashes involving occupant fatality and in one-third of the fatal pedestrian crashes. [31] Data are not available to determine that alcohol is, in fact, the cause of such crashes. However, the debilitating effects of excessive consumption of alcohol on perception, on the motor-sensory system and, in some cases, on personality, are well known from experimental studies. It can be inferred that the risk of a crash increases as the driver's performance capability degrades. What is not known is how to alter this cultural habit or separate the task of driving from alcohol use.

There have been several notable attempts to curb or control the use of alcohol with driving. The Alcohol Safety Action Program in the United States and the Scandinavian drunk-driving laws are examples.

The National Highway Traffic Safety Administration sponsored 35 local Alcohol Safety Action Programs (ASAP) at a cost of about **$70** million over a 2-year period. In the ASAP communities, enforcement activities regarding drunk-driving laws were intensified, and efforts to identify and rehabilitate problem drinkers were increased. NHTSA initially claimed a small reduction in fatalities as a result of the ASAP program. Other researchers have disputed this claim, stating that year-to-year fluctuations in fatalities in ASAP areas could account for changes that occurred during the program. [32] NHTSA, when discussing ASAP in annual reports, makes no claim to any safety improvements as a result of the program, The success of ASAP is said to be the improvement in the local traffic safety system, and the fund of experience gained. [33]

Scandinavian countries have had fairly strict drunk-driving laws for over **30** years. Their approach is characterized by the routine penalty of imprisonment for attaining a specified level of blood alcohol, determined by scientific tests. Studies in Sweden indicate that the incidence of intoxication in fatally injured drivers is about **30** percent, or somewhat less than the **50** percent found in this country. However, a recent analysis of the Scandinavian data raises questions regarding the credibility of this information and casts doubt on the effectiveness of strict drunk-driving laws as a deterrent to drunk driving. ”

Other countermeasure programs have been tried in the United States, Canada, Austria, Great Britain, and Czechoslovakia. While few of these programs have been thoroughly and systematically analyzed, there is doubt about their success and the practicality of the countermeasures employed.

Several findings in the literature are noteworthy. Alcohol abuse is not solely a problem on the highways although symptoms and consequences of the problem can be found there. The use of alcohol by society is widespread and accepted. Moderate use of alcohol may even have beneficial effects on some users. Yet the United States appears to lack any consensus on what constitutes responsible use of alcohol .[35] This statement could be extended to include drugs used for medicinal and other purposes, Without consensus on what constitutes excessive use, there is a limited justification for enactment of alcohol-related highway safety countermeasures.

[30] U. S. Department of Transportation, National Highway Traffic Safety Administration, *National Highway Safety Forecast, A 1990 Traffic Safety Outlook*, September 1 976.

[31] U.S. Department of Health, Education, and Welfare, Public Health Service, National Institute on Alcohol Abuse and Alcoholism, *Second Special Report to the Congress on Alcohol arid Health* June 1 974.

[32] Paul L. Zador, 'Statistical Evaluation of the Effectiveness of Alcohol Safety Action Projects," *Accident Analysis and Prevention* Vol. 8, No. *1*, February 1976.

[33] U.S. Department of Transportation, National Highway Traffic Safety Administration, Federal Highway Administration, *Highway Safety* 2977, DOT HS-803 372, June 1978.

[34] Laurence H. Ross, "The Scandinavian Myth: The Effectiveness of Drinking-and-Driving Legislation in Sweden and Norway, ' The *Journal of Legal Studies*, Vol. 4, No. 2, June 1975.

[35] U.S. Department of Health, Education, and Welfare, *Alcohol and* Health

Support Systems

Support systems include data collection, construction and maintenance, procedures, traffic laws, enforcement, insurance, product liability, and emergency medical service, Many of these items have significant potential for safety improvement policy in the short and long term. Some of these improvements are listed as prospective countermeasures in tables **89** to 91.

Improved construction and maintenance practices are shown to be very cost-effective. Improved emergency medical countermeasures could potentially save many lives. In 1975, it was reported that 47 percent of traffic fatalities died either en route to the hospital **(6** percent), in the emergency room (35 percent) or in the hospital **(6** percent) .3' Emergency medical service is an important element in highway safety, both in appropriate trauma treatment and rapid evacuation to an appropriate facility.

Goals

Specific goals for vehicle emissions and fuel economy have shown themselves to be useful and effective. It is important to consider the utility of specific and quantitative goals as a way to promote future traffic safety. Section 401 of the Highway Safety Act of 1966 states that "the Secretary is authorized and directed to assist and cooperate . . . to increase highway safety. " Section **402** of the same law states that: "Each State shall have a highway safety program . . . designed to reduce traffic accidents and deaths, injuries, and property damage resulting therefrom. " The preface to the National Traffic and Motor Vehicle Safety Act of 1966 states: "That Congress hereby declares that the purpose of this act is to reduce traffic accidents and deaths and injuries to persons resulting from traffic accidents. " The question arises, however, whether these goals, as written, provide sufficient stimuli for achievement and whether some of these stated objectives would have been met if it had not been for the 17-percent reduction in fatalities that occurred in 1974 for other reasons.

In 1968, just 2 years after enactment of the major safety legislation, the Department of Health, Education, and Welfare issued a report of the Secretary's Advisory Committee on Highway Safety.[37] In discussing the relatively uncharted areas of the highway safety field, the report stated:

> There do not exist even the most rudimentary standards of performance by which to measure achievement. This suggests that traffic safety might well be one of the first areas of national effort to be made the subject of a carefully elaborated and comprehensive set of national goals. At that point it will become possible to make dependable calculations as to what allocation of resources will be required to achieve goals that have been set . . . ***it is in the context*** of ***such*** *national goals the research and program priorities* ***should be established. "3***[8]

The data collection and analysis process necessary to formulate specific goals and assess progress toward reaching them is within the current state-of-the-art. Data now collected by the States, and the present (FARS) and future (NASS) data collection programs of the DOT may be adequate for such a purpose. But the adequacy is not universally accepted, and the outcome of the continuing debate will, by necessity, lead to improving the data. The data are most limited in the areas of selecting and evaluating safety countermeasures that might be used to meet specified goals, Also, there is considerably less data on traffic injuries than on traffic deaths.

The difficulty with safety goals is in the process of setting them, and the framework, the plan, and the lines of responsibility for achieving them. Safety goals could be expressed either as some target for reduction of total deaths, injuries, and property damage resulting from accidents or as a scheduled reduction in the rates of deaths, injuries, and property damage based on exposure to risk (e. g., miles of travel or years of vehicle occupant exposure).

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[16]U.S. Department of Transportation, National Highway Traffic Safety Administration, *1975 Societal Costs of Motor Vehicle Accidents*, DOT HS-802 119, December 1976.

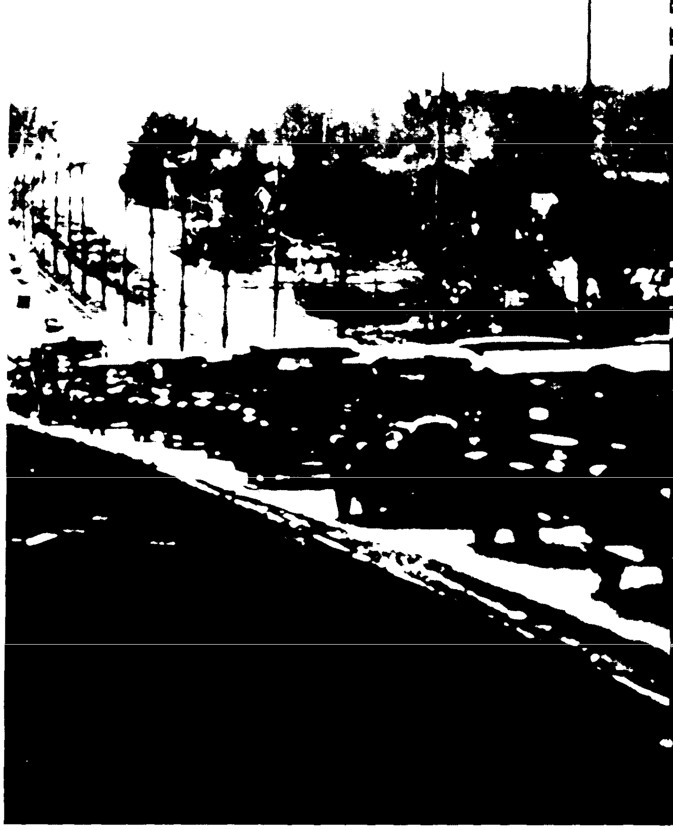
[17]U.S. Department of Health, Education and Welfare, *Report of the Secretary's Advisory Committee on Traffic Safety*, February 1968,

[18]Ibid., pp. 72 and 73.

Such goals could be set either for the Nation as a whole or for each State. Alternatively, States could set their own goals in consultation with the Federal Government. The national goal would thus become the sum of State goals. Safety goals could be established either systemwide or for each element of the automobile transportation system (i. e., vehicles, highways, and highway users) and for specified subclasses within each element. For example, there might be separate goals for large and small passenger cars, or there might be separate goals for each class of roads.

Safety goals could provide a focus for long-range, comprehensive safety planning which, until now, has been inadequate or nonexistent.[39] The nature of the problem is such that the achievement of goals will require participation by all parties to improve all elements of the transportation system. Goals could provide a direct stimulus for coordinated action. This, in turn, could help to resolve the stifling negotiations on implementation of technological improvement. Further, setting goals and formulating plans to achieve them would focus attention on the levels of expenditures needed and on the payoffs from these investments—both in monetary terms and in the quality of life.

[39] A review of the literature has uncovered no comprehensive safety plan at the Federal or State level. The only suggesiton of one is in the recent DOT study, *National Transportation Trends and Choices*, January 1977.



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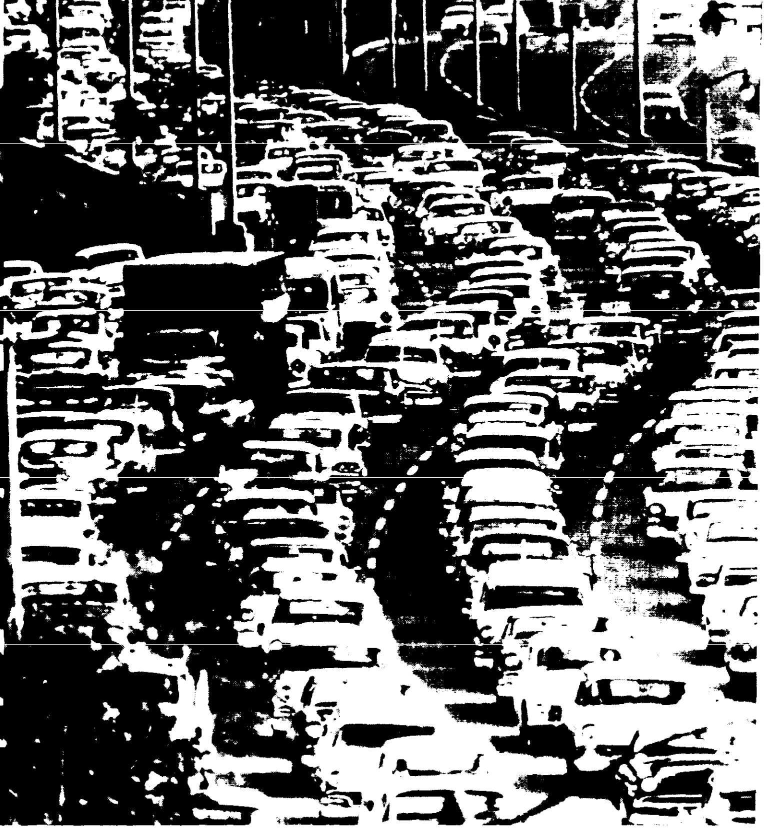

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Chapter 8
MOBILITY ISSUES, POLICIES, AND FINDINGS

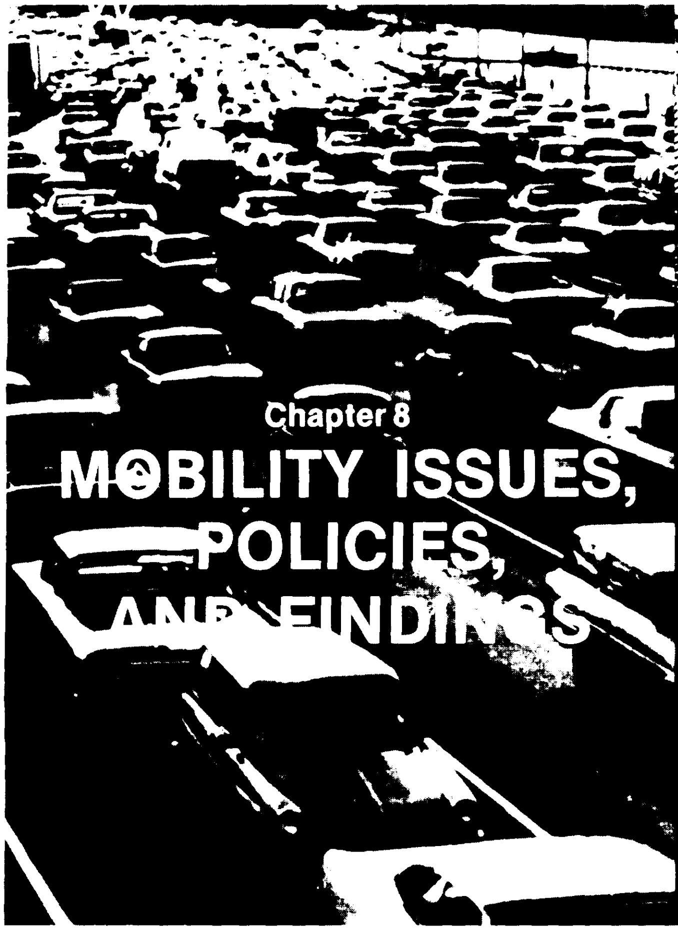
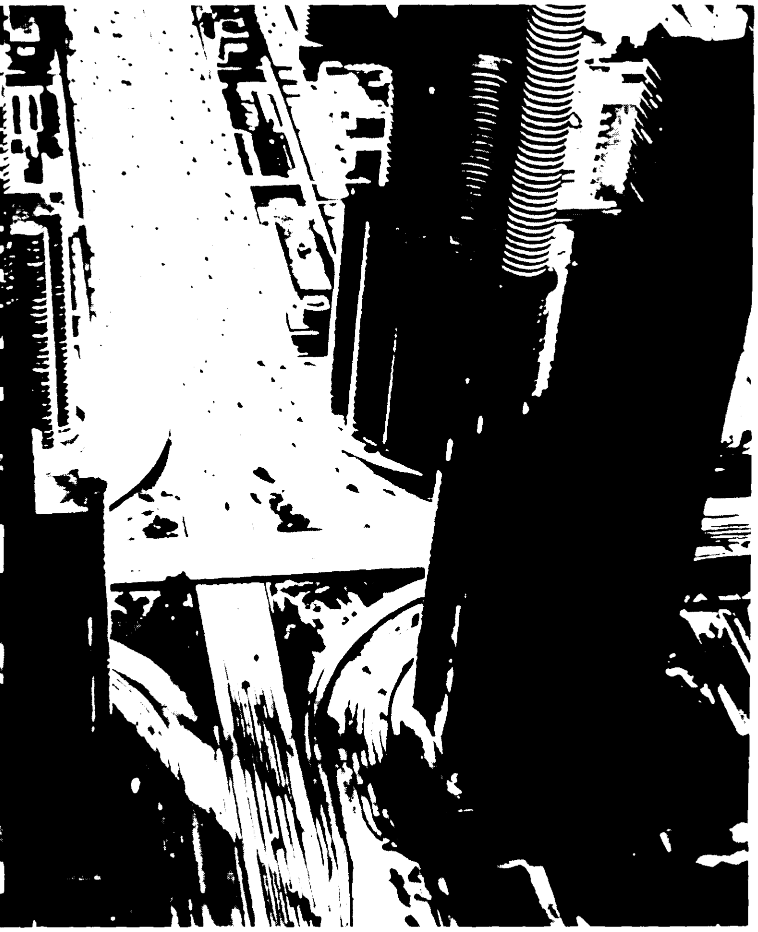


Photo Credit: U.S. Department of Transportation



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Chapter 8.—MOBILITY ISSUES, POLICIES, AND FINDINGS

LIST OF TABLES

MOBILITY ISSUES, POLICIES, AND FINDINGS

CHAPTER 8

SUMMARY

Past and present Government policies have promoted increased personal mobility as a principal national objective. The automobile is the main means of travel for all but the longest intercity trips and trips within the densest urban areas. The automobile, however, does not well serve the needs of some handicapped, elderly, young, and poor persons, for whom remedial policies are required.

It is projected that auto travel will grow by 75 percent between 1975 and **2000.** Stricter fuel economy standards, reduced highway construction, and auto disincentives currently programmed to conserve petroleum and improve urban air quality will have little effect on the amount of auto travel. Only a severe petroleum shortage or gasoline rationing could bring about major reductions in auto use. In the long run—50 years or so—changes in urban development policies to channel growth into "high accessibility" areas would also be effective by reducing the need to travel. Changes in lifestyle or development of telecommunications as a substitute for travel could also have significant impacts on the auto system, but probably not before **2000.**

Under current policies, congestion—particularly on urban highways and streets—is expected to increase substantially. By 2000, urban drivers will encounter congested conditions 3 times more frequently than today. To avoid this congestion and maintain present levels of service on the Nation's highways through the year 2000 would require construction expenditures more than **60** percent higher than those forecast for the Base Case. Highway maintenance will also continue to be an important concern. The Nation's highways will deteriorate greatly, unless strong Federal initiatives are taken to increase maintenance.

Consideration was given to several measures to improve mobility. Major expansion of public transit assistance could increase transit ridership by as much as 55 percent in 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) —about 5 times more than the 1975 expenditures 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 per year, close to today's levels.

Transportation system management techniques could be used in the short run to improve traffic flow and provide greater efficiency in the use of transportation facilities.

The utility of paratransit services was also analyzed. It was determined that a special services program funded at $5oO million annually could increase the mobility of the handicapped and elderly by 80 percent. (The young and the poor would benefit most from improvements in conventional transit.) Other forms of paratransit to provide community or general transit service would be beneficial, but extremely expensive under prevailing wage and labor conditions.

Within metropolitan areas, ridesharing has the potential to reduce petroleum consumption, automobile emissions, consumer costs, and traffic congestion. Increased acceptance of this form of transportation depends more on institutional changes than on financial assistance. Ridesharing would gain greater acceptance if accompanied by transportation use controls.

Except for gasoline rationing or allocation, none of the policies examined in this study would affect automobile travel by more than 4

percent. However, drivers and passengers will have to accommodate themselves to certain changes in the comfort and convenience of the automobile. The typical car of the future will be smaller and less powerful. It will carry fewer passengers, but not necessarily with any loss of comfort. Automobiles will have improved safety features but, because of the deterioration in roads and bridges, the ride may be less smooth, and perhaps less safe.

BACKGROUND

One of the goals of society is to enable citizens to take part in activities that improve and maintain their social and economic well-being. Essential to the attainment of this goal is the ability to reach jobs, consumer goods, recreation sites, and other desired activities. To this end, the Federal Government has acted as a major provider and regulator of transportation services. The challenge today is to find new technological and institutional solutions that will improve the individual's ability to reach desired and necessary activities by a mode of transportation that is compatible with other national goals—energy conservation, environmental protection, and public safety.

Mobility can be measured as the number of transportation options available for a trip as well as the cost, comfort, convenience, safety, reliability, and speed of the trip. Mobility can be improved by improving one or more of these seven characteristics of personal tripmaking.

There are two alternatives to improved mobility. The first is to improve accessibility by bringing people and activities into greater proximity. The other is to reduce the need for travel, by promoting substitutes for travel (such as telecommunications) or by fostering changes in attitudes and lifestyles to reduce the desire to travel.

The Federal Government has financed transportation since 1823 and has regulated it since 1887. Originally these activities were prompted by a national interest in opening up undeveloped parts of the country. Because legal and constitutional limitations prevented the States from undertaking some transportation-related activities, a strong Federal role began to evolve.

The first Federal-aid highway act was passed in 1916. The Federal-Aid Road Act of 1916[1] provided for Federal and State sharing of highway construction costs on a 50/50 basis. Each State was to establish a highway department that would develop management and construction standards acceptable to the Federal Government. This was followed by other highway acts which, in addition to providing more Federal monies, increased Federal involvement.

Other milestones in the history of Federal highway policymaking include:

- 1930's—beginning of Federal aid for local roads,
- 1956—creation of the Highway Trust Fund, financed by taxes collected on petroleum products and tires,
- 1962—comprehensive State planning required as a condition for receipt of highway construction monies from the Federal Government,
- 1973—the Federal-Aid Highway Act of 1973[2] allowed local jurisdictions to divert Highway Trust Fund monies to mass transit capital expenditures.

Mobility will continue to be an issue of major public importance. For most of this century, mobility has been steadily improving; and the degree of Federal involvement has grown. Substantial redirection of transportation policy may now be necessary to maintain current levels of mobility or to expand mobility further.

[1] *Federal-Aid Road Act of 1916, Statutes at Large 39, sec. 355 (1916).*

[2] *Federal-Aid Highway Act of 1973 Statutes at Large* 87, sec. 250 (1973], *U. S Code*, Vol. 23, sec. 101 (1973).

PRESENT POLICY AND PROJECTIONS

The future mobility of the population will be strongly influenced by demographic trends and future economic conditions and by Federal transportation policies. Between 1975 and 2000, the population is expected to increase over 20 percent. The urbanization of the population will continue. More persons (particularly women) will be in the labor force, and real incomes will double. Thus, by 2000, it is projected 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 driving will increase by almost 75 percent to 1.8 trillion vehicle miles annually.

The Base Case assumes that the Federal Government will not build new highways at a pace sufficient to keep up with the growth in personal automobile travel. Although it is assumed that total highway spending by all levels of government will remain the same in constant dollars, the proportion spent on new construction will decline by 2000 to half of what it is now. As a result, travel times will increase, particularly in urban areas where average speeds will be 10 to 15 percent slower and where motorists will encounter congested conditions 3 times as often as today.

Transportation System Management (TSM) techniques can be used to improve the movement of persons and vehicles in urban areas at 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. However, the responsibility for TSM is spread across many programs in the Department of Transportation (DOT), with no central focus. For the Base Case, therefore, TSM is assumed to have limited impacts on mobility.

The highway funding assumptions for the Base Case envisage that more money will be available for maintenance. However, much of it will be absorbed by minor reconstruction and bridge replacement, leaving roadways in appreciably worse condition than today.

Fuel economy mandates will make the typical car of the future smaller and less powerful than the automobiles of the 1960's. However, equipping all cars with passive restraints by 1984 and making them more crashworthy will make occupants less vulnerable to death and serious injury. It is assumed in the Base Case that the level of compliance—or noncompliance—with the 55 mph speed limit will not change significantly and that there will be little change in automobile safety or travel time.

Federal Government support for public transit has been growing in recent years. Financial assistance programs are assumed to continue growing until 1985 and then remain at that level through 2000. Operating deficits, already rising steadily, will grow even faster since the new services provided with this Federal assistance will also require subsidies. By 2000, the State and local transit burden could rise to $4.9 billion annually. Total ridership on conventional transit would increase only modestly (about 15 percent) over this period. Without an increase in the level of support, ridership by the transit dependent would decline slightly on a per capita basis.

As part of the RD&D program of UMTA, four downtown people mover systems are expected to be operating by 1985. Future installations will depend on the success of these demonstrations. Urban rail systems currently under construction will be completed, and several existing systems will be expanded. It is expected that only two or three new rail rapid transit systems will be started; UMTA will probably show a strong preference for light rail. These systems will have important effects on local mobility, but the improvements will be barely perceptible on a national basis. The future for automated guideway technologies is uncertain, but they are expected to have little or no impact on mobility by 2000. It is assumed that fares, which averaged 33 cents per ride in 1975, will fall to 20 cents by 1985 (in 1975 dollars) to encourage ridership. Fares are assumed to remain at that level until 2000. Most of the fare decrease will be in the form of reductions for the elderly and handicapped.

ISSUES AND POLICY ALTERNATIVES

Five mobility issues were identified for the automobile assessment. The first three raise the questions of whether, how, and for whom mobility should be expanded. The latter two, which are examined later in this chapter, consider alternatives to reduce the need or desire for vehicular travel. These mobility issues were used to construct the two alternative policy sets examined later in this chapter.

The Amount and Distribution of Mobility

The three issues pertaining to the amount and distribution of mobility are:

- To what extent and by what means should the Federal Government promote increases in the level of general mobility?
- To what extent should the Federal Government seek to change the distribution of mobility by changing transportation policy to aid the transportation disadvantaged?
- To what extent should the Federal Government discourage automobility as a policy for meeting national goals?

Americans have come to regard mobility as an inalienable right. To assure this right, all levels of government have been involved in sponsoring the auto-highway system. However, this arrangement has created two basic problems that have received increasing recognition in the last decade:

- The automobile is not the ultimate in mobility for large numbers of the population.
- The automobile imposes great costs on society because of its energy consumption, environmental pollution, and safety problems.

Recognition of these shortcomings is causing changes in automobile design and in the way that Government provides transportation services. Projections indicate that the automobile will remain the primary means of personal mobility, but changes need be brought about in the way in which the automobile system operates.

There are several ways to expand personal mobility:

- Enlarge the highway system,
- Expand public transportation and encourage ridership,
- Implement TSM projects,
- Encourage paratransit,
- Aid the transportation disadvantaged,
- Promote advanced transit technologies, and
- Restrict certain types of automobile travel.

Build More Highways

The first alternative, enlarging the highway system, was adopted by the Federal Government in 1916 and is still the most widely supported mobility policy of the Federal Government. Since the first "Road Act" in 1916, the level of service offered by the Nation's highways has constantly increased. Construction of interstate highways, the keystone of the system, has maintained this service up to the present day. Ninety percent of this system is now in place, and the remainder is scheduled for completion by 1990. While it would be possible to expand mobility further by means of new highways, this can be done only at great expense.

Provide More Transit

On the other hand, there are a growing number of environmentalists, energy conservationists, city officials, and transportation planners who maintain that the automobile has had too much Federal support. They feel that assistance should now be directed toward public transportation. They argue that mass transit systems are more energy efficient, less polluting, less disruptive to neighborhoods, and are the main source of mobility for the transportation disadvantaged.

Federal assistance to public transportation has grown considerably since the early 1960's. Current aid to mass transit is approaching $3 billion annually.[3] The assistance requested by AMTRAK for FY 1978 was $545 million.[4] Recently, intercity bus operators began lobbying for assistance to stem their deteriorating financial condition and to compensate for the detrimental effects of AMTRAK competition.[5] There are now proposals before Congress to aid rural and small-town public transportation as part of a new combined nonmetropolitan highway and transit program.[6]

Transportation Systems Management

One alternative to expensive new highway projects in urban areas is to improve the management and efficiency of existing transportation systems. This is known as Transportation Systems Management (TSM) and includes such actions as reserved lanes for high-occupancy vehicles, promotion of carpools and vanpools, shared-ride taxis, improved transit service, and automobile disincentives (tolls, parking bans, and parking taxes). (See table 97.)

Recognizing the need for TSM, UMTA and FHWA issued a joint regulation in 1975[7] requiring that TSM be part of the Urban Transportation Planning Process. This regulation labeled TSM as the short-term element of urban area transportation planning. Most TSM actions are designed to produce two principal effects: to improve the flow of vehicles on existing rights-of-way, and to improve the load factors of the vehicles on these rights-of-way.[8] However, many of the technologies listed in table 97, such as congestion pricing and auto-restricted zones, are still foreign to the American city. Further, many of these strategies will work at the expense of some stakeholder groups, even though benefiting others.

Table 97.—Spectrum of TSM Actions

Improved vehicular flow
- Improvements in signalized intersection
- Freeway ramp metering
- One-way streets
- Removal of on-street parking
- Reversible lanes
- Traffic channelization
- Off-street loading
- Transit stop relocation

Preferential treatment of high-occupancy vehicles
- Freeway bus and carpool lanes and access ramps
- Bus and carpool lanes on city streets and urban arterials
- Bus preemption of traffic signals
- Toll policies

Reduced peak-period travel
- Work rescheduling
- Congestion pricing
- Peak-period truck restrictions

Parking management
- Parking regulations
- Park-and-ride facilities

Promotion of nonauto or high-occupancy auto use
- Ridesharing
- Human-powered travel modes
- Auto-restricted zones

Transit and paratransit service improvements
- Transit marketing
- Security measures
- Transit shelters
- Transit terminals
- Transit fare policies and fare Collection techniques
- Extension of transit with paratransit services
- Integration of transportation services

Transit management efficiency measures
- Route evaluation
- Vehicle communication and monitoring techniques
- Maintenance policies
- Evaluation of system performance

SOURCE U S. Department of Transportation, Federal Highway Administration and Urban Mass Transportation Administration, *Transportation System Management State of the Art*, February 1977, p V.

Unlike master planning of land use and long-range transportation planning, TSM has not yet become institutionalized. Although there are a number of funding options for the Federal Government to support TSM, they are scattered over a number of separate categorical grant programs with differing requirements and matching ratios. This situation creates disincentives to an effective local TSM program.[9]

[3] "UMTA Asks Congress for Transit Money," *Passenger Transport* 36 (Apr. 7, 1978): 1,3.

[4] "Amtrak Asks for $56.5 Million More," *Railway Age* 178 (Oct. 10, 1977): 26.

[5] U.S. Congress, House, Committee on Public Works and Transportation, *Highway* Transit Proposals, hearings before the Subcommittee on Surface Transportation, 95th Con,, 2d sess., 1978, sec. 405(a).

[6] U.S. Congress, Senate, *Highway Improvement Act of 1978*, S. 2440, 95th Con., 2d sess., 1978, sec. 405(a).

[7] *Federal Register* 40 (Sept. 17, 1975): 42976-42984.

[8] Most definitions of TSM include paratransit. The benefits of "ridesharing" or "pooling" in improving traffic flow are obvious. The small-bus and special services, while not necessarily having a significant impact on traffic flow, are more closely tailored to very specific markets and operate more effectively than conventional transit.

[9] "UMTA Red Tape Costs Millions," *Passenger* Transport 36 (Apr. 7, 1978): 1.

Many actions now labeled as TSM have been instituted in urban areas as part of normal traffic control improvements. In some cases, these TSM actions were adopted as alternatives to larger scale improvements which could not be funded. The joint regulation of TSM projects by UMTA and FHWA has institutionalized this process. As a result, TSM actions must undergo the same regional review and approval process as major long-range, capital-intensive projects. In addition, many TSM actions must also be submitted for DOT review and approval. UMTA is currently attempting to add staff and to decentralize its grant approvals to hasten this process.

While there can be little argument with the inherent virtues of TSM, the projected high growth in urban traffic congestion makes it clear that TSM alone is not the solution. A large capital improvement program is necessary just to maintain current conditions. Additionally, there is a limit to the amount of TSM that can be carried out in a given area without TSM programs themselves becoming capital-intensive.

Paratransit

One concept, often considered a part of TSM, is paratransit, This includes ridesharing and small-bus or special systems. Ridesharing (carpooling, vanpooling, buspooling) generally offers the rider cost-savings, reliability, and freedom from having to drive himself. A recent study of 21 cities revealed that 18 percent of the commuters traveled in carpools,[10] An additional incentive for a vanpool driver is the free use of the van nights and weekends. In some pools, where the institution organizing the pool owns or leases the van, a small mileage charge may be levied. A vanpool driver can sometimes make a small profit if the vehicle is subscribed to capacity.

Carpooling is currently the most popular form of ridesharing, mostly for workers at large installations. Carpools are generally formed by the riders, although there is a growing tendency for employers or communities to help organize carpools. Most vanpools are employer-sponsored, with the employer owning or leasing the vehicles and riders covering the operating expenses.

There are some major impediments to widespread pooling. The first is the loss of convenience. Pool vehicles run on tight schedules, and all riders must conform. There is no "late bus. " Unless priority is given to the pool vehicle, the trip usually takes longer than driving alone. The biggest impediment is in forming pools, For commuting, there must be enough willing people with similar origins, destinations, and work hours for the idea to work. Thus, pools are usually inappropriate for small towns, dispersed small-employment sites, and low-density residential areas.

The greatest potential for pooling would be achieved if a large share of commuters in a particular area or corridor would shift from private autos to higher occupancy vehicles, Congestion, travel times, and requirements for highway capacity would be reduced. Such conversions are unlikely without some strong incentive.

Paratransit most commonly connotes small-bus operations or special services. Even taxis are included in some definitions. In general, paratransit is expected to serve those travel markets (particularly the transportation disadvantaged) not well-served by the private car or conventional bus and rail transit. Also, certain other urban transit markets (i. e., low-density service or feeders and distributors) can be more efficiently served by small vehicles, dial-a-ride, or door-to-door service. However, the productivity and operating costs of these services are inferior to regular bus service, and paratransit often requires heavy subsidies. Many systems have trouble with the labor protection provisions of the Urban Mass Transportation Act that generally require the use of union operators. When a small bus replaces a large one, there is little opportunity for savings since most transit revenues go to pay the operator's wages.

The Transportation Disadvantaged

For physical, social, or economic reasons, certain segments of society lack the degree of mobility enjoyed by the majority of the population. These persons are commonly called the "transportation disadvantaged, " "transit dependent, " or "carless. " They include some of the

[10] U.S. Department of Commerce, Bureau of the Census, *Selected Characteristics of Travel to Work in 21 Metropolitan Areas: 1975* February 1978, p, 1.

elderly, the handicapped, the young, the poor, and the chronically unemployed. There are significant numbers of each. For example, there are some 10 million nonhandicapped elderly.[11] Persons under 17 represent 34 percent of the population.[12] People living below the officially designated poverty level (including some elderly, handicapped, and young) make up over 12 percent of the population.[13] Nationwide, nearly 20 percent of all households do not own a car.

During the past decade, the Federal Government directed special attention to the mobility problems of the handicapped and elderly; and today there are more than **30** Government-sponsored programs for these groups. These programs are of two general types:

1. Specialized transportation services (often paratransit), and
2. Reduced fares and physical improvements to make federally aided mass transit systems easier to use.

For the poor who are neither elderly or handicapped, there have been few programs to improve mobility—unless one includes public subsidies for mass transit systems. A justification often given for such subsidies is that they represent a form of welfare aid to low-income households. But, at best, this aid is indirect and limited to areas where mass transit exists. Large numbers of poor people live in rural or suburban communities, where there usually are no alternatives to the automobile. To overcome these disadvantages, proposals have been advanced to replace or combine mass transit subsidies with direct "user-side" subsidies to members of each disadvantaged group. The subsidies would enable individuals to choose the available transportation system that best fits their needs—automobiles, transit, or taxis.

The most commonly stated rationale for aiding the transportation disadvantaged is that higher mobility will reduce poverty and improve social well-being. However, the validity of this proposition has not been fully tested. The

Photo Credit: Washington Metropolitan Area Transit Authority

prospect for Federal commitment to transportation aid for low-income individuals depends, in part, on whether it can be shown that inadequate transportation—as opposed to low income—restricts shopping, working, recreation, and other activities beyond walking distance.

This issue is complex. It involves not only the disadvantaged, but also transit and taxi operators, vehicle manufacturers, all levels of government, and a variety of regulatory agencies. Progress is being made as more is learned about the problem. Recently implemented regulations require all federally funded systems and improvements to be fully accessible to the elderly and handicapped. This goal should be achieved by the mid-1980's, as new and replacement vehicles are purchased and as older transit stations are modernized. Independent mobility for the young and the poor will depend upon prospects for expansion of public transportation service. While current levels of capital assistance to buy buses and build and modernize rail systems are large and still growing, operating assistance is quickly being swallowed up by rising operating costs. Paratransit, which can be tailored to

[11] *Sydec/FEA*, p. III-42.
[12] Ibid.
[13] U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States: 1976*, p. 415.
[14] Motor Vehicle Manufacturers Association, *Motor Vehicle Facts & Figures '77* (Washington, D.C.: MVMA, 1977), p. 38.

special needs, is less cost-effective. The elderly of tomorrow, many of whom live in the suburbs today, will increasingly create a suburban transit demand as their driving skills wane.

Advanced Transit Technologies

One of the new approaches proposed for meeting urban transportation needs is the use of automated vehicle systems operating on exclusive rights-of-way. New heavy-rail systems such as in Washington, San Francisco, Baltimore, and Atlanta are extremely costly and feasible only in high-density corridors. Buses are limited by other street traffic. Automated Guideway Transit (AGT) systems provide an intermediate alternative. Three classes of AGT systems are summarized in table 98.

The only AGT system currently operating in regular urban transportation service is in Morgantown, W.Va. (although often referred to as a Personal Rapid Transit (PRT) system, this is really an example of Group Rapid transit (GRT)). A similar system, AIRTRANS, operates at the Dallas-Fort Worth Airport. Several other airports (Miami, Seattle, Houston) and some private theme parks also have AGT systems, but with less complex networks. UMTA has committed $22o million to assist demonstrations of four Downtown People Movers (DPM), which should be in operation by 1985. Additional installations will depend on the results of these demonstrations.

The mobility benefits of AGT depend on the type of system and the proximity of stations to

Table 98.—Characteristics of Automated Guideway Transit

	Shuttle-loop transit (SLT)	Group rapid transit (GRT)	Personal rapid transit (PRT)
Operations	• Simple, single route. • Switching in a constant manner.	• Complex multiple routes. Prescheduled. • Switching reacts to vehicle identity.	• Very complex multiple routes. • Vehicles actively responsive to demand. • Switching is tailored for each passenger's destination.
Passenger convenience	• Passengers use any vehicle. • Stops at each station. • All passengers on a route travel together.	• Passengers share assigned vehicle. • May bypass some stations. • Passengers travel in groups.	• Passengers are assigned vehicles. • No stops en route. • Passengers travel alone or in small, private groups.
System configuration	• Shuttles and loops. • Online stations. • Switches seldom required.	• Lines branch and merge. • Online and offline stations. • Switches required.	• Coupled guideways. • Off-line stations. • Many switches required.
Areawide formation network	• Many interfacing shuttles or loops.	• Multiple interfacing GRT systems.	• Single integrated PRT systems.

SOURCE: U.S. Congress, Office of Technology Assessment, *Automated Guideway Transit: An Assessment of Personal Rapid Transit and Other New Systems*, OTA-T-8, June 1975.

passenger origins and destinations. An important benefit of AGT is speed of travel, achieved primarily by operating on a private right-of-way. However, separation from other traffic contributes to the high cost of AGT systems. Automation reduces the labor costs to operate AGT systems, but not without increased maintenance expenditures, The energy savings of AGT have not been proven; however, since sources other than petroleum can be used to generate electricity, AGT systems have a distinct advantage over automobiles, buses, and paratransit. A 1975 OTA assessment of AGT suggested that more research was necessary on the economics, acceptability, and technical aspects of AGT operation.[15]

Restricted Automobile Travel

Ever since the private passenger car emerged as a significant mode of travel, mobility and automobility have been synonymous. Any attempt to restrict freedom of automobile use has been regarded as limiting mobility. However, it is now recognized that unrestrained automobility may conflict with other national goals and that reducing automobile travel may be an important means (albeit not the only means) of achieving significant energy, environmental, and safety benefits.

Limiting automobility and increasing overall mobility are not necessarily incompatible goals— not even in the short term. Knowledge of how the automobile best functions in a transportation system is imperfect, and it is not known at what point increased automobile use leads to diminished automobility,

The Department of Transportation has proposed restricting automobility as a means of improving mobility in general. DOT aims to increase the load-carrying efficiency of congested highways through incentives to use carpools or existing transit systems. One such incentive is the creation of special lanes for buses and carpools. Commuters who take advantage of these reserved lanes typically save 15 to 20 minutes per trip. Under favorable conditions, the commuters in single-occupancy vehicles can be little worse off (and possibly better off) than they would be without the lane restrictions, Another strategy, vanpooling, is believed to be one of the most energy-efficient modes of surface transportation.[16]

The issue of limiting automobile use often comes down to a question of the importance the Nation attaches to clean air, safety, and energy conservation compared to automobility. The Federal Government has already adopted at least one policy that favors some other goal over automobility. The Clean Air Act requires reduced emissions from mobile sources, including automobiles.[17] Many large cities will not be able to meet the ambient air quality standards by 1982 through stationary and mobile source controls alone.[18] In such cities, EPA may require the use of "transportation control strategies," including parking limitations, auto-free zones, and improved transit to attract drivers out of their cars. The Act also provides for withholding Federal highway funds in areas where EPA finds that reasonable progress is not being made toward attainment of the standards. The requirement for the transportation control strategies has resulted in many court cases in the past. However, in general, EPA has retained the authority to require implementation in areas where air quality standards cannot be met by other means.

The controversy over reducing automobility to promote other social goals raises many questions. Can the American public modify its preference for automobility —a preference encouraged by the Government for decades and fostered through billions of industry advertising dollars? Will the intended reductions in automobile usage actually occur and will projected energy, environmental, and safety benefits materialize? Will, for example, parking restrictions for city commuters merely result in more auto trips by family members in the suburbs, using the cars that are left at home? Will a higher gasoline tax or a special tax on heavy,

[15] U.S. Congress, Office of Technology Assessment, *Automated Guideway Transit: An Assessment of Personal Rapid Transit and Other New Systems*, OTA-T-8, June 1975.

[16] U.S. Congress, Congressional Budget Office, *Urban Transportation and Energy The Potential Savings of Different Modes* prepared for U.S. Senate, Committee on Environment and Public Works, 95th Con., 1st sess., Committee Print No. 95-8, September 1977.

[17] "Clean *Air Act Amendments of 1977*, Public Law 95-95, 91 Stat, 685, U.S. Code, Vol. 42, sec. 7401 -7626, (1977).

[18] The Clean Air Act Amendments of 1977 contain special requirements for areas that cannot achieve carbon monoxide and oxidant standards by 1982, These areas must develop plans for achievement of the standards no later than 1987.

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Photo Credit: U.S. Department of Transportation

fuel-inefficient, polluting cars discourage their purchase, but actually increase the distances driven per carowner as consumers begin switching to fuel-efficient automobiles?

As technologies for pollution control, alternate energy sources, and automobile safety emerge, these problems could decline in importance. The leadtime for these technologies, however, is as long as 30 years, and significant actions may be necessary in the interim. Base Case projections indicate that insufficient progress on the air pollution question will be made by 2000, when at least 54 Air Quality Control Regions are expected to remain in violation of the oxidant standard and 24 regions will still be in violation of the carbon monoxide standard. Base Case projections through the year 2000 indicate that with the 27.5 mpg standard automobile petroleum consumption could be as much as 10 percent below current levels. The number of crashes, injuries, and fatalities will continue to rise despite some improvements in automobile safety. Thus, it appears that it will be necessary to reexamine the relationship between automobility and other goals of our society.

Reducing the Need and Desire to Travel

A fundamental alternative to improved mobility is offered by policies to reduce the need or desire to travel. Such policies raise two major issues:

- To what extent should the Federal Government promote land use controls as a long-term measure to improve accessibility while reducing the environmental and energy problems of the automobile?
- To what extent should the Federal Government attempt to reduce travel demand by

supporting nontransportation alternatives such as telecommunications, or by encouraging less travel-dependent activities and lifestyles?

The traditional approach to facilitate carrying out the activities of daily life has been to provide more and better transportation. There is an alternative—reducing the distances people must travel or reducing the need for travel.

Federal programs have supported the general trend toward low-density urban development. Federally funded highway construction has increased both the speed of travel and the distances that can be traveled in a given time. Federal mortgage loan programs have enabled families to buy new housing in the suburbs with low downpayments. These Federal programs have been very popular.

Recently, however, concern about neighborhood disruption by highway construction, worsening air quality, and increased dependence on foreign oil have caused some to question the desirability of continued highway building, urban sprawl, and the increasing costs that accompany them. In general, the effects of Federal policies that have led to scattering of development are not offset by strong land use control at any lower level of government. In a few limited instances, States have begun to take action to preserve valuable natural assets, such as the California and Oregon coastal zone and some of the more sensitive farm areas. Current Federal policy pertaining to development and land use planning merely supports analysis of land use impacts and information on certain grant programs. Federal policy provides no real encouragement for improved decisionmaking processes or stronger controls on development.

Changes in land use policies and tax laws could, in principle, counter urban sprawl by encouraging greater proximity between new residences and businesses. With higher densities and mixed land uses, trip lengths would be shorter, transit could become a more attractive alternative, and walking could replace some vehicular travel. The result of such a development policy would be a significant increase in small, self-contained, high-density communities.

There are basic uncertainties about the benefits of such a pattern of development. One uncertainty is whether the costs of providing energy and public services for high-density centers of multistory buildings might not be higher than for medium-density development

Photo Credit: U.S. Department of Transportation

composed mainly of two- and three-story buildings. The other question is whether the benefits of reduced automobile dependence justify the personal and intangible costs of high-density living. Based on current housing patterns, most Americans prefer low-density living, even with its attendant costs of pollution, energy waste, and neighborhood disruption.

Possible avenues of Federal involvement include:

- Eliminating tax deductions for mortgage interest and property taxes on single family homes,
- Requiring State or local land use controls either by law or as a precondition for Federal transportation aid, and
- Encouraging State land use planning through planning grants.

National interest in land use changes could increase substantially in the next decade as energy and air quality problems intensify. However, most benefits of land use controls would not become manifest for at least 20 or 30 years. Controls would affect only new construction and not existing development. It might take a generation or more for these controls to have an appreciable influence on the pattern of community development.

Telecommunications devices could reduce the need for business or private travel by enabling more people to work at home. However, the effects on travel demand are by no means certain. Increased use of telecommunications could expand the range of distant business opportunities and thereby increase the need to travel to conduct face-to-face business. The use of radio, telephones, and television does not appear to have diminished travel demand in the past.

In many ways, the policies of the Federal Government exert a direct and powerful influence on lifestyles and activities. Highway building, income tax deductions for home mortgage interest, and the welfare system are but three examples. But the inverse is also true. Government policy reflects, however imperfectly, the prevailing values of society. The recent concern for environmental quality is one example of public values influencing Federal programs. Other values may emerge as well—less emphasis on materialism, opposition to unrestricted growth, or even new public attitudes toward travel. Such new attitudes could be the impetus for change in federal policy.

If such fundamental changes in societal values occur, or if there are shifts in the priorities assigned to present values, the consequences for the automobile transportation system could be profound. While it would be speculative to predict the course that changes in attitudes and lifestyles might take, it is clearly important to recognize that the personal transportation system exists solely to serve society's ends. If those ends change, so will the means by which they are served.

ANALYSIS OF INCREASED MOBILITY POLICIES

Historically, Federal Government policy has emphasized increased mobility to open up undeveloped lands, promote westward expansion, assist marketing of agricultural products, and stimulate economic development. The economic prosperity and social structure of the country have been viewed as dependent on widely available, low-cost transportation. The policies studied in the Increased Mobility Case are based on the premise that it is desirable to expand the capacity and efficiency of highway and transit systems in the interest of promoting the continued economic and social well-being of the United States.

The Increased Mobility policies call for increased funding of highway and transit construction programs. The transit programs also emphasize improved services for the transportation disadvantaged. For highways, construction of new roads is supplemented by an extensive and vigorous program of transportation system management. Also included in the Increased Mobility policies are measures to improve vehic!e crashworthiness and to discourage fuel-inefficient automobiles by means of taxation.

Effects

Highways

A major aim of the Increased Mobility policies is to expand the highway system to accommodate the expected growth in VMT and to avoid the congestion and speed reductions that are projected to occur under Base Case conditions. Instead of decreasing annual expenditures for highway construction to $7 billion by 2000, as in the Base Case, they would rise to $20 billion by 1985 and remain at that level until 2000. (see table 99.) An additional annual outlay of $1.5 billion would be allotted for TSM projects, (ramp metering, lane controls, driver advisories, and safety improvements) benefiting autos, trucks, and buses. Expenditures for maintenance and other highway needs are assumed to be the same as in the Base Case.

Under the Increased Mobility policies, travel speeds in urban areas would be maintained at their 1975 levels, instead of the 12-percent reduction expected in the Base Case. Because of the higher levels of service, urban VMT in 2000 would be approximately 6 percent higher than in the Base Case, as shown in table 100.[19] Approximately one-half of the increase in traffic volume and speed is due to the expenditure of funds for TSM improvements. The other half results from capital expenditures for new highways and highway widenings.

The programmed annual expenditure of $1.5 billion for TSM would not be as effective in the early years as it would be after 1985. Before 1985, it will be difficult to find significant numbers of opportunities where TSM will provide

[19] Details of the assumptions used in these computations are given in *Sydec/EEA*, pp. VI-16 to VI-18. These computations are based on S. Schleifer, S. Zimmerman, and D. Gendell, *The Community Aggregate Planning Model* prepared for the 54th Annual Meeting of the Transportation Research Board, 1975; Yacov Zahavi, *Travel Time Budgets in Urban Areas*, prepared tor U.S. Department of Transportation, Federal Highway Administration, May 1974; and Jack Faucett Associates, System Design Concepts, Inc., Methodology *for Estimating the Impacts of Changes in Highway Performance*, prepared for U.S. Department of Transportation, Federal Highway Administration.

Table 99.—Assumed Highway Expenditures, Increased Mobility Case (billions, 1975 dollars)

	Actual	Base Case		Increased Mobility	
	1975	1985	2000	1985	2000
Capital	14.3	11.2	7.0	20.0	20.0
TSM	0	0	0	1.5	1.5
Maintenance	7.1	8.7	10.8	8.7	10.8
Other (administration, police, debt, etc.)	6.8	8.3	10.4	8.3	10.4
Total	28.2	28.2	28.2	38.5	42.7

SOURCE *Sydec/EEA*, p VI.15

Table 100.—Vehicle Miles of Travel and Speeds, Increased Mobility Case

	Actual	Base Case		Increased Mobility	
	1975	1985	2000	1985	2000
Rural highways					
Daily VMT (millions)	1,180	1,510	1,890	1,510	1,900
Average speed (mph)	48	48	48	48	48
Urban highways[a]					
Daily VMT (millions)	1,630	2,410	3,000	2,460	3,190
Average speed (mph)	33	33	30	34	33
All highways					
Daily VMT (millions)	2,810	3,920	4,890	3,970	5,090
Average speed (mph)	38	38	35	39	38

[a]The distribution of speeds by type of road for the Increased Mobility Case is the same as for the Base Case in 1975
SOURCE: *Sydec/EEA*, p. VI-18.

large transportation improvements per dollar. However, by 2000, the growth in urban highway travel will provide more opportunities to employ this strategy.

It is expected that the condition of highways in the Increased Mobility Case will be as good or better than in the Base Case. Although the same amount of maintenance funds will have to be spread over more lane-miles, the construction program would allow the replacement of many badly deteriorated roads, which have high maintenance costs per mile.

The revenue sources for highway funding have not been estimated for the Increased Mobility Case as they were for the Base Case. However, the assumption has been made that the fleet fuel cost per vehicle-mile would be held constant.[20]

[20]The fuel economy standard is expected to remain at 27.5 mpg between 1985 and 2000 as in the Base Case. Diesel penetration of the new car market is expected to be 10 percent by 1985 and 25 percent by 2000.

Transit

To assure balanced improvements in mobility for all segments of the population, this set of policies provides increased funding for rail and bus transit systems above Base Case levels. An important feature is a major increase in the level of Federal operating assistance for transit systems to lower what would otherwise be a heavy burden on State and local governments. A portion of this subsidy would be used for special services for the handicapped and elderly.

The funds made available to transit under this financial assistance program are shown in table 101. The Federal capital funds to provide increased rail and bus service would almost double between 1975 and 1985 and then remain at the 1985 level until 2000. This constitutes more than twice the increase assumed for the Base Case.

The biggest change, however, is in operating assistance. With Federal operating funds in **2000**

Photo Credit Sydec

being 5 times greater than in the Base Case, the State and local operating subsidy would be cut from $4.47 billion to $2.12 billion. The amount of transit service provided by these funds would be 15 to 20 percent higher than the Base Case in **2000,** and 65 to 80 percent higher than in 1975.[21] (See table 102.)

Despite the new transit service which would be provided and the TSM improvements which would improve bus speeds and reliability, overall transit ridership would increase only slightly above Base Case levels. (See table **103.)** This is because TSM improvements will also benefit auto travel. The added and improved highway capacity will enable the auto to remain relatively more attractive than transit for many travelers. In the Improved Environment Case, a similar program for conventional transit is provialed, but with auto disincentives. The result is **8.7** billion riders in **2000** compared to **6.8** in the Increased Mobility Case.

The $500-million special services program would be effective in improving the mobility of the handicapped and elderly. It would serve a projected 333 million riders per year by 1985, in addition to the **530** million rides by the handicapped and elderly on conventional services.[22] The poor, the young, and other nondrivers would benefit more from the expansion of conventional services. Although the number of poor in the population would be decreasing, their ridership would increase somewhat. Ridership by those under 18 would increase from the 1970 level at about the same rate as their growth in the total population. These estimates are summarized in table **103.**

[21]Sydec/EEA, pp. III-36 to III-39, III-81, and VI-10 and VI-11.

[22]Ibid., pp. VI-35 to VI-37.

Table 101 .—Transit Financing Assumptions, Increased Mobility Case (millions, 1975 dollars)

	Actual	Base Case		Increased Mobility	
	1975	1985	2000	1985	2000
Federal assistance					
Capital [a]	$1,210	$1,710	$1,710	$2,360	$2,360
Operating —conventional service	300	930	930	1,610	4,420
Operating —special service	70	70	70	400	400
Total	$1,580	$2,710	$2,710	$4,370	$7,180
State/local share					
Capital [b]	$ 300	$ 430	$ 430	$ 590	$ 590
Operating— conventional service	1,410	2,270	4,470	1,780	2,120
Operating—special service	—	—	—	100	100
Total [c]	$1,710	$2,700	$4,900	$2,470	$2,810

[a]Includes Federal aid for transit projects built in lieu of interstate highways
[b]Assumed at 20 percent of project cost
[c]Excludes some small transit operations

Table 102.—Transit Service Levels, Increased Mobility Case

	Actual	Base Case		Increased Mobility	
	1975	1985	2000	1985	2000
Fixed guideway miles.	560	650	860	680	990
Rail cars	10,800	11,700	15,700	12,200	18,200
Buses	51,500	60,200	75,400	63,100	89,300
Transit vehicle-miles (millions)	1,990	2,320	2,950	2,430	3,480

Table 103.—Projected Annual Transit Ridership, Increased Mobility Case (millions)

	Actual	Base Case		Increased Mobility	
	1975	1985	2000	1985	2000
Conventional transit					
Elderly and handicapped (not poor)	440	520	560	530	580
Poor (over 17, not elderly, not handicapped)	820	1,040	1,170	1,040	1,170
Total young[a]	1,390	1,360	1,520	1,390	1,570
All transit dependent	2,650	2,920	3,250	2,960	3,320
Other riders	3,280	3,560	3,230	3,610	3,480
Total conventional ridership	5,930[b]	6,480	6,480	6,570	6,800
Services *for elderly and* **handicapped**					
Conventional transit	440	520	560	530	580
Special services	40	40	40	330	330
Total service	480	560	600	860	910

aExcludes school bus riders.
bRldershlp In 1975 was 56 billion
SOURCE Adapted from *Sydec/EEA,* pp S-54, S.55, and VI-35 to VI-38

Other Mobility Effects

The improvements in the quality of the highway system in the Increased Mobility Case are expected to cause auto VMT to rise by about 4 percent over the Base Case level in **2000.** A detailed analysis was not carried out on auto ownership and new car sales, but it is assumed that Base Case trends would be followed. The excise tax on fuel-inefficient automobiles would tend to deter sales of large cars and to exert such a strong influence on size class shares that, by 1985, 90 percent of new car sales would be small cars. Standard-size cars would all but disappear. These projections are summarized in table 104.

Table 104.—Auto Ownership and Other Impacts of Increased Mobility Policies

	Actual	Base Case[a]		Increased Mobility	
	1975	1985	2000	1985	2000
Annual new car sales (millions)	8.6[b]	13.1	16.4	13.1	16.4
Percent of small cars[c]	46	69	69	90	90
Percent of diesels	(d)	10	25	10	25
Total auto registrations (millions)	107	131	164	131	164
Total autos in operation (millions)	95	118	148	118	148
Autos per licensed driver	.73	.78	.84	.78	.84
VMT (trillion)	1.03	1.43	1.80	1.45	1.87
Average travel speed (mph)					
All highways	38	38	35	39	38
Urban areas	33	33	30	34	33

aBase Case A as defined in chapter 3.
b1977 new car sales totaled 11.2 million.
cIncludes subcompact, compact, and small luxury cars
dInsignificant.
SOURCE: Adapted from *Sydec/EEA*.

As part of the program of improving mobility, a safety policy of increased vehicle crashworthiness was included to lower auto-occupant fatalities and injuries. It is estimated that the effect of this policy would be 6,000 fewer auto-occupant fatal i ties by 2000. [23]

Impacts

The policy of expanding and improving the Nation's highway system inhibits achievement of energy and environmental benefits. Assuming the same fuel economy and emission standards and diesel penetration rates as in the Base Case, Increased Mobility policies lead to 4 percent more petroleum usage by automobiles and 4 percent more emissions of CO, HC, and NO_x in 2000—both increases being directly proportional to the rise in auto VMT. (See tables **105** and **106.**)

[23]Ibid., pp. IV-76 and VI-28

Noise and water quality impacts are expected to be similar to those in the Base Case. However, the smaller automobiles in this case would reduce solid waste and recycling requirements somewhat, beginning in the **1990's.** Highway-related displacements in **2000** are expected to be more than double those of the Base Case due to increased highway construction. (See table **107.)**

The growth in highway construction would have an impact on employment. The Increased Mobility policies are estimated to yield 50 percent more construction jobs than in the Base Case. The net increase in construction employment in 1985 over 1975 levels would be 17 percent, as annual spending (in 1975 dollars) rises from $13.2 billion to $18.4 billion. " Employment impacts in the year **2000** were not computed.

Employment in the auto manufacturing industry is expected to stay close to the levels pro-

"Ibid., p. }'1-31 and **['1-32.**

Table 105.—Automobile Energy Demand, Increased Mobility Case

	Actual	Base Case[a]		Increased Mobility	
	1975	1985	2000	1985	2000
Automobile VMT (trillions)	1.03	1.43	1.80	1.45	**1.87**
Diesel penetration (percent of new car sales)	(b)	10	25	10	**25**
New car fuel economy (mpg)					
Regulation—EPA certification value	none	27.5	27.5	27.5	**27.5**
Attained—EPA certification value	15.6	28.5	29.4	28.5	**29.4**
Attained—actual driving	14.0	23.2	25.0	23.2	**25.0**
Fleet fuel economy (mpg)					
Attained—EPA certification value	15.1	24.0	28.5	23.9	28.5
Attained—actual driving	13.6	19.4	24.6	19.4	24.6
Annual auto fuel consumption					
Billions of gallons	76.0	73.9	73.3	74.9	76.2
MMBD equivalent	5.0	4.8	4.8	4.9	5.0
Percent of domestic consumption	30.6	23.9	21.4	24.3	22.1

[a]Base Case A as defined in chapter 3.
[b]Insignificant.
SOURCE: Adapted from *Sydec/EEA*.

Table 106.—Air Quality Impacts of Increased Mobility Policies[a]
(million tons per year)

	Base Case		Increased Mobility	
	1985	2000	1985	2000
Carbon monoxide	32.6	27.3	33.9	28.3
Hydrocarbons	3.5	2.9	3.6	3.1
Nitrogen oxides	2.7	2.9	2.8	3.0

[a]All differences between the Base Case and the Increased Mobility Case are due to the 3.9-percent increase in automobile VMT.
SOURCE: *Sydec/EEA*, pp. VI-23 to VI-26 and supplementary report.

Table 107.—Average Annual Displacements Due to Highway Construction, Increased Mobility Case

	Actual	Base Case		Increased Mobility	
	1971-75	1985	2000	1985	2000
Residential units.	10,800	5,500	4,300	7,700	9,700
Businesses	2,500	1,800	1,600	2,400	3,700
Farms	200	200	160	220	370
Nonprofit organizations. . .	100	80	70	100	170

SOURCE Sydec *EEA* p VI 34

jected for the Base Case. Although the same number of cars would be sold, the mix would change to an even higher proportion of small cars. This would affect auto suppliers (e. g., steel manufacturers) more than the auto industry itself. Service stations and the repair and maintenance industry would benefit from the increasing VMT between now and 2000.

The impact of vehicle crashworthiness standards on automobile prices has not been estimated. However, it is anticipated that one result of improved automobile safety would be to lower insurance costs in **2000** by about 10 percent compared to the Base Case projections. [25]

ANALYSIS OF IMPROVED ACCESSIBILITY POLICIES

Increased interaction among the members of society does not necessarily mean expanding the personal transportation system. The Improved Accessibility Case was constructed to test the hypothesis that economic, social, and cultural activities can be carried out satisfactorily without relying as heavily on the movement of people by private automobile and public transit.

The critical assumption is that the Federal Government would be able to influence land use planning at the local level and thereby promote a long-term change from low-density, scattered development patterns to more concentrated and self-sufficient "high accessibility" dwelling and business complexes. This would require a basic change in the Federal policy on urban development. Eligibility for Federal assistance in land development would be determined by criteria such as reduced energy consumption, conservation of natural resources, and lower travel time or costs. [26]

The role of the Federal Government would be to ensure that appropriate goals are set and to focus on criteria for measuring attainment of these goals, The Federal Government would not make local land use and transportation decisions. Instead, it would evaluate the performance of local agencies in reaching the objectives they set for themselves. Although it appears that such a program would not require any new powers at the Federal level, it is assumed that if such powers were required, they would be sought and obtained.

Many existing Federal programs have an influence on urban development patterns: housing, highways, mass transportation, schools, water supply, waste treatment, and economic development, to name a few, It is assumed that there would be closer coordination of these programs and that all programs would be made consistent with a common set of Federal policy goals.

The intent of this policy is to coordinate community development programs as a way of channeling metropolitan growth into areas most suited for development. This redirection of new development could begin on a modest scale within the next 10 years, and by 1990 half of all new development could be shaped into high-accessibility areas with the following characteristics:

- Land development would be completely contiguous, as contrasted with current suburban and exurban patterns where leapfrog

[25] Ibid., p. VI-31.
[26] Ibid., pp. VII-7 and VII-15.

development typically results in **40** to **80** percent of the land being left undeveloped.

- Balanced communities would be created with well-defined multipurpose centers at their cores.
- Housing would be closely integrated with the multipurpose centers to facilitate walking from residences to most activities.
- Transit service would link the parts of the high-accessibility community to the multipurpose center.
- High-accessibility communities would be directly linked by high-speed bus or rail transit to the metropolitan central business district (CBD) and to other nearby centers.
- Jobs and the resident labor force within each high-accessibility community would be in approximate balance. This would minimize the need for long distance commuting except for work trips to the CBD, which would be made largely by transit.
- Each high-accessibility community would provide a variety of dwelling units to serve the housing market. Incentives in the form of amenities to achieve clustering, open space, and somewhat higher densities would be included.
- Pedestrian and bicycle facilities would link neighborhoods with convenience centers, schools, and community facilities. This would maximize both the mobility of nondrivers and the opportunity for nonvehicular travel for trips within the community.
- Population density would average about 10,000 persons per square mile, roughly the present density of central cities such as Washington, D.C.

Effects

The effects of these policies would not emerge fully until well into the next century. By 2000, most of today's infrastructure would still be in place, but pockets of high-accessibility communities would have begun to appear—either as new developments or evolutionary replacements of present communities.

It might take 10 years or more to inaugurate such a program. It is anticipated that local opposition (and possibly court tests) would persist for some time, particularly in areas where State and local statutes conflict with Federal policy. Because no specific time frame for these factors can be foreseen, the 1985 and **2000** time points are only rough indicators of the pace of change envisioned.

Highways

The highway program in this set of policies is designed to concentrate on maintenance needs and to provide some support for new construction, mostly within the new high-accessibility areas. Typical facilities would include local and collector streets as well as arterial connections to regional freeways. Pedestrian and bicycle grade-crossings would be largely eliminated. Capital and maintenance funding for highways would be equivalent to Base Case levels, but with the addition of **$200** million per year for TSM projects. These would include ramp metering, traffic surveillance systems, bus and carpool lanes, auto-free zones, transit malls, and traffic relief in neighborhood and community activity centers.

Vehicle miles of auto travel would grow to 1.76 trillion in this case, slightly less than the 1.80 trillion forecast for the Base Case. (For comparison, VMT in 1975 was 1.03 trillion.) This lower level of VMT would occur because VMT per capita in high-accessibility areas would be approximately two-thirds that of typical suburban areas today.[27] This effect would become more pronounced nationally later in the 21st century. Although the average auto trip length would continue to grow-10.1 miles in **2000** compared to **8.9** miles in 1975—it would still be somewhat less than the Base Case value of **10.3**.[28] Most of this difference would be due to reduction or elimination of short auto trips within communities. Urban travel speeds would decline in this case, but not as much as in the Base Case.

[27] Ibid., p. VII-28.
[28] U.S. Department of Transportation, Federal Highway Administration, *National Personal Transportation Study*, Report No. 7, 1972, p. 4; *Sydec EEA*, p. VII-28.

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Transit

The transit program in the Improved Accessibility Case emphasizes expanded service, particularly community-oriented transit and use of small buses. As shown in tables **108** and **109,** expenditure for capital improvements would be the same as in the Base Case. However, slightly reduced emphasis on rail systems would lead to a bus fleet 43 percent larger than in the Base Case by 2000. Transit VMT would be 10 percent higher than in the Base Case. Small buses would make up approximately 5 percent of the fleet in **1985** and *10* percent in **2000.** The community-oriented, small-bus services would differ somewhat from the "special services" described in the Increased Mobility Case since they would be part of regular transit operations serving all types of riders.

State and local support for transit would be greater than in 1975, but considerably below the Base Case levels. Compared to the Increased Mobility Case, total State and local contributions under Improved Accessibility policies would be **20** percent lower in **1985** and about equal in **2000.** After 2000, higher operating subsidies would probably be required to offset deficits for extensive bus service,

Under Improved Accessibility policies, transit ridership would be strongly encouraged, and new highway capacity would not be provided for automobiles as in the Increased Mobility

Table 108.—Transit Financing Assumptions, Improved Accessibility Case (millions, 1975 dollars)

	Actual	Base Case		Improved Accessibility	
	1975	1985	2000	1985	2000
Federal assistance					
Capital [a]	$1,210	$1,710	$1,710	$1,710	$1,710
Operating —conventional service	300	930	930	2,010	4,820
Operating—special service	70	70	70	70	70
Total	$1,580	$2,710	$2,710	$3,790	$6,600
State/local/share					
Capital [b]	$ 300	$ 430	$ 430	$ 430	$ 430
Operating —conventional service	1,410	2,270	4,470	1,550	2,440
Operating—special service	—	—	—		—
Total [c]	$1,710	$2,700	$4,900	$1,980	$2,870

[a]Includes Federal aid for transit projects built in lieu of interstate highways
[b]Assumed at 20 percent of project cost.
[c]Excludes some small transit operations.
SOURCE: *Sydec/EEA*, p. VII-33.

Table 109.—Transit Service Levels, Improved Accessibility Case

	Actual	Base Case		Improved Accessibility	
	1975	1985	2000	1985	2000
Fixed guideway miles	560	650	860	640	790
Rail cars	10,800	11,700	15,700	11,500	14,400
Buses	51,500	60,200	75,400	68,000	108,000
Small buses	—	—	—	3,500	10,700
Transit vehicle-miles (millions)	1,990	2,320	2,950	2,040	3,240

SOURCE *Sydec, EEA,* p VII 32

Case. Between 1975 and 2000, transit ridership would rise 35 percent, higher than in either the Base Case or the Increased Mobility Case. (See table 110.) The handicapped and elderly, who would be able to reach many destinations on foot within high-accessibility areas, would use transit only slightly more than in the Base Case.

Other Mobility Effects

Close to 10 percent of the population could live in high-accessibility areas by **2000.** It is estimated that almost half of the nonwork trips in such areas might be made by walking or transit.[29] In the 1970 Census, it was determined that 7.4 percent of all work trips were by walking.[30] In balanced communities, this percentage would reach as high as 15 percent.[31]

By **2000,** total automobile VMT would be 2 percent lower than in the Base Case. In urban areas, VMT would be **4** percent lower. New car sales and total auto registrations would also be lower. Because of the "gas guzzler" tax assumed for this case, automobiles would be smaller and more fuel-efficient. The general effects of Improved Accessibility policies on automobile travel are summarized in table 111.

Greater crashworthiness for automobiles is assumed, with improved front-end design to reduce pedestrian and cyclist injury. Safety would also be enhanced by the pedestrian and bicycle facilities built in high-accessibility areas. Quantitative estimates of the combined effect of these safety features have not been made. In general, however, reductions in fatalities and injuries can be expected by 1985. More significant reductions should occur by *2000* when the entire auto fleet would be equipped with improved safety features, and when auto-free zones and pedestrian facilities have become more prevalent,

Impacts

The Improved Mobility Case yields greater energy and environmental benefits than the Base Case. The factors leading to these improvements are stricter fuel economy and emis-

[29] *Sydec/EEA*, p. VII-10.

[30] U.S. Department of Commerce, Bureau Of the census, *Journey to Work 1970 Census of Population*, PC(2)-6D, January 1974.

[31] *Sydec/EEA*, pp. VII-34 and VII-35.

Table 110.— Projected Annual Transit Ridership, Improved Accessibility Case (millions)

	Actual	Base Case		Improved Accessibility	
	1970	1985	2000	1985	2000
Conventional transit					
Elderly and handicapped (not poor)	440	520	560	540	600
Poor (over 17, not elderly, not handicapped)	820	1,040	1,170	1,090	1,280
Total young[a]	1,390	1,360	1,520	1,490	1,860
All transit dependent	2,650	2,920	3,250	3,120	3,740
Other riders	3,280	3,560	3,230	3,740	3,860
Total conventional ridership	5,930[b]	6,480	6,480	6,860	7,600
Services for elderly and handicapped					
Conventional transit	440	520	560	540	600
Special services	40	40	40	50	50
Total service	480	560	600	590	650

[a] Excludes school bus riders
[b] Ridership in 1975 was 56 billion
SOURCE Adapted from *Sydec/EEA*, pp S-54, S-55, VII.31, and VII.50

sion standards and the relatively greater emphasis on public transit as opposed to highways, As shown in table 112, fleet fuel economy is expected to rise to **28.4** mpg by **2000,** compared to **24.6** mpg in the Base Case. Greater fuel economy, combined with a 3-percent decrease in VMT, is expected to reduce automobile petroleum consumption in **2000** by **20** percent, compared to the Base Case. [5] (See table 112.) The *58.7* billion gallons of gasoline used annually by automobiles would be *23* percent less than the *76.0* billion gallons consumed in *1975,* It is also significant that petroleum consumption by automobiles would then account for only 18 percent of domestic consumption, down from 31 percent in **1975.** As this would be a contribution to petroleum conservation, the question could then arise whether an acceleration of the trend toward high-accessibility communities might not be in the national interest as a means to reduce further our dependence on foreign oil.

The decreased automobile VMT under Improved Accessibility policies, combined with the stricter NO_x standard of 0.4 gram per mile that has been assumed for this case, is expected to yield further improvements in air quality over the Base Case in 1985 and 2000. (See table 113.) Projections beyond 2000 have not been made, but it is expected that the environmental benefits of high-accessibility communities would mount steadily as this pattern of land use becomes more prevalent.

Noise and water quality impacts would be similar to the Base Case. Because the assumed level of highway construction is also the same as for the Base Case, Improved Accessibility policies are expected to have little, if any, impact on average annual highway-related displacements of homes and businesses. For the same reason, employment in highway construction will be about the same. Due to reduced new car sales, employment in auto manufacturing, which was projected to fall slightly in the period 1975-85 in the Base Case, would fall slightly more as a result of Improved Accessibility policies. However, the magnitude of this potential decrease is within the error of the estimating process.

"Electric vehicles would account for about 5 percent of auto VMT by 2000 in this case. Their energy requirements are not included

Table 111 .—Auto Ownership and Other Impacts of Improved Accessibility Policies

	Actual	Base Case[a]		Improved Accessibility	
	1975	1985	2000	1985	2000
Annual new car sales (millions)	8.6[b]	13.1	16.4	12.9	15-16
Percent of small cars[c]	46	69	69	90	90
Percent of diesels	([d])	10	25	10	(d)
Total autos in operation (millions)	95	118	148	117	141
Autos per licensed driver	0.73	0.78	0.84	0.77	0.80
VMT (trillions)	1.03	1.43	1.80	1.39	1.76
VMT per licensed driver	7,900	9,500	10,200	9,200	9,900
Average highway travel speeds (mph)	38	38	35	(e)	(e)
Urban areas	33	33	30	(e)	31

[a]Base Case A as defined in chapter 3
[b]1977 new car sales totaled 11.2 million
[c]Includes subcompact, compact and small luxury cars
[d]Insignificant
[e]Not estimated
SOURCE *Sydec/EEA*, pp VII 18 and VII 26

Table 112.—Automobile Energy Demand, Improved Accessibility Case

	Actual	Base Case[a]		Improved Accessibility	
	1975	1985	2000	1985	2000
Automobile VMT (trillions)	1.03	1.43	1.80	1.39	1.75[b]
Diesel penetration (percent of new car sales)	(c)	10	25	10	(c)
New car fuel economy (mpg)					
Regulation— EPA certification value	none	27.5	27.5	27.5	**40.0**
Attained—EPA certification value	15.6	28.5	29.4	30.4	**40.0**
Attained—actual driving	14.0	23.2	25.0	24.6	**34.0**
Fleet fuel economy (mpg)					
Attained—EPA certification value	15.1	24.0	28.5	24.3	33.4
Attained—actual driving	13.6	19.4	24.6	19.7	28.4
Annual fleet fuel consumption					
Billions of gallons	76.0	73.9	73.3	70.6	58.7
MMBD	5.0	4.8	4.8	4.6	3.8
Percent of domestic consumption	30.6	23.9	21.4	23.1	17.8

[a]Base Case A as defined in chapter 3
[b]Includes 85 billion electric vehicle VMT
[c]Insignificant
SOURCE Adapted from *Sydec/EEA*

Table 11 3.—Air Quality Impacts of Improved Accessibility Policies (millions tons per year)

	Base Case		Increased Mobility	
	1985	2000	1985	2000
Carbon monoxide	32.6	27.3	31.6	25.4
Hydrocarbons	3.5	2.9	3.4	2.8
Nitrogen oxides	2.7	2.9	2.6	2.1

Factors influencing change in 2000

	CO	HC	NO.
Base Case projection	27.30	2.94	2.94
Decreased VMT	– 1 .91'	– 0.20	– 0.21
Stricter Nonstandard	—	+ 0.09	– 0.65
Improved Accessibility Case	25.39	2.83	2.08

SOURCE *Sydec/EEA,* pp VII.40 to VII.42 and supplementary report.

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Chapter

COST AND CAPITAL ISSUES, POLICIES, AND FINDINGS

Chapter 9.—COST AND CAPITAL ISSUES, POLICIES, AND FINDINGS

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COST AND CAPITAL ISSUES, POLICIES, AND FINDINGS

CHAPTER 9

SUMMARY

The Federal Government provides about $7 billion of the $28 billion spent each year on the highway system, most of this through the Highway Trust Fund. Federal assistance for mass transit, which amounts to about $2 billion per year, is funded from general revenues.

If present trends continue, highway construction will decrease through the year 2000, and the new miles added to the system will fall far short of 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 burden on State and local governments. A major increase in Federal assistance for transit operation and highway maintenance will be needed to retain the current level of mobility and protect the investment in the existing highway system.

The automobile industry faces a major challenge in meeting Federal Government mandates for improved fuel economy, lower emissions, and greater safety. As a more competitive and less differentiated market for automobiles is likely to evolve, the smaller domestic manufacturers will face severe financial difficulties, and their survival will be threatened.

The cost of automobile ownership and operation (in constant dollars) decreased steadily from 1960 to 1973. However, the trend has reversed since 1973 —due primarily to increased fuel prices, higher insurance costs, and increased cost of repairs and maintenance. The trends to 1985 and 2000 are uncertain, but Federal Government policies and regulations could be major determinants in future cost changes.

INTRODUCTION

The public and private costs of the automobile transportation system include the direct, private costs that individuals pay” to own, operate, and maintain an automobile and the indirect costs that individuals pay in the form of taxes to support the system of streets and highways on which automoblies are operated. There are also social ccsts —borne by automobile users and nonusers alike —which include air pollutio)n, noise, highway death and injury disruption of communities, negative impacts on the quality of life, and many more.

As these costs rise, or are perceived to rise, and as it becomes necessary to budget limited financial and material resources to attain an increasing number of social goals, three major issues could emerge:

1. The distribution of public funds for the automobile transportation system,
2. The appropriate role of the Federal Government with respect to the automobile and highway industry, and
3. The private costs of owning and *operating* an automobile.

Underlying these issues are fundamental questions about whether the Federal Government should intervene to affect future automobile system characteristics and use and, if so, for what purposes, to what extent, and by what means.

Historically, the Federal Government's role in the automobile transportation system has been limited to providing financial support for developing and maintaining the highway system. Since **1956,** Federal support has totaled approximately $109 billion. Recently, however, the economic and social costs of developing and maintaining the highway system have risen and the awareness of the social costs of the automobile transportation system has grown. Questions have been raised as to whether and how the Federal Government should extend its involvement and financial support to achieve other goals related to the personal transportation system. In this assessment, a general examination was made of the process and mechanisms used to finance the highway system and of the distribution of the Federal Government's financial support for highways and other personal transportation modes.

The automobile has a pervasive impact on the national economy. It accounts for about one-fourth of our petroleum use. Investment in the federally aided road system has added approximately *$26* billion to the gross national product. About one out of every six to eight workers is employed in an industry related to the automobile. For every *250,000* new car sales lost, it is claimed that automobile manufacturers lay off an estimated **21,000** workers and that the automobile-related industries lay off another **41,000.** Thus, policies affecting the automobile industry have profound consequences for the economy.

To change the characteristics of the automobile transportation system, the Federal Government has customarily relied on regulations and performance standards and has left to the auto industry the tasks of acquiring capital and developing the technology to comply with Government standards. Recently mandated fuel-economy standards will force manufacturers to produce a greater proportion of smaller, light-weight automobiles. This will curtail the wide variety of product sizes characteristic of the American automobile market and increase the competition between domestic and foreign manufacturers.

The smaller domestic manufacturers will have problems competing in this market and raising the capital necessary to finance the requirements for fuel-economy, emissions, and safety standards. Consequently, their economic viability and the present structure of the industry are seriously threatened. The interrelationship between the automobile industry and the national economy raises the issue of whether the Federal Government should seek to preserve or change the structure of the automobile industry,

Over **80** percent of all households own one or more vehicles, each of which is driven an average of *25* miles per day. The direct and indirect personal costs of owning and operating these vehicles include the costs of gasoline and oil, maintenance and repair, motor vehicle taxes, credit, property damage, lost wages and medical expenses due to accidents, and insurance premiums. The total cost of private transportation over the last 9 years has increased about **66** percent—5 percent less than the cumulative effect of inflation. However, some components of automobile cost—repairs, maintenance, and insurance—have increased almost *90* percent, which is greater than the rate of inflation,

Total automobile-related costs account for an increasing share of the household budget, since the number of households owning more than one car has increased and the number without cars has declined. In all but the lowest-income families, automobile-related expenditures rank as the second or third largest expenditure. Because of the public's dependence on the automobile transportation system for mobility and because of the size of the personal financial investment in the automobile, the question arises as to whether the Federal Government should intervene to influence the individual cost of ownership and use.

PUBLIC FUNDING OF HIGHWAYS

None of the many advances in transportation made during this century has transformed our lives as much as automobiles and highways. The United States is, in fact, a highway-dependent nation. Virtually everyone, drivers and nondrivers alike, is affected. Almost all intercity and intracity passenger travel is by automobile, and a major portion of our freight is delivered on highways, Highways are now a part of our physical landscape, There are in the United States today some **3.8** million miles of roads, approximately 1 mile of roadway for every square mile of land. The total area covered by roads and their rights-of-way is estimated to be about *24,000* square miles, an area equal to the size of West Virginia. [1]

The extent of the highway system is due, in part, to the emphasis placed on highways by public transportation funding policy. In 1977, for example, the Federal Government contributed about *$7* billion of the total **$28** billion spent on highways. The cost of the entire Federal-Aid Highway Program for the period beginning with the establishment of the Highway Trust Fund in **1956** until *1976* amounted to $109.2 billion. '

The Federal Government's investment in highways is reflected by the size and extent of the Federal-aid highway system, which constitutes 22 percent of the Nation's total highway mileage. The most heavily funded program, the Interstate System, comprises *42,500* miles of interconnected roads and receives almost half of all Federal-aid highway funds, approximately **$3.5** billion annually.' The Federal-Aid Primary System totals *260,000* miles and receives 18 percent of the Federal highway authorization. [4]The secondary system of rural collector routes totals 405,000 miles and receives about 5 percent of the total Federal highway aid. In **1970,** a separate urban system—formerly a part of the secondary system—was established. It consists of about 130,000 miles of arterials and collectors

[1]A.Q. Mowbray, *Road to Ruin* (New York: J.B. Lippincott Co., 1969), p. 12.

[2]Library of Congress, Congressional Research Service *The Highway Trust Fund Time for a Change?* by W. A. Lipford Issue Brief #77044, May 12, 1977 p. 4

[3]U S D(, partment of Transportation, Federal Highway Administration, *America on the Move The Story of the Federal Highway Program and the Federal-State Relationship I 1 977* p11.

"*U .5 Code* Vol *.23,* sec.103(IQ701

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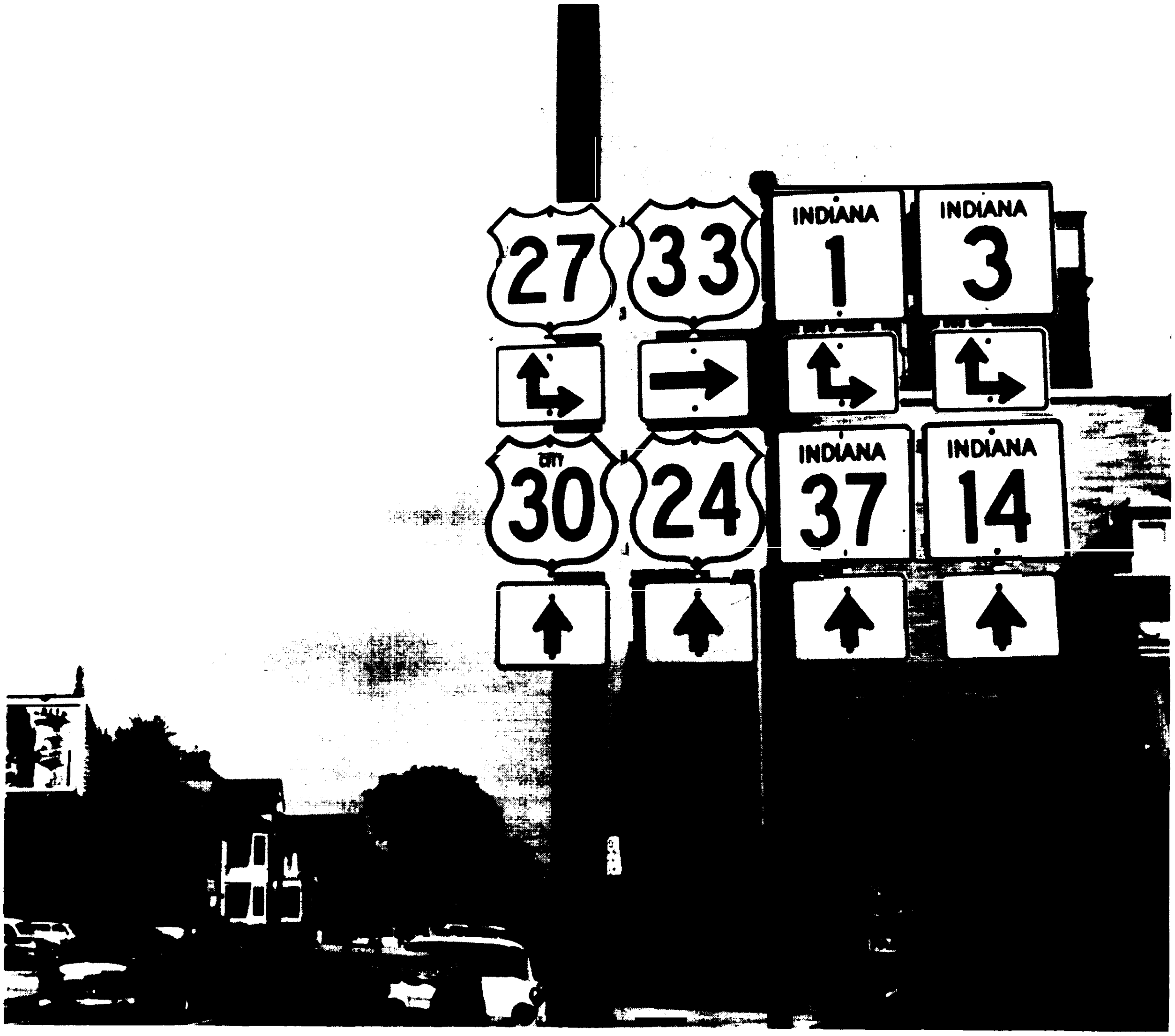

Photo Credit: U.S. Department of Transportation

and receives approximately 10 percent of Federal funding—$800 million in FY 1978.[56]

The influence of the Federal Government on the Nation's transportation and highway system is greater than its financial contribution to the Federal-aid system alone might suggest. Under the Federal Highway Act of 1966, the Secretary of Transportation was authorized to develop standards and criteria for Fedinvestment in transportation facilities. By making Federal-aid contingent on State compliance with specified conditions and regulations, the Federal Government can influence the extent, design, quality, and use of the road system. Through the financing process and the funding mechanisms used to channel investments into highways, the Federal Government can also influence the distribution of the costs of developing and maintaining the system. The Federal Government's influence over the highway system has grown, and can be expected to continue to grow in the future, as the number of specific-purpose programs increases.[7]

[5]The remaining 17 percent of the Federal highway budget is devoted to programs designed to address national needs that are not specific to any one portion of the system. These include programs for highway safety, emergency relief, public lands, rural highway public transportation demonstrations, and planning and research.

[6]U.S. Department of Transportation, Federal Highway Administration, *America on the Move*, p. 11.

[7]U.S. Congress, Congressional Budget Office, *Highway Assistance Programs: A Historical Perspective*, Background Paper, by Porter Wheeler, February 1978, p. xiv.

In view of the extent of the highway system and the Federal Government's role in its development, it is easy to understand how Federal investment in highways has become a major policy issue. This **was** not always the case, however. In the earliest days of highway building, the major policy question was how to get the Federal Government involved in the development of highways. Although the Constitution provided the authority to establish national highways, the Federal Government used this authority only reluctantly in response to ad hoc needs and pressures, some of which were only tangentially related to transportation.

In the early years of the automobile, the Government was pressed to increase its financial commitment to roadbuilding to improve personal mobility, to overcome the economic and social isolation of rural areas, to alleviate the congested conditions of urban life, and to stimulate the economic development of major parts of the country. The benefits of highway construction appeared to outweigh the costs. Popular support for Federal aid to highway development culminated in 1956 with the passage of the Highway Act and the Highway Revenue Act.

The highway legislation of *1956* significantly increased the Federal Government's Financial contribution to the highway program, but the funding soon fell far short of requirements. The costs of constructing the Interstate System were severely underestimated, and the projected receipts from the highway user taxes were overestimated. Within 2 years after passage of the law, it was clear that additional measures were required to meet rising costs.

During the next two decades, the gap between tax receipts and highway expenditures was closed by increasing the rate of taxation and by extending the life of the program. Thus, in economic terms alone, the Interstate System developed into a very different program from the one Congress originally anticipated. What had been projected to be a highway system constructed over a period of 15 years at a cost of $27 billion became a $184 billion highway program spanning a period of 35 years.[8]

There was also a growing disillusionment with some of the purported benefits of highway construction. Highway building did not, for example, reduce congestion on city streets, as the sponsors had predicted. By the late 1960's, there was mounting evidence that the expansion of highway facilities had increased highway use without solving the problem of congestion.

New social and environmental concerns added to the dissatisfaction with the highway program. The automobile's contribution to air pollution was not fully understood in **1956.**[9] Ten years later, however, as the connection between air quality and automobile use was established, environmentalists joined the growing ranks of those disenchanted with highways.

While recent economic, social, and environmental developments have contributed to a reconsideration of our national highway policy, nothing has dramatized the issues as much as the battle over the segments of the Interstate System in urban areas. Highway opponents, concerned about social and environmental impacts of highway building on urban life, began to protest new highway construction in the late 1960's. In their eyes, the extension of highways into urban areas has caused a series of social iIls that threaten the viability of city life.

More and more people began to question the Federal Government's policy of what appeared to them to be unlimited support for highway construction. By 1970, it was almost impossible to get a major highway program approved in most large American cities.[10] Highway opponents gained the ears of policy makers during the 1973-74 oil embargo, when it suddenly *became* apparent that the world could be shifting from an era of relative abundance of energy to one of relative scarcity.

As the Interstate System nears completion, a reevaluation of the Federal-Aid Highway Program may be in order. While the legislators of 1956 were concerned with how to provide funds to stimulate highway construction, those of today are concerned with how to use the Federal Government's resources to devise a balanced transportation program reflecting all of society's needs. Several policies to make more efficient and equitable use of the Federal Government's

[8] Gary T. Schwartz, "Urban Freeways and the Interstate System," *Southern California Law Review* 49 (March 1976): p. 442.

[9] Ibid., p. 482.

[10] Ibid., p. 444

resources have been proposed. Three of these are examined in this assessment: highway financing, highway maintenance, and road pricing.

Highway Financing Policies

For the purpose of this analysis, the question of highway financing can be divided into four major policy options:

1. A policy to continue the Highway Trust Fund in its present form to serve as the primary mechanism by which highways are financed,
2. A policy to finance all Federal transportation expenditures from one general trust fund,
3. A policy to establish separate trust funds for each transportation mode, and
4. A policy to finance highways, as well as all transportation expenditures, from general revenues.

Legislative History

The debate over highway financing has been somewhat confused because, in the eyes of many people, the Highway Trust Fund is the symbol, if not the equivalent, of the Federal-Aid Highway Program. Highway supporters and opponents alike tend to view the Highway Trust Fund as the key factor determining the nature and the extent of the highway system. Therefore, it is not surprising that the highway debate is often focused on the Highway Trust Fund. The trends and developments that have given rise to a reconsideration of our highway construction program have also provoked criticism of the mechanism used to finance it.

Approximately **90** percent of all Federal highway-related expenditures are financed from the Highway Trust Fund which was established by the Highway Revenue Act of 1956, a companion to the Highway Act of 1956.[11] The Highway Revenue Act was designed to encourage the construction of the highway system and, in particular, the Interstate System. The Highway Revenue Act increased the Federal Government's contribution to highway construction and established a funding mechanism for the Federal-Aid Highway Program. In addition to fixing the Federal share for interstate construction at 90 percent, the Revenue Act raised the number of Federal user taxes and created a Highway Trust Fund into which all these revenues were channeled to be made available for highway expenditures without additional authorization.[12]

The Highway Revenue Act of 1956 was less revolutionary than has often been assumed. The Federal Government had granted contract authority to the States since 1922. What the 1956 Act changed, however, was the source of the funds to meet these contract obligations. Before the establishment of the Fund, highway expenditures were appropriated from general treasury funds. With the exception of the Highway Trust Fund, the system of highway financing established in 1922 remains in effect today.[13]

Although the Federal disbursements for highway construction increased substantially after 1956, there remained a large gap between the projected cost of the highway system and the funds available. In fact, the history of the Federal-Aid Highway Program in the years after 1956 has been characterized by a search for ways to close the gap between increasing costs and insufficient revenues.[14-15]

[11] Although the Federal-Aid Highway Program and the Highway Trust Fund have come to be identified over the years, their separation was deliberately maintained in the legislation. The Act was divided into two distinct titles the first dealing with the Highway Program and the second with the financing mechanism. This division of the legislation means that, even if the Highway Trust Fund were to be eliminated, the Federal-Aid Highway Program would not have to be restructured.

[12] U. S Congress, Congressional Budget Office, *Highway Assistance Programs* pp. 14-18.

[13] The Highway Trust Fund is financed from user taxes, two-thirds of which are derived from the 4 cents per gallon tax on gasoline. (The original 3 cents per gallon tax was increased in October 1969.) There are also taxes of 6 cents per gallon on motor oil, 10 cents per pound on highway vehicle tires and inner tubes, and 5 cents per pound on retread rubber. There is an annual use tax on heavy trucks and buses (over 26,000 pounds) of 3 cents per 1,000 pounds of gross vehicle weight. The 10-percent tax on the manufacturer's sale price of new trucks, buses, and trailers, and the 8-percent tax on truck and bus parts and accessories also go into the Highway Trust Fund.

[14] Only 2 years after the passage of the Highway Act, the Bureau of Public Roads reestimated the total cost of the Interstate Highway System of $44 billion, an increase of $14 billion over the original projection. To meet this deficit, Congress temporarily suspended the "pay as you go" provision in 1958 and increased the gasoline tax from 3 cents to 4 cents a gallon. Costs for the Interstate System continued to grow, forcing Congress to increase its authorizations in 1965, 1966, 1968, 1970, and 1973. In 1975, the official cost estimate was increased again, this time to $89 billion. The Comptroller General made an estimate in the same year and predicted that the total system might cost between $111 and $184 billion.

Photo Credit: U.S. Department of Transportation

The extent to which the Highway Revenuei Act generated funds for highway construction can be seen by looking at how Federal aid for transport at i on has been distributed among modes for the years 1955 to 1975. As can be seen from table 114, almost two-thirds of all Federal outlays for transportation were for highways. Highway programs accounted for **98** percent of all Federal aid for ground transportation. [16]

Before 1956, only 50 percent of all Federal aid for transportation went to highways. By 1960, the figure was almost 100 percent. Ten years after the passage of the 1956 highway legislation, Federal highway assistance had increased more than 5 times. [17] The readily available funding undoubtedly stimulated the construction of highways, which was the intent of the law.

Despite the skyrocketing costs of building the Federal-aid highway system, the Government did not begin to reevaluate its highway policy until the late 1960's. And, even then, this policy reevaluation was undertaken not so much in response to the increasing financial cost of the system as to the growing appreciation of some of the social costs involved in highway construction.

Ironically, while attributing many of our social problems to highway construction, some people have begun to view the Highway Trust Fund in an entirely new light. Once considered to be the inexhaustible source of funding responsible for an unbalanced national transportation policy, the Highway Trust Fund is now viewed by some as a potential resource for meeting the Nation's total transportation needs. Mass transit advocates, urban officials, and transportation planners are calling for increased flexibility in highway financing and are asking for a share of the Trust Fund to finance mass transportation programs.

The move towards greater flexibility in highway financing began in 1968 when Congress

[15] Schwartz, p. 439.
[16] James V. Cornehls and Delbert A. Taebel, *The Political Economy of Urban Transportation* (Port Washington, N.W.: Kennikate National University Publications, 1977), pp. 39-40.
[17] Ibid.

first provided Federal assistance for public transportation as a part of highway legislation. Greater flexibility in highway financing was also achieved by increasing the number of programs eligible for financial assistance from the Highway Trust Fund.[18] This trend is apparent in the summary of major highway legislation shown in table 115.

Despite the trend towards greater flexibility, Congress has been unable to agree on a method of highway financing. Although the 1976 Highway Act extended construction of the Interstate System to 1990, the Highway Trust Fund was extended only until 1979. By extending the Highway Trust Fund temporarily, Congress deferred the decision on its long-term future. In taking such an action, Congress had no intention of postponing a discussion of the issues involved in highway financing. The conferees explicitly stated that:

> The extension of the interstate program through **1990** does not address the question of the source of funds for construction during that program. The conferees expect that during the next Congress methods of financing highway construction will be considered.[19]

[18] In the late 1960's, Congress authorized a major set of highway beautification and safety programs to be financed from the Trust Fund. By 1974, these programs had proliferated to the point that Congress had to make 55 separate authorizations for highway-related programs. These new aut horizations included programs for economic developmen t growth centers, bridge safety, rail grade-crossings seen ic highways, hazardous locations, and removal of roadside obstacles. More recently, Congress instituted a program to resurface older segments of the Interstate System. In addition, severa l established programs (e, g, forest highways) have been transferred to the Highway Trust Fund.

[19] U.S. Congress, House, Federal Aid Highway Act, House Report 94-1017 to Accompany H.R. 8235, 94th Congress, 2d sess., Apr. 7, 1976, cited in U.S. Congress, Congressional Budget Office, Highway Assistance Programs, p. *62,*

Table 114.—Size and Distribution of Federal Appropriations for Transportation, 1955-75 (millions of dollars)

Agency or program	1955	1960	1965	1970	1972	1975[a]
Department of Transportation						
Highway	$636	$2,978	$4,069	$4,507	$4,923	$5,020
Aviation	122	508	756	1,223	1,834	2,120
Railroad	2	3	3	17	57	267
Coast Guard	190	238	367	588	661	903
Urban mass transit	0	0	11	106	327	1,351
Other	0	0	23	-8	22	6
Offsetting receipts	0	0	-20	-16	-19	—
Subtotal	950	3,727	5,209	6,417	7,805	9,667
Other agencies	342	539	818	715	986	1,153
Total	$1,292	$4,266	$6,027	$7,168	$8,791	$10,820

[a] Already made or planned.
SOURCE: James V. Cornehls and Delbert A. Taebel, *The Political Economy of Urban Transportation*, 1977, p.38

Table 115.— Legislation Relating to Highway Financing

Federal Aid Highway Act of 1968	Provided Federal assistance to local governments to help finance parking lots serving carpools and bus patrons.
Highway Act of 1970	Extended Federal aid for highway transit by permitting the use of urban highway funds for the development of exclusive bus lanes and other nonrail public transportation facilities.
Highway Act of 1973	Permitted local governments to substitute mass transportation projects for unwanted, withdrawn segments of urban interstates. (Such projects were, however, to be financed from general funds.)
Highway Act of 1976	Refined and liberalized the provisions of the 1973 Act, making $800 million of Trust Fund monies available for urban systems, to be used either in highway construction or for mass transit projects.

SOURCE: Library of Congress, Congressional Research Service, *The Highway Trust Fund: Time for a Change?*, by W.A. Lipford, May 12 1977, p. 4

Policy Options

Continuation of the Highway Trust Fund.—Supporters of the Highway Trust Fund argue that it provides an effective, equitable, and efficient mechanism for securing funds and allocating the costs of highway construction. Trust fund financing provides a continual source of funding for, and assurance of, a long-term Federal commitment to the national system of highways.[20-21] State and local governments require assurance of a long-term Federal commitment if they are to be induced to invest their own resources. Trust funds are one way to give this guarantee, both as to the magnitude of funding and the length of commitment.

Most supporters of the Highway Trust Fund resist proposals that would diminish the funds available for highways. They also oppose the growing practice of including new programs, regardless of their nature, among those financed by the Fund. Typical of this position is that of the Automobile Association of America:

> Since 1956 the Highway Trust Fund has been burdened with the expense of many transportation activities far beyond those envisioned when the Trust Fund was established. AAA believes that the Trust Fund should be used only for the construction and improvement of the Interstate System and the urban and rural primary arterial networks.[22]

The traditional defense of the Highway Trust Fund is that the dedication of the user taxes to highway expenditures makes them legitimate in the eyes of the public. It is argued that dedicated user taxes are the most equitable and efficient method for distributing the costs of highway construction and highway use. Many economists agree. For example, in testimony before the Senate Committee on Environment and Public Works, Alice Rivlin, Director of the Congressional Budget Office, noted:

> User charges represent a way of recapturing from the actual beneficiaries some of the costs to the general public. Levying ***user*** charges promotes economic efficiency because users pay, directly or indirectly, for the services they receive. Proper incentives are provided, since heavier use imposes greater costs on the users, and at the same time, generates revenues to expand facilities.[23]

Opponents of the Highway Trust Fund and the present system of highway financing have proposed alternative methods and mechanisms. Their criticisms of the Highway Trust Fund can best be seen by examining the alternatives they have advanced.

Financing Highway-Related Expenditures From General Funds.—Basic to all of the arguments calling for an elimination of the Highway Trust Fund, is the belief that all Federal programs should compete in the marketplace of political, economic, and social ideas. It is argued that, by providing earmarked funding, the Highway Trust Fund encourages the building of highways at the expense of other transportation modes. ” If transportation facilities are to be made available to everyone at the lowest cost to society, the costs and benefits of using alternative modes in different situations must be weighed. This would require replacing the Highway Trust Fund with a more flexible funding mechanism. ”

Trust fund financing also makes it difficult for Congress to make transportation decisions in the light of other societal values. Highway programs, for example, affect energy, environmental, and land development policies. Some groups feel that as long as highway financing decisions are made outside the normal budgetary process, they will not reflect total national needs.[26]

The Highway Trust Fund circumvents the normal congressional budgetary process. Since

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[20] It has been noted, however, that the ability of the present system to provide a continual source of funding may be due as much to the plenitude of dedicate funds—about $6 billion are devoted to the Highway Trust Fund annually—as to the Trust Fund device itself.

[21] U.S. Congress, House, Committee on the Budget, *Impact of Highway and Mass Transit Programs on the Federal Budget and Associated Federal Urban Investment*, hearings before the Task Force on Community and Physical Resources, 95th Cong., 1st sess., 1977, p. 55.

[22] U.S. Congress, Senate, Committee on Public Works, *Future of the Highway Program*, hearings before the Subcommittee on Transportation, 94th Cong., 1976, p. 1290.

[23] Statement of Alice M. Rivlin, Director, Congressional Budget Office, before U.S. Congress, Senate, Committee on Public Works, Feb. 7, 1978, p. 8.

[24] U.S. Congress, House, Committee on the Budget, *Impact of Highway and Mass Transit Programs*, p. 55.

[25] Ibid.

[26] Rivlin, pp. 1-2.

the Highway Trust Fund obtains its revenues from earmarked taxes, the budgetary authority for any year depends on the receipts deposited in the Fund and not on a congressional authorization. Congress, therefore, has almost no way to assert budgetary control over highway financing. One way of achieving such control would be to eliminate the Highway Trust Fund. The highway programs then would compete with other transportation programs—as well as with all other federally aided programs—for the revenues of the general treasury.

A Transportation Trust Fund.—The imbalance in the present transportation system is attributed by some, not to the existence of the Highway Trust Fund, but to the lack of similar trust funds for other modes.[27] They advocate conversion of the Highway Trust Fund into a user-financed, general transportation fund, in part because gasoline taxes are well-established and because their justification is greater than ever in view of the Nation's long-term energy needs. With the establishment of such a fund, transportation decisions would no longer be distorted in favor of highways. Modal decisions could be based on a comparative, cost-benefit analysis.

The concept of a transportation trust fund has some drawbacks, While it might facilitate development of a coordinated, multimodal transportation policy, it could not guarantee a specific Federal commitment to any particular mode. As a system of financing, a transportation trust fund is subject to the same criticism as the Highway Trust Fund—that is, a trust fund would be inflexible in the face of changing societal needs and would be exempt from the normal congressional process of budgetary control.[28] There is also a question of whether it would be politically feasible. Various institutions have been erected around every transportation mode at all levels of government—each with its own distinct organizational needs and priorities. Because of these institutional barriers, a policy providing for a common transportation fund might 'be difficult to implement.[29]

A Trust Fund for **Each** Mode.—An alternative popular among mass transit advocates is establishment of individual trust funds for each transportation mode. The advocates of multiple trust funds point to the success of the Highway Trust Fund as the rationale for extending this approach to other modes. The argument used to support this proposal is the same as that used to support the Highway Trust Fund: State and local governments need assurance of a long-term Federal commitment. Since all modes of transportation have long-term development and construction requirements, all should be financed through trust fund mechanisms.

Representative James Howard, Chairman of the House Public Works Committee and sponsor of legislation designed to bring highway and mass transit under one authorization but two separate funds, has argued thus:

> Mass transit has been a mess for years, not only because there has not been a sufficient amount of money available, but the money was available on a general revenue basis. We will never get a sensible, forward-looking mass transit program until we get a trust fund for mass transit.[30]

The advocates of a mass transit trust fund believe that the need for assured funding is greater than the need to make intermodal transportation decisions.

Opponents of individual trust funds believe that this approach could lead to an inflexible system of financing. Since each fund would be financed from earmarked revenues, investment decisions for one mode would be made without having compared the costs and benefits of investing in other transportation modes. Establishment of individual trust funds might also promote creation of new organizations and bureaucracies. In time, these organizations would develop their own institutional interests in maintaining the system and could resist change.

One major difference between the proposed mass transit fund and the Highway Trust Fund is the source of funding. Since most mass transit systems are presently operating at a deficit, it is unlikely that a mass transit fund could be sustained by user taxes.

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[27] U.S. Congress, House, Committee on the Budget, *Impact of Highway and Mass Transit Programs*, pp. 55-56.
[28] Rivlin, p. 7.
[29] Ibid., p. 10.

[30] Rochelle L. Stanfield, "A Truce May be on the Way in the Highway-Mass Transit Conflicts," *National Journal*, Nov. 19, 1977, p. 1815.

The arguments for and against each of the four policy options are summarized in table **116.**

In evaluating these policy options, it is important to remember that the Highway Trust Fund is not the equivalent of either the highway program or the highway financing process. Even if the Highway Trust Fund were dissolved, highway user taxes might be maintained, for example, and deposited in the general treasury fund. As the early history of the highway program demonstrates, it is not necessary to have a trust fund in order to link user taxes to highway expenditures. Similarly, long-term authorizations could be, and have been, made within the context of the congressional budgetary process.

Highway Maintenance

Another issue that could have a significant effect on the future of the highway transportation system is highway maintenance. Each year, Federal, State, and local governments spend approximately one-fourth of all highway funds to maintain the 3.3 million miles of national highways. Highway maintenance has traditionally been the responsibility of State and local governments—a quid pro quo for receiving Federal aid. As long as the federally aided highway systems were relatively small, the States were able to fulfill their obligations without undue hardship. In fact, the State governments consistently

Table 11 6.—Advantages and Disadvantages of Transportation Financing Options

Opt ions	'-Advantages	Disadvantages
Continuation of present policy . . .	Continual source of funds. Long-term commitment. System already in place. Relatively equitable distribution of costs.	Slow to respond to changing needs. Unsuitable as a framework for comparing costs and benefits. Exempt from budgetary control. Procedural discrimination against other modes.
Unified Transportation Trust Fund	Continual source of funds. Long-term commitment to transportation. Elimination of procedural discrimination among modes. Facilitates the development of a coordinated, multimodal transportation policy.	Unable to provide long-term financial commitment to a particular mode. Slow to respond to changing needs. Exempt from normal budgetary process. Present user taxes insufficient to finance general transportation fund. Institutional costs involved in dismantling present system.
Separate Trust Funds for each mode	Provide equal access to transportation funds for each mode. Provide assurance of long-term Federal commitment. Politically appealing because costs are least visible.	Least flexible system of financing. Exempt from normal budgetary process. Modal decisions would be independent of other transportation and societal decisions. Create institutional rigidities.
Financing for general funds.	Most responsive to changing needs. Eliminates procedural disc rimi nation i n competition for funds. Suitable framework for comparing costs and benefits of investing in al l transportation modes. Subject to budgetary control.	Would entail transportation subsidies. Fails to provide guaranteed financial commitment. Politically cost l y.

rejected proposals that might reduce their responsibilities for, and authority over, highway maintenance activities.

With the growth of the highway system and the costs of maintaining it, the financial burden on State and local governments has taken on unforeseen proportions. The costs of maintenance are likely to increase further in the future, as the number of vehicle miles traveled rises and as many of the highways built in the last **20** years near the end of their service lives. If the present rate of deterioration continues, the investment in the national highway system will be significantly depreciated, and the costs of rehabilitation greatly increased. Steps must be taken to preserve the system if it is to continue providing the same level of service as today. Thus, the question is raised as to whether the Federal Government should—even in the face of State opposition—assume part of the burden of maintaining its investment in the Nation's highways.

Present Policy

The Federal-Aid Highway Program provides for building, improving, and maintaining highways. These tasks have been divided by law into the categories of construction and maintenance. Highway construction includes new construction, reconstruction, and highway betterment. Betterment, in turn, includes the tasks of resurfacing, restoration, and rehabilitation of roads or bridge decks as necessary for safe and efficient utilization.[31]

Maintenance is usually defined as "the preservation of the entire highway, including surface, shoulders, roadsides, structures, and any traffic control devices that are necessary for its safe and efficient utilization."[32] The ambiguity of the definition of maintenance has led to varied and controversial interpretations. In practice, the term maintenance has come to mean all those highway-related tasks that do not fit within any specific construction category.[33] While the Federal Government is primarily responsible for financing and setting standards for the construction of the highway system, the States bear sole responsibility for maintenance.

The States have been responsible for maintenance since the beginning of the Federal-Aid Highway Program. The Federal Aid Road Act of 1916 assigned to the States responsibility for maintaining all roads constructed under the provisions of that Act. The States' duty to maintain the federally aided roads was reiterated in 1921, the last time that the Federal-State division of labor for highway responsibility was contested.

In the Highway Act of 1921, the Secretary of Agriculture was authorized to place the highways "in proper condition of maintenance," charging the costs against a State's allotment from Federal funds and prohibiting further projects until the Federal Government had been reimbursed for the maintenance expenses. This rarely invoked clause was amended by the Federal Highway Act of **1950,** which provided that the Federal Highway Administration could, after **90** days notification, withhold approval of further Federal-aid projects until the States had satisfactorily completed maintenance work.

The Federal Highway Administration has never used its authority to withhold funds. Nor has it prescribed standards for highway maintenance.[34] Although the Federal Government has been reluctant to interfere with State jurisdiction over highway maintenance, the existing institutional framework is flexible enough to allow the Federal Government to assume a more active role in this area.

Despite increased outlays for highways by all levels of government in recent years, highways have been deteriorating **50** percent faster than they are being restored.[35] A review of the factors underlying this trend will help to illustrate the magnitude and urgency of the highway maintenance problem.

The accelerated rate of highway deterioration can be accounted for, in part, by the rate of inflation. Since 1967, State highway maintenance costs have increased at an annual rate of 7.3 per-

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[31] U.S. General Accounting Office, *Improving and Maintaining Federal-Aid Roads—Department of Transportation Action Needed*, Feb. 2, 1977, p. 5.

[32] Ibid.

[33] When a road requires a significant improvement to increase capacity or to meet a design standard, or significant reconstruction or maintenance to restore it to normal use, expenditures are usually considered outlays for capital improvements. The Federal Highway Administration defines maintenance costs as those expenditures required to keep the highway in usable condition. They would include such activities as routine patching, bridge painting, and removal of snow and ice.

[34] Ibid, p. 6.

[35] Ibid.

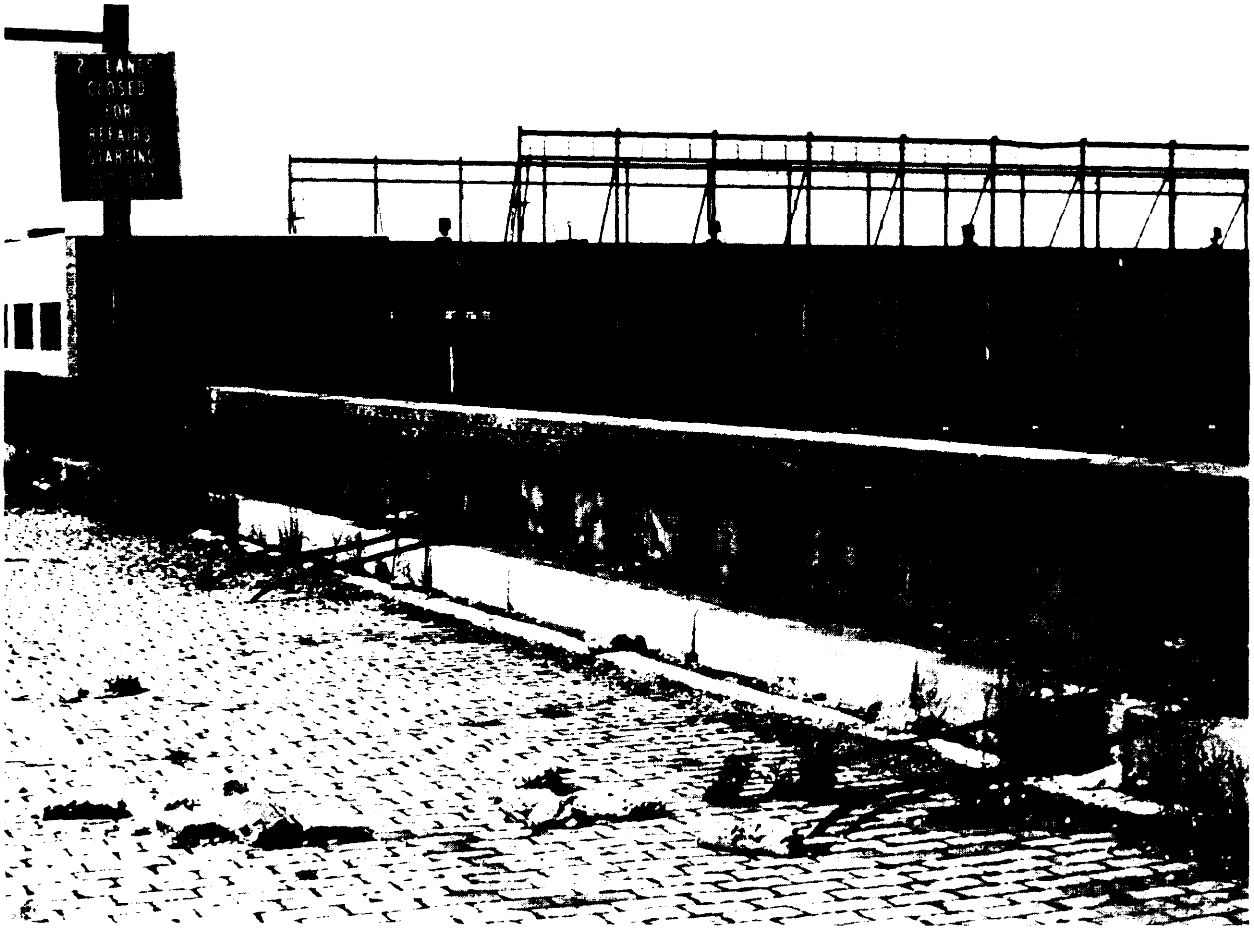


Photo Creditf Sydec

cent. The largest share of the increase is attributable to rising material and equipment costs.

Despite a twofold increase in annual expenditures for maintenance in the years between 1967 and 1976, the amount of real maintenance purchased—in terms of today's purchasing power—was only 7 percent.[36] This 7-percent increase in real maintenance expenditures contrasts sharply with the 41-percent increase in VMT, the 37-percent increase in the number of cars on the road, and the 88-percent increase in the number of trucks on the road.

The development of the Interstate System has also added to the States' highway maintenance burden. Interstate funds could not be used for reconstruction until 1976 and even then, only on a very limited basis. States responded to the favorable 90/10 matching ratio for new highway construction by building new roads instead of maintaining existing roads.[37] Acknowledging that the States' responsibility for maintaining the Interstate System has reached sizable and unanticipated proportions, the Department of Transportation, in the 1974 Transportation Report, noted that:

> As the Interstate System approaches completion, the costs of maintenance represent an increasingly larger share of State highway expenditures. This expense over the life of the System is expected to be more than double the States' initial capital investment in the System.[38]

Maintenance expenditures have also been increasing as a result of the Federal Government's decision to raise the permissible size and weight of trucks and large vehicles using the Interstate

[36] Sydec FEA, p. III-32

[37] U.S. General Accounting Office, *Improving and Maintaining Federal-Aid Roads*, p. 5.

[38] U.S. Department of Transportation, *1974 National Transportation Report, Current Performance and Future Prospects* (Washington, D.C.: Government Printing Office) July 1975, p. 514.

System. Under the 1956 Highway Act, no vehicle weighing more than 18,000 pounds on a single axle, 32,000 pounds on a tandem axle, or having a gross weight of over 73,000 pounds could use the Interstate System. When the Federal-Aid Amendment to the Highway Act raised the limits to 20,000 pounds on a single axle, 34,000 pounds on a tandem axle, and 80,000 pounds gross weight in an effort to save energy, an estimate was made of the potential maintenance and capital costs involved. Testifying before Congress, Federal Highway Administrator Tiemann pointed out that size and weight increases on the order of those proposed would increase highway maintenance costs by $40 million (adjusted to 1977 dollars) and would increase combined capital and maintenance costs by $200 million.[39]

The combined effects of rising inflation, expansion of the highway system, and the increase in the size of vehicles authorized to use the system have contributed to the steady rise of State expenditures for highway maintenance. In the years between 1967 and 1976, for example, State expenditures on highway maintenance and related operational expenditures tripled from $1.1 billion to $3.3 billion. Because of these increases in the size of maintenance and other noncapital highway expenditures, a smaller share of the total highway disbursements is being devoted to capital improvements. (See figure 47.)

[39]U.S. Congress, Senate, Committee on Public Works, *Hearings on Truck Sizes and Weights*, 93d Cong., 2d sess., Feb. 20, 1974, Part 2, p. 20.

The trend in the distribution of State highway disbursements is almost identical to that for total disbursements. State governments have traditionally provided about 80 percent of all capital expenditures for highways but, in recent years, they have been unable to sustain this proportion of investment. The share of State budgets available for capital expenditures has decreased from 71 percent in 1962 to 58 percent in 1974, as the costs of maintenance, administration, law enforcement, and debt service have increased. Continued decline in the level of capital improvement will, over time, increase the rate at which highways deteriorate and cause the long-range costs of highway maintenance to rise.

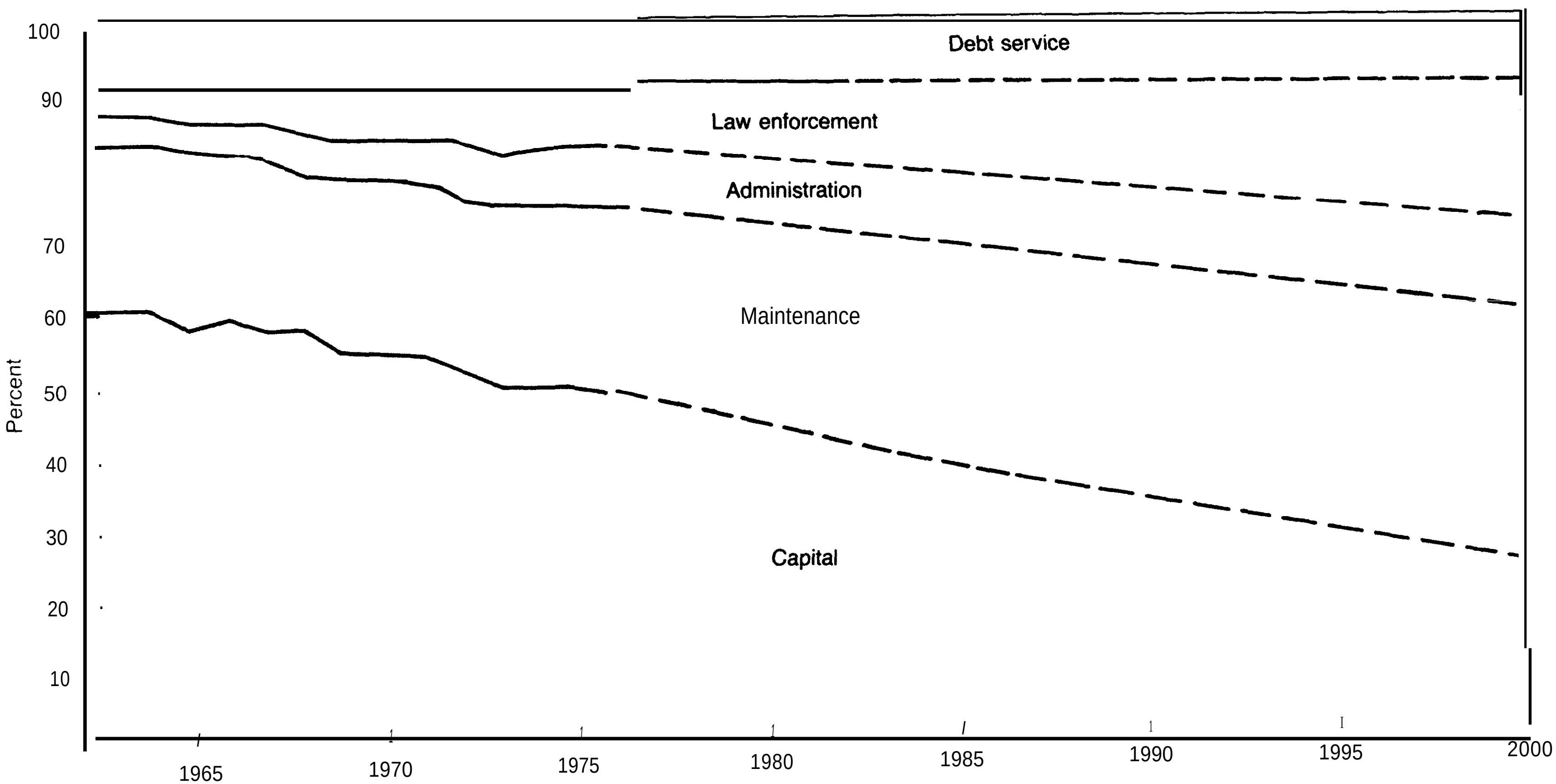
Projections under Base Case conditions suggest that these trends will continue. For example, it is assumed in the Base Case that a portion of the capital expenditures for highways will be used for the scheduled completion of the Interstate System by 1990. The cumulative capital expenditures from 1976 to 2000 are projected to total $257 billion in 1975 dollars. About $38 billion of this amount would be required for completion of the Interstate System. The remainder is assumed to be expended on other highway systems in proportion to historic patterns. Increasingly more of the expenditures of the diminishing capital programs for all systems would be devoted to reconstruction of existing obsolete pavement and structures. The effect would be a decline in highway system performance.

Table 11 7.— Historical and Projected Distribution of Highway Disbursements

	Total highway disbursements (percent)				State highway disbursements (percent)			
	1965	1975	1985	2000	1965	1975	1985	“ 2000
Capital	58	51	38	25	69	61	47	28
Maintenance	23	25	32	35	14	16	23	31
Administration	5	7	9	13	5	6	9	13
Law enforcement	4	7	11	17		7	11	17
Debt service	10	10	10	10	8	10	10	10

SOURCE *Highway Staff stics* through 1975, Sydec protections to 2000

Figure 47.—Historical and Projected Distribution of Total Highway Disbursements



SOURCE *Highway Statistics* through 1975 Sydec projections to 2000

In the Base Case, maintenance and other noncapital expenditures are assumed to increase 1 percent per year as a proportion of total expenditures. The increased mileage of interstate and other new highways over the last 20 years will also add to the costs of maintenance as these roads age. Vehicle miles of travel will increase more rapidly than the supply of highways, placing additional demands on the maintenance budget. Consequently, under Base Case conditions, maintenance expenditures per lane-mile are expected to increase from the 1975 levels of $2,627 to $3,180 in 1985 and to $3,936 in 2000 in 1975 dollars.

Policy Options

The following have been identified as policy options to deal with the problem of highway maintenance:

- Improve highway maintenance through management training, promotion and demonstrations of new ideas, and research and development.
- Establish Federal maintenance standards and a process of Federal inspection or State inspections to meet Federal standards.
- Divert revenues from an increased user tax on gasoline to State and local governments for capital and maintenance expenditures.
- Incorporate maintenance as well as capital programs in the highway planning process.
- Increase categorical funding and promote low-capital expenditures.
- Permit the transfer of funds from capital categories to maintenance activities.
- Provide block grants to States—with pass-through provisions for localities to be used on any reasonable mix of maintenance work or, alternatively, provide block grants directly to localities.

The arguments for and against a more active role for the Federal Government in highway maintenance have been summarized below to indicate the range of policy questions that will have to be addressed.

Arguments in Favor of an Increased Federal Role in Highway Maintenance.—

- Given the size of the social and economic investment in the highway system, the Federal Government should act to preserve that system.
- The highway dollar is under intense pressure from mass transit advocates, environmentalists, planners, and local governments. Matching funds for highway con struction have become scarce, and States are reluctant to obligate the recently released impounded funds because of matching requirements. To free sufficient funds for a fully balanced highway program, States must be relieved of the entire maintenance burden.
- State and local governments need assistance to offset the effects of inflation and the inability of State user and property taxes to keep pace with needs.
- State legislatures have reduced maintenance expenditures in favor of capital expenditures to take advantage of Federal aid available for capital projects.
- The present, loosely managed highway maintenance program would be more effective if it were subjected to standards and inspection requirements in exchange for Federal aid.
- Federal aid for maintenance would provide State and local governments with greater flexibility in developing a proper mix between maintenance and capital investment.
- The 3R program provides evidence that maintenance projects can be adequately coordinated and promoted at all levels of government.
- Maintenance of Federal-aid highways is currently required by States, and the FHWA is authorized to review the adequacy of State maintenance programs. Thus, policies providing for an increased Federal role are compatible with the institutional division of responsibility.

Arguments Against an Increased Federal Role in Highway Maintenance. —

- Since State and local governments are close to the problems, only they can provide a flexible response to diversified local needs.
- There is historical precedent for State and local governments to maintain their own streets and roads.
- Federal aid for maintenance will unnecessarily increase red tape.
- Federal aid for highway maintenance will increase Federal control of accounting procedures, disbursements, and program mixes.
- There are no adequate work-performance measurements or standards for highway maintenance.
- Maintenance activities are carried out by a variety of work forces—State and local forces, private contractors, convict labor—making standardization almost impossible.
- Federal aid to maintenance would divert funds from the effort to complete the Interstate System.
- Unanticipated maintenance work such as the damage to highways created by storms or accidents cannot be planned or standardized.

Congestion Cost= Pricing

During the 1950's and 1960's, highway congestion was considered the major transportation problem, and highway construction was the preferred means of dealing with it. In the 1970's however, attitudes changed and highway construction came to be viewed by many as the cause of serious social problems. The highway building program was also criticized from the standpoint of equity. It was argued that the costs of building and maintaining additional lanes to deal with congestion are really commuter subsidies, since commuters are not taxed in proportion to their share of the costs.

As the economic costs of construction continue to escalate and as the social costs of highway building are reassessed, new strategies to cope with congestion are being sought. One such strategy, which aims to provide both increased capacity and a more equitable distribution of the cost of highway mobility, is the policy of congestion cost-pricing.

Factors and Trends Affecting Congestion

The problem of congestion is not an evenly distributed one geographically. Congestion has rarely been a problem in rural areas, except around major recreational sites. In urban areas, congestion is most severe during morning and afternoon hours on roads that serve high- density activity centers. Even within cities, the congested area is usually only a small part of the metropolitan region (typically less than 10 percent), and periods of congestion usually total only 4 to **6** hours per day. [40]

Given their present low levels of congestion, rural highways could accommodate future increases in the number of vehicle miles traveled—predicted to be in the range of 60 percent for all rural highways—without significant changes in average speeds. In urban areas, however, the picture is quite different. Increased growth in highway travel projected for the next **25** years will result in more congestion in urban areas. [41] As figure 48 indicates, this growth will occur on roads that already carry a large percentage of urban auto travel. Figure 49 indicates that there will be large speed decreases on these roads, and their current speed advantages over other highways will be considerably reduced.

The proportion of urban interstate highway travel occurring under congested conditions is projected to increase from about 10 percent in 1975 to about 34 percent in the year **2000.** Figure 48 also shows that for "other freeways and expressways" in urban areas, travel under congested conditions is projected to increase from about 11 percent of VMT per day to **30** percent. This means that the typical urban motorist in the year 2000 can expect to encounter stop-and-go traffic on freeways about 3 times as often as today.

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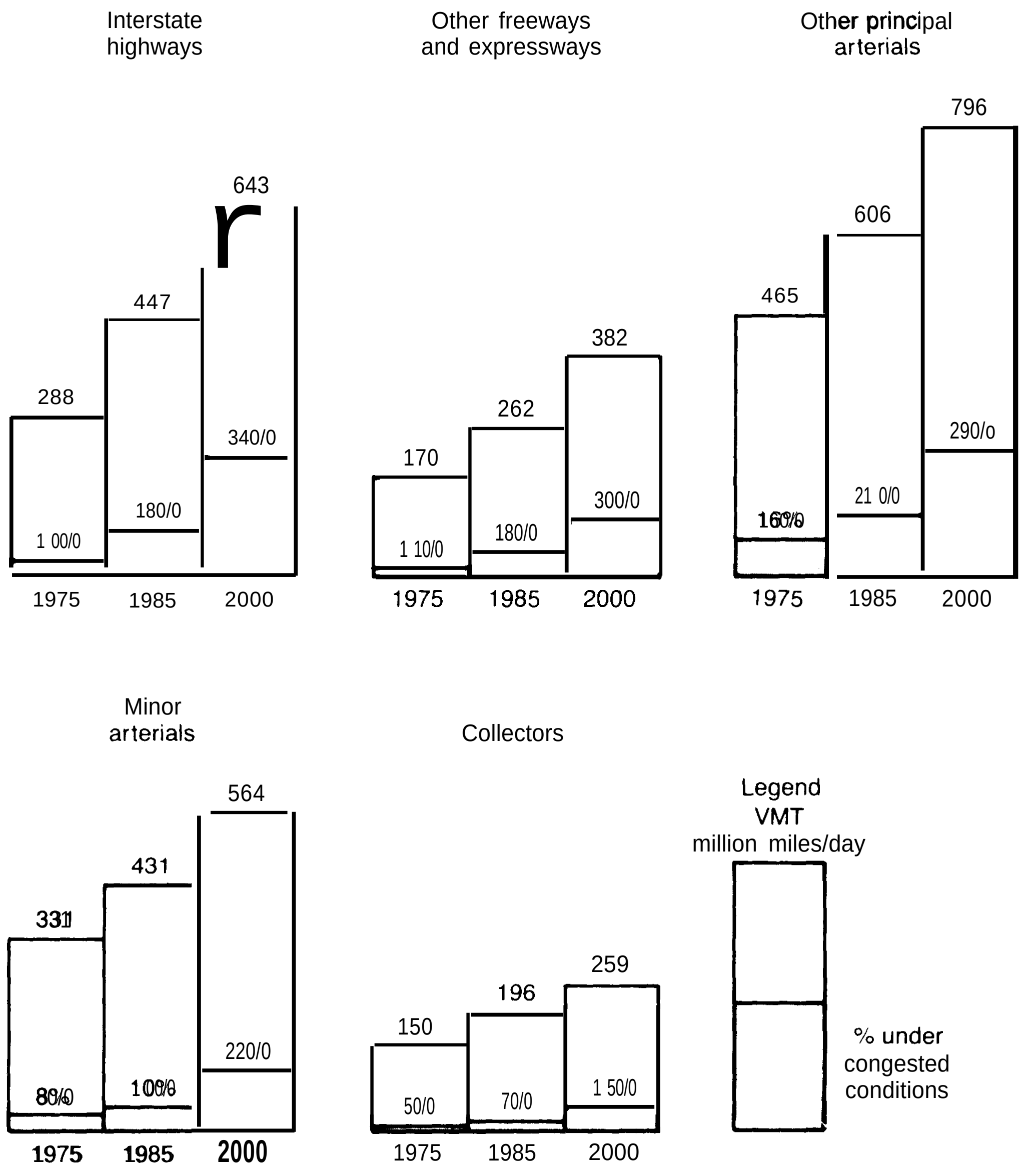
[40] Joel L. Horowitz, "Pricing the Use of the Automobile to Achieve Environmental and Energy Goals: A Comparison of Measures and Effects," *Urban Transportation Pricing Alternatives*, papers presented at a conference on May 14-17, 1976, Easton, Md., conducted by the Transportation Research Board, National Academy of Sciences, p. 3.

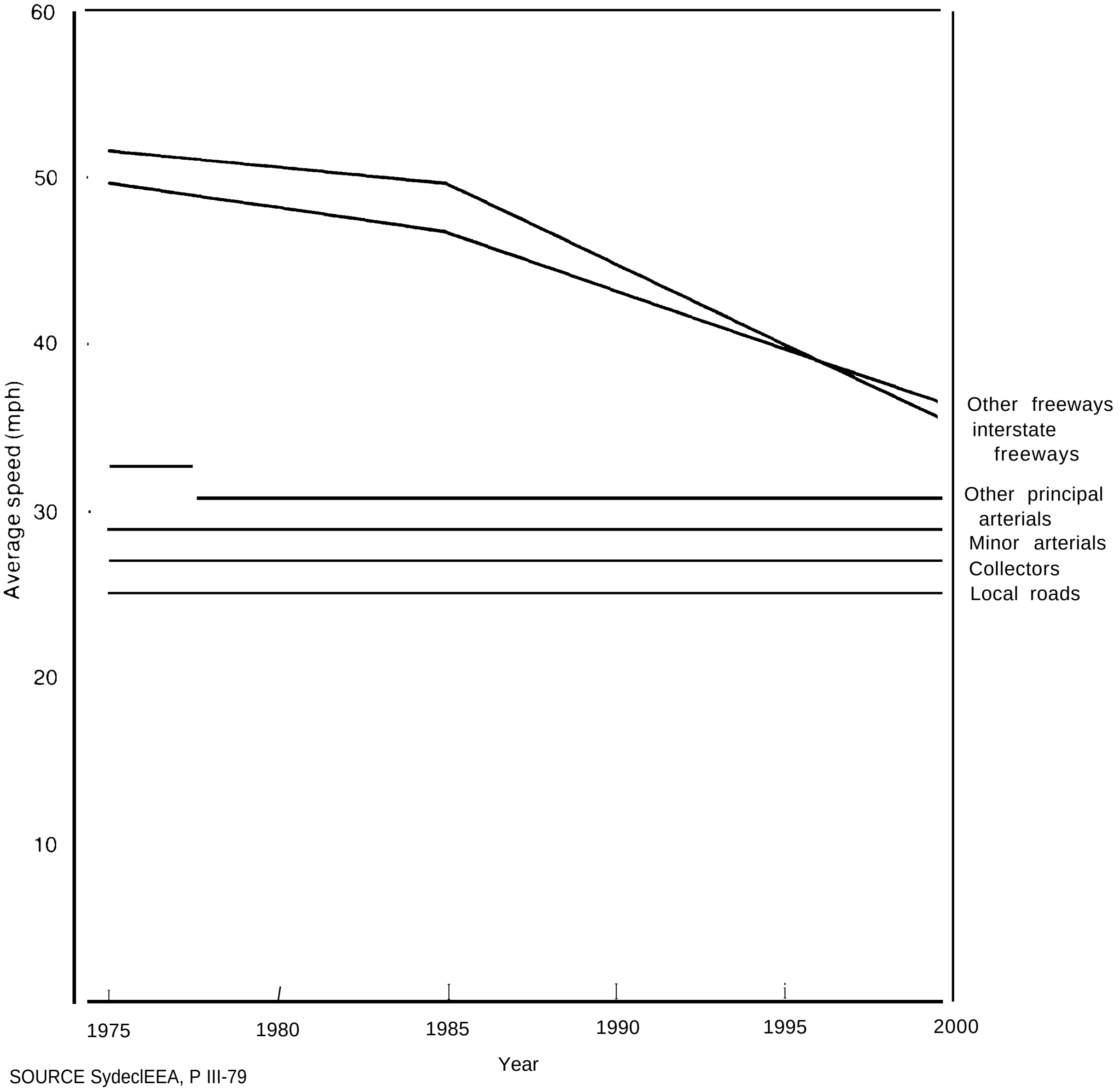
[41] *Sydec EFA*, p. 77.

Figure 48.—Total Urban Automobile Travel Under Congested Conditions for 1975, 1985, and 2000



SOURCE: Sydec EEA, p, 77

Figure 49.—Projected Average Speed in Urban Areas



SOURCE SydeclEEA, P III-79

Present Policies

Because urban congestion was not considered to be a major transportation problem until the 1950's, Federal highway policy was aimed not at relieving congestion in the cities, but at connecting isolated rural areas. Provisions for a continuing urban area highway program were first contained in the Federal Aid Highway Act of 1944.[42] The need to build urban highways was reaffirmed with the establishment of the Interstate Highway Program, which allocated 9,249 miles to the urban system.

From the beginning, however, there was disagreement as to whether the urban system should be designed primarily to extend intercity highways into urban areas or to serve the specific needs of metropolitan areas.[43] At the heart of the justification for the urban interstate was the argument that the construction

[42] U.S. Congress, House, Committee on Public Works, *Urban System Study*, Report of the Secretary of Transportation to the U.S. Congress, 94th Cong., 2d sess., December 1976, p. 13.

[43] Schwartz, pp. 470-477

of additional highways would reduce congestion by allowing a freer flow of traffic and reducing driving time. This claim was not borne out by events. Highway building could not keep pace with the growth in urban traffic, some of which was induced by the construction of additional highways.[44]

In the face of increased construction costs and public opposition to urban freeways, new major construction was slowed down in the 1970's. The Federal Government's approach to reducing congestion shifted from capital-intensive investment to strategies designed to make more efficient use of existing facilities and to allow greater local flexibility in choosing the means to reduce congestion. Evidence of the Federal Government's commitment to reducing traffic congestion can be found in the Federal Highway Code which states:

> The Congress hereby finds and declares it to be in the national interest that each State should have a continuing program within the designated boundaries of urban areas of the States designed to reduce traffic congestion and to facilitate the flow of traffic in the urban area. "

Federal planning regulations required that after October 1975, transportation plans should explicitly deal with short-term as well as long-term strategies and with operational as well as capital improvements. Subsequently, each metropolitan planning organization was required to submit a transportation system management (TSM) plan aimed at bringing about more effective usage of existing transportation capital stock. One of the options consistent with this mandate is congestion cost-pricing,

Policy Options

Economists often argue for congestion cost-pricing as a low-cost solution to the problem of congestion. In their view, such a policy not only would lead to optimal resource allocation and the efficient use of capacity, but also would cover the full social costs of the resources used.[46] Drivers would be charged for operating a vehicle—or, more effectively, for operating a low-occupancy vehicle—during the peak hours in highly congested sections of urban areas.[47]

Efficient use of streets would be achieved, since the price charged to drivers would link trip decisions to travel time. During peak hours, drivers would pay a fee proportionate to what they contribute to the total congestion on the highway. The price would be economically efficient if it equaled the social costs that the motorists imposed minus the actual payments in the form of other taxes, fees, and their own time expenditures.[48]

One of the arguments in favor of road-pricing is that it is a flexible strategy whereby prices can be adjusted in accordance with the levels of improvement desired. Road-pricing also provides an element of choice. An individual can still choose to drive, but he does so at a price. Road-pricing is not only an inexpensive method of discouraging auto travel, but also a means of generating new revenue that can be used to develop alternative means of transportation. Pricing programs can also be combined with other programs designed to limit the use of energy, to reduce automobile emissions, or to encourage the use of alternate means of transportation.[49]

Although several methods and mechanisms have been proposed for administering road-pricing schemes, the most popular is some form of supplementary licensing. Licensing would be flexible, comprehensive in its application, relatively easy to enforce, and inexpensive to implement.

Several Federal Government agencies have been evaluating congestion cost-pricing. A National Science Foundation study recommended Federal support for a site-specific demonstration

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[44] Ibid., p. 490.

[45] "Transportation Improvement Program," *Federal Register* 40 (Sept. 17, 1975): p. 42978.

[46] *SRI*, p. E-5.

[47] Congestion represents a situation in which the sum of all costs (money, time, discomfort, etc.) of all vehicles using a road exceeds the sum of the cost if each vehicle were to use it separately. This situation occurs because the level of service decreases (or alternately, the level of congestion increases) as each additional vehicle enters the road. Thus, when a motorist enters a road, he imposes a cost on other drivers that exceeds the extra time and discomfort that he will have to pay to use the road. It is for this additional cost that the motorists would be charged under a policy of congestion cost-pricing.

[48] Kiran Bhatt, *What Can We Do About Traffic Congestion? A Pricing Approach* (Washington, D.C.: The Urban institute, April 19701, p. 15.

[49] Tom Higgins, *Comparing Strategies for Reducing Traffic Related Problems The Case for Road Pricing* (Washington, D.C.: The Urban Institute, September 197tJ).

Photo Credit: U.S. Department of Transportation

planning project.'" The Office of Service and Methods Demonstration in the Urban Mass Transportation Administration (UMTA) has been actively involved in developing such a project since 1974. A panel representing several Government agencies and private concerns, all interested in mass transportation, energy, and the environment, has been established to provide advice.[51]

In the demonstration project, a congested area of the city will be designated an "area of experiment" during certain hours of heavy travel. Private automobile drivers, wishing to drive in this area during peak hours, will be required to purchase and display a license.[52] The Office of Service and Methods Demonstrations has adopted criteria for selection and has conducted a preliminary screening of candidate cities. Preliminary sketch designs will be made in approximately three to five cities, and actual implementation will be carried out in at least one.[53]

In conjunction with FHWA and EPA, UMTA is evaluating the congestion pricing scheme in use in Singapore. They are also conducting a study to determine the potential of parking policies for reducing the use of low-occupancy vehicles in congested areas.[54]

Effects and Impacts

If the arguments in support of congestion cost-pricing are valid, why has no local government sought to implement such a program in an effort to reduce automobile congestion? The reluctance of local officials to institute road- pric-

[50] Bert Arrillaga, "The UMTA Transportation Program," *Urban Transportation Pricing Alternatives*, p. 10.
[51] Ibid., pp. 11-12.
[52] Ibid.
[53] Ibid.
[54] Ibid.

ing appears to be related to its potential repercussions. Although the economists' assertion that congestion cost-pricing will have net social benefits might be true, such a policy is likely to have impacts and costs that are not equally distributed.

Automobile users will be most affected. Those who continue to drive, in spite of the congestion charges imposed, will pay a fee that might or might not outweigh the value that they place on the time saved or the convenience gained.[55] Even if motorists value their time highly, they are likely to resent the imposition of congestion fees. Some drivers will be forced to forego trips in congested areas during peak hours.

Businessmen and the owners of parking facilities in downtown areas would also be directly affected by the imposition of congestion charges although the degree of impact would depend on other variables, such as the existence and convenience of alternate modes of transportation. Lacking empirical evidence, it is difficult to predict exactly how a road-pricing scheme would affect business in downtown areas. However, what is important to local politicians is the belief of local businessmen that their interests would be impaired.

[55] Damian Kulash, *Congestion Pricing: A Research Summary*, (Washington, D.C.: Urban Institute, July 1974), p. 3.

Current transit riders, who have to share facilities with additional riders, would also be affected by a policy of congestion cost-pricing. Some of the burden on public transportation might be eliminated if there were more room on highways for high-occupancy vehicles and if road-pricing revenues were channeled into the improvement and expansion of alternative modes of transportation.

Since congestion is not evenly distributed, the question of how much money the Federal Government should spend to reduce the problem is also likely to be an issue. If the funding available for all highway-related needs remains more or less the same, then any money spent on reducing congestion will beat the expense of other highway-related programs. In this sense, all those who are not the direct beneficiaries of congestion cost-pricing—rural dwellers and noncommuters, for example—would be negatively affected, although in a minor way, since the funding necessary to support such a scheme would be relatively small.

Any effort to predict the effects and impacts of a road-pricing policy would be speculative, since there have been no attempts to implement such a policy in the United States. To the extent that the conditions in Singapore are comparable to those in the United States, some useful

Photo Credit U S Department of Transportatlon lessons can be drawn from that city's efforts to reduce traffic congestion. The World Bank has monitored the program and made an initial evaluation, from which the following observations are drawn.[50]

In an effort to reduce congested conditions and to prevent what, on the basis of growth trends, was predicted to be an extreme level of congestion, the City of Singapore instituted in 1975 a program of road-pricing designed to reduce peak-hour traffic by 25 to 30 percent. The traffic restraint scheme includes parking fees, area licenses, and a park-and-ride system to provide motorists with an alternative mode of transportation. To enter a designated area where congestion is to be reduced, a driver has to display a supplementary license that can be bought in the post office or in other public service areas. Public transportation and other high-occupancy vehicles, including carpools, are exempt from the licensing requirement. Within 6 months after implementing the program, the volume of traffic entering the restricted zone had been reduced by 40 percent.

The Singapore experience was also judged successful in terms of the ease with which it was implemented. Although the park-and-ride facilities proved to be unpopular and the price of licenses may have been set too high initially, the program was relatively easy to administer and acceptable to the general public. Enforcement proved not to be a serious problem. Apart from the expense of constructing fringe parking facilities and erecting new signs, the cost of the program was approximately $3 million. ”

It is sometimes said that road-pricing schemes can kill three birds with one stone: reduce congestion, improve air quality, and reduce energy consumption. Preliminary analysis suggests, however, that the net effect on air quality and energy consumption would be insignificant. Since the characteristics of congestion, air pollution, and energy consumption vary, so must the measures that are applied to deal with them.[58] Since congestion pricing is aimed at changing the time and not the volume of automobile use, the net value in reducing pollution and energy consumption is likely to be negligible.[59]

GOVERNMENT= INDUSTRY RELATIONS

To achieve changes in the characteristics of the automobile transportation system, the Federal Government has traditionally relied on regulations and performance standards, leaving to the industry the tasks of acquiring capital and developing the technology to comply. Table 118 lists the major regulatory measures that have been enacted for automobiles by the Federal Government in the past 15 years.

With the growing awareness of the problems related to the automobile and with the increased cost and technology required to deal with these problems, the Federal Government has become more directly involved in financing and conducting research and development of new technologies to meet national goals. Although there is general agreement that the new development of technology requires substantial capital and technical resources, there is strong disagreement about whether the Federal Government should intervene in the free market either to stimulate technological innovation or to preserve or alter the present structure of the market.

An important factor in the relationship between the Federal Government and the automobile industry is the importance of the industry to the national economy. The automobile industry's role in the economy can be seen in figure 50 and table 119, which depict the contribution of the industry to personal consumption, investment, and the national income. Equally revealing are the employment statistics for the automobile industry and related services and business shown in table 120.

Given the scope of the automobile and auto-related industries, it is clear that policies affecting these industries will affect the national

Edward P. Holland and Peter L. Watson, Ekistics, July 1976, pp. 14-18, reprinted from *Finance and Development* 13 (March 1976).

Ibid., p. 16.

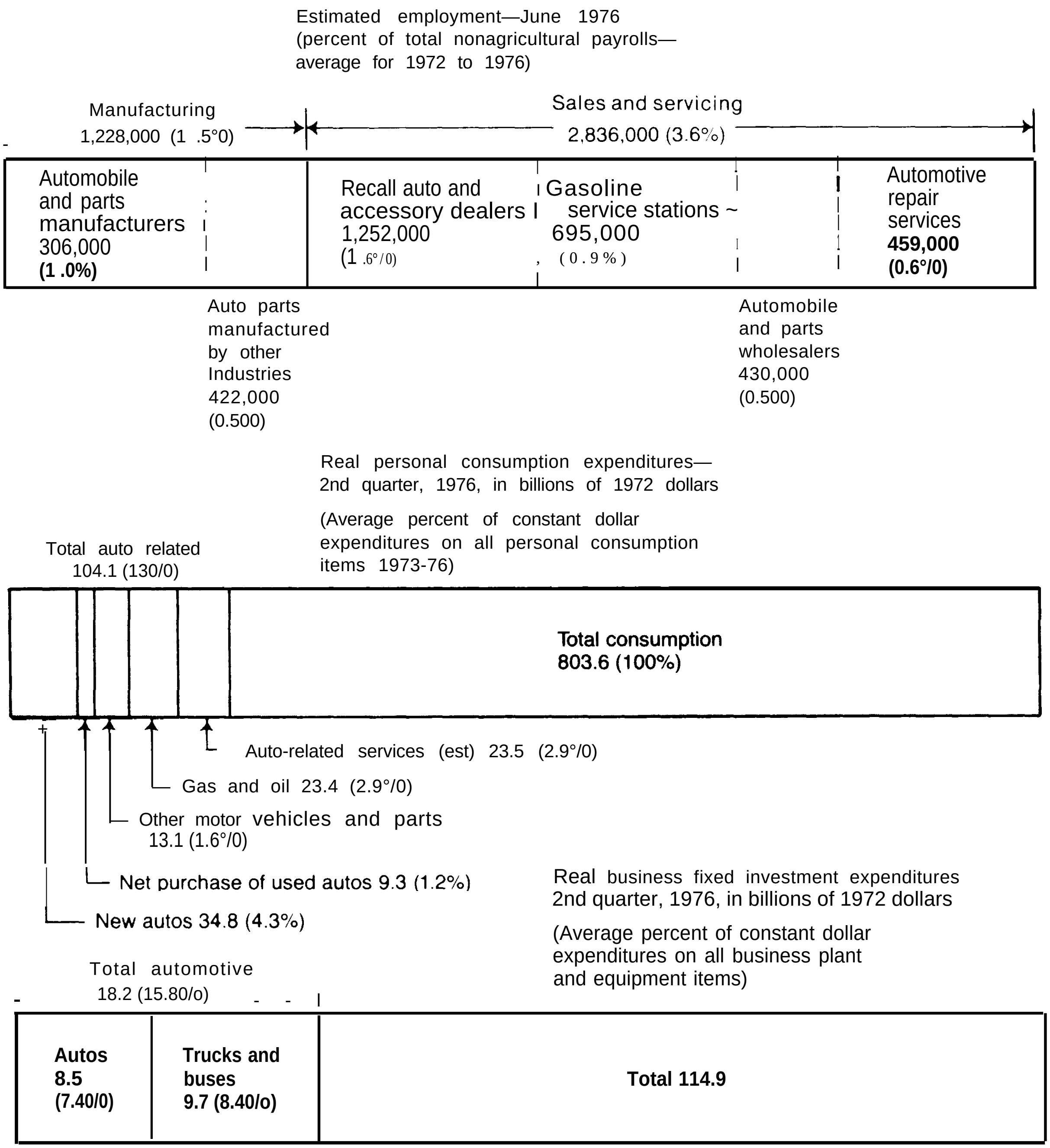
Horowitz, p. 15.

Ibid.

Table 118.—Legislation Affecting Automobile System Characteristics and Use

Safety	
1963	*The Roberts Bill, Public Law 88-515.* —Required that motor vehicles purchased by the Federal Government meet safety standards.
1968	*National Traffic and Motor Vehicle Safety Act and Amendments (1970, 1972, 7974), Public Law* 89-563,–Established safety standards, with mandatory inspections for motor vehicles i n interstate commerce.
1972	*Motor Vehicle /formation and Cost Savings Act and Amendments (1974, 1975), Public Law* 92-513.–Required manufacturers to disclose information indicating compliance with the standards set for bumpers and odometers. Required DOT to publish consumer information on new cars (not yet implemented).
cost	
1956	*Automobile Dealer Suits Against Manufacturers, Public Law 84-1026.* —Enabled franchise automobile dealers to bring suit against manufacturers for failure to comply with terms of franchises.
1958	*Automobile Information Disclosure Act and Amendment (1972), Public Law 85-506.* —Required full disclosure of information in the distribution of new automobiles.
1974	*Magnuson-Moss Warranty —Federal Trade Commission /improvement Act, Public Law 93-637.* — Provided disclosure standards for consumer product warranties i n regard to used motor vehicles.
Energy	
1974	*Energy Supply and Environmental Coordination Act, Public Law 93-319.* —Authorized a fuel-economy study to be undertaken by the Department of Transportation (120-day study) to establish a fuel-economy improvement standard.
1975	*Energy Policy and Conservation Act, Public Law 94-163.* —Established standards for motor vehicle fuel economy with a goal of *27.5* mpg for 1985.
1976	*Electric and Hybrid Vehicle Research, Development, and Demonstration Act, Public Law* 94-413.—Authorized a Federal program of research and development for electric vehicle technologies and demonstrate ion of their feasibility.
Environment	
1963	*Clean Air Act and Amendments (1965, 1966, 1967, 1970, 1971, 1973, 1977), Public Law 88-206.* —Encouraged greater efforts to develop devices and fuels that will reduce air pollution from motor vehicles.
1965	*Motor Vehicle Air Pollution Control Act, Public Law 89-272.* —Required standards for automotive emissions control on new motor vehicles.
1972	*Noise Control Act, Public Law 92-574.* —Established noise regulations for motor carriers engaged in interstate commerce.

Figure 50.—Scope of U.S. Automotive Industry



SOURCE Unpublished report of the A J Kearney, Inc Management Consultants, for the U S Environmental Protection Agency April 1977 pp II-5 and II-6

Table 119.—Contribution of the Motor Vehicle and Equipment Industry to National Income in 1973 and 1975[a] (billions of 1975 dollars)

	1973	1975
All industries (excluding government)		
Domestic income	$898	$1,025
Employee compensation	633	729
Corporate profits[b]	99	92
All manufacturing		
Income	284	310
Employee compensation	230	251
Corporate profits[b]	44	46
Motor vehicles and equipment manufacturing		
Income	$23.1	$18.5
Percent of all industries	2.5%	1.8%
Percent of manufacturing industries	8.2%	6.0%
Employee compensation	$16.4	$15.7
Percent of all industries	2.6%	2.2%
Percent of manufacturing industries	7.1%	6.2%
Corporate profits[b]	$5.8	$0.9
Percent of all industries	5.9%	1.0%
Percent of manufacturing industries	13.2%	1.9%

[a]Without capital consumption adjustment by industry.
[b]With inventory valuation adjustment.
SOURCE: Unpublished report of A. J. Kearney, Inc. Management Consultants, for the U.S. Environmental Protection Agency, April 1977 pp IL5andIL6

Table 120.—Automobile industry Employment,1976

Industrial sector	Employment
Motor vehicle and parts manufacturing	948,000
Auto and parts retail dealers	1,116,000
Auto and parts wholesale dealers	380,000
Service and garages	447,000
Gasoline service stations	627,000
Construction of highways and streets	299,000
Petroleum industries	397,000
State and local highway departments	582,000
Total	4,796,000

SOURCE Transportation Assoclatlon of America, *Transportation Facts and Trends*

economy significantly. Projections of the future of the automobile industry, therefore, will have an important bearing on the kinds of policies that the Federal Government might consider.

Trends and Implications

The Base Case contains the following assumptions and projections about automobile technology and the industry's response to present policies:

- It is expected that the basic technology will be available to meet Government standards on fuel economy, emissions, and safety by 1985.
- Incorporating this technology will increase the average price of a new car by about $5oO (in 1975 dollars).
- In order to achieve fuel-economy standards, manufacturers will reduce the size and weight of automobiles, perhaps by an average 800 to 1,000 pounds between 1977 and 1981. Further size and weight reductions are expected during the period 1981 -2000.[60]
- The major impact of Government policies and changes in demand will become evident by 1985. After that, changes will occur more slowly but in the same direction.
- The impact of increased auto prices on sales will be more than offset by general economic trends and by reductions in the real cost of automobile ownership and operation. As a result, new car sales are expected to increase from 10 million in 1976 to 13 million in 1985 and 16.4 million by 2000.

[60]U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*, Summary Report, Feb. 28, 1977.

New Car Sales and Prices

The implications of these trends for new car sales and prices are shown in tables 121 and 122. While new car sales are expected to increase 29 percent overall between 1976 and 1985, the bulk of this increase will occur in the subcompact, compact, and small luxury classes. Sales of intermediate and standard cars will fall dramatically, largely as a result of fuel-economy standards. New car prices by size class are predicted to increase between **$470 and $510 by 1985 (in** 1975 dollars).

Prices within size classes (excluding the impact of Government standards) are expected to remain about the same as today. However, if manufacturers downsize cars without reducing their price, the prices for the smaller size classes shown in table 122 might be somewhat understated.

The impact of Base Case projections of automobile sales on employment depends on productivity. If the rate of domestic new car sales per employee continues to increase by **2.7** percent annually, employment in 1985 will be 2.2 percent less than 1975, a loss of 18,000 jobs. Lower productivity gains in other motor vehicle manufacturing activities, a decline in the share

Table 121.–Change in the Distribution of New Car Sales, 1976-85

	Percentage		Volume (thousands)		
	1976	1985	1976	1985	Percent change
Subcompact.	22	30	2,225	3,940	+ 77.1
Compact.	19	30	1,921	3,940	+ 105.1
Small luxury	5	9	506	1,196	+ 136.4
Intermediate.	29	16	2,831	2,111	– 25.4
Standard	20	7	2,022	936	– 53.7
Large luxury	6	7	606	936	+ 54.4
Totals	100	100	10,110	13,058	+ 29.2

SOURCE: *Sydec/EEA*, pp. III-165.

Table 122.—Projected Sales and Economic Data for the Auto Industry (1975 dollars)

		1985	
New car price by size of class	1976	Base Case	All other cases
Subcompact	$3,600	$4,080	$4,080
Compact ., ...	4,200	4,710	4,710
Intermediate ... , ...	4,600	5,090	5,090
Standard	5,400	5,890	5,890
Small luxury.	5,650	6,130	6,130
Large luxury.	8,800	9,270	9,270
Gross revenue per domestic car sold	4,990	5,220	4,880
Annual domestic sales (thousands)	8,610	10,710	10,550
Annual domestic sales revenue ($ millions). . ... , . .	$42,950	$55,940	$51,460
Capital investment ($ millions).	$ 3,640		
New capital requirements for fuel-economy standards (millions, cumulative 1977-85).		$7.6	$7.6-$8.0[a]
Auto manufacturing employment (domestic)[b]. . . .	808,800	790,800	780,000

[a] The higher capital requirements are associated with higher diesel penetration rates in the Petroleum Conservation Case.
[b] Employment figures are for the four major domestic manufacturers and include only passenger car and auto parts manufacture.

SOURCE: *Sydec/EEA*, pp. III-163 to III-172 and *Supplementary Report*.

Table 123.—Net income and Net Income as a Percent of Sales in the U.S. Automobile Industry, 1969-76

	Net Income ($ millions)					Net income as percent of sales				
	GMC	Ford	Chrysler	AMC	Total	GMC	Ford	Chrysler	AMC	Total
1969	$1,710.7	$546.5	$ 99.0	$ 4.9	$2,361.2	7.0	3.8	1.2	0.7	5.0
1970	609.1	515.7	(7.6)	(56.2)	1,132.4	3.2	3.4	(0.1)	(5.2)	2.8
1971	1,935.7	657.0	83.7	10.2	2,686.5	6.8	4.1	1.1	0.9	5.0
1972 ., ...	2,162.8	870.0	220.5	30.2	3,283.4	7.1	4.4	2.3	2.1	5.3
1973	2,398.0	906.5	225.4	86.0	3,645.9	6.7	4.0	2.2	2.6	5.0
1974	950.0	360.9	(52.1)	27.6	1,286.4	3.0	1.6	(0.5)	1.4	1.9
1975	1,253.0	322.7	(259.5)	(35.6)	1,280.7	3.5	1.4	(2.2)	(1.5)	1.7
1976	2,908.0	993.0	15.5	(34.4)	4,274.0	6.2	3.4	3.4	(1.5)	4.6

SOURCE: Wards Communications, Inc., *Ward's 1977 Automotive Yearbook*

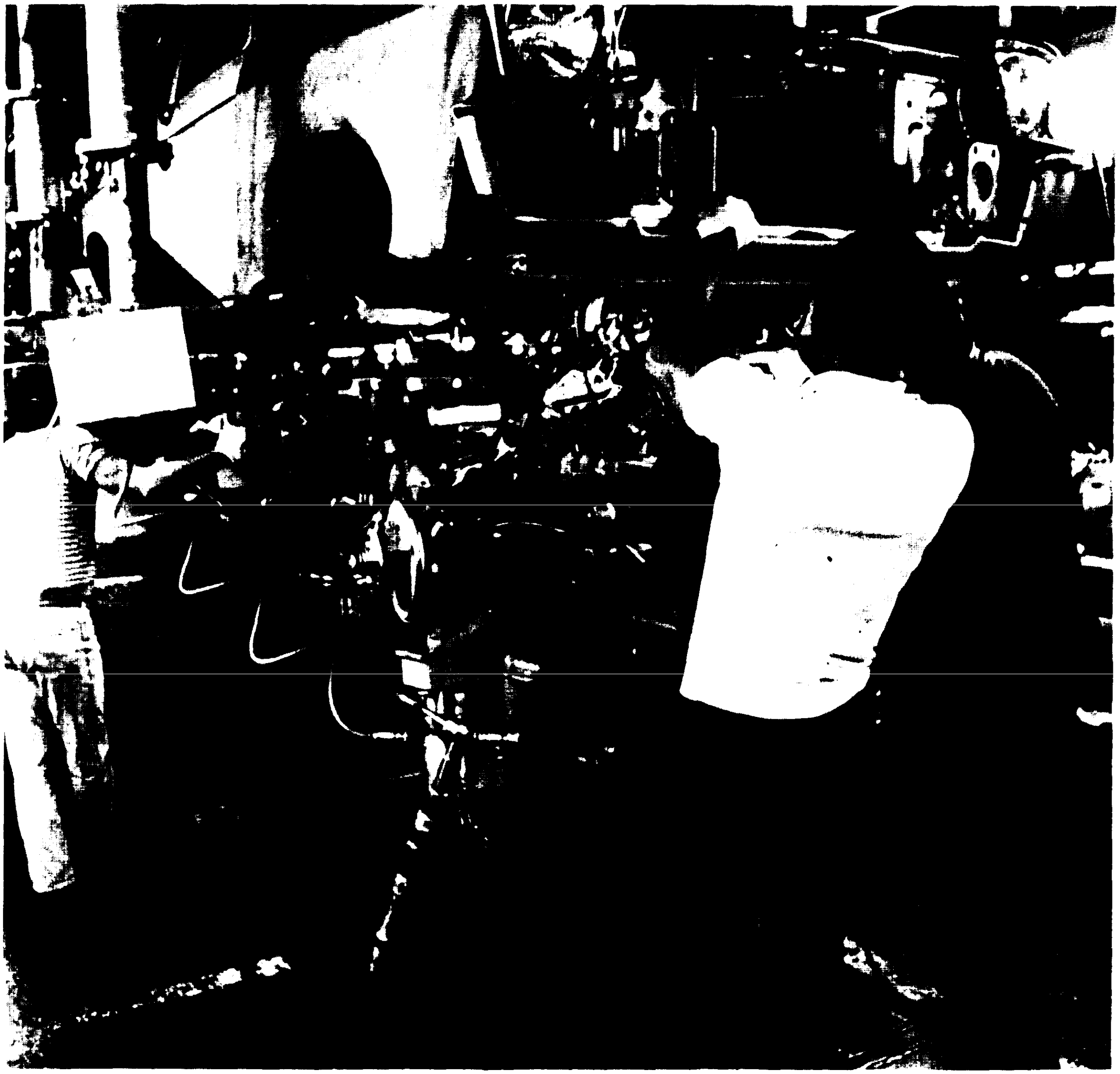


Photo Credit General Motors Corp

of imports, or the movement of foreign firms into the United States might act to offset some or all of this decline in employment.

The rate of profit in the automobile manufacturing industry varies considerably from year to year, depending on the company and the business cycle. Table 123 shows net income and net income as a percent of sales for the four major domestic manufacturers for the years 1969 to 1976. Although record gains in net income were experienced in 1976, net income as a percentage of sales was lower than it had been in several years. On the whole, however, the industry's return on equity and profit margins were comparable to those in other manufacturing industries. General Motor's profits were significantly higher than those of the other manufacturers, evidence of the relationship between profits and sales volume.

The significant increases in the rate of growth in sales improves the outlook for industry profitability. Because it is assumed that the increased costs of Government standards will be passed on to the consumer in the Form of higher prices, no reduction in profit levels is expected. The effect of Government standards and regulations on product mixes could, however, reduce industry profits.

Although precise data relating the rate of profit to car class and size are unavailable, all indications suggest that the smaller the car, the smaller the profit. A study, conducted in 1976 for the Department of Transportation, estimated that the variable profit margin—the revenue per car less variable costs—for two domestic manufacturers was 19 to 23 percent for compacts and subcompacts, 27 to 32 percent for

Photo Credit General Motors Corp

medium-sized cars, and 38 to 40 percent for large cars.[61]

The profit rate is highly sensitive to changes in volume of sales. Meeting Government standards and changing the mix of production will increase fixed costs, which are generally allocated to new car prices on the basis of anticipated volume of sales. Volume growth above expectations, therefore, will increase profits; whereas growth below expectations will cause a significant decline.

[61] D. J. Chupinsky and M. R. Harvey, *Development of a Motor Vehicle Materials Historical, High-Volume Industrial Processing Rates Costs Data Bank*, Volumes I and II (Warren, Mich.: Pioneer Engineering & Manufacturing Co., May 1976 and November 1976).

Industry Structure

The domestic auto-manufacturing industry consists of four major producers: General Motors, Ford, Chrysler, and American Motors. General Motors accounts for over 50 percent of domestic sales; GM and Ford account for over 80 percent. The market shares of manufacturers and their nameplates for the years 1947, 1957, and 1976 are shown in table 124.

Capital investments to meet Government standards and to accommodate changes in demand will increase the sales volume necessary for each firm to realize a profit. If a firm fails to make the required profit, it would have to rely on external sources of capital. While Ford and General Motors are conservatively financed and

Table 124.—Market Shares of U.S. Passenger Car Manufacturers in Selected Years (percent)

	1947	1957	1967	1976
Chevrolet	19.58	24.90	25.93	23.69
Pontiac	6.27	5.61	11.57	9.24
Oldsmobile	5.39	6.38	7.47	11.36
Buick	7.53	6.66	7.57	9.63
Cadillac	1.63	2.50	2.88	3.68
Total, GM	40.44	46.05	55.60	57.60
Plymouth	9.86	10.73	8.23	7.75
Dodge	6.52	4.78	6.72	6.45
DeSoto	2.29	1.92	—	—
Chrysler	3.04	1.94	3.25	1.50
Imperial	—	0.62	0.21	—
Total, Chrysler	21.71	19.99	18.41	15.70
Ford	16.93	24.89	18.60	17.59
Edsel	—	0.89	—	—
Mercury	3.51	4.50	3.84	5.12
Lincoln	0.82	0.61	0.46	0.76
Continental	—	0.01	—	0.71
Total, Ford	21.26	30.90	22.90	24.18
Total, Big Three	**83.41**	**96.94**	**96.91**	**97.48**
Hudson	2.82	0.02	—	—
Nash	3.19	0.06	—	—
Rambler	—	1.78	3.09	2.52
Total, American Motors		1.86	3.09	2.52
Crosley	0.54	—	—	.
Kaiser- Frazer	4.06	—	—	—
Packard	1.57	0.09	—	—
Studebaker	3.48	1.11	—	—
Willys	0.93	—	—	—

SOURCE Ward s Communications Inc *Ward s 1977 Automotive Yearbook* pp 116-117 would have many options open to them, American Motors and Chrysler, having had poor earnings records in recent years, would probably find it difficult to raise funds in the market.

The capital and cost requirements associated with meeting standards will probably deprive the smaller firms of the flexibility needed to invest in both regulation-induced activities and those related to product improvement and productivity. As figure 51 shows, Chrysler is the most highly leveraged of the four companies.[62]

[62]General Motors is one of the most conservatively structured corporations in the United States, with a debt-to-equity ratio of approximately 0.1, compared to a national average of about 0.5. Although Chrysler and American Motors are much more leveraged than General Motors, their debt-to-equity ratios are fairly common for U.S. corporations.

[63]The ability of the larger firms to respond to changing demands is greater than that of the smaller firms. Because of the differences in production volume, all new car changes occur more rapidly at Ford and General Motors than at Chrysler and AMC. Faced with changing demand or production requirements, the smaller firms either have to write off investments faster or face potential market erosion. It is not surprising, therefore, that General Motors is currently the only manufacturer planning to downsize its entire line by 1980.

This disadvantage, together with the ability of larger firms to withstand cyclical demand conditions[63] and American Motors reliance on outside firms to provide improved engines and equipment to meet Government standards, will further decrease the competitiveness of the smaller firms.

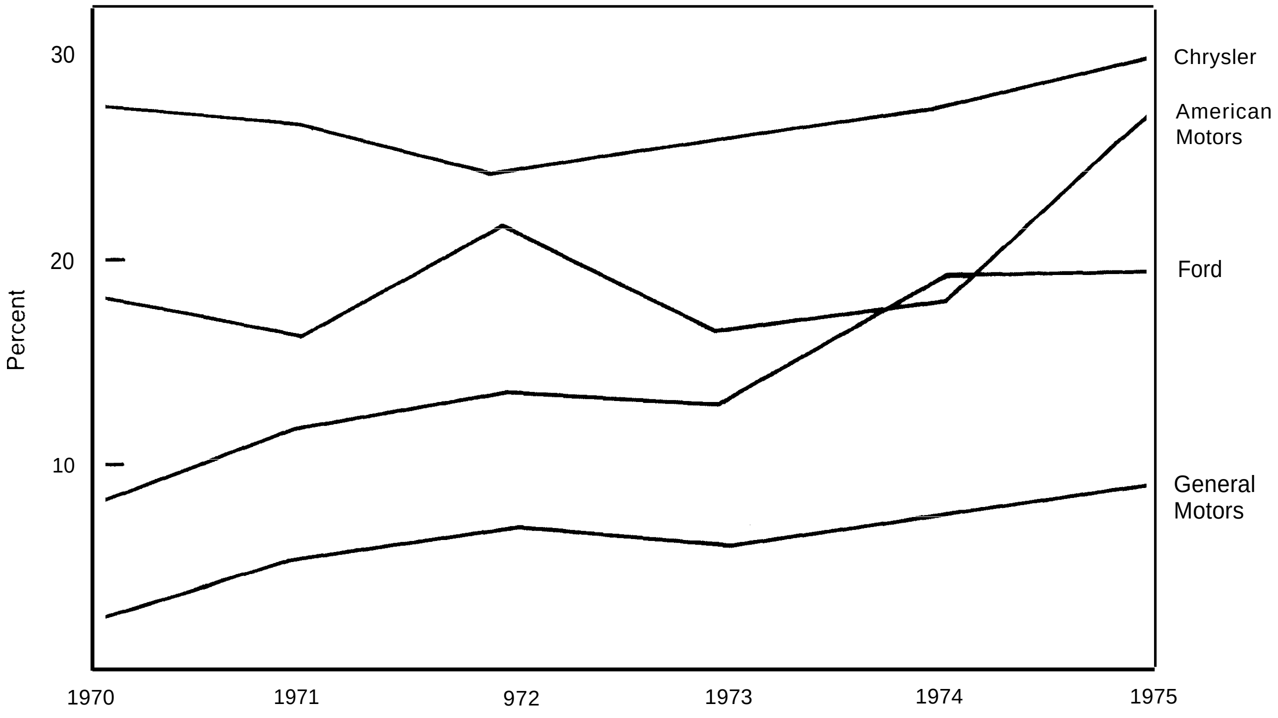
Policy Options

In view of the relationship between the automobile industry and the national economy, the Federal Government might choose to adopt policies designed to have a direct effect on the structure or economic well-being of the industry. The following discussion suggests potential changes in Federal Government policy with respect to regulation, capital allocation, and research and development that merit further study.

Regulation

The Federal Government's policy of setting regulations and performance standards to deal with automobile-related problems has met with

Figure 51 .— Long-Term Debt as a Percent of Equity



SOURCE .*Sydec/EEA* p III-182

strong criticism and strong resistance by the industry. As late as July 1977, for example, the automobile manufacturers were preparing to turn out 1978 model cars while Congress was amending the emission standards that applied to that model year. Had Congress failed to pass the Clean Air Act Amendments in time, the 1978 cars would have been in violation of the law. The controversy over automobile regulatory policy is not surprising, considering the economic stakes and the fact that regulations must be set and implemented in the face of imperfect knowledge about the causal relationship between automobile improvements and safer travel, cleaner air, and reduced fuel consumption.[64]

Supporters of the present regulatory system can be found among environmentalist groups, safety advocates, and automobile owners. Regulatory advocates argue that standards are necessary to force technological change within the industry. They prefer standards to market incentives as a means of achieving national goals, because standards, unlike taxes, address the problem directly and provide the public with symbolic assurance that some action is being taken.[65]

Those who oppose the regulatory system on principle argue that intervention of the Government in industrial decisionmaking has led to an increasing maze of regulations which are inconsistent and generally unresponsive to changes in technology or consumer attitudes and preferences. In their view, the regulatory system has sheltered the industry against competitive pressures, led to higher prices, and has served the public poorly. They strongly advocate the use of market incentives, which they claim are more effective and economically efficient.

The automobile industry does not necessarily oppose standards on principle, but on the grounds that the technology for meeting them is unavailable and the costs cannot be fully recovered even by increasing the price to the consumer. Testifying before the Automobile Industry Task Force, Lee Iacocca, former President of the Ford Motor Company, stated that, between 1975 and 1980, $1.8 billion would have to be spent by the industry to meet Government standards for vehicle safety, damageability, and pollution control.[66]

Capital Allocation

The costs of research and development of automobile technology to meet Federal environmental, safety, and energy standards have promoted a number of suggestions for Government programs to help companies that experience long-term difficulties raising capital. Manufacturers have traditionally raised capital through the sale of commercial paper in the marketplace, in competition for funds with bank certificate deposits and U.S. Treasury bills. In periods of restrictive monetary policy, the cost of raising funds in this way increases dramatically and aggravates the industry's problem of acquiring capital.[67]

Despite the problems of raising capital, the automobile industry has continually opposed proposals for the nonmarket allocation of funds. Testifying before Congress, the chief economist of the Ford Motor Company argued that the only way to improve the industry's capital position is for the Government to eliminate unnecessary and costly regulations and standards and to improve general economic conditions. "I see no way of maintaining a viable privately owned and operated automobile industry in the country if, (in addition to the Government's present involvement), the Government finances our capital expenditures."[68] A representative of American Motors was somewhat less emphatic in his opposition. Although opposed to the Federal allocation of capital, American Motors urged that the Government facilitate conventional borrowing by providing loan guarantees.[69]

The United Auto Workers (UAW), on the other hand, favor credit allocation as a means of providing capital for the development of energy-related technology. Speaking to the Automobile Industry Task Force, Leonard

[64] John B. Heywood and others, *Regulating the Automobile* Draft Paper, Report 77-007 (Boston: MIT Energy Laboratory, July 1977), p Iv.
[65] Ibid. p 4 16

[66] U. S. Congress, House, Committee on Banking, Currency, and Housing, *The Automobile industry and Its impact Upon the Nation Economy*, hearings before the Automobile Industry Task Force, 94th Cong., 2d sess., Vol. 1, June 1975, p. 286.
[67] Ibid.
[68] Ibid, p. 105.
[69] Ibid, p. IJQ,

Woodcock of the UAW urged the Government to create a National Production Energy Board empowered to make loans to the private sector, contract with the private sector, enter into joint ventures, and (when necessary) take a direct initiative in development technology.[70]

Government Research and Development

Some supporters of direct Government intervention argue that if the appropriate technology is to be made available, the Government will have to develop it. In their view, the auto industry will be unable to develop technology in response to federally mandated performance standards, because sufficient resources have not been invested in the right kinds of technology. This pattern will continue, since the private sector, operating under normal market incentives, will always tend to underinvest in research for which it is difficult to capture a full return. Federal involvement would be justified on the grounds that the benefits would accrue to both automobile users and nonusers alike. The United Auto Workers have advocated Government research and development in the areas where the private sector has failed to respond.[71]

Opponents of a more direct Government role in research and development argue that the industry can perform adequately on its own and that standards are too stringent in view of available technology, consumer prices, and product demand. The cost of research and development should not be borne by the general taxpayer, since it is the automobile owner who imposes the pollution costs of emissions and who will benefit most from fuel-efficient cars. Although the automobile industry has not opposed Government research and development in areas of general national interest, it has opposed Government efforts to develop specific technological devices.[72]

CONSUMER COSTS

Consumer costs of automobile travel represent a substantial portion of personal consumption expenditures in the United States. The Department of Commerce and the Department of Labor, the two most reliable sources of these data, estimate that user-operated transportation costs represented between 13 and *20* percent of consumer expenditures in 1973, the last year for which data from both sources are available.[73] The cost of owning and operating an automobile has not changed appreciably over the long term. However, the percentage of the household budget devoted to automobile transportation has risen as the number of households owning more than one car has increased and the number of those without cars has declined. In virtually all but the lowest income categories, expenditures on automobile transportation have replaced food as the second largest item in the household budget.

Trends Affecting Personal Transportation Costs

Figure 52 and table 125 trace the recent history of elements that comprise the cost of private automobile transportation. The total cost of owning and operating an automobile declined steadily in real terms rom *1962* to 1973.[74] After 1973, total automobile costs rose

[70] Ibid., p. 32.

[71] Ibid.

[72] Ibid., p. 239.

[73] Part of the reason for the different estimates is that the Department of Labor restricts the definition of consumer expenditures to those that are made for household items, while the Department of Commerce does not. The Department of Commerce includes in user-operated transportation insurance premiums, less claims paid, while the Department of Labor includes the entire cost of premiums. Department of Commerce data for the past 10 years show the costs of user-operated transportation to be increasing as a percentage of personal consumption expenditures, from 12.2 percent in 1966 to 13.0 percent in 1976.

[74] Total ownership and operating costs include the elements shown in figure 52, with appropriate weights, plus other items such as used car prices, tires, repairs and maintenance, insurance, registration and license fees, and parking charges. The index is adjusted to remove cost escalation associated with improvements in the quantity or quality of the products to provide as pure a measure of price trends as possible. For example, if some design feature or accessory is added to the list of items included in the base price of a new car the effect on price has been removed in calculating the index.

slightly and, by 1976—due primarily to the sharp increase in gasoline and motor oil costs—they reached a level that erased some of the decline of the previous decade. The decline in the real cost of gasoline and motor oil after 1973 was offset by an increase in other cost components—notably new cars and insurance—during the recession of 1974-75.

Gasoline and motor oil costs were declining more rapidly than total costs until 1973-74, when the OPEC price increases raised these costs to a slightly higher level than 15 years earlier. Auto repairs and maintenance costs held constant through the mid-1960's but have gradually and steadily declined by about 10 percent in real dollars during the last decade. New car costs decreased steadily and at a greater rate than other components—more than a 30 percent decline over 15 years in real terms.

Figure 53 describes trends in the major components that make up total automobile-related costs, as they have been identified by FHWA.[75] Cost projections have been made for the years 1985 and 2000.

Although insurance costs have declined in real terms, it is unlikely, according to the FHWA, that such declines will continue. Recent data on insurance rates tend to support this view. Modest decreases might be realized from new safety standards, if they are not offset by the downsizing of cars.

Similarly, the costs of garage, parking, and tolls are not expected to change significantly. Slight decreases have occurred and might continue. As suburbanization continues, a relatively constant number (but smaller proportion) of cars pay garage and parking charges, which are common only in central cities. This might be

[5]Major cost components have been converted to cents per mile (in 1975 dollars). In contrast to the Consumer Price Index, the FHWA data provide a basis for estimating the overall ownership and operat ing cost of autos and the mutually exclusive components. The FHWA data must be treated with caution, since they are drawn from only one city, the Baltimore metropolitan area.

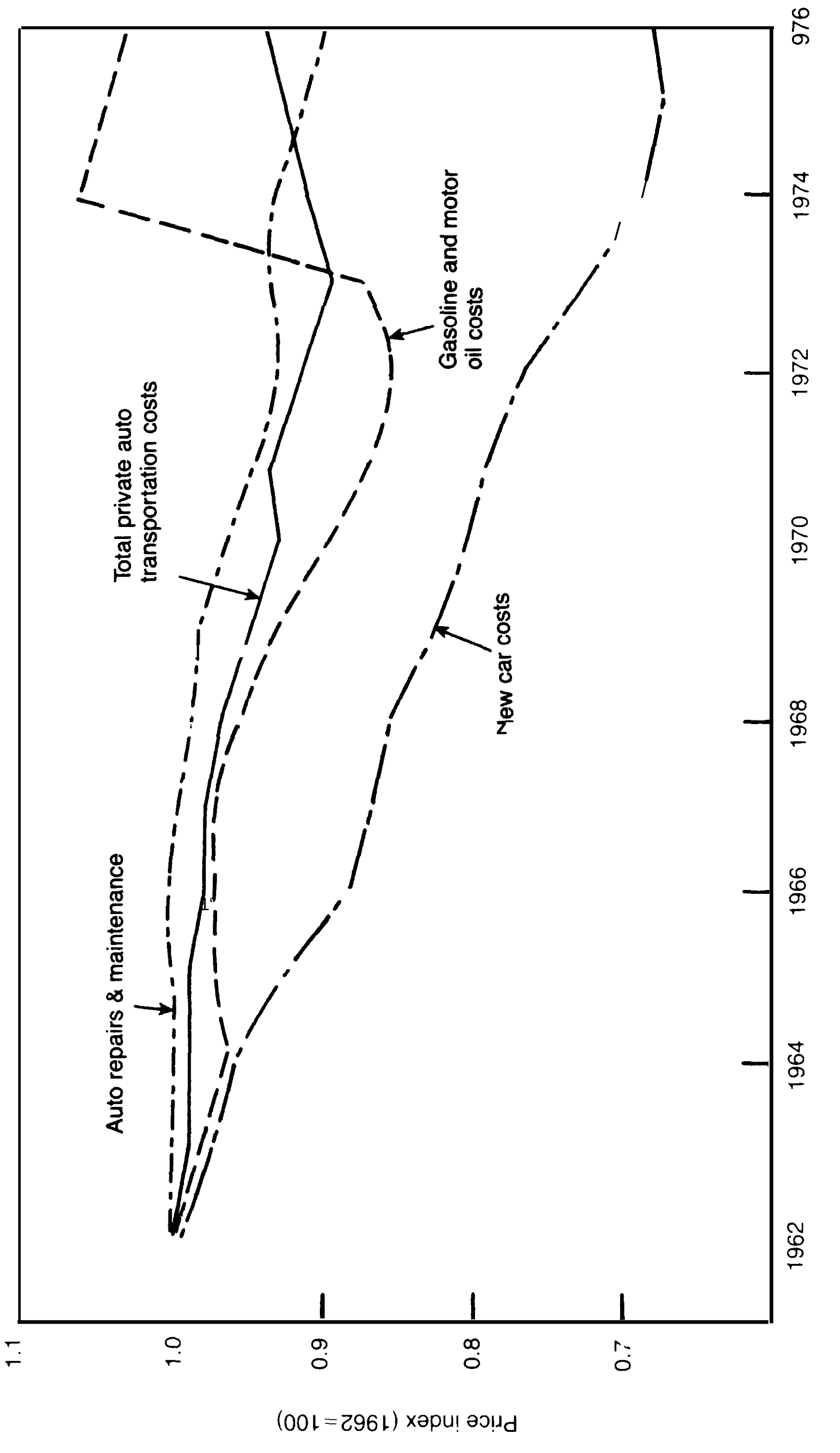
The FHWA studies, particularly the earlier ones, were ad hoc efforts rather than a time+ series analysis such as the Consumer Price Index. Also, the definition of the "standard" car used by FHWA has changed over successive years so that time-series trends in costs have little meaning,

Table 125.—Cost of Owning and Operating an Automobile—1 950 to 1976 (cents per mile, in 1975 dollars)

Type of automobile	Depre-ciation	Maintenance, accessories, parts, & tires	Gas & oil (excluding taxes)	Garage, parking & tolls	Insurance	State & Federal taxes	Total costs
1976 Standard . . .	4.7	4.0	3.1	2.1	1.6	1.5	17.0
976 Compact . . .	3.6	3.2	2.4	2.0	.5	1.1	13.9
976 Subcompact	3.0	3.0	1.7	2.0	.4	0.9	12.0
974 Standard . . .	4.6	3.7	3.5	2.2	.8	1.6	17.4
974 Compact . . .	3.2	3.0	2.8	2.2	.6	1.3	14.1
974 Subcompact	2.5	2.7	2.2	2.2	.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 dr. Sedan. .	4.4	2.6	2.6	2.5	2.4	1.9	16.5
19684 dr. Sedan .	4.3	3.3	2.6	2.8	2.2	1.9	17.0
19604 dr. Sedan	4.5	3.6	2.9	2.0	2.4	2.2	17.8
19504 dr. Sedan. .	3.1	2.9	3.1	2.0	2.0	1.6	14.8

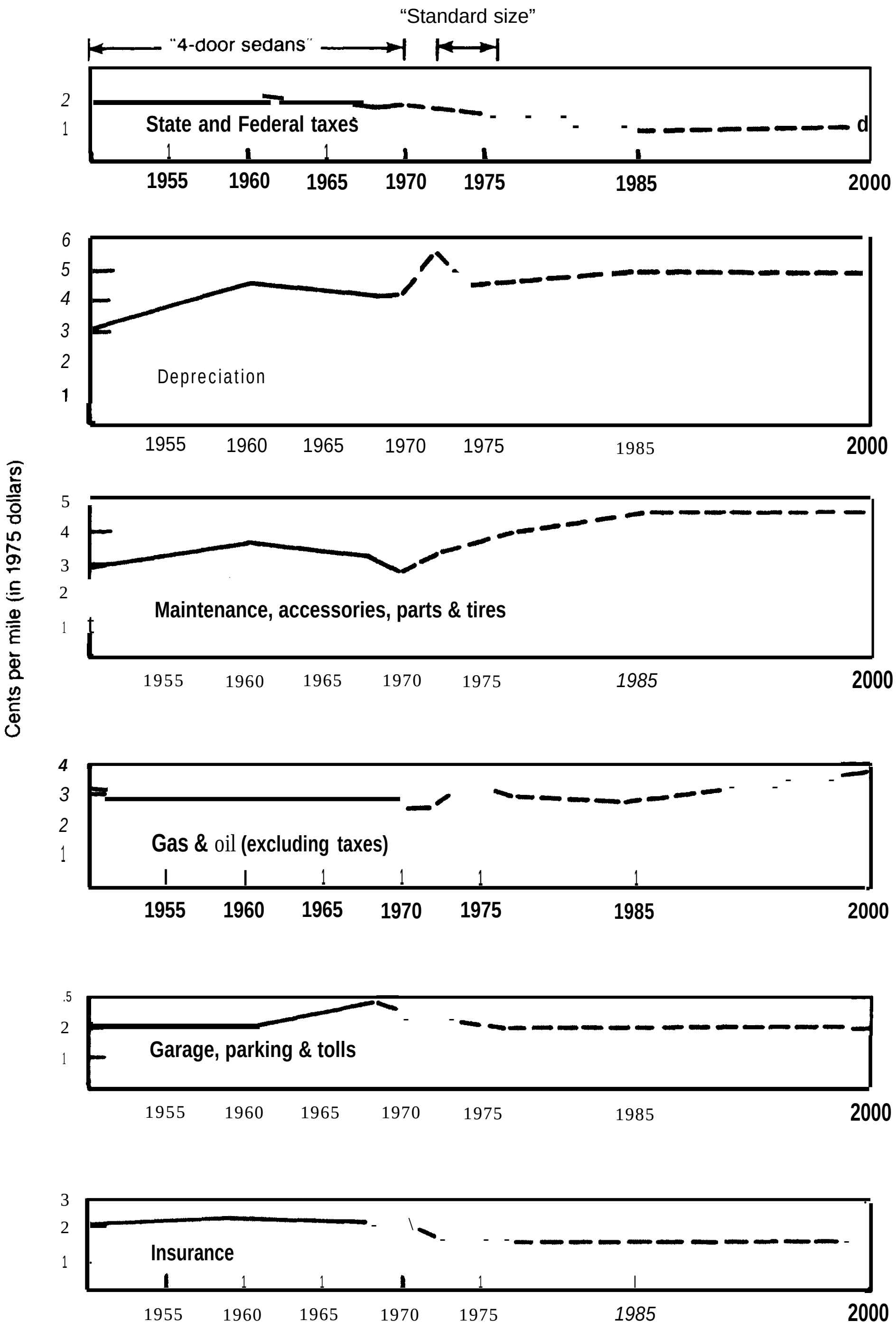
SOURCE U S Department of Transportation, Federal Hlghwa~ Admlmstratlon C;st 01 Owrrlrrg *arrd Operafing* an *Auforrrob//e* 1976

Figure 52.—Comparative Trends in Selected Components of Auto Owner ıip and Operating Costs—Deflated by the Consumer Price Index



SOURCE: U.S. Department of Labor data on components of Consumer Price Index. All values divided by CPI and adjusted to a 1962 base.

Figure 53.—Forecasts for Components of Ownership and Operation Costs of a Standard-Size Auto



SOURCE: *Sydec/EEA,* p. III-153

offset by rate increases in cities seeking to discourage auto commuting. Toll facilities will handle a declining proportion of VMT for similar reasons. Because fewer toll roads are being built, they represent a declining proportion of total highway mileage.

Base Case projections of future gas and oil costs, excluding taxes, are based primarily on fleet miles per gallon, vehicle miles of travel, and projected gasoline prices. Oil costs are projected to change in proportion to gasoline costs. The modest decline in real cost predicted for standard cars from 1976 to 1985 is a continuation of long-term trends. Weight reduction and improved fuel efficiency are expected to contribute to declining cost for the standard-size car through 1985.

Depreciation costs are projected to rise about **9** percent in real terms from 1976 to 1985. Based on new car price trends, a decline of about 2 percent per year, or about 18 percent total over the 9-year period, might be expected for a fixed auto design. [76]

The cost of maintenance, accessories, parts, and tires is projected to increase by about 16 percent in real terms between *1976* and 1985. This increase is slightly above the historical annual rate of increase for the four-door, standard-size car assumed in the FHWA studies, and is greatly above the Consumer Price Index trend, which shows a 10-percent decrease for the auto repair and maintenance cost index over the last 15 years. This upward projection allows for increased maintenance costs that might accompany new safety and emission control equipment.

Table 126 shows forecasts of total ownership and operating costs per mile for each class of new automobile and for the average new car fleet. The overall new car fleet average cost is expected to drop slightly from 15.3 cents to 14.9 cents per mile in 1975 dollars. Because of the projected shift to smaller size cars, this slight decrease in cost is expected to occur despite the price rise of **2** to *6* percent projected for each class.

Because the changing mix of new car sales for 1985 to 2000 cannot be predicted with accuracy, the same method cannot be used to forecast average new car costs per mile for the long term. Generally speaking, costs per mile for the three size classes of cars are expected to increase between **4** and *5* percent between *1985* and 2000. Because of this trend and because the shift to smaller classes will have been largely accomplished, the new car fleet average cost per mile is expected to increase slightly after 1985, reaching approximately the 1976 level of 15.3 cents (in 1975 dollars) by **2000.** Expressed as a proportion of real total personal disposable income, auto ownership and operating costs are projected to decline because real income is forecast to grow at a rate substantially higher than VMT.

[76] This projection allows for a total real increase, relative to price trends, of about 3 times the currently projected cost of $488 (or about 9 percent of the 1975 price of new standard-size cars) for all safety, emissions, and fuel-economy regulatory improvements defined for the Base Case. It makes an allowance for the possibility of having underestimated the costs of these regulatory requirements or of having failed to identify auto cost escalation factors. Similar provisions are made in the 1985 to 2000 forecast by holding the real cost of depreciation constant in spite of past sustained long-term cost decreases of about 2 percent per year.

Table 126.— Estimated Average New Car Costs of Ownership and Operation Based on Projected Shifts in Size Classes

	1976			1985		
Size class	Proportion of fleet in class	cost x per= mile	Contribution to average fleet cost/mile	Proportion of fleet in class	cost x per = mile	Contribution to average fleet cost/mile
Subcompact	0.22	11 .9¢	2.6¢	0.30	12.6¢	3.8¢
Compact	0.19	13.8	2.6	0.30	14.3	4.3
Intermediate	0.29	15.4	4,5	0.16	15.8	2.5
Standard	0.20	17.0	3.4	0.07	17.3	1.2
Small Luxury	0.05	18.5	0.9	0.09	18,8	1.7
Large Luxury	0.06	20.1	1.2	0.07	20.2	1.4
Totals	1.00		15.3¢	1.00		14.911

SOURCE The new car fleet mix forecast is based on the EEA auto stock model Ownership and operating cost forecasts by Sydec are based on methods described in Sydec EEA pp III-150 to III 162

Table 127 shows the projections of ownership and operating costs for 1985 and 2000 by automobile size class. Within size classes, costs are expected to increase during both the 1975-85 and 1985-2000 periods. This increase is due primarily to rises in depreciation, maintenance and parts, and gasoline and oil. The Environmental Policy and Conservation Act (EPCA) fuel-economy standards are expected to cause a shift of new car sales among size classes that will be sufficient to offset these increases in each class by 1985, As a result, the weighted overall fleet average costs per mile are forecast to decline slightly from 15.3 cents per mile in *1976* to *14.9* cents in 1985 (in 1975 dollars). By the year 2000, however, the cost reduction due to shifts to smaller cars will be more than offset by continuing increases in the real price of petroleum, so that the average cost per mile for the fleet will return to about the *1976 level.*

Policy Options to Control Consumer Costs

Government policies to control the cost of automobile ownership and use might be directed toward any of the major costs of automobile transportation. Three that have been selected for consideration here are those that deal with the costs of insurance, repair, and maintenance—the three components of ownership and use cost that might rise more steeply than others between now and 2000. The specific policies considered are:

- A Federal law providing for no-fault insurance and other modifications in insurance practices,
- State regulation of repair practices, and
- Federal incentives or standards to increase automobile durability and maintainability.

Automobile Insurance

Projected increases in the number of automobiles and in vehicle miles traveled foreshadow an increase in the number of accidents. This trend, coupled with the rising costs of medical care and vehicle repairs, could lead to increased insurance premiums. Historically, insurance companies have used a system of risk assessment to minimize their losses. Under this system, the decision of whether or not to issue a policy is based on the applicant's driving record, age, sex, marital status, and drinking habits. Critics argue that risk assessment prevents some drivers from obtaining insurance at prices they can afford. Although insurance companies are required to participate in assigned risk pools that make insurance available to high-risk applicants, the rates are so high that many drivers do not buy coverage.

Table 127,—Costs Per Mile of Owning and Operating an Automobile in 1976, 1985, and 2000 (all values in 1975 dollars)

	Subcompact	Compact	Intermediate	Standard	Small luxury	Large luxury
1976. ......, ...	0119	0.138	0.154	0.170	0.185	0.201
Base Case						
1985. ...., ...	0.126	0.143	0.158	0.173	0.188	0.202
2000.	4°/0 to 5% increase over *1985* due to gasoline price increase.					
Petroleum Conservation						
1985. .., ...	3°/0 above 1985 Base Case due to gasoline price.					
2000.	4 % above 2000 Base Case due to gasoline price.					
Improved Environment						
1985. , ...	*5%* above 1985 Base Case due to gas price and air quality equipment.					
2000.	3°/0 above 2000 Base Case due to air quality equipment.					
Increased Mobility						
1985.	30/. above 1985 Base Case due to gasoline price.					
2000, ...	1% below 2000 Base Case due to insurance cost decrease.					
Improved Accessibility						
1985. ..., ...	3% above 1985 Base Case due to gasoline price.					
2000.	4% above 2000 Base Case due to gasoline price.					

SOURCE 1976 data are from FHWA. *Cost 01 Owning and Operating an Automobile* 7976, all values adjusted to 1975 dollars based on CPI Sydec forcasts are based upon detailed analysis of cost trends for all components of ownership and operating costs and the !nfluence of each policy case on these costs

It is also argued that the present system is inefficient and fails to provide complete coverage. The late Senator Phillip A. Hart stated that . . . of $5.1 billion of personal and family losses suffered by one-half million serious injury and fatality victims of automobile accidents in 1967, the auto insurance fault system provided only $813 million. . . ." Averaging all degrees of economic loss, the ratio of recovery to loss ranges from 21 to 36 percent.

The present system has also been criticized for prolonged delays in payment of claims when the responsibility for payment must be determined by trial. In some States, there have been delays of 3 years and longer. Although relatively few suits for claims actually go to trial, settlements are often not negotiated until the trial date approaches.

Thus, consumers have a minimum of three basic complaints about automobile insurance: high cost, perceived inequities in the process of setting rates and making insurance available, and excessive time required to collect claims. An important issue is the role that the States and Federal Government should play in shaping an automobile insurance system that is responsive to these concerns.

Until 1970, the prevailing system in the United States was one that required drivers, judged to be at fault, to pay reparations to accident victims. Because most drivers carried liability insurance, these payments were typically made by insurance companies on behalf of negligent (accident-causing) drivers. Unless fault could be determined through negotiation of the parties and a monetary settlement agreed upon, the matter was decided in a court of law, with the plaintiff having the right to a trial by jury. If successful in obtaining a judgment, the plaintiff received reparations to the extent that the defendent's assets, including any insurance coverage, sufficed to pay the judgment. Often, the substantial delay between the time of the accident and the time of judgment meant that the plaintiff himself had to shoulder the expenses of medical care, loss of work, and substitute means of transportation. The negligent driver, under this system, received no financial assistance, unless he had purchased first-party insurance coverage.

In 1970, Massachusetts became the first State to institute a "no-fault" reparation scheme whereby each driver in an accident is paid immediately, by his own insurance company, for medical expenses incurred up to $2,000. Since 1970, 23 other States have instituted some type of no-fault insurance plan. Insurance companies cannot independently adopt a no-fault insurance scheme since, under present regulations, they must follow the law of the State in which they operate.

Theoretically, a pure no-fault plan would avoid the need to go to court to determine liability and the amount of reparation to be made by the negligent driver. The question of fault would be irrelevant, and compensation for economic loss would be made to all injured parties on an established payment schedule. A pure no-fault system would also prohibit any suit in tort for damage recovery, making accident victims dependent on established schedules for recovery, However, no State has adopted a pure no-fault system. All 23 States have established thresholds such that, if a person suffers economic loss above a certain amount, he can sue for further recovery in the courts. Therefore, many drivers in no-fault States continue to carry liability insurance to guard against the possibility of a substantial court judgment against them.

The Federal Government could approach the problem of automobile insurance in three ways: continue to let the States regulate all automobile insurance, establish national insurance standards, or expand existing Federal social programs to deal with the problems faced by drivers involved in automobile accidents.

If the Federal Government were to establish a national plan to deal with the costs of automobile accidents, it might either set standards for States to meet or exceed, or it might impose specific requirements. A precedent for Federal involvement exists with the uniform safety standards established for the States.

The idea of setting Federal insurance standards is not new. Legislation to that effect was introduced in the 92d, 93d, 94th, and 95th Congresses. Two identical bills were introduced in April 1977, under which basic standards would be established for no-fault benefit plans providing for rehabilitation of, and compensation for, motor vehicle accident victims. (S. 1381 and H.R. 66ol: The Standards for No-Fault Motor Vehicle Benefit Act.) These bills allowed each State to establish its own no-fault plan, as long as it met or exceeded Federal standards. The proposed standard benefits included:

- Emergency treatment and care and medical and rehabilitation expenses up to $100,000 (in some cases $250,000), with optional coverage of up to $1 million,
- Wage losses up to $12,000,
- Replacement services for up to 1 year to allow accident victims to hire someone to perform tasks that they could no longer perform as a result of their injury, and
- Funeral and death benefits of $1,000.

The power of insurance companies to refuse to renew or to cancel policies would be strictly limited under these bills. Access to the courts would be provided only in cases of death, serious disfigurement, or other serious or permanent injury. States would be required to develop a plan for making insurance available to everyone a t reasonable rates.

Since no-fault provisions for vehicle damage were not included in the proposed legislation, such claims would be dealt with in the traditional manner. States that have tried to incorporate compensation for vehicle damage in their no-fault plans have experienced serious problems. Massachusetts, for example, repealed the vehicle damage provisions of its no-fault plan in 1974. Michigan, while including such coverage, provides for a $100 deduction similar to the so-called “collision” insurance plans.

If federally imposed no-fault standards were adopted, accident victims would receive immediate financial assistance to pay for medical treatment, to make up for lost wages, and to secure substitute services. The time required to establish “fault“ would be eliminated, except in cases of extreme hardship. All parties harmed in an accident would receive assistance— in most cases, more than they would receive under existing State programs.

Discrimination between policyholders as a result of ratesetting processes, policy cancellations, and nonrenewal of policies would be recognized as specific problems to be dealt with at the State level. While the cost savings would not be dramatic—since more people would be receiving benefits—there would probably be some savings due to reduction in the number of court cases. To the extent that the number of cases would be reduced by the Federal plan, courts would be freer to deal with other matters of concern.

One group that would stand to lose by the implementation of such a plan is the legal profession. Claimants would need legal representation only when necessary to prove fault. Historically, lawyers fees for handling a plaintiff’s case have accounted for one-quarter of a settlement reached prior to trial and one-third of the plaintiff’s recovery if the matter was resolved in the courts. Fees for defending a client are also significant. By removing the issue of fault from all but the most serious cases, and by having compensation awarded on the basis of established schedules, there would be little for lawyers to argue about in court.

Except in the most severe cases, injured parties would be unable to recover damages for “pain and suffering, ” If the no-fault plan were to include a deductible amount, each claimant would suffer an equal loss regardless of “fault. ” Without such a clause, minor claims would add significantly to insurance costs, as evidenced by present pricing practices for deductibles. Most no-fault programs that have been proposed require compulsory insurance coverage, an issue that is not necessarily tied to no-fault.

The cost impacts on consumers cannot be predicted with confidence since potential reductions of legal fees are offset by the prospect of having to compensate a greater number of accident victims.

Automobile Repair

Institutions that record consumer complaints identify automobile repairs as the leading cause of consumer dissatisfaction. Consumers complain that repair services are too costly, poorly performed, misguided, unnecessary, and sometimes fraudulent. Even new car owners, with recourse to warranty policies, complain of unsatisfactory repair services. The early breakdown of parts—in some cases on brand-new vehicles—creates a considerable cost and inconvenience for the owner. In the coming years, consumer problems with automobile repairs are likely to increase as cars become more complicated and as the number of trained mechanics fails to meet increased demand.

Part of the cause of unsatisfactory repair service is that manufacturers make 90 percent of their profits on the sale of new cars, and only 10 percent on the subsequent sale of parts. The pressure on dealers is to sell. While manufacturers have canceled dealer franchises because of poor sales performance, they have seldom, if ever, done so because a dealer has failed to service cars adequately. Warranty repair work is not in the interest of either the automobile manufacturers or the automobile dealer. Manufacturers, in fact, have discouraged dealers from doing warranty repair work by requiring extensive paperwork and, at times, by refusing to reimburse all of their claims fully.

Photo Credit: U.S. Department of Transportation

With the exception of the Magnuson-Moss Warranty-Federal Trade Commission Improvement Act (also known as the Consumer Product Warranty and Federal Trade Commission Improvement Act) that requires warranties to be stated clearly and that prohibits manufacturers from disclaiming or modifying implied warranties of the common law, the Federal Government has not intervened in the area of automobile repair. Rather, the responsibility for consumer protection has rested with the States. Three basic types of automobile repair laws have been developed: disclosure laws (truth-in-auto-repair laws), facility-licensing laws, and mechanics-licensing laws.

Disclosure laws typically require that a customer be given a written estimate of the repair costs, that a customer authorize repairs in writing before they are begun, that the customer be provided with a written invoice detailing the parts used and labor performed, and that the customer be allowed to inspect the parts.

Facility-licensing laws require auto repair facilities to obtain licenses for the purpose of doing business. Often, such facilities must pay a fee and post a bond. In the event of fraud or deceptive practices, the license can be suspended or revoked.

Mechanics-licensing laws require that repair work be either performed or supervised by a certified, licensed mechanic. Licensing typically requires that the applicant pass a competency examination.

To date, 15 States and 3 local governments have legislated one or more of these forms of regulation of automobile repair services. Table 128 shows the States that currently have automobile repair laws, according to the type of legislation in effect.

It is, perhaps, too early to evaluate the effectiveness of State actions to improve automobile repair services. If these policies are successful, the Federal Government might continue its present passive policy with respect to automobile repair. If the States are unsuccessful, the Federal Government might choose to take a more active role by passing national legislation designed to regulate or control the quality of repair service.

Table 128.—State Regulation of Automobile Repair

	Disclosure laws[a]	Facility licensing laws[b]	Mechanics licensing laws[c]
California	x	x	
Connecticut	x	x	
Florida	x		
Hawaii	x	x	x
Maryland	x		
Michigan	x	x	x
Montana	x		
Nevada	x		
New Hampshire	x		
New Jersey	x		
New York	x	x	
Ohio	x		
Rhode Island		x	
Utah	x		
Wisconsin	x		
District of Columbia	x	x	x
Montgomery County, Md.	x	x	
Prince Georges County, Md.	x	x	
Dallas, Tex.	x	x	

[a]Disclosure laws typically require that a customer be given a written estimate of the repair costs, that he authorize repairs in writing before they are begun, that he be provided with a written Invoice detailing the parts used and labor performed, and that he be allowed to Inspect parts.
[b]Facility licensing laws require auto repair facilities to obtain licenses for the purpose of doing business
[c]Mechanics licensing laws require that repair work be either performed or supervised by a certified, licensed mechanic
SOURCE *SRI*, pp F-27 to F-29

Photo Credit U S Department of Transportation

Automobile Durability

Automobile durability has a significant effect on consumer costs and is directly related to depreciation, which constitutes about one-quarter of the average cost per mile of operating an automobile. Durability of individual components is, moreover, a major element in repair and maintenance costs, which account for another *20* percent of the average cost per mile.[77]

The present economic system provides essentially no incentives for increasing automobile durability. Consumers have no channels through which to express a preference for more durable vehicles, nor do they have the know-how to assess the durability of the cars that they buy. The magnitude of the private investment required to own and operate an automobile gives rise to the question of whether the Federal Government should intervene in the market in an effort to increase the durability of the private automobile.

The average automobile engine produced in the United States lasts 100,000 miles before needing overhaul, and some engines have a life of 150,000 miles or more. At the point when overhaul is required, many vehicles are scrapped. Others are outfitted with a new engine and can be driven for an additional period. Other major components of the drive-train, body, and suspension system, might last longer than the engine.

The lifetime of accessories and components such as radiators, water pumps, distributors, alternators, and carburetors is often less than half that of the major power train parts. Optional accessories such as power steering, power brakes, and air-conditioning have similarly

[77] SRI, pp. F27-F29.

shorter life spans, as do seats, floor mats, door panels, and other appearance items. Degradation of such parts is a major factor leading to junking of the vehicle before the major components are worn out, The durability of all of these items could be greatly enhanced at relatively modest cost.

Corrosion of body parts caused by ice-dissolving chemicals also shortens the life of the automobile. Corrosion could be controlled rather inexpensively by using more galvanized sheet steel in the automobile body or by improved undercoating,

Although overall durability varies from car to car and from manufacturer to manufacturer, it is generally agreed that the smaller the car, the shorter its life span. Most likely, smaller cars are less durable then larger ones because they are operated at a greater proportion of their available power or capacity.

Durability is also a function of the manner in which a car is operated and maintained. While periodic motor vehicle inspections—first instituted in Pennsylvania in 1929—were designed to remove unsafe vehicles from the road, they had a secondary effect of promoting automobile maintenance and repairs, thereby increasing the life of the vehicle. The National Highway Traffic Safety Administration now requires every State to implement such a safety inspection program, although only 31 States and the District of Columbia have actually done so.

If the Federal Government were to seek to control automobile ownership costs, it might consider policies to improve durability. Among these are:

- Establish uniform warranties (or guaranteed life standards for all major automotive components, and enforce compliance,
- Require life testing and verification of all new cars as is now done in the case of emissions,
- Expand and fully implement a periodic maintenance and vehicle inspection program to cover safety, emissions, fuel economy, noise, and durability,
- Provide incentives such as rebates, taxes, or development subsidies individually, or in concert, to encourage durability,
- Establish an experimental durable car program analogous to the Research Safety Vehicle Program, and
- Provide the public, or require that the public be provided with, detailed information about the longevity, maintenance, and repair requirements of all makes and models of cars. 78

[78] The Motor Vehicle Information and Cost Savings Act (1972) requires that such information be provided, but this law has not yet been implemented by NHTSA.

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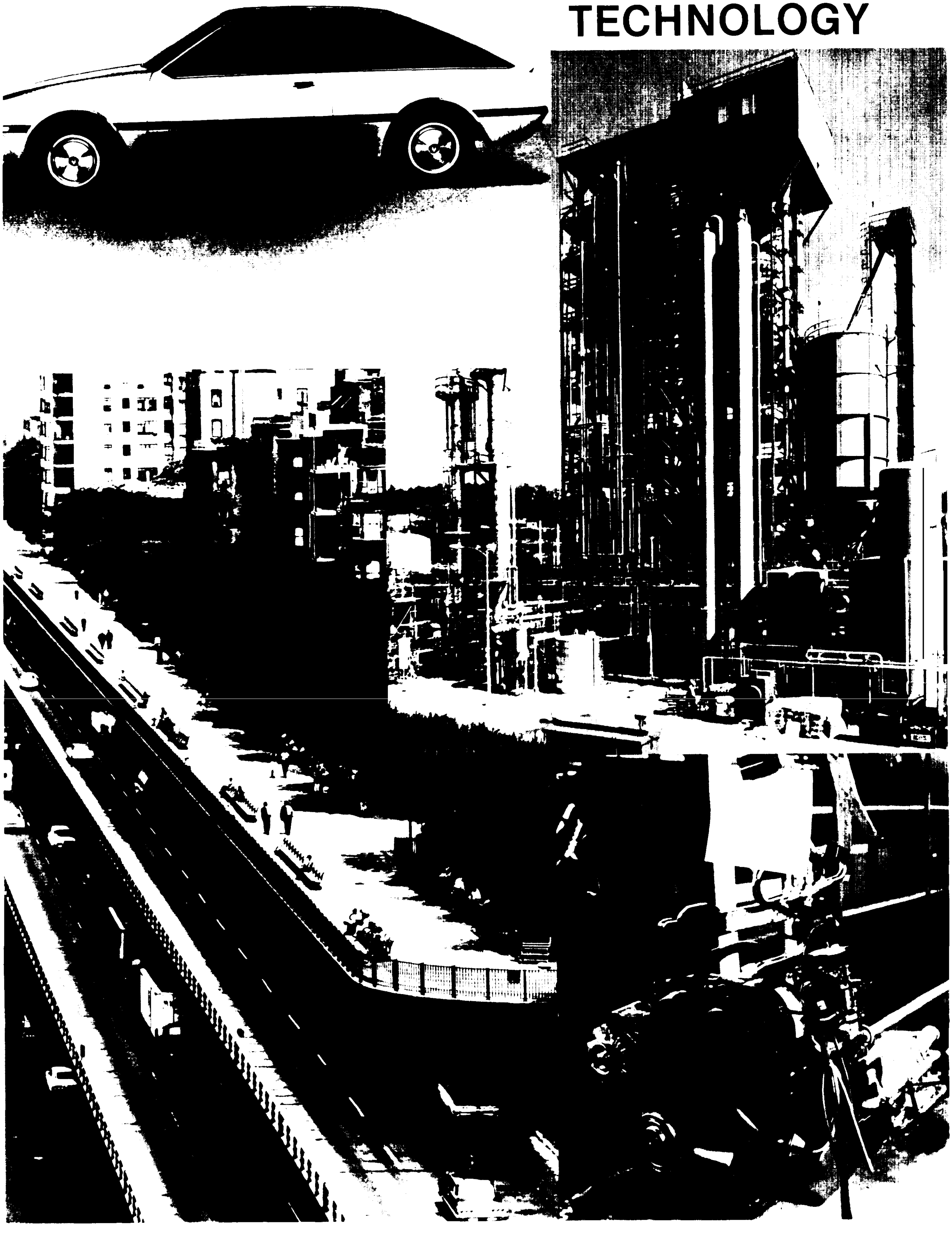
Chapter 10
TECHNOLOGY



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CHAPTER 10

SUMMARY

During this century, automobile manufacturing has evolved from a small group of struggling entrepreneurs into a massive industry and Government complex. The evolution of the industry has been largely determined by the capability of automobile manufacturers to mass produce vehicles to satisfy public demand at an affordable price. While there has been intense competition among manufacturers, the technology that has developed is remarkably uniform in terms of vehicle size, performance: and component characteristics. Until recently, the factors that influenced general vehicle characteristics and the success of particular models were styling, performance, comfort, convenience, reliability, and cost. As this formula was mastered by automobile manufacturers, the climate of the industry became that of an established and mature technology.

Within the past decade, however, the established pattern may been upset. Through a combination of public concern, Government action, and the force of circumstances, automobile technology has had to take new directions. The industry has had to be more mindful of environmental impacts, fuel economy, and safety. This has introduced new design requirements, new production techniques, new manufacturer responsibilities, and new costs. The characteristics of the automobile have begun to undergo a transformation in terms of both the technology employed and the rate at which changes are introduced. Some of these changes will be seen in the near term, by 1985. Others will take much longer to emerge and may not be on the market until sometime around 2000.

The technological aspects of the automobile transportation system that are likely to change in the near term are:

- Downsizing programs now underway will reduce the average size and weight of the vehicle fleet. Wasted space resulting from styling and image features will be greatly reduced.
- Substitution 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 increases in fuel economy will be achieved by improvements in transmissions and drive trains and by reduced power requirements for accessories.
- Several new engines or refinements of existing engines have been introduced recently or probably will be on the market in the near future:
  - —diesels (several offered now),
  - —stratified charge (offered now by Honda),
  - —Ford PROCO type (single-chamber) stratified charge,
  - —valve selectors (ready now, but not on the market), and
  - —turbocharging (offered now by GM and Ford).
- Electronic fuel control and ignition systems will come into widespread use and will help to maintain efficient engine performance and to reduce the need for tuneups.
- The introduction of these technological improvements should permit the 1985 automobile fuel-economy goals to be met, and possibly exceeded.

41-079 O - 79 - 20

- Emission goals, as currently legislated, can be met using existing technology and anticipated refinements without serious penalty in fuel economy.
- Vehicle safety will be enhanced by the addition of passive restraints in the early 1980's.
- On the other hand, small cars increase the potential for serious injury, unless crashworthiness is improved. Small cars can be designed to match the crashworthiness of present full-size cars at a nominal weight and cost penalty.
- Basic design and manufacturing processes will not change substantially, except where the use of new materials requires new processes .
- Advanced vehicle and propulsion technologies such as Stirling and turbine engines, electric vehicles, and alternative fuels will not significantly penetrate the marketplace by 1985.
- Other characteristics, such as comfort, handling, and convenience options will be much like today. Durability, damageability, and maintenance and service requirements will be essentially the same. The variety of products now offered by manufacturers will remain, but the sales mix will shift toward smaller vehicles.

There are several research and development programs on automobiles and fuels now being conducted by Government and industry. The outcomes of these programs are expected to have an important influence on the direction that automotive technology will take in the period 1985-2000. These research and development activities include:

- the gas turbine development program;
- development of the Stirling engine, and its derivatives;
- R&D on electric and hybrid vehicles and identification of prospective markets and roles;
- long-range development of highly efficient engines, such as the adiabatic turbocompound diesel;
- R&D on materials—including ceramic components for engines, base metal catalysts, and energy-absorbing composites;
- development of a homogeneous, all-plastic tire;
- definition of the health effects of automobile emissions—both those now regulated and those expected from new engines and fuels; and
- exploration of the processes and facilities needed to provide new fuels—alcohol, broad-cut petroleum fuels, synfuels, and hydrogen.

INTRODUCTION

The future of the automobile transportation system will be determined in part by the new technologies introduced in the next 25 years. In order to assess new technologies and their effects and impacts on the future characteristics of the automobile transportation system, it is necessary to make estimates of a number of factors:

- Which new technologies are likely to be developed within the next 25 years?
- What potential benefits do they offer in terms of improved mobility, reduction of emissions, energy conservation, or improved safety?
- What are the technical or social drawbacks of these technologies?
- When will they be commercialized and at what rate will they penetrate various markets?
- How much will they cost the consumer?
- How much will the development process cost?
- How do they compare with alternative technologies?

In addressing these questions, this chapter first describes the present technology of automobiles and the automobile industry, and changes through 1985 that are already in prospect because of Government regulations, industry commitments, and firm economic and marketing considerations. The following topics are covered:

- vehicle characteristics,
- manufacturing and materials,
- fuel economy,
- emission control,
- safety technology,
- Otto cycle engines,
- diesels,
- drivetrains and accessories, and
- electronics.

The final part of the chapter discusses research on future systems or improvements beyond **1985,** including major technological problems and opportunities. Included are discussions of advanced-propulsion systems, advanced-vehicle designs, safety improvements, electric and hybrid vehicles, and alternate fuels.

HISTORICAL AND CURRENT TRENDS

The U.S. auto industry has accumulated a monumental store of technological expertise, experience, and research facilities in almost all aspects of its business. In addition to the multitude of products and developments brought to public attention, the auto industry engages in extensive research and development activities. Although some of these R&D activities are publicized, many are not, either for competitive reasons or because the results were negative (as is the case for much of the research in all industries), or because the research lacks direct or current applicability.

Some of the more important elements of the overall technological base and the factors which influence technology are discussed in this section, both to describe the probable vehicle and system characteristics through 1985 and to serve as a basis for forecasts to 2000 and beyond.

Several determining characteristics of the U.S. automobile industry and transportation system have been:

- a high degree of standardization of vehicles and components,
- high production rates and relatively low unit prices,
- uniformity of service and repair facilities, and fuel supply systems,
- aggressive industry advertising aimed at selling more cars and at influencing consumer tastes,
- R&D efforts focused on targets of high marketability or, in recent years, high public or governmental concern,
- a high degree of sales competition among domestic firms and with imports,
- a business system which is characterized by a conservative, predictable, low-risk approach in order to maintain competitive strength, and
- a market which has traditionally been resistant to abrupt or unusual product changes.

As a consequence of such influences, U.S. passenger car models have evolved into remarkably similar groups of vehicles in terms of size, performance, and component characteristics. Competition has centered on performance, comfort, and convenience—leading to gradual, incremental increases in size and weight. Different buyer needs and levels of affluence have been accommodated by each manufacturer by supplying a similar range of vehicles, with prices that were highly competitive within size and performance categories.

Many variations of the basic four- to six-passenger car have evolved — two-passenger sports cars, economy cars, limousines, and recreational vehicles—but the basic concept and mechanical components remain much the same. The primary industry goal continues to be to supply a range of products (at a profit) that will meet the mobility needs of most U.S. family units. In recent years, this range has broadened considerably.

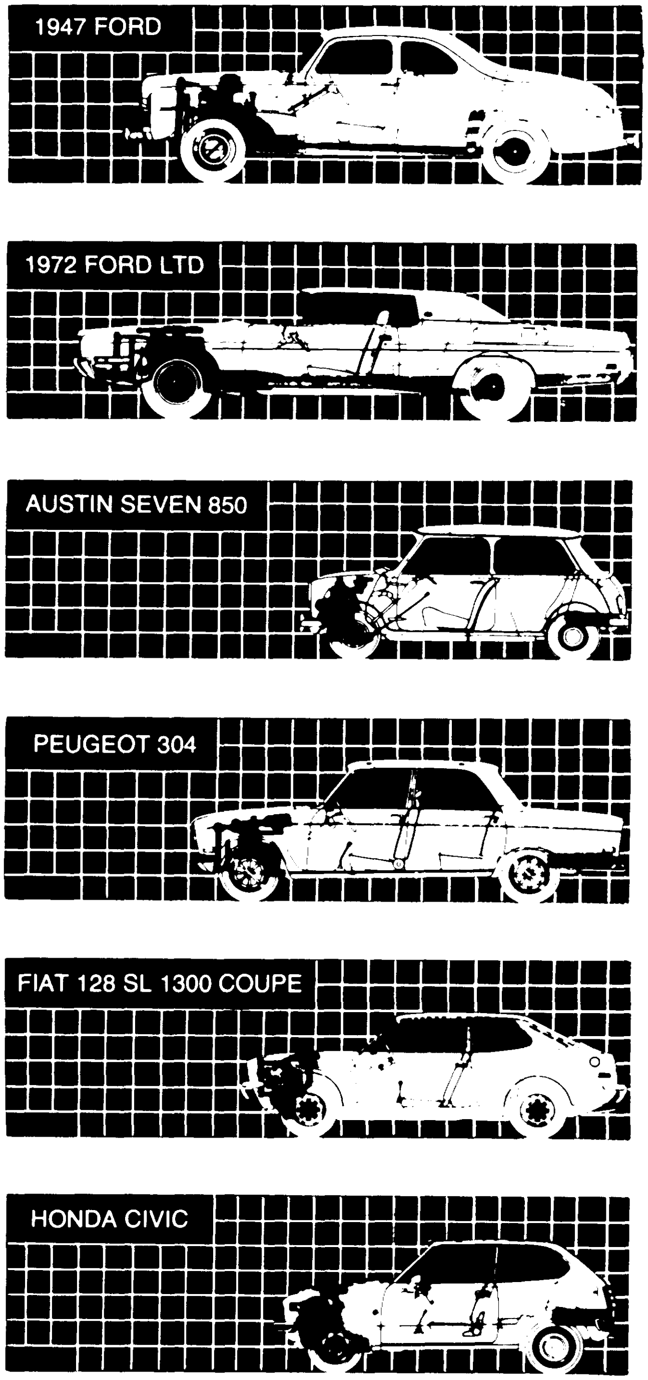
The size and performance characteristics of specific models or classes of vehicles have shown a trend of reasonably steady increases over the past 30 years. Recently, however, emission regulations required tuning engines to lower performance ratings, and in 1977, overall vehicle downsizing began to reduce weight for added fuel economy. The most popular U.S. sizes were in the range of 115- to 118-inch wheelbase and 3,000- to 4,500-pound curb weight. The sales-weighted average passenger car weight remained remarkably constant at about 3,350-pound curb weight from the late-1940's to 1974. The sales-weighted average price also remained essentially constant in constant dollars over these years.[1]

Figure 54 shows selected past and recent U.S. and foreign models to illustrate the wide variety of packaging efficiency, and the potential for length reduction without significant change to the length and height of the passenger compartment. Table 129 shows that over the past 25 years, the basic passenger compartment for standard-size vehicles of U.S. manufacture changed little in its critical dimensions, despite the wide range and steady increase in overall size and weight.

During this same period, an increasing number of comfort and convenience options were introduced and enthusiastically accepted. (See figure 55.) A leveling off of purchases of some of these options and sharp declines in some, particularly the V-8 engine, is forecast in the next few years. Most of these devices add appreciably to fuel consumption and to manufacturers' profits, as their percentage markup is typically on the order of half again that of the basic vehicle.

In the mid- and late-1950's, imports, typically with 80- to 110-inch wheelbase and 1,500- to

Figure 54.—Illustrative Automobile Sizes



SOURCE: *Road and Track Magazine*, various issues.

[1] SRI International, *Potential Changes in the Future Use and Characteristics of the Automobile*, contractor report prepared for OTA, January 1978; and supplemental submissions (hereinafter cited as SRI Supplement).

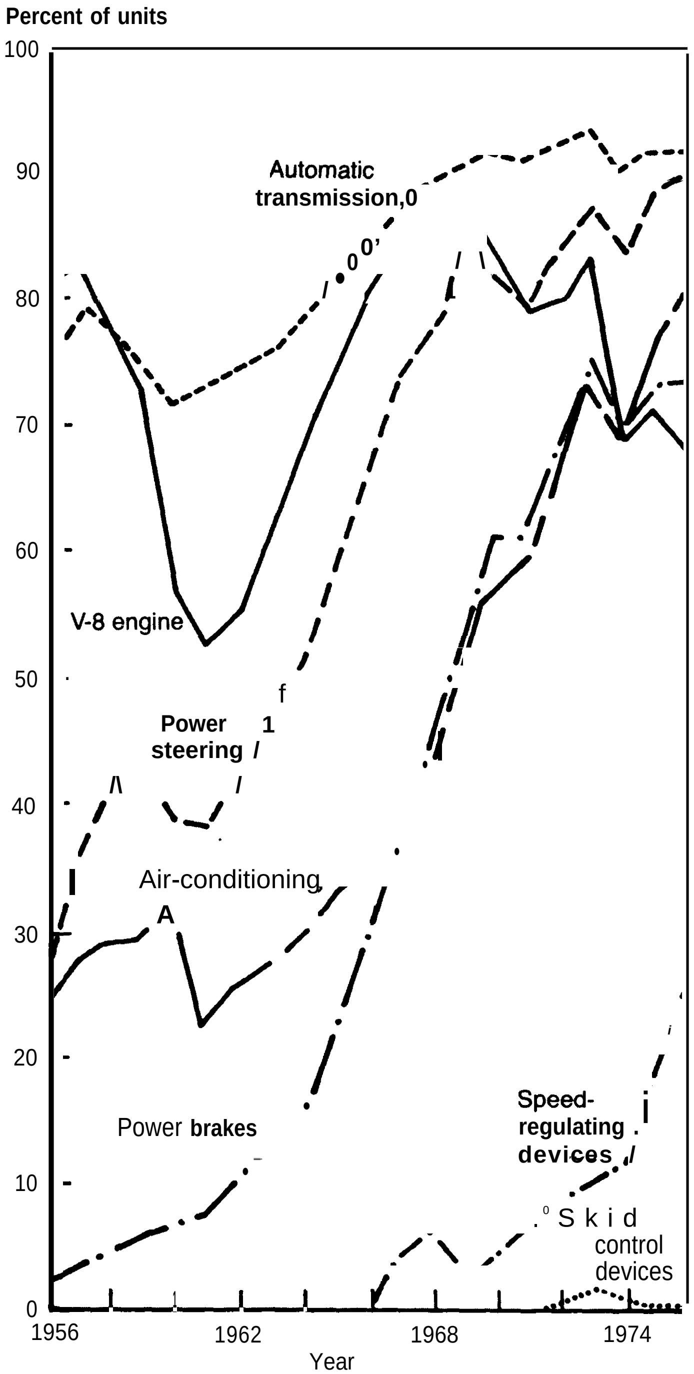
2,800-pound curb weight, began to capture an increasing share of the market. The U.S. manufacturers' response was to introduce a family of compact and intermediate-sized cars, which reduced the import penetration from 10 percent to 5 percent in 3 years. However, the smaller U.S. cars began to grow steadily in size and weight and by 1975, the import share of the market rose to over 18 percent—a share that they still hold.[2] Imports are attractive for the feature content, efficiency of space utilization and, in many cases, performance, handling, and subjective views of quality and image.

During the early *1970's,* the U.S. auto manufacturers moved more strongly into overseas manufacture and assembly for the U.S. market. Efforts to bring captive imports into the United States were marginally successful, and some died out after a few years of promising performance. (See table 130.) Under existing fuel-economy regulations, captive imports cannot be averaged into the U.S. manufacturers' fuel-economy figures after 1980. Thus, the extent of overseas manufacture and assembly of cars and parts for U.S. sale will be reduced significantly after that date.

The foreign-based import sales in the United States come mostly from a few large companies—typically the top five firms hold more than 65 percent of the U.S. market.[3] Most of these firms are large, broadly based, and technologically innovative. There are also several smaller firms that export to the United States. They and the larger firms often try new technologies or novel vehicle layouts at a relatively early stage of development as a market entry tool.[4]

All of these major trends in the United States auto industry occurred with little direct regulatory pressure. However, when the influences of fuel-economy, emissions, noise, safety, and

Figure 55.—Factory Installation of Selected Equipment from 1956 to 1976



SOURCE Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures, '78.*

[2] Motor Vehicle Manufacturers Association, *Motor Vehicle Facts and Figures 78*

[3] In 1976, the top five import firms were Toyata, Datsun, Volkswagen, Honda, and Fiat. They accounted for 969,587 of a total of 1,491,910 import sales, R.A. Wright, "Imported Cars Draw U.S. Attention, " *Automotive News 1977 Market Data Book issue,* Apr. 27, 1977, p. 70.

[4] Examples of this are the Honda stratified-charge engine (CVCC), the Mazda rotary engine, the VW diesel engine, and the many import firms offering the increasingly popular front-wheel-drive layout.

Table 129.—Vehicle Characteristics (full-size Chevrolet 4-door sedan)

	1950	1957	1967	1974	1975	1976	1977
Wheelbase (in.)	115	115	119	121.5	121.5	**121.5**	116
Length	197.5	200	213.2	222.7	222.7	**222.7**	212.1
Width (in.)	73.9	73.9	79.9	79.5	79.5	**79.5**	76
Height (in.)	65.75	61.5	55.4	53.9	54.5	**54.7**	56
Front headroom (in.)		36	39.1	39.6	38.9	**38.5**	39
Front legroom (in.)		44.7	42.2	42.5	42.5	**42.6**	42.2
Curb weight (lb)	3,145	3,304	3,570	4,389	4,318	**4,361**	3,771
Standard engine displacement (cu in.)	216.5	283	327	350	350	**350**	305
Optional engine displacement		348	427	454	454	**454**	350

SOURCE: *Automotive Industries Magazine*, Statistical Issues, 1950-1978

Table 130.—U.S. Sales of Captive Imports (thousands)[a]

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Opel	40	82	91	83	89	69	68	59	40	10	29
Capri	—	—	—	16	56	92	113	75	55	30	22
Simca	6	5	7	6	5	3	—	—	—	—	—
Colt	—	—	—	—	28	21	36	43	60	49	71
Arrow	—	—	—	—	—	—	—	—	—	30	47
Cricket	—	—	—	—	28	13	4	—	—	—	—
English Ford	12	23	21	10	—	—	—	—	—	—	—
Challenger/ Sapparo	—	—	—	—	—	—	—	—	—	—	3
Fiesta	—	—	—	—	—	—	—	—	—	—	41

[a]Values are approximate because of rounding and use of several data sources.
SOURCE: *Automotive News, 1978 Market Data Book* and earlier Almanac Issues

damageability regulations are added, it is obvious that the industry and its products have entered a period of unprecedented change.

Materials, Design, and Manufacturing Processes

Capabilities in the field of automotive materials, design, and manufacturing processes have reached a very high level in the automobile industry. Requirements, schedules, and future goals are relatively clear. Production volumes are adequate to make exploration of relatively minor improvements worthwhile. The design goal is the optimum combination of performance, cost, risk, and flexibility of application.

A typical car includes about 50 percent carbon steel, 15 percent cast iron, 8 percent other iron and steel, 6 percent rubber, 2.5 percent plastics, 2.5 percent glass, and 2.6 percent aluminum. (See table 131.) The primary manufacturing processes of concern are sheet-metal stamping and welding, followed by ferrous casting. These are well-established processes with little chance for innovations other than responses to the changing economics of energy and process emission control.

Alloy steels are used in gears, bearings, forgings, and other highly stressed parts. Typically, these parts are forged and machined, and are continually the subject of improved manufacturing processes. “Chipless machining” concepts

Table 131 .—Automobile Material Used in a 1974 Plymouth Valiant

	lbs/car	% Wgt.
Plain carbon steel	1,630	52.4
Cast iron	436	14.2
Other iron & steel	254	8.2
Aluminum	70	2.6
Rubber	183	5.9
Plastics	77	2.5
Glass		2.5
Copper/zinc/lead	89	2.9
Soft trim	76	2.4
Sound deadeners	52	1.7
Misc. (fluids, paint, solder)	165	5.3
Total	3,111	100

SOURCE SRI, p V 37

such as spline rolling and powder metal fabrication are preferred and are being expanded as fast as their process economics become favorable.

Most aluminum parts are cast or made of stamped sheet. Aluminum usage has risen to about 100 pounds per car in **1977,** and is expected to go to 150 pounds by 1980. Extensive R&D on stamping and spot welding of aluminum may enable carmakers to replace more and more steel parts with aluminum. The need for weight reduction and the availability of cylinder wall-coating processes (e. g., the Nikasil or the Kawasaki exploding wire scheme) could conceivably reawaken interest in the Chevrolet Vega die-cast aluminum-engine concept. If such a cylinder block went into production, it would replace heavier cast iron with another **50** pounds or so of aluminum per car. Also, manufacture of aluminum wheels of competitive price and performance out of strip with a welded-in center section has recently been accomplished, These parts are expected to replace a fair percentage of steel wheels.

Years ago, plastic parts were generally injection molded or extruded, In recent years, the use of sheet-molding compounds has taken over the bulk of plastic applications by weight. The use of plastics rose to about **160** pounds per car in **1977,** and is expected to go up to 240 pounds per car by 1980, replacing heavier materials. Research into the use of plastics and integrated foam structures for structural and body parts may provide further possibilities in this area,

Because iron and steel are plentiful, and because many parts of cars can 'be made of alternate materials, automotive materials are not viewed as a problem, either from a standpoint of availability or ability to meet performance needs well beyond **1985.**

The basic design and structure of the automobile has remained essentially unchanged for many years. Two basic configurations have evolved—the unit body and frame and the "conventional" separate body and frame. In the latter, the vehicle consists of a steel chassis or

Photo Credit. General Motors Corporation frame to which the suspension system, wheels, engine, and drivetrain are attached. The vehicle body (consisting of floor, firewall, roof, door, fender, hood and trunk panels, along with inner panels, support members, seats, etc., welded and bolted into place) is then fastened to the frame.

In the unit body and frame concept, the suspension, drivetrain, and engine are attached to reinforced areas of the body, rather than to a separate frame. A variation of this theme is the stub frame concept in which the engine and front suspension are mounted to a short or stub frame attached to the unit body in the vicinity of the firewall. A unit body and frame is generally lighter and more compact, but it is much more difficult to isolate the occupants from engine and road noise. U.S.-manufactured pickup trucks are all of the full-frame type. Two of the three U.S.-built vans have unibody construction.

All of these vehicle structures offer comparable qualities of durability, cost, ease of manufacture, marketability, etc. The level of efficiency achieved through these assembly processes allows the automobile industry to produce an average of 25,000 to 30,000 passenger cars per day.

Propulsion Systems

The first patented internal combustion engine (ICE) was a two-cycle, developed by a Belgian named Etienne Lenoir in Paris around 1860. The four-cycle engine was developed 20 years later by a German, Nicholas Otto. Ironically, coal gas, which was over half hydrogen, was the primary fuel for these early engines. Petroleum products came into play as the industry developed.[5]

In the early years, the ICE faced stiff competition from electric motors and steam engines. However, because of the ICE's higher thermal efficiency and the ability to run long periods of time at high speeds, it became the primary powerplant in motor vehicles.

The ICE began as a one- or two-cylinder machine. It was heavy, noisy, dirty, and only semidependable. As the industry expanded and progressed, so did the engines, into 4-, 6-, 8-, 12-, and even 16-cylinder engines. In the 1950's, the smooth, dependable overhead-valve V-8 engine was introduced on a wide scale and rose in popularity quickly. In recent years, it has been used in more than 70 percent of passenger cars manufactured in the United States. (See figure 55.) However, the need to reduce fuel consumption is expected to reverse this trend as more smaller and lighter cars are introduced.

In the post-World War II period, engine efficiency was increased through higher compression ratios and reduced friction. Increased efficiency was accompanied by an increase in the octane rating of motor fuel. As octane numbers approached 100, refining costs increased much more rapidly, and high-performance engines were approaching the point where only marginal gains in efficiency could be achieved from higher compression ratios. Also, anticipated increases in international shipments of refined petroleum products acted to keep U.S. octane levels more in line with the lower levels elsewhere in the world. As a result, octane numbers peaked around 1970. (See figure 56,)

In response to early emission control requirements (1968), engines were detuned (e. g., retarded spark, changed valve timing, and fuel mixture changes). In 1971, engines were modified to accept lead-free gasoline. The modifications included reducing compression ratios and making related changes to valves and seats. With the advent of catalytic converters in 1975, engines were retuned to attain optimum performance and minimum fuel consumption. Now most engines are designed to run on regular-grade (91 octane) unleaded fuel.

Drivetrain

With few exceptions, U.S. passenger cars for the last 50 years have used a front engine with attached transmission and rear-wheel drive. Automatic transmissions first appeared in the late 1930's; they now comprise about 90 percent of the market.

Early mechanical schemes, including automatic clutches and preselected gear changes,

[5] John B. Rae, *The American Automobile* (Chicago: University of Chicago Press, 1965).

flourished briefly, as did fluid couplings (no torque multiplication). However, these lost out to the hydrokinetics torque converter combined with two- or three-speed planetary gear sets which are engaged by disc or band clutches. These units are the only automatics available today in the U.S. passenger cars. Some four-speed automatics and some automatics with torque converter lockup were available in the 1940's and 1950's, but disappeared because of cost and lack of interest in fuel economy.

A manual transmission with a single-disc, dry-plate clutch is the only alternative to the automatic now available. These transmissions are usually associated with sports, performance, or economy cars. For U.S.-made cars, the majority of manual transmissions have been three-speed. Four-speed units are usually associated with the large high-performance engine or with fuel-efficient imports. In the last few years, four-speed and even five-speed units have become available for economy cars. Essentially, all manual and automatic transmissions are direct drive in the final gear, although a limited number of U.S. cars have been available with an overdrive attached to the manual transmission. Although overdrive had a gear ratio as low as 0.7 and provided some improvement in fuel economy, it was never particularly popular.

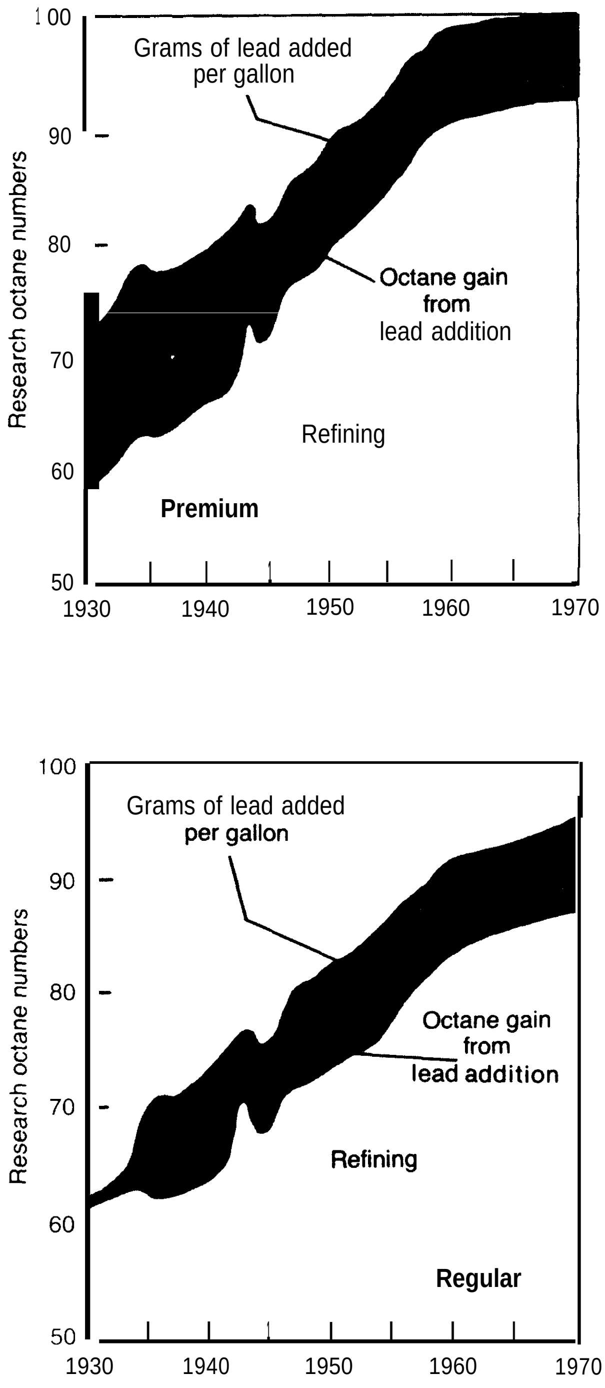
U.S. cars have almost universally used a unit rear-axle housing with a hypoid geared differential. In order to achieve improved fuel economy, this final drive gear ratio has dropped in recent years from the range of 3.5 to **4.o** to about 2.o for large cars.

Regulation

Traditionally, the passenger car industry has been regulated only in the tax, antitrust, and similar business-oriented areas. In the 1960's, it became apparent that automobiles and their use were responsible for a number of serious social problems, and a series of emission control and safety regulations were initiated. In 1973, the oil embargo prompted Government regulation of fuel economy.

Attempts to improve consumer protection by controlling automobile design features have been initiated, and appear to be at least some-

Figure 56.—Historical Source of Octane Quality in Commercial Gasolines



SOURCE S/3/, p v-10

what effective. Mandatory provision of product information may also influence vehicle designs.

The major remaining area in which regulation is likely is the limitation of places or conditions of auto use. (See chapter **6.)** Auto use restrictions are of concern technologically because they could increase the demand for small, low-performance, nonpolluting commuter cars. However, specialty cars probably will not become a significant part of U.S. auto production through the year **2000** unless specific policies encouraging such vehicles are adopted.

Other potential regulatory topics such as recycling and materials use do not yet appear on the horizon, although at some point they may be of importance from the perspective of overall national goals.

Emissions

The history of U.S. auto emissions control is presented in table 132. The regulatory effort progressed from a relatively modest start in California to a major broadly based Federal effort characterized by frequent changes to the regulated emission levels. A strong regulatory agency evolved and industry responses soon became a major part of their R&D activities.

Early efforts in controlling vehicle emissions resulted in penalties in fuel economy. The oil embargo made clear the requirement for a balanced approach to reduced emissions and improved fuel economy. Fortunately, some of the technological responses, such as the stratified-charge engine or the catalytic converter, allow substantial reductions in emissions and operation at minimum fuel consumption. Health effects, atmospheric phenomena, and other aspects of air quality are not completely understood, but air pollution is widely perceived by the public as a health problem and a blight to cities. Thus, vehicular emission control will undoubtedly be continued and possibly even tightened.

Currently, three products contained in the exhaust of automobiles are controlled on the basis of grams per mile emitted. They are hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO_x). The manufacturers must certify that their engines will meet the grams per mile emission requirements for **50,000** miles of vehicle travel before their vehicles can be sold to the public.

The Federal requirements for 1979 model year passenger cars are 1.5 grams per mile HC, 15 grams per mile CO, and **2.o** grams per mile NO,. In 1981 and beyond, the Federal requirements will be 0.4 HC, 3.4 CO, and 1.0 NO_x. California has a different, more stringent schedule and lower allowable levels for these emissions. (See table **132.)**

Table 132.—Summary of California and Federal Passenger Vehicle Exhaust Emission Standards, 1970 to 1982 and Later

	Hydrocarbons (gm/mi)		Carbon monoxide (gm/mi)		Oxides of nitrogen (gm/mi)	
Model year	California	Federal	California	Federal	California	Federal
1970[a]	2.2	2.2	23	23	no std.	no std.
1971[a]	2.2	2.2	23	23	4.0	no std.
1972[b]	3.2	3.4	39	39	3.2	no std.
1973[b]	3.2	3.4	39	39	3.0	3.0
1974[b]	3.2	3.4	39	39	2.0	3.0
1975	.9	1.5	9	15	2.0	3.1
1976	.9	1.5	9	15	2.0	3.1
1977	.41	1.5	9	15	1.5	2.0
1978	.41	1.5	9	15	1.5	2.0
1979	.41	1.5	9	15	1.5	2.0
1980	.41	.4	9	7	1.0[c]	2.0
1981	.41	.4	3.4	3.4	1.0[c]	1.0
1982 and later	.41	.4	7	3.4	.4	1.0

[a]Tests conducted using 7 mode" test cycle a 137 second driving cycle
[b]Tests conducted using crs-72 test cycle, a constant volume sample including cold start For 1975 and later the test cycle is a crs 75, which includes cold and hot starts
[c]For California only, a 100.000 mile certification is optional with the NO_x standard at 1 5 g mi/mi
SOURCE *SRI* p V 23

Several components and systems for meeting these emission standards are currently being used or are in the development or planning stages. These include designs for improved combustion (e.g., electronic control of ignition timing and fuel metering, stratified-charge concepts), improved after-treatment systems (e. g., three-way catalyst), diesel engines, turbines, and Stirling engines.

The detailed list of technological options is long, and there is a high probability of meeting regulatory goals. The present exploratory phase of industry development will gradually shift toward full exploitation of the optimum combinations that evolve. The manufacturers will probably choose different combinations of options, although electronic control of the air-fuel ratio and ignition timing will probably be virtually universal by 1981.

The announcement of a 0.4-gram-per-mile NO_x standard for California passenger cars in 1982 and beyond introduces a more difficult technical problem than does the Federal standard of 1.0 gram per mile. To date, no concepts have been demonstrated that can meet this level with typical large U.S. spark-ignition engines (SIE). Volvo, Saab, and GM have demonstrated that they can meet this 0.4 NO_x requirement with a three-way catalyst system on four-cylinder engines. However, the ability to meet the requirement for 50,000 miles without maintenance and under high-production conditions has not been demonstrated.

Fuel Economy

Passenger car fuel consumption in the aggregate is measured on the basis of gasoline tax receipts and total vehicle miles traveled (VMT). These measures reflect a long-term decline in fuel economy per auto from about 15.3 mpg in 1940 to 13.1 mpg in 1973.[6] The national speed limit of 55 mph, the catalytic converter, and industry efforts to improve fuel economy resulted in improvement to 13.5 mpg by 1975. Total fuel consumption is a function of VMT, the way these miles are driven (speed, acceleration, etc.), and the inherent efficiency (expressed as miles per gallon) of the average vehicle. Only the latter parameter is considered in this section.

[6] *SRI*, p. V-12. (Originally from U.S. Statistical Abstracts and MVMA data.)

The Energy Policy and Conservation Act of 1975 mandated new car fuel economies of 20 mpg by 1980 and 27.5 mpg by 1985 on a manufacturer's fleet average basis.[7] It seems that these goals can be met, but the industry is concerned about consumer acceptance of the vehicle modifications that are necessary. Prospective methods for meeting the goals include weight reduction; improved engine efficiency; reduced losses in tires, drive line, transmission, and accessories; and improvements in aerodynamics and overall vehicle optimization. The challenge lies in finding the combinations that meet the public needs of adequate performance, capacity, emissions, safety, cost, durability, and general appeal.

Safety

Regulation of motor vehicle safety above and beyond evolutionary improvements in the design, construction, performance, and handling of motor vehicles, is achieved primarily through the application of the Federal Motor Vehicle Safety Standards, issued and enforced by the National Highway Traffic Safety Administration (NHTSA). Approximately 50 safety standards are in effect, most of which apply to passenger cars. (See table 133.) The technology required to meet many of the Federal Motor Vehicle Safety Standards is not particularly complex; once it is developed and incorporated into a vehicle, the unit cost in most cases is not great. The regulated vehicle safety features are considered to be partially responsible for the reduction in the rate[8] of highway deaths since 1966.

Another responsibility of NHTSA is the investigation of vehicle defects, often leading to recall campaigns by the auto manufacturers. In

[7] These fuel consumption values are based on chemical analysis of the exhaust (done as part of emission testing) and are not necessarily comparable to the previously mentioned values. The Environmental Protection Agency values of fuel consumption are up to 20 percent higher than actual values. U.S. Environmental Protection Agency, Emission Control Technology Division, Office of Mobile Source Air Pollution Control, *Evaluation of the Representativeness of EPA Fuel Economy Estimates*, January 1978.

[8] The fatality rate, expressed in deaths per hundred million vehicle miles of travel, dropped from 5.7 in 1966 to 3.4 in 1975. (U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety '76:* A Report by the President on the Administration of the Highway Safety Act of 1966, as amended, Jan. 1, 1976 - Dec. 31, 1976) and to 3.2 in 1976 (U.S. Department of Transportation, National Highway Traffic Safety Administration, *Motor Vehicle Safety '77*).

Table 133.—Chronology of Federal Motor Vehicle Safety Standards and Regulations

Date Issued	Standard	
January 31, 1967	Standard No. 101	Control Location, Identification, and Illumination
	Standard No. 102	Transmission Shift Lever Sequence, Starter Interlock, Transmission Braking Effect
	Standard No. 103	Windshield Defrosting and Defogging
	Standard No. 104	Windshield Wiping and Washing Systems
	Standard No. 105	Hydraulic Brake Systems
	Standard No. 106	Brake Hoses
	Standard No. 107	Reflecting Surfaces (Chrome Trim)
	Standard No. 108	Lamps, Reflective Devices, and Associated Equipment
	Standard No. 111	Rearview Mirrors
	Standard No. 201	Occupant Protection in Interior Impact
	Standard No. 203	Impact Protection for the Driver From the Steering Control System
	Standard No. 204	Steering Control Rearward Displacement
	Standard No. 205	Glazing Materials (Automobile Windshield Glass)
	Standard No. 206	Door Locks and Door Retention Components
	Standard No. 207	Seating Systems
	Standard No. 208	Occupant Crash Protection
	Standard No. 209	Seat Belt Assemblies
	Standard No. 210	Seat Belt Assembly Anchorages
	Standard No. 211	Wheel Nuts, Wheel Discs, and Hub Caps
	Standard No. 301	Fuel System Integrity
November 8, 1967	Standard No. 109	New Pneumatic Tires
	Standard No. 110	Tire Selection and Rims
February 12, 1968	Standard No. 202	Head Restraints
April 24, 1968	Standard No. 112	Headlamp Concealment Devices
	Standard No. 113	Hood Latch Systems
	Standard No. 114	Theft Protection
July 3, 1968	Standard No. 115	Vehicle Identification Numbers
August 13, 1968	Standard No. 212	Windshield Mounting
December 24, 1968	Standard No. 116	Motor Vehicle Brake Fluids
January 17, 1969	Part No. 567	Certification Regulation
	Part No. 569	Regrooved Tires
March 23, 1970	Standard No. 213	Child Seating
July 17, 1970	Standard No. 118	Power-Operated Window Systems
October 22, 1970	Standard No. 214	Side Door Strength
November 5, 1970	Part No. 574	Tire Identification and Recordkeeping
December 31, 1970	Standard No. 302	Flammability of Interior Materials
February 10, 1971	Part 573	Defect Reports
February 19, 1971	Standard No. 121	Air Brake Systems
April 9, 1971	Standard No. 215	Exterior Protection (Bumpers)
April 14, 1971	Standard No. 117	Retreaded Pneumatic Tires
December 3, 1971	Standard No. 216	Roof Crush Resistance
March 1, 1972	Standard No. 122	Motorcycle Brake Systems
	Standard No. 125	Warning Devices
March 31, 1972	Standard No. 124	Accelerator Control Systems
April 4, 1972	Standard No. 123	Motorcycle Controls and Displays
May 3, 1972	Standard No. 217	Bus Window Retention and Release
August 3, 1972	Standard No.126	Truck-Camper Loading
January 17, 1973	Part No. 577	Defect Notifications
January 22, 1973	Part No. 555	Temporary Exemptions From Federal Motor Vehicle Safety Standards
January 31, 1973	Part No. 580	Odometer Disclosure Requirements
July 26, 1973	Part No. 572	Anthropomorphic Test Dummy
August 9, 1973	Standard No. 218	Motorcycle Helmets
November 5, 1973	Standard No. 119	New Pneumatic Tires
May 20, 1975	Part No. 575	Consumer Information—Uniform Tire Quality Grading
June 9, 1975	Standard No. 219	Windshield Zone Intrusion
September 4, 1975	Part No. 552	Petitions for Rulemaking, Defect and Noncompliance Orders
	Part No. 570	Vehicles in Use Inspection Standards
January 19, 1976	Standard No. 120	Tire Selection and Rims for Vehicles Other Than Passenger Cars
January 22, 1976	Standard 220	School Bus Rollover Protection
	Standard No. 221	School Bus Body Joint Strength
	Standard No. 222	School Bus Seating and Crash Protection
February 27,1976	Part 581	Bumper Standard (Incorporates Standard 215)

SOURCE U S Department of Transportation, National Iilghway Traffic Safety Adm[rlstratlon. *Traffic Safety '76*

the period 1966 to 1975, 52 million vehicles were recalled, or 43 percent of total production.

It is generally agreed that the majority of crashes are the result of driver error or misperception. Thus far, there are few suggestions for improving the capability and reliability of the typical driver. Regulatory efforts have focused on improved occupant protection and, to a lesser extent, accident avoidance.

Accident avoidance includes features such as better acceleration, improved brakes, improved lighting and visibility, and improved handling. Such features are marketable commodities, but some are costly. Also, there is not clear evidence that all of these features contribute significantly to reductions in the number of crashes.

In contrast, occupant protection is effective, and the results can be evaluated. Passive restraint systems are required for introduction in the 1982-84 model years. This technology is developed and no technical difficulties are foreseen. However, the data on the effectiveness of these systems are still being debated and additional field experience is desirable. Also, public acceptance of passive restraints is presently unknown.

Most safety goals conflict with fuel-economy goals since additional safety equipment or structure means more weight and lower fuel economy. Also, small fuel-efficient cars have the potential for relatively higher fatality rates because occupant protection is partly a function of crush distance and relative vehicle weights.

Although the "no-damage" bumper was introduced under Federal Motor Vehicle Safety Standard 215, there is a slim justification for considering this to be a safety feature. It is now part 581 of the 1972 Motor Vehicle Information and Cost Savings Act. It is expected that this requirement will stay in effect and, through design improvements, the cost and weight penalties will be minimal.

Potential Regulatory Areas

Passenger car noise will probably become the subject of Federal regulation in the future. However, at present, trucks are by far the loudest sources of highway noise and are more appropriate targets for regulation.

So far the only significant passenger car noise standards are those in California. The California limits are 76 dBA below 35 mph and 82 dBA above 35 mph. Current gasoline-powered automobiles already meet the California standards. Diesel engines are noisier than spark ignition engines at low speeds, but at medium and high speeds, tire and wind noise dominate for both types of vehicles. Reduction of tire noise is the object of much research.

In the case of radiation of electromagnetic energy by the automobile's ignition system, it is reported that the industry is establishing standards of its own.[9] However, some Federal agency may well add this to its regulatory spectrum.

Regulations designed to control corrosion damage may evolve in the near future, particularly in view of the obvious and unnecessary financial impacts of corrosion. Canada is working very hard on establishing a uniform code that would limit corrosion damage.

As one avenue of engine design turns more and more to very lean mixtures and high compression heterogeneous fuel/air charges (Ford PROCO, Texaco TCCS), ignition systems with even higher energy content per discharge are required. Some contemplated systems could produce a lethal shock for the unwary mechanic. Products such as these are unlikely to be offered in the general marketplace.

Recent information indicates that various fluorocarbon gases react with the ozone in the Earth's atmosphere, with the potential for increasing the amount of sunlight (at certain wavelengths) that reaches the Earth's surface. To minimize this effect, such compounds are being eliminated as propellants for spray cans. Similar compounds (e.g., Freon®, 12) are the preferred working fluid in most small refrigerative air-conditioners, including those used in motor vehicles. All such vehicle systems are of the nonhermetically sealed type, and thus have a potential for leakage, either when in use or when scrapped. As a result, such systems may be inappropriate. An alternative approach is to use a refrigerative cycle where the air to be cooled is the working fluid (e. g., ROVAC or turbo expander). These systems, at least in their present forms, are bulkier, more complex and more costly. As experience is gained, this situation may be greatly improved.

Under the 1972 Motor Vehicle Information and Cost Savings Act, NHTSA must determine crash susceptibility, crashworthiness, associated insurance costs, and ease of diagnosis and repair of mechanical and electrical problems. This information must then be made known to the public for each make and model of car. Although Sweden has had most elements of such a program in effect for years, this program has yet to be implemented in the United States. If it should, the effects on the competitive posture of at least some of the various domestic and import automobiles would likely be noteworthy. Small cars might suffer a setback in public acceptance for safety reasons, and favorable ratings would be crucial to the survival of smaller manufacturers.

[9]SRI, p V-38

AUTOMOTIVE TECHNOLOGY TO 1985

As discussed in the previous section, many of the regulatory patterns and resulting technological responses that will appear between now and **1985** have already been established—at least in broad terms. The auto industry has publicized a number of alternative plans for meeting regulated economy goals, and it is generally conceded that the goals can be met from the standpoint of technology.

However, the changes involved are costly in terms of R&D, tooling, and facilities, and are required on a schedule that is much faster than normal industry response times. Also some of the changes could easily affect customer acceptance of major segments of the new car offerings. The industry feels that if sales were to drop significantly, cash flow would be affected and the ability to finance these massive changes would be a problem. Accordingly, this is viewed by the industry as a period of high risk in which only the technologies with a high probability of success can be relied upon.

Downsizing and Materials Substitution

The most important changes which are slated to occur between now and 1985 center around the requirement to meet a corporate average fuel-economy level of 27.5 mpg and, simultaneously, the statutory emission standards of 0.41 HC, 3.4 CO, and 1.0 NO_x. The industry response has been to embark on a major program of downsizing all cars in the product line, reducing weight by changes in materials, design, and vehicle layout, and instituting fuel-saving features in almost every component of the vehicle. Simultaneous developments in engine modifications and new engines and fuels are being pursued; Government incentives and assistance are being provided in this latter area. Individual major aspects of this overall program are discussed below.

Major gains in weight reduction are being achieved by both downsizing and materials substitution. Materials substitution includes the use of lightweight designs and materials, and is a somewhat slower process than simple size changes.

Weight reduction by downsizing generally takes the form of closer packaging of the main vehicle components reducing interior waste space and, in some cases, reducing width from three- to two-abreast seating. Some of the most important gains are achieved by shortening the trunk overhang and reducing styling-induced waste space from the firewall forward. Such major body changes are equivalent to, but more extensive than, the major styling changes that the industry previously undertook for competitive reasons. In the smallest car categories, it is generally agreed that the most practical way to achieve maximum efficiency of packaging power train components is to use a front engine, front-wheel-drive layout. Many small European cars and several U.S. cars have adopted this concept. Costs are slightly higher than for a conventional rear-wheel-drive layout, but this may now be offset by the importance of saving weight and optimizing interior volume. As more experience is gained, front-wheel drive will probably be tried on new, lightweight larger cars.

Weight reduction by materials substitution is inextricably intertwined with considerations of cost, performance, appearance, durability, materials compatibility, and similar parameters. Some substitution concepts allow the redesign of not only the principal part but also associated parts. This effect is referred to as "cascading," that is, the iterative effect of weight reduction.

Other forms of weight reduction include elimination of the spare tire as a result of improved tire durability and puncture resistance, use of a smaller tire for the spare, reduction of engine block casting-wall thickness, and lighter wheels and batteries. Most of these are "one-shot" opportunities, but not all have been exploited.

Associated with downsizing is the planned reduction in engine size, usually described as cubic inch displacement (CID), and reduction in the size of all related transmission and drive-train components. The size of these components can be reduced to the minimum level that will produce acceptable performance (typically zero to 60 mph acceleration times of about 16 to 18 seconds).

Engine downsizing results in improved fuel economy because of reduced weight and because the engine is run with the throttle open farther more of the time. This reduces throttling loss, which is a factor affecting overall engine efficiency. However, too small an engine for a given car can actually result in reduced fuel economy because much of the time, the engine would operate in an overloaded, inefficient power range.

Department of Transportation (DOT) studies indicate that a 10-percent reduction in weight with a reduction of engine size for constant acceleration performance can produce a 6.8-percent improvement in fuel economy. This, in conjunction with other efficiency improvements in vehicle systems, constitutes the general strategy for meeting the fuel-economy goals set at 27.5 mpg for 1985.

Presently, it appears that there are no major technical problems with downsizing. However, there are technical limitations on materials substitution; progress in this area is being accomplished as the industry develops designs and processes that are compatible with other manufacturing processes. The weight reduction program requires considerably greater expenditures than the industry's customary annual investments for redesign and retooling. Cost considerations are particularly important in the area of materials substitution. Some substitution of lightweight materials (plastic, aluminum, and high-strength steels) has occurred, but only when the cost was lower and all other capabilities of the substitute material were equivalent to or higher than the original material. However, it is expected that greater emphasis will be placed on weight saving, despite a slight increase in cost.

One potential drawback to the downsizing plan is safety. It has been reported that the rate of fatality or serious injury in a multiple-car collision is twice as high in a small car as in a large car. In a crash, the rate and duration of deceleration of the vehicle is part of the mechanism that produces injury. This is a function of the distance through which the deceleration occurs, referred to as the stopping distance or crush distance. Smaller cars have much less crush distance available. Theoretically, 4 feet is sufficient to decelerate a properly restrained, forward-facing human from 60 mph, so that the person incurs little or no injury. Most small cars today have that distance in front of the windshield.[12] However, the occupant compartment typically extends beyond the windshield. Since the engine is incompressible, the available crush distance is reduced further. Even in the largest cars, the crush distance is only marginally adequate.

For small cars, additional mechanisms are required to help decelerate the occupants in high-speed barrier crashes. The only current contenders are energy-absorbing restraint systems, such as air bags, or special belt systems that allow the occupants to decelerate while moving closer to the dash and firewall (thus utilizing all of the available interior space as well as the vehicle crush distance). At this time, this is somewhat academic, since current barrier crash requirements, set at 30 mph, are easily met by large and small cars.

Another obvious drawback to downsizing is the reduction in capacity of vehicles, and the reduction in comfort associated with space. The current six-passenger full-size sedan will most likely be replaced by a car offering the same level of comfort for only four passengers.

The reduction in engine sizes to achieve higher fuel economy and the increased engine efficiency, achieved through operating with the throttle closer to wide open, may reduce engine life expectancy. In addition, increased emissions of nitrogen oxides can occur.

The major domestic manufacturers are deeply involved in extensive downsizing programs. These programs are projected to reduce average inertia weight by about 800 to 1,000 pounds during the 1978-81 model years. A second round of downsizing is also planned to permit achievement of the 1985 fuel-economy standards.

The corresponding improvements in new car

[10] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Fatal Accident Reporting System: 1976 Annual Report*, November 1977.

[11] W. Haddon, Jr., "Reducing the Damage of Motor-Vehicle Use," *Technology Review*, July-August 1975, p. 59.

[12] Data from the Insurance Institute for Highway Safety.

fleet fuel economy expected from the initial downsizing programs are about 3 to 4 mpg. Table 134 summarizes the potential new car fleet average inertia weight achievable through body redesign by 1981.

The specific plans for downsizing and for alternatives for different conditions of timing and emission penalties were submitted by the U.S. manufacturers in response to a Federal inquiry. GM, for example, reduced the length—both wheel-base and bumper-to-bumper—of its 1977 model year full-size cars to obtain weight savings of 650 to 950 pounds.

The manufacturers' plans have been adjusted many times, and may well be changed again. However, it seems likely that the response will be along the lines illustrated by the General Motors Alternative III approach, which consists of:

- weight reduction by redesign and materials substitution;
- use of some diesels; and
- engine, transmission, and miscellaneous improvements.

The general categories of changes, the projected timing, model-by-model differences, and engine selections are given in figure 57 and tables 135 and 136, using the GM documentation as an example. Changes will differ among companies, and additional changes beyond those listed may be made as 1985 approaches. Some of these differences include:

- Timing and sequence of weight reduction redesigns by car model will differ.
- Schedules for improvements in engines, transmissions, and miscellaneous components will differ.
- Ford appears to be pursuing stratified-charge technology rather than diesel as a means of achieving a modest step-improvement in specific fuel consumption (SFC)[13] and emissions.
- Weight reductions resulting from materials substitution are already being introduced on a scheduled basis, and could be called upon to provide improvements beyond those presently planned.
- A surge of interest in safety considerations could require weight additions that are not included in the current planning.
- Further emissions control requirements could cancel some of the anticipated gains in engine efficiency.
- Scheduling of such extensive and costly product changes 8 years ahead of the final goal must be considered tentative and will be subject to many unforeseen economic, social, and regulatory pressures.

Materials substitution is a continuing process in the auto industry; however, special emphasis on materials substitution is expected in the 1982-85 period. On a part by part basis, aluminum can, in some instances, save up to 50 percent of the weight of the original part. Plastics can sometimes offer even greater savings. The attractiveness of materials substitution lies in the cascading effect which it produces. Reducing the weight of a car's body by 50 pounds through the use of substitute plastics or aluminum can lead to as much as 75 pounds of other savings. This is because the chassis can then be made lighter and a smaller engine can be chosen (which in turn reduces the structural needs). Table 137 illustrates some of the recent trends in the use of materials in automobiles. Table 138 shows a hypothetical case of materials substitution illustrating the cascading effect.

Downsizing and materials substitution have important cost implications for the auto industry. In the past, many components of the suspension and running gear systems, accessories, and even some of the body panels remained the same during a major model change. However, with downsizing almost all of these components will change completely. Also, the complete product line will have to change in less than 8 years. This represents a difficult task from the standpoint of required capital, design and production, and engineering effort. The historical expenditures for new plants and equipment are shown in figure 58.

Capital requirements for vehicle downsizing depend partly on the capacity and flexibility of

[13] U.S. Department of Transportation, National Highway Traffic Safety Administration, Office of Automotive Fuel Economy, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards* Document 2, Vol. 1, Feb. 28, 1977,

Table 134.—Vehicle Weight, 1976 and 1981

Manufacturer	Current (1976) average inertia weight	Downsized (1981) average inertia weight
Chrysler	4,150	3,400
Ford	4,100	3,300
General Motors	4,450	3,480
American Motors	3,550	3,400

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*, February 1977.

Table 135.—General Motors Weight-Reduction Technology (weight[a] in pounds)

		Baseline		Body redesign		Material substitution	
Car concept	Performance	Curb	Inertia	Curb	Inertia	Curb	Inertia
Full-size regular sedan	Lo	3,700	4,000	—	—	3,410	3,500
	Med	3,800	4,000	—	—	3,430	3,500
	High	4,000	4,500	—	—	3,570	4,000
Wagon	Med	4,260	4,500	—	—	3,940	4,000
	High	4,400	4,500	—	—	3,940	4,000
Full-size luxury sedan	Med	4,170	4,500	—	—	3,870	4,000
	High	5,190	5,000	—	—	—	—
Mid-size regular sedan	Lo	3,830	4,000	3,200	3,500	3,000	3,500
	Med	3,830	4,000	3,220	3,500	3,020	3,500
	High	4,260	4,500	3,500	3,500	3,155	3,500
Wagon	Med	4,300	4,500	3,470	4,000	3,270	3,600
	High	4,420	4,500	3,590	4,000	3,390	3,500
Mid-size luxury sedan	Med	—	—	3,590	4,000	3,390	3,500
	High	4,340	4,500	3,610	4,000	3,410	3,500
Mid-size special sedan	Med	4,060	4,500	3,245	3,500	3,045	3,500
	High	4,180	4,500	3,370	3,500	3,170	3,500
Compact regular sedan	Med	3,330	3,500	2,680	3,000	2,480	2,750
	High	3,500	4,000	—	—	—	—
Wagon	Med	—	—	3,050	3,500	2,850	3,000
	High	—	—	3,170	3,500	2,870	3,000
Compact special sedan	Med	3,460	4,000	2,900	3,000	2,700	3,000
	High	3,600	4,000	—	—	—	—
Subcompact regular sedan	Lo	—	—	2,270	2,500	2,120	2,500
	Med	2,690	3,000	2,290	2,500	2,140	2,500
Wagon	Med	2,740	3,000	2,360	2,740	2,210	2,500
Subcompact mini sedan	Med	2,060	2,500	1,820	2,000	1,820	2,000
Subcompact special sedan	Med	—	—	3,250	3,500	3,100	3,500
	High	3,670	4,000	—	—	—	—

[a] "Inertia" weight refers to the equivalent weights needed for the simulated urban and highway driving cycle dynamometer tests used in emissions measurements.
SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*, February 1977.

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Table 136.—General Motors Corporation Alternative Ill, Model Year 1985 Engine Production Summary

Engine (CID)	Number of cylinders	Transmission	Percent sales
85.0	4	A	1.83
85.0	4	M	2.08
Subtotal			3.91
98.0	**4**	**A**	**2.40**
98.0	**4**	**M**	**2.00**
Subtotal			**4.40**
151.0	6	A	24.35
151.0	6	M	2.27
Subtotal			26.62
231.0	6	A	29.55
231.0	6	M	0.21
Subtotal			29.76
301.0	8	A	9.30
305.0	8	A	3.34
350.0 (diesel)	8	A	22.67
Subtotal			35.31
Total			100.00

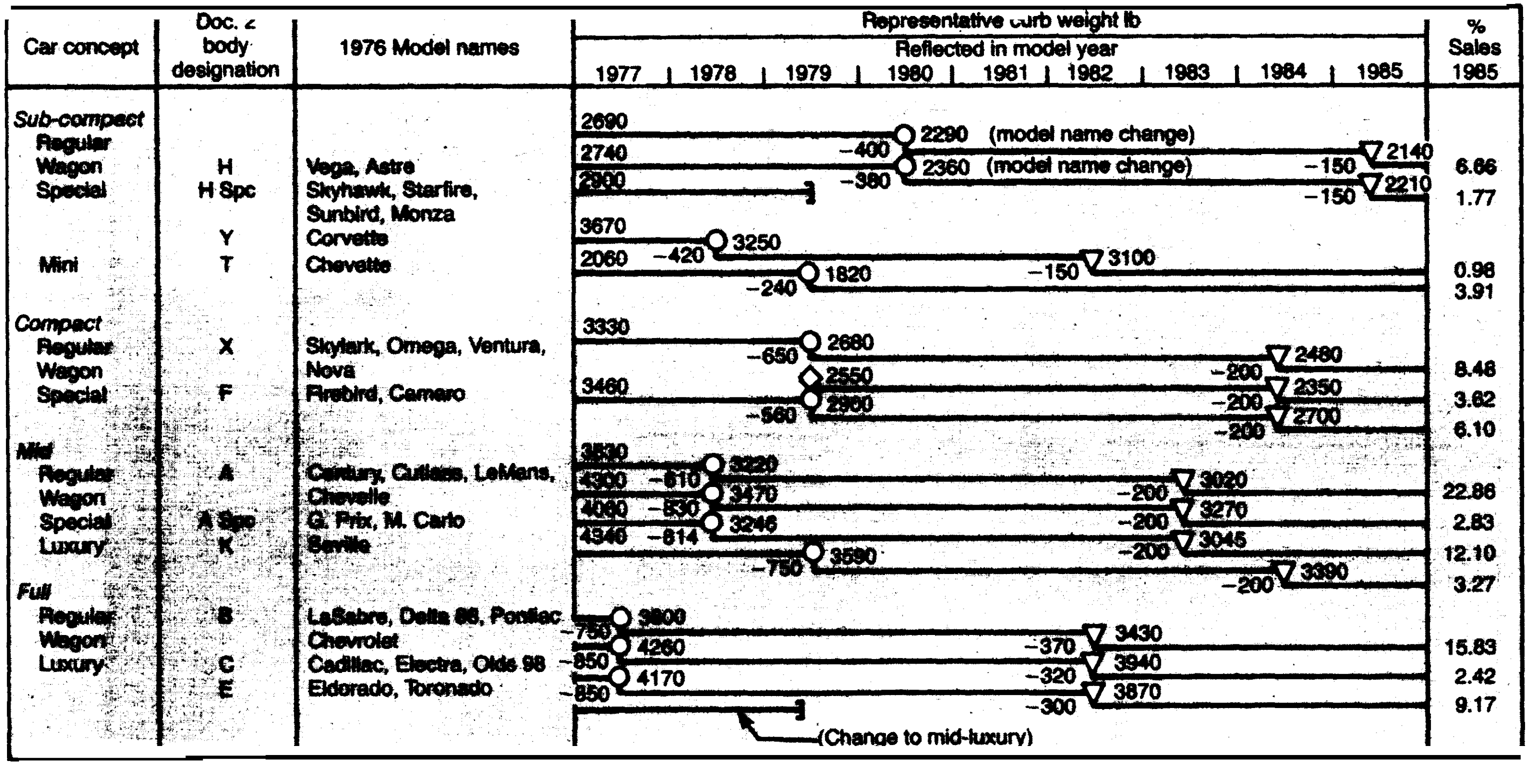
[a]A = automatic, M = manual.
SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*, February 1977.

Table 137.—Materials Used in a Chevrolet Impala (pounds)

Material	1974	1977	Percent change
Steel	2,708	2,221	– 18
Iron castings	690	620	– 10
Plastics	138	200	+ 43
Glass	107	115	+ 7
Aluminum	59	69	+ 17
Nontire rubber	37	35	– 5
Copper	27	25	– 7
Zinc	24	20	–17
Other	548	405	–26
Total	4,338	3,710	–14

SOURCE: *Business Week*, Aug. 2, 1976, and May 23, 1977.

Figure 57.—Time-Phased Introduction of GMC Weight-Reduction Technology



KEY
- ○ Body redesign
- ▽ Material Substitution (Alternatives II & III Only)
- ◇ New car concept

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*, February 1977.

Table 138.—Hypothetical Vehicle Upper and Lower Body Weight Reductions (pounds)

Area and component	Original weight	Materials substituted	Total weight savings
Upper body			
Windshield, cowl, dash	90		14
Center pillar	25		5
Qtr. panel, wheel hsg.	124	High-strength steel (reduced thickness)	19
Deck panel shelf	54		7
Roof, rear window	66		9
Front-end sheet metal	237		43
Hood assembly	105	Aluminum (increased thickness)	46
Deck-lid assembly	55		33
Door assembly	170	Aluminum on panels; Ultra-high strength steel on door guard Beams	27
Glass & tracking	110	Thinner glass	17
Interior & exterior trim & seats	279	Aluminum & high-strength steel in selected components	42
Lower body			
Underbody (rails, floor pan)	272	High-strength steel	62
Sills	49	Iterative reductions	12
Total bodyweight savings			333

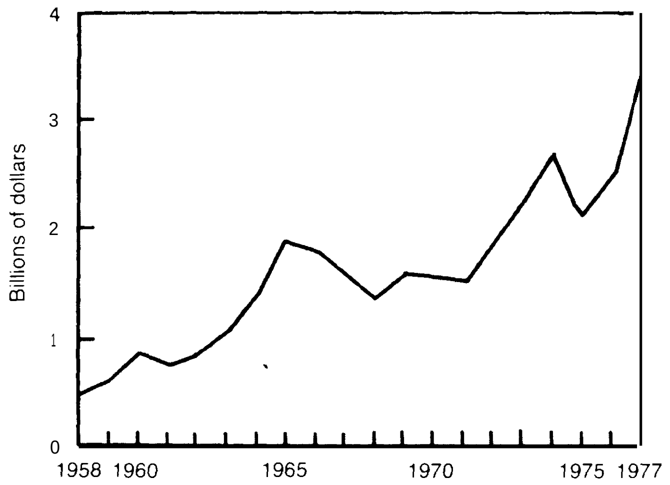
Area and component	Original weight	Materials substituted	Savings from chassis materials substitution	Iterative savings from: Body	Iterative savings from: Chassis	Total weight savings
Chassisgroup						
Power plant	793	High-strength steel		109	13	122
Final drive	188	High-strength steel		39	5	44
Forestructure	181	High-strength steel	7	47	5	59
Suspension	248	High-strength steel	9	60	7	76
Steering system	76	High-strength steel		21	2	23
Brakes	199	High-strength steel		56	6	62
Wheels&tires	244	High-strength steel	10	52	6	68
Exhaust system	46			14	2	16
Fuel system	33			5	1	6
Bumpers	177	Aluminum&high-strength steel	22	44	5	71
Total chasis weight savings			48	447	52	547
Other	459					
Total	4,280					880 (21%)

SOURCE SRL p V-18

the existing plants. Capital requirements for conversion of all the necessary production facilities for a 400,000-unit-per-year capacity assembly plant have been estimated to be in the area of $150 million to $250 million. This includes provision for unassociated 1o-to20-percent increase in small-engine production capacity. Capital requirements for downsizing a major part of a manufacturer's annual production (e.g., 1 million cars) have been estimated to be in the range of $4OO million to $7oO million. This is a one-time expense, and compares with total industry projected capital expenditures of $21.3 billion in the 1976-80 time frame (roughly $5 billion per year)." This adds up to about $50 billion by 1985.

"Ibid,

Figure 58.—U.S. Auto Industry New Plant and Equipment Expenditures



SOURCE: *SRI*, p. V-16.

Otto Cycle Engines

This category of engines includes the conventional spark ignition engine, which uses a homogeneous mixture of gasoline and air that is premixed upstream of the intake valve. It also includes prechamber and single-chamber stratified-charge concepts, and various forms of rotary engines.

The vast majority of automotive experience and R&D effort is associated with Otto cycle engines. There appears to be opportunity for improving such engines in terms of emissions, size, weight, and specific fuel consumption. In addition to direct engine improvements, there is considerable potential for cleanup of exhaust emissions downstream of the basic engine. Also, various methods for reducing effective engine size, such as turbocharging or the Eaton valve selector, can help improve vehicle fuel economy.

Most of the changes that have been made to meet emissions and fuel-economy regulations affect internal or external aspects of conventional engines. Examples of "internal" changes include:

- control of ignition timing and duration,
- higher energy spark,
- quick warmup features,
- modifications to manifold flow passages,
- valve timing and overlap,
- increased swirl in the combustion chamber for better combustion,
- improved mixture preparation, and
- optimum mixture ratios through more accurate control systems (e. g., electronic).

The "external" approaches have included:

- exhaust gas recirculation (EGR),
- air injection into exhaust ports (air pump system),
- catalytic converters, and
- feedback control of mixture ratio (control system with external sensors).

Continuations, refinements, and extensions of these concepts are proceeding in a variety of development programs. These developments will probably contribute significantly to meeting the emission requirements and mandated fuel-economy goals.

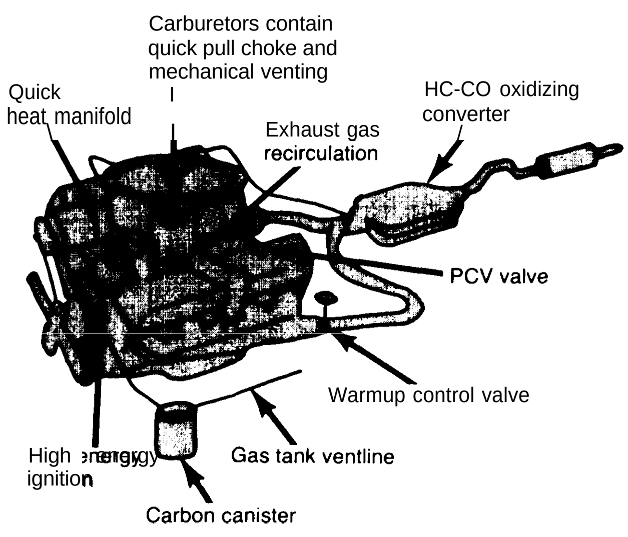
Catalytic Control of Exhaust Emissions

The typical emissions control system on most domestic new cars is shown in figure 59. Its main components are the oxidation catalyst and supportive engine controls. The oxidation catalyst was first installed on most domestic new cars in model year 1975. Through exhaust gas recirculation (EGR), NO_x emissions are generally controlled by diluting the incoming charge with relatively inert exhaust gases. This added exhaust gas reduced peak combustion temperature (a controlling factor in the reaction of nitrogen and oxygen to form NO_x).

The two-way oxidation catalyst commonly uses platinum and palladium to oxidize hydrocarbons and carbon monoxide. It can meet the emission standards of 0.41 gram per mile for HC and 3.4 grams per mile for CO in almost all cases. Oxidation catalysts generally operate at lower temperatures and allow engine tuning for better fuel economy than is achieved by thermal reactors (used by at least one foreign manufacturer) that require excess oxygen.

The three-way catalyst is expected by most industry sources to be the system chosen for achieving 1981 Federal emission standards while obtaining close to maximum fuel economy. This system is now used in some California cars.

Figure 59.—Typical Emission Control System



SOURCE: Harbridge House, Inc., *Automobile Technology Assessment: Case Studies of Foreign Government Policies and Experience,* Draft, March 1977,

The three-way catalyst employs platinum, rhodium, and palladium as the active noble metal ingredients for conversion of CO, HC, and NO_x. Very precise air/fuel ratio control is required, and this can be provided by carburetors or fuel injection in conjunction with an oxygen sensor feedback control system. Optimim emission control and close to optimum fuel economy are achieved simultaneously by running at stoichiometric (chemically correct) air/fuel ratio.

There are no significant technical restraints accompanying the use of the oxidation catalyst in meeting current emissions requirements other than degradation of this system over time. There is some concern that the system will not perform well near the end of the 50,00&mile lifecycle and that consumers may not replace the catalysts when necessary.

Early indications that the oxidation catalyst was a fire hazard have subsided. Also, a suspected increase of emissions of sulfur oxides through the use of the catalytic converter has proven unfounded.

Primary obstacles to marketing the three-way catalyst are:

- Rapid depletion of the available supply of rhodium may result from using a high platinum/rhodium ratio in the construction of the three-way catalyst and from high platinum loading per cubic inch of engine displacement. The naturally occurring platinum/rhodium mine mix of 19:1 is being experimented with, although a platinum/rhodium ratio of 5:1 gives better control. The development of base metal catalysts would be desirable in order to relieve the demand for noble metals.
- The oxygen sensor, critical for operation of the system, currently lasts about' 15,000 miles, and replacement is necessary.
- The cost of the complete three-way emission control system is somewhat higher than that of the two-way catalyst. EPA's summary of retail sticker price increases, derived from manufacturers' estimates, shows a range of $113 to $176 over 1977

model year base prices for the three-way system.

Catalyst reactor systems have been applied in new cars since **1975.** Use of even more effective catalyst-based emission control systems may become universal in 1981.

Volvo has installed the Engelhard three-way catalyst and electronic feedback control on some of its 1977 cars. Ford and General Motors have introduced this system on a limited number of their 1978 new cars in California in order to comply with the tighter California emission standards and to gain operating experience prior to full-scale use. Further research by U.S. automakers involves refinement of the equipment for greater durability and improved efficiency.

The prospects for development of an effective and durable base-metal catalyst are uncertain and no realistic time frame can be suggested. However, this advance is important from a standpoint of protecting against disruption or diminution of foreign sources of noble metals.

Some small additional investment in R&D on advanced catalyst systems will probably continue, and work on base-metal catalysts will continue. Much of this will be funded by the suppliers to the auto industry as well as the auto manufacturers.

Stratified-Charge Engines

In a general sense, the term stratified charge is applied to any engine in which combustion occurs with large variations in mixture ratio in the overall combustion chamber. Charge stratification is a fundamental aspect of any engine where fuel is injected directly into the combustion chamber and ignition occurs before the fuel air mixture becomes homogeneous (as a result of diffusion, turbulence, swirl, etc.). All diesels, direct-injection gasoline engines (such as PROCO, TCCS and the like), and most external combustion engines can be included in this category.

Another general form of charge stratification has received much attention in recent years. It uses two separate chambers with a rich fuel/air ratio in one (usually a small prechamber containing the spark plug) and a very lean mixture in the other (or main) combustion chamber. In most such engines, a relatively homogeneous gasoline-air mixture is fed into both chambers; the flame from the fuel-rich prechamber ensures ignition and relatively complete combustion of all of the lean mixture in the main chamber. This concept originated early in the century and was the subject of research by British, French, Russian, American, and other developers. The Honda CVCC (Compound Vortex Controlled Combustion) and current U.S. efforts are relative latecomers on the scene.

The two-chamber stratified-charge engines attempt to reduce emissions by two mechanisms. First, the two chambers operate at mixture ratios such that NO_x formation is reduced. Second, the flame ignition of the main charge is supposed to be vigorous enough so that the amount of unburned hydrocarbons is reduced at all load conditions. These effects do occur, but the Honda CVCC currently requires an exhaust manifold reactor to meet HC regulations and will require EGR to meet future NO_x standards. Fuel economy should be little different from any other engine running at the best overall economy mixture ratio (slightly below stoichiometric). Disadvantages of this system include the higher cost of the more complex cylinder head, prechamber, and third-valve system, and the extra maintenance associated with these components.

The single-chamber, direct-injection *strati*fied-charge engines include the Ford PROCO (Programmed Combustion), Texaco TCCS (Texaco Controlled Combustion System), GM DISC (Direct Injection Stratified Charge), MAN-FM (Maschienenfabrik Augsburg—Nurnberg A. G.-Frau Meurer), and others. Several of these can use a variety of fuels ranging from diesel to high-octane gasoline. The MAN-FM is generally viewed as being a spark-ignited diesel, while the others are viewed as direct-injection gasoline engines.

The direct-injection gasoline engines have either very low or no octane requirement, and generally operate at moderate compression ratios. At 11:1 compression ratio, the PROCO can operate on 80-octane gasoline, while the TCCS has no octane or cetane limit.

The PROCO engine proponents feel that its performance will equal or excel that of **a** typical passenger car diesel in all important parameters, including emissions, fuel economy, noise, cost, starting, weight, size, and durability.

In the PROCO engine, intake manifold and ports handle only air and, if EGR is used for NO_x control, exhaust gas. Therefore, the intake manifold system need not contend with the fuel atomization, vaporization, and distribution problems common in other Otto engines. Fuel is injected into the swirling air in the main combustion chamber under moderate pressure during the compression process, and injection terminates before ignition occurs. The proper timing of fuel injection and ignition events is important to satisfactory operation of the engine. The PROCO engine utilizes either one or two spark plugs per cylinder. An oxidation catalyst is required if HC emissions are to be less than 1 to 2 grams per mile, especially in larger cars.

The current PROCO engines operate at 11. O- to 11.5 -to-l compression ratio, and EGR of up to **25** percent will be required to meet future NO_x limits. The engine was originally developed to run unthrottled with output controlled by the amount of fuel injected, as in a diesel. However, to meet the HC requirements, a modest amount of throttling is required at part load and idle.

Physically, the TCCS and DISC engines are very similar to the PROCO, differing mainly in details of fuel injection timing and pattern, and in combustion chamber geometry and air flow patterns. The various types of direct-injection stratified-charge engines offer considerable potential for simultaneously achieving low emissions, good fuel economy, and tolerance for a wide range of fuels. Particulate and odor problems, however, may be similar to those of current diesels.

Honda has been successful in marketing their stratified-charge engine (the CVCC). No other manufacturers have chosen to produce the dual-chamber stratified-charge engine, although Honda has sold the rights to at least one U.S. manufacturer.

Domestic car companies are investing primarily in the single-chamber direct-injection version. However, investment levels are unknown and production and marketing of these engines is not expected until the mid-1980's,

Valve Selector

Eaton Corporation recently developed a system for keeping selected valves closed in an internal combustion engine, while the rest of the engine continues to operate normally. The result is a reduction from six-cylinder operation to five, four, or three cylinders, depending on the power requirements. A solenoid-controlled device is added to the rocker arms of the selected valves and, upon activation, these valves stay closed. Keeping the intake and exhaust valves closed on one cylinder means that the air in the cylinder is repeatedly compressed and expanded with much less loss in energy. An improvement in fuel economy of about 10 percent is typical, although this varies for different engine/vehicle combinations.

The second part of the system is an electronic control that selects the number of cylinders to be deactivated depending on speed and load. Transition from operation of all cylinders to half the number can be quite smooth, and engine roughness or wear is not a problem.

This system has been tested on a variety of four-, six-, and eight-cylinder engines. It is currently scheduled to be introduced in 1980 on a Ford V-8 engine.

Turbocharging

Turbocharging is a concept in which the energy in the exhaust of an internal combustion engine is used to compress the incoming air or fuel/air mixture. Turbochargers for passenger car use are typically small high-speed devices (up to 140,000 RPM) with a centrifugal compressor and radial inflow turbine mounted on a common shaft. With the engine throttle wide open, most turbos will supply a continually increasing amount of air until the engine fails. To avoid this, an automatic waste gate control is usually provided to bypass some of the exhaust around the turbine.

In theory, turbochargers should provide an improvement in fuel economy (and sometimes in emission control) through a variety of mechanisms. The fundamental engine cycle efficiency is improved, and mixing and vaporization of the incoming fuel/air charge is usually improved. Hydrocarbons and carbon monoxide in the exhaust are usually more fully consumed. Finally, a smaller engine may be used, so that fuel economy is better (more time is spent closer to wide-open throttle, thus reducing throttling losses); maximum performance is retained because the turbo becomes more effective at the higher RPM. In practice to date, however, only the last factor has proved significant.

A number of problems accompany the use of turbocharging and the several previous attempts by U.S. manufacturers usually lasted for only a few years. Cost is considerably higher than for conventional engines (about $550 for the 1978 Buick). Mechanical complexity and related maintenance, service, and repair problems are much greater. Also, because the indicated mean effected pressure is increased and the incoming charge is heated by being compressed, it was necessary to add a safety system to the 1978 turbocharged Buick. This system detects detonation and automatically retards the ignition timing. (One result is that trailer towing is specifically not recommended.)

There are several alternative solutions to the detonation problem, some of which have been developed for trucks and racing cars. These solutions include aftercooling and antidetonant injection, as well as a more responsive waste gate control. There are over 20 factory-type passenger car turbo projects in progress worldwide, although most are aimed at the performance image rather than at fuel economy.

Turbocharging and the Eaton valve selector are almost parallel concepts for achieving "small" engine fuel ecomomy while retaining full power for the occasional times when it is needed. In terms of simplicity and cost the valve selector should be superior, but consumer preference for the turbo/racing image may prove to be important. If consumer acceptance is favorable, turbocharging can be added to almost any Otto cycle or diesel engine, although increased structural strength of the engine may be required in some cases.

Rotary Engines

Over the last 40 to 50 years, a wide variety of rotary engines have been conceived or developed to various stages. The Wankel is the most prominent of these, although it is not generally realized that the engine that was finally produced is only 1 of over 130 significantly different configurations explored by the inventor. The currently produced Wankel consists of an approximately triangular rotor, turning inside an epitrochoidal housing. The housing is cooled by water (or air) and the rotor is cooled by the engine oil. The fuel/air mixture enters and exits through ports (in the periphery of the housing and/or the end plates) as they are uncovered by the rotor.

The practical geometry of the system prevents high compression ratios (a two-stage version was required to reach diesel compression ratios), and the combustion chamber is characterized by high surface-to-volume ratios. The tips and sides of the rotor must seal against the housing and end plates, and these strip-seals proved to be a difficult design and development problem. The seals must slip over the port openings as in a two-cycle engine, and the intake and exhaust port areas are at considerably different temperatures, thus leading to thermal distortions. All of these features led to serious reliability and life problems with the early Mazda Wankels; however, the engine has gradually evolved into a reasonably acceptable form.

The basic Wankel configuration provides high specific output (in terms of both weight and volume) and can be "stacked" in any number of modules on the crankshaft. It is extremely smooth but somewhat lower in torque than a comparable reciprocating engine at low RPM. Wear of the seals is a serious problem unless exotic and costly combinations of materials are used. Early engines required the use of oil mixed in the fuel (or injected separately) to minimize the seal wear.

Because of the low compression ratio and built-in EGR (blowby), NO. emissions from a Wankel are usually low. However, the large surface-to-volume ratios and corners in the combustion chamber shape result in higher hydrocarbon emissions than from a reciprocating engine.

Wankels have been produced commercially by NSU and Mazda for passenger cars, and by other companies as motorcycle, snowmobile, outboard, diesel, and various other engines. GM purchased the rights to produce Wankels for $5o million but, shortly before reaching production, returned the project to R&D status. GM later terminated work on the Wankel engine. The combination of cost, durability, emissions, and fuel consumption of the Wankel does not appear to be sufficiently competitive with that of a comparably performing reciprocating engine. However, a variety of companies are continuing experimentation on Wankels.

Diesel Engines

The diesel is a form of stratified-charge internal combustion engine that uses the heat of compression for the ignition of distillate fuel. Fuel and air are not premixed outside the cylinder as in carbureted gasoline engines; instead, air is drawn into the cylinder through an unthrottled intake manifold and compressed. Fuel is separately injected near the top of the piston's compression stroke and burns with the air already in the cylinder. Ignition from spark plugs is not required but is being considered for advanced engines as a means of obtaining more accurate timing of the ignition point.

Diesel engine combustion systems are normally divided into two categories—direct injection, and precombustion or indirect injection. The direct-injection engine has a single combustion chamber, usually formed in the piston crown. Fuel is injected directly into the space above the piston. The injection process is considered a critical component of the direct-injection system since it must optimize fuel atomization and penetration into the air in the combustion chamber. Air utilization and engine performance are improved by creating air swirl in the combustion chamber. This is accomplished by using directional intake ports and by proper shaping of the piston crown. Combustion begins before the piston reaches the top of the compression stroke (top dead center) and causes relatively high gas temperature and pressure rises.

The design of the indirect-injection diesel includes a prechamber, which connects to the main chamber by means of an orifice. All of the fuel is injected into the prechamber. Two types of prechamber designs—quiescent and swirl—are in automotive use. The quiescent indirect-injection engines are designed for prechamber-to-total-combustion-chamber volume ratios of 1 to 4. (Combustion chamber volume is measured with the piston at the top dead center.)

The swirl chamber employs a larger volume ratio (up to one-half) and the prechamber is characterized by a spherical or near-spherical design. The throat is arranged to permit a fast air swirl or vortex to be formed in the prechamber, thus promoting rapid burning of the entire charge. Heat release rates are lower with this design and rates of pressure rise are reduced, lowering noise and structural requirements.

Traditionally, passenger car diesel engines have demonstrated advantages in fuel economy. However, these same vehicles have suffered from excessive weight, poor cold-starting ability, high cost, odor, smoke, need for frequent oil changes, poor acceleration, high noise, and high emissions of particulate and nitrogen oxides. Research during the past few years has concentrated on trying to find ways of eliminating these disadvantages.

Fuel Economy

Direct-injection diesels generally give about 5 to 10 percent better fuel economy than the indirect-injection types. However, at the present state of combustion technology, indirect-injection diesels are required for passenger car engines in order to reduce loads on the rods and crank, allow high RPM, and improve starting.

The fuel-economy advantage of a diesel over a comparable gasoline engine varies according to the operating mode. In steady, high-speed operation on the open road, the diesel has only a small advantage. In city traffic the efficiency of the diesel may be as much as **40** percent greater than the gasoline engine. NHTSA estimates that for average driving conditions, the diesel offers a 25-percent fuel-economy advantage on a miles-per-gallon basis.[15] A part of this advantage stems from the fact that diesel fuel contains about 10 percent more energy per gallon than gasoline. Thus, on a "per-barrel-of-crude-oil" basis, the diesel engine is about 15 percent more efficient than a gasoline engine. Features—such as valve selectors, electronic fuel metering, and turbocharging—could be added to improve the specific fuel consumption of gasoline engines, but some of these features (e.g. turbocharging) could also be added to diesels and allow them to

[15] Specific fuel consumption is a measure of the efficiency of an engine, expressed in pounds of fuel consumed per horsepower-hour (lb/hp-hr).

retain their relative advantage. On the whole, the diesel—due to its higher compression ratie—would remain more fuel efficient than a comparable gasoline engine.

Durability

Heavy truck engines achieve excellent durability (e.g., 500,000 miles before overhaul) by a combination of conservative design, best possible materials and components, heavy construction, careful maintenance, and very consistent and favorable operating conditions. Also, they operate at relatively low compression ratios compared to the lightweight, high-speed passenger car diesel engines (i. e., 13.5 to 18 versus 21 to 23.5). Average U.S. large gasoline engines last well over 100,000 miles, but small engines and imports tend to require overhaul appreciably earlier and to be much more variable in this regard.

Popular opinion, encouraged in part by optimistic manufacturers, tends to ascribe to a passenger car diesel all of the virtues that are found in truck and industrial engines, However, this is not necessarily true.

The recently introduced passenger car diesels (GM and VW) are conversions to diesel from a production gasoline engine. "Simple conversion" of the GM 350 CID gasoline engine to diesel required replacement of the cast iron crankshaft with a forged version employing larger bearings, but durability is still a serious concern. The only inherent durability factor favoring a "converted" diesel is that the incoming charge of air that is compressed prior to ignition has no fuel in it and, therefore, does not wash the thin film of lubricant from the cylinder walls. Also, corrosiveness of the exhaust and crankcase gases may well be different, but not necessarily better.

As a result, the durability of the "converted" diesels (GM and VW) could be less than their basic gasoline engine counterparts initially. However, their durability will probably be raised to the level required for public acceptance. Also, from the public's point of view, engine durability is frequently judged on accessories rather than fundamental factors affecting the combustion process. Improvements in these accessory features depend upon the manufacturer's cost estimates and assessment of market potential, rather than technological feasibility.

Weight

"Converted" diesel engines weigh more than the engine from which they are derived (111 pounds more in the case of the Oldsmobile 350 CID design). Future plans for weight saving in conventional engines by using thinner walled castings will not be possible for the diesel version. Thus, future savings of 5 to 15 percent in the total engine weight must be given up for diesels. In addition, there are vehicle weight increases associated with the diesel; these include dual batteries, and increased cooling capability.

Emissions

Passenger cars powered by modern diesel engines meet all HC and CO emissions standards without after-treatment. NO_x emissions, however, can present problems, depending on the stringency of the standards. Two nonregulated pollutants—particulates and aldehydes—also are found in diesel exhaust in much greater concentrations than in spark-ignition engine exhaust.

Formation of nitric oxide is dependent on the duration and temperature of the combustion process. Reducing peak cycle temperatures during the diesel's combustion phase will reduce the NO_x levels. Current design concepts that reduce NO_x formation include reduced compression ratio, fuel injection modifications, water injection, and exhaust gas recirculation. The use of EGR has some disadvantages. The recirculation of exhaust gases through the cylinders also recirculates particulate matter and thereby increases engine wear. The EGR also tends to cause an increase in hydrocarbons.

It appears that diesel engines perform better than gasoline-powered engines in terms of degradation of emissions of the presently regulated pollutants. In tests of up *to* 80,000 miles, the rate of increase of emissions from diesel engines has been shown to be 2 to 3 times lower than those of a comparable gasoline-powered engine.[15] However, diesels may encounter problems with pollutants that are now unregulated.

[15] Private communication by contractor with Dr. Hergenrath, Transportation Systems Center, Cambridge, Mass.

EPA is conducting research on the potential carcinogenic properties of the particulate and aldehydes in diesel exhaust. Preliminary tests indicate that the particulate are mutagenic. Further tests to determine if, and to what degree, diesel exhaust is carcinogenic are in progress. ”

In summary, it may be difficult for diesel engines, especially large-displacement engines, to meet the 1981 Federal NO_x standard of 1.0 gram per mile or the California standard of 0.4 gram per mile. A further difficulty is meeting the particulate emissions standard recently proposed by EPA. However, small diesels have demonstrated the ability to meet both these requirements. The interest in diesels by foreign and domestic manufacturers indicates some confidence that future diesels will have satisfactory emission characteristics and offer fuel savings over the gasoline engine.

Cold Starting

Most high-speed diesels currently used in automobiles require starting aids to preheat the air in the precombustion chamber. Current diesel designs combat cold weather starting difficulties by several means: designing passenger car diesels for a higher compression ratio than large truck engines; using glow plugs to preheat the air; using block heaters; and adjusting properties of the diesel fuel.

The minimum compression ratio of diesel engines depends in part on the cetane number of the fuel used. Swirl prechamber design is usually used for high-compression, high-speed, automobile engines.

From a fuel-economy standpoint, the optimum compression ratio for diesel engines is around 12 to 14 to 1; piston ring friction becomes more important than increased cycle efficiency above this range. Passenger car engines suffer from this loss in efficiency, plus decreased durability and greater noise, in order to meet cold-starting and high RPM requirements.

Noise

Diesel-powered vehicles produce noticeably higher noise levels during idle than carbureted vehicles. At road speed, tire noise is predominant. In general, the noise transmitted by the diesel engine to the passenger compartment can be attenuated through the use of proper acoustical materials.

Time Frame

Presently announced plans for diesel engine penetration of the U.S. market include the following:

- GM introduced a 350-CID diesel for the Oldsmobile, for the Cadillac Seville, and for some light trucks in **1978;** GM may supply diesels for a greater portion of its fleet later.
- VW diesel Rabbits and Dashers have been available in the United States since model year 1977. The Mercedes 240D, Mercedes 300D, and Peugeot 504 diesel are also available.
- In addition to the above companies, various other European and Japanese firms now produce or are planning production of diesel passenger cars; any or all of these could be brought to the U.S. market. These companies include Opel (GM), Ford of England, British-Leyland Motor Company, Chrysler-France, Nissan, Fiat, Citroen, and Volvo (using a VW engine).
- **1978** production rates for both GM and VW were planned to be 100,000-plus. GM's actual production was approximately 65,000; the planned level of production for 1979 is 190,000 units.

VW will probably allocate its diesel cars worldwide. Both VW and GM will use considerable caution in testing consumer acceptance and checking for unforeseen field problems. However, both companies can expand production quite rapidly, since the engines in question are basically gasoline engines currently being made on existing, high-capacity production lines. Peugeot and other small producers are largely locked into existing specialized diesel production lines of low or modest capacity. The need to build new plants will seriously constrain entry into the field and/or expansion by many of the potential diesel-engine passenger car suppliers.

The technology of passenger car diesels will have a significant effect on their acceptance, as

[17] Telephone conversation with Richard Briceland, U.S. Environmental Protection Agency, Apr. 11, 1978.

well as on their achieved fuel economy. Other problems with diesels so far have included parts availability, repair infrastructure, and unfamiliarity on the part of do-it-yourself mechanics.

Investment and Costs

Depending on the extent of retooling necessary, the capital cost necessary to convert a spark-ignition engine assembly plant to the production of diesels could range from $30 million to $150 million for a 400,000-unit capacity line. Assuming annual new car sales to be 11.8 million in 1985 with 10-percent diesel penetration, total capital expenditures could range from $90 million to $440 million.

The added cost (price premium) of diesel cars and multipurpose vehicles in 1977 ranged from about $195 to $2,200. The GM premium was $740 or $850, depending on the engine it replaced. A major portion of the additional cost of the diesel is for the fuel injection system. The low VW price differential of $195 is somewhat misleading, since their gasoline engine has fuel injection, whereas the GM gasoline counterpart does not.

In addition to the direct-injection and indirect-injection engines whose differences have been discussed, several other types of diesels are in use or under development. The most common of these is the two-stroke diesel engine. This version is lighter than a comparable four-stroke engine, but is generally slightly lower in fuel economy and emits more pollutants. It is quite competitive in heavy trucks and bus operations, but probably would not be competitive in a passenger car application.

A form of diesel that was recently developed for a British tank engine employs what are essentially two Wankel engines in series. The first partially compresses the incoming charge of air, and the second completes the compression and handles the combustion. Other promising variations in diesel technology, particularly the adiabatic diesel (and additions to it such as turbocompounding and bottoming cycle) are discussed later in this chapter.

Drivetrain

A major factor in achieving better fuel economy is the ability to operate an engine at the combinations of throttle position and RPM where the lowest possible values of specific fuel consumption can be achieved. This is approximated by changing transmission gear ratios under varying conditions of vehicle acceleration and speed. In the case of an automatic transmission, the torque converter smooths the transition between gear ratios and supplies increased torque to the wheels at low engine speeds, but with some loss of power.

Typical power losses in the automatic transmission, drive line, differential, and rear axle for a full-size car vary with speed, approximately as shown in table 139. Only 3 to 4 percent of these losses are in the axle, differential, and drive line. Improvements in this area are generally limited to greater precision in manufacturing processes and improvements in lubrication.

Table 139.—Drivetrain Losses

		Drivetrain loss	
Speed (mph)	Total wheel horsepower	Hp	%
20.	5.0	1.24	25
40.	14.4	3.17	22
60.	31.7	5.09	16
80.	60.0	7.99	13

SOURCE Environmental Protect Ion Agency *Factors A ffecf[ng Fue/ Economy,* May 1976

Transmissions, like engines, have a variety of basic types. These may be categorized as hydrokinetics (torque converter), standard gear change (“stick shift”), hydrostatic (e.g., Orshansky or Sunstrand Responder), traction (e.g., GM Toric, Tracer, or Forster), variable sheave (e. g., “Vee” belt), clutched gear sets, and oscillatory. Each of these transmission types has a variety of possible configurations—for example, the hydrokinetics transmission is currently available with three, four, or five elements, torque multiplications from 2:1 to 6:1, all fixed or some movable vanes, and lockup features. Many of these transmissions are used in combination with each other and with associated clutches, dual path schemes, and retarders. For example, the conventional passenger car “automatic” uses a torque converter plus clutched gear sets. Control systems include mechanical, hydraulic, and electronic types. Improved automatics with a lockup clutch, tighter tolerance torque converter, and a wide ratio, four-speed gear set are considered by the auto industry to be the most likely candidates for providing the desired near-term improvements in efficiency. Because of their better internal efficiency, the lockup feature and gear ratios that optimize the engine/vehicle match, fuel-economy improvements up to 18-plus percent over a present day 3-speed automatic have been obtained in experimental vehicles. (table 140).

Table 140.—Hydrokinetic Transmission Improvements

Transmission type	Percent improvement
3-speed automatic with low slip torque converter	2-3
3-speed wide ratio automatic	3-6
3-speed automatic with TCLU[a]	3-6
3-speed wide ratio automatic with TCLU	8-13
4-speed automatic with TCLU	8-13
4-speed wide ratio automatic with TCLU	8-18

[a]Torque converter lockup.
SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*, February 1977.

A typical, present-day passenger car automatic contains a three-element, fixed-vane torque converter of about 2 to 1 multiplication and a three-speed planetary gearbox with hydraulic control. Efficiency of the torque converter ranges from zero at stall to 91 percent; most driving occurs in the 80 to 90 percent region. Typical efficiencies of the various transmission types (table 141) show there is interest in the efficiency of the newer traction, sheave, and oscillatory types—as well as in their continuously variable feature.

Other less obvious (but still worthwhile) improvements which will be made in conventional automatic transmissions include reduced clearance in the torque converter, lower viscosity oil, reduced band and clutch drag, and reduced oil pump power.

Ford is planning to introduce a four-speed automatic transmission in the early 1980's. The capital costs involved in converting to a four-speed transmission will be an added financial burden to the auto manufacturers, but will not be as serious as engine changes.

Capital requirements for producing three- and four-speed automatic transmissions with torque converter lockup (TCLU) features in a 500,000-unit facility are estimated by industry to be:

- three-speed automatic with TCLU—$5 million to $10 million, and
- four-speed automatic with TCLU—$150 million to $200 million.[18]

Both of these values are believed to be based on making the changes with minimal disturbance of existing production (which typically operates on a three-shift basis). The conversion to the three-speed TCLU would consist of minor changes to the existing plant; however, the change to four-speed TCLU would probably require installation of an almost parallel facility beside the existing plant. (A totally new plant would cost on the order of $350 million.) Total capacity (and/or productivity) of such a facility would probably be increased significantly.

[18]U.S. Department of Transportation, *Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards*.

Table 141.—Current and Potential Transmission Efficiencies

Transmission element	Efficiency[a]
Torque converter (automotive types, including 3, 4, and 5 element)	75-91% for majority of use 0% at stall
Change gear	97% + per gear set
Hydrostatic	88% maximum at no multiplication
Traction (rolling balls or discs)	80-90%
Variable sheave (metallic)	90-93%
Mechanical oscillatory	91-96%
Clutched gear (planetary)	95% per gear set

[a]Values include efficiency of the basic mechanism and a typical value for parasitic losses (e.g., windage, control hydraulics, bearings, etc.). Values are approximate because of wide variations in mechanism and system configurations.
SOURCE: *SRI*, p. V-46.

Accessories and Accessory Drives

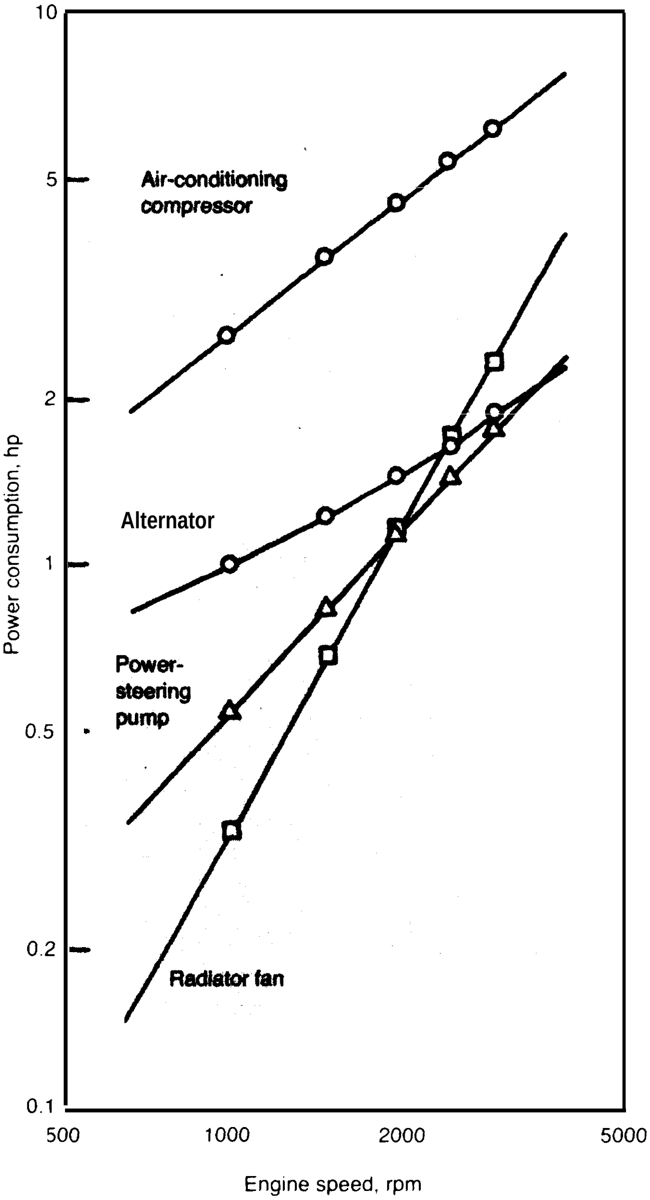
Power-driven systems (fan, water pump, alternator, oil pump) and options such as air-conditioning have traditionally consumed a significant amount of engine power, as shown in figure 60. Large percentage reductions in the power required can be achieved for the fan and air-conditioner through the use of effective demand drive units. Most power-steering systems have recently been converted to a type that requires very little power, except when turning.

Demand drive systems are already on the market, but have received only limited acceptance because of the prior unimportance of fuel economy. Systems likely to see widespread future use include:

- electric motor drive for cooling fans;
- air-conditioner drive and control system that fully disconnects except when cooling is required (already widely used); and
- speed-limiting drive for water pump, alternator, and oil pump.

Full utilization of these systems should provide an overall fuel-economy improvement of about 4 percent.

Figure 60.—Accessory Horsepower



SOURCE: Jet Propulsion Labs, *Should We Have A New Engine?, An Automobile Power Systems Evaluation*, August 1975.

Electronics

Electronic controls for fuel metering and ignition, as well as for a number of other vehicle systems, have become a subject of importance to the automotive and electronics industries. Emission control, fuel economy, safety, comfort, convenience, and maintainability will all benefit from the rapidly evolving technology. The list of present and potentially different types of electronics systems for passenger cars numbers over 50. The electronics industry estimates that at least 6 million units of electronic engine control systems will be used on 1981 model cars. These include the ignition, fuel metering, EGR, and valve selector functions handled by a central microprocessor, Additional capabilities will be built into the microprocessors and, by 1985, as many as a dozen different systems may be controlled by the central unit. As confidence and interaction between the two industries grows, the number of electronics applications will probably increase.

[19] Demand drive units are components that allow their respective accessories to "free-wheel" or to draw essentially no power when they are not needed. For example, a thermostatically controlled fan could probably be cut out of the system except during long periods of idling or pulling heavy loads in hot weather. This feature is already in use by some foreign manufacturers. All U, S.-manufactured cars with air-conditioning have used a viscous drive fan which limits the maximum power absorbed as engine speed increases.

However, there is continued competition between electronic and the more conventional mechanical/hydraulic controls. Considerable improvement in these latter systems could result from the stimulus of such competition, possibly reducing the magnitude of the trend to electronics,

Multiplexing or other sophisticated wiring concepts may be considered as a subset of automotive electronics. Such schemes promise some reduction in vehicle assembly cost and in the use of copper, with the benefit of improved recyclability. It is probable that such systems will not be introduced on a production basis until well after a central microprocessor comes into general use,

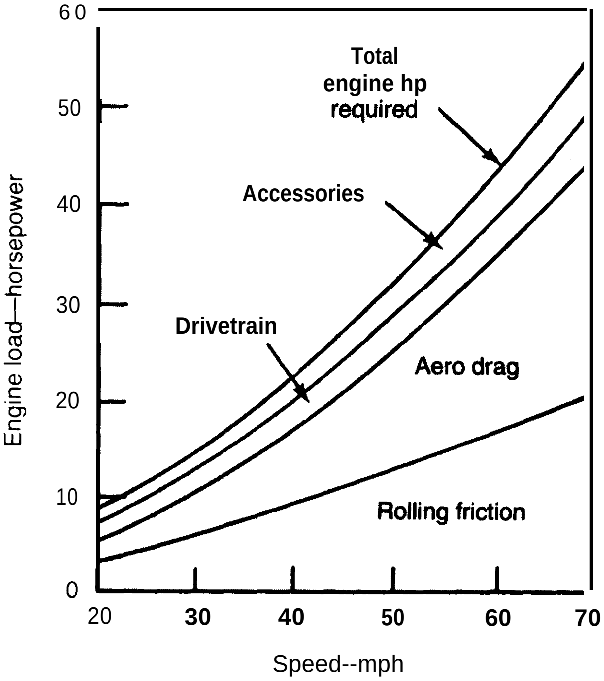
Aerodynamic Drag and Friction

The importance of the effects of rolling friction and aerodynamic drag on required engine power are shown in figure **61.** Rolling friction is almost entirely a result of energy loss due to deformation of the tires as they contact the roadway. Rolling friction increases almost linearly with speed. Radial tires can have up to 20 percent less rolling resistance than bias-belted tires and 40 percent less resistance than plain bias tires, producing a fuel-economy improvement of up to 3 percent. Higher inflation pressures also reduce rolling resistance, but require suspension changes and affect tire-roadway adhesion.

Aerodynamic drag increases with speed much more rapidly than does rolling resistance (i. e., as the square of velocity). At 55 mph, it absorbs about 40 percent of engine power. Drag is also a direct function of vehicle size and shape (more specifically of frontal area and the drag coefficient). Minimum frontal area is essentially fixed by the requirements of passenger compartment size plus the safety-related lateral crush distance. Automobile height is remarkably standard; heights are within 2 inches for a Ford LTD and an Austin Mini or Honda Civic. Typical frontal areas for current U.S. passenger cars are shown in table 142.

Drag coefficients for present day production cars range from about 0.50 to 0.325, averaging about 0.45. An experimental low-drag model

Figure 61 .—Effect of Speed on Power Requirements (Standard-size car)



SOURCE Jet Propulsion Laboratories, *Shou/d We Have A New Engtne~, An Automobile Power Systems Evaluation,* August 1975

has reached about 0.16.[20] A 25-percent reduction in drag may be expected to improve fuel economy over the composite driving cycle by about 5 percent .21 Theoretically, fuel savings associated with drag reduction are on the order of 10 to 15 percent over the driving cycle, with greater savings at steady high speeds. Some reduction in drag can be achieved through changes in body styling, but perhaps at the expense of reduced volume-efficiency compared to present "boxy" body designs. Further reduction of drag could be accomplished by elimination or redesign of features such as outside mirrors, rain gutters, roll-down windows, and wheel covers.

[20] The Pininfarina test model shown in the photograph, and the Mercedes C lll/3 have demonstrated a drag coefficient of .16.

21 Jet Propulsion Laboratory, California Institute of Technology, *A Study of Automotive Aerodynamic Drag,* prepared for U.S. Department of Transportation, Office of the Secretary, Report No, DOT-TSC-OST-75-28 (Pasadena, Calif.: Jet Propulsion Lab), September 1%'5.

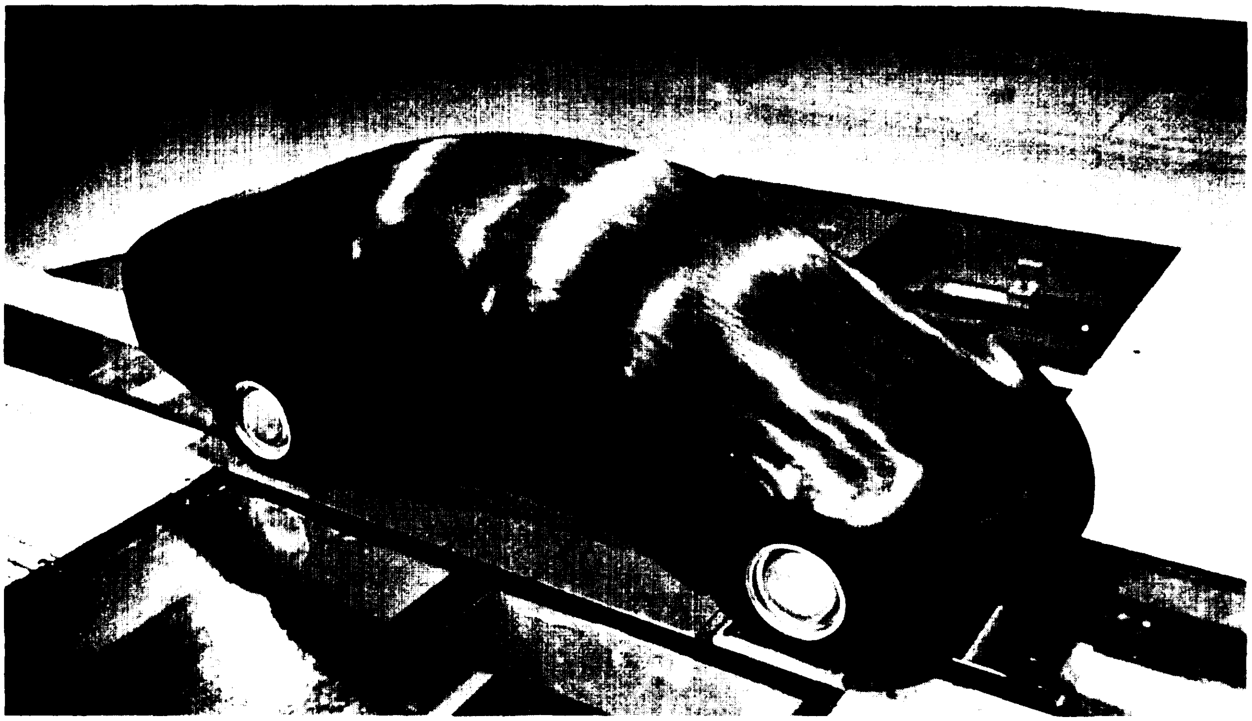


Photo Credit Automotive News

Aerodynamic body model by Pinninfarina

Table 142.—Frontal Area for Typical Passenger Cars

	Curb weight (pounds)	Frontal area (square feet)
Subcompact	2,500	17.5
Compact	3,200	19.0
Standard	4,400	21.5
Luxury	5,300	22.5

SOURCE: Jet Propulsion Laboratory, *Should We Have a New Engine? An Automobile Power Systems Evaluation*, August 1975

Safety Technology

There are many technological approaches to vehicles and roadways that can be applied to both crash severity reduction and crash avoidance. The technologies discussed in this section (near-term) are those which are likely to be implemented by **1985.**

Vehicles

The U.S. Department of Transportation recently issued a safety plan in which proposed revisions of existing standards and new areas of rulemaking were identified. Table 143 shows those standards applicable to the **1985** time period.

All of these proposed requirements have been under consideration for years and should not require any major new technological achievements. The most significant feature is the extension of passenger car standards to light trucks and multipurpose vehicles. Other important revisions are in upgrading the quality of seat belts (FMVSS 208), upgrading side door strength (FMVSS 214), improving rear vision (FMVSS 111), and improving direct fields of view (new standard). However, the major piece of safety equipment to be added in the near-term is the passive restraint system (FMVSS 208), required in the 1982 model year for large cars and for all cars by the 1984 model year.

The ongoing evaluation of the safety standards should provide important information on the regulatory process and on technologies for the future.[22] This evaluation focuses on whether vehicles are performing in accordance with the standards and whether the standards, as written, are actually addressing the problem for which they were intended.

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[22] Discussion with U.S. Department of Transportation, Office of Program Evaluation, April 1978.

Table 143.—Federal Motor Vehicle Safety Standards, Near-Term Improvements Under Consideration for Passenger Vehicles

Current standards	Inclusion of light trucks[a]	Upgrading of standard
FMVSS No. 201 —Occupant Protection in Interior impact.	XX	
FMVSS No. 2034—impact Protection for the Driver from the Steering Control Systems	XX	X
FMVSS No. 204—Steering Control Rearward Displacement.	XX	X
FMVSS No. 208—Occupant Crash Protection.	XX	X[b]
FMVSS No. 213—Child Restraint Systems		X
FMVSS No. 214—Side Door Strength.	XX	X
FMVSS No. 101 —Control Location, Identification, and Illumination.	XX	X
FMVSS No. 105—Hydraulic Service Brake, Emergency Brake, and Parking Brake Systems.	XX[c]	
FMVSS No. 108—Lamps, Reflective Devices, and Associated Equipment	XX[c]	X
FMVSS No. 109—New Pneumatic Tires.	(d)	X
FMVSS No. 11 1—Rearview Mirrors.	X	X
FMVSS No. 114—Theft Protection	XX	X
FMVSS No. 115—Vehicle Identification.		X
New proposed standards[e]		
Exterior protrusions, (minimize)		
Truck Rear Underride Guard (heavy trucks)		
Low Tire Pressure Warning		
Direct Fields of View		
Handling and Stability performance requirements		
Brake System Inspectability		
Speedometers/Odometers (limit speed indication)		

[a] Items marked X already apply; marked XX are intended to apply.
[b] Upgrading quality of active seat belts prior to passive restraint requirement.
[c] Will be extended to all motor vehicles (except motorcycles).
[d] For passenger car tires, many of which are used on light trucks.
[e] Vehicle applicability not always specified.
SOURCE: U.S. Departmnet of Transportation, National Highway Traffic Safety Administration, "Five Year Plan for Motor Vehicle Safety and Fuel Economy Rulemaking and Invitation for Applications for Financial Assistance," *Federal* Register 43. pp 11 100-11107

Restraint Systems

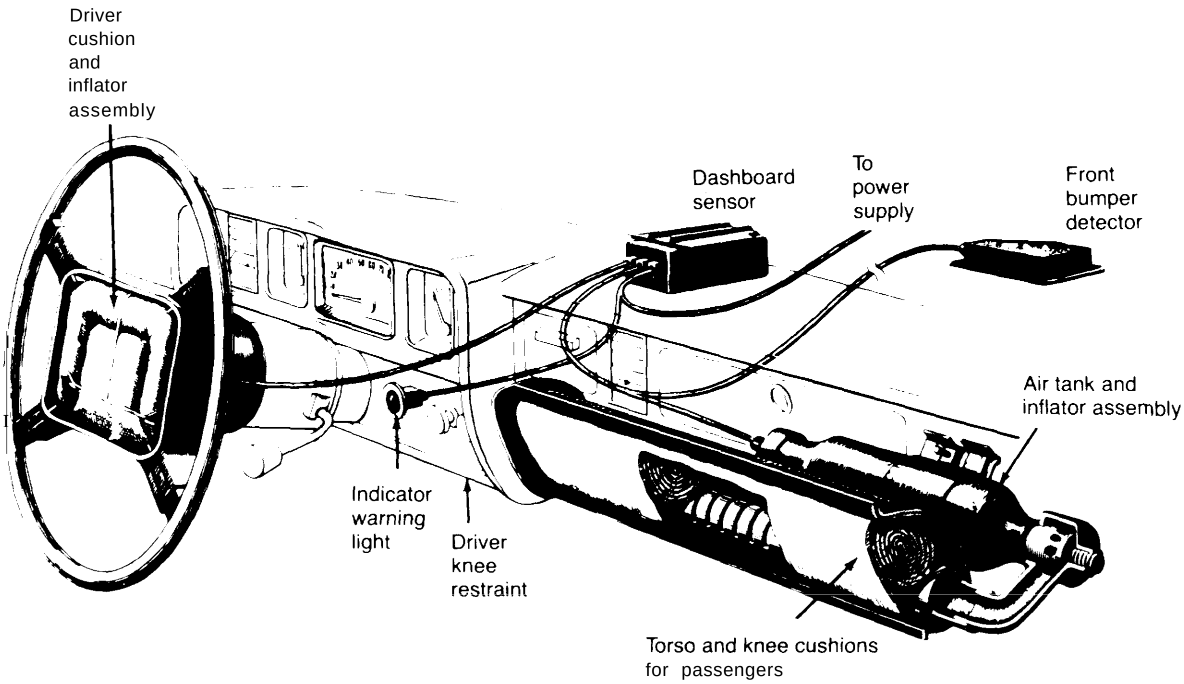
The air cushion restraint system (ACRS), or air bag, was first conceived of in the 1950's and the basic principles are unchanged today. A sensor mechanism, activated by a crash (usually a barrier-equivalent crash of 12 mph or greater) activates an inflator (either compressed gas or a chemical gas generator). This fills a nylon bag in the area in front of the driver and front-seat passengers. The driver bag is housed in the steering wheel hub. The passenger bag is in the area typically used for a glove compartment (figure 62).

Technically, the system is extremely reliable. Operationally, it provides good protection in front-end collisions, which account for more than 50 percent of vehicle occupant fatalities. The probability of inadvertent inflation of the ACRS is virtually nil; experiments have demonstrated that if it does occur, no real problems, such as loss of control of the vehicle, are likely to occur.[23] It is possible to utilize air bag technology for protection of other than front-seat vehicle occupants, although that is clearly the most effective use of the system.

Safety belts come in a variety of configurations—lap belts, three-point lap/torso belts, torso belt with knee bolster, and the four-point

[23] Committee on Commerce, Science, and Transportation, *Automobile Crash* Protection, Report No. 95-481, Oct. 7, 1977.

Figure 62.—Schematic of Air-Cushioned Restraint System



SOURCE Allstate Insurance Company, *Autornotwe Air Bags C?uesf/ons and Answers,* June 1977

lap/shoulder harness. Several effectiveness enhancement features are also possible. These include pretensioning devices, energy-absorbing systems, inflatable belts, and force-limiting belts. Also there has been a recent surge of interest in passive belts, which automatically go into place after the occupant is seated.

Three-point safety belts provide a leveI of protection almost equivalent to that of the ACRS. In general, they are better than the current air bag alone in multiple impact, rollover, or side collisions. The ACRS with the lap belt offers better high-speed protection. (See table 144.) However, there is still. a possibility that many individuals will disconnect the passive belts unless they are made to be very comfortable.

The air bag system is considerably more expensive than the simple seat belt system. Estimates of the cost difference range from $112 to $235. The passive belt system is estimated to cost **$25** more than the conventional three-point system.[24]

Highways

Improvements in highway features that could reduce the incidence or severity of traffic crashes are shown in table 145, Most of the devices or design techniques have been developed, but have not been universally applied. Skid resistance requires more research since it involves trade-offs with tire noise, tire wear, pavement cost, and durability.

[24]Ibid.

Table 144.—Occupant Crash Protection System Effectiveness Estimates'

	Lapbelt	Lap and shoulder belt	Air cushion	Air cushion and lapbelt	Passive belt and knee bolster	Knee bolster
A IS injury level:						
1	0.15	0.30	0	0.15	0.20	0.05
2	.22	.57	.22	.33	.40	.10
3	.30	.59	.30	.45	.45	.15
4-6	.40	.60	.40	.65	.50	.15

[a]Effectiveness shown is the fraction of the vehicle occupants not injured at the specified Injury level who would be injured without the use of the restraint system
SOURCE Committee on Commerce, Science, and Transportation, *Automobile Crash Protection*, Report No 95.481. Oct 7, 1977

Table 145.—Technical Features for Highway Safety

1. Impact absorbing roadside safety devices.
2. Skid resistance.
3. Breakaway sign and lighting supports.
4. Guardrail.
5. Bridge rails and parapets.
6. Bridge widening.
7. Shoulders.
8. Wrong-way entry avoidance techniques.
9. Roadway lighting.
10. Traffic channelizaiton.
11. Roadway alinement and gradient.
12. Clear roadside recovery area.
13, Median barriers.
14. intersection sight distance.
15. Railroad highway grade-crossing protection.
16. Pavement marking and delineators.

SOURCE Abbreviated from the countermeasures examined in the *National Highway Safety Needs Report*, U.S Department of Transportation, Aprtl 1976

Recycling

The recovery of motor vehicle scrap metal is a relatively well-established industry. Wrecking yards and scrap processors recycle about 80 percent of junked motor vehicles. The wrecker removes salvageable parts for resale and the scrap processor extracts the ferrous material in as pure a form as possible—usually well below that of industrial ferrous scrap. Shredding is the favored process and produces the highest purity product. It is also a high-volume, capital-intensive process with only about 100 shredder units in operation in this country.

As the content of plastics and nonferrous metals in cars increases, separation problems will become more difficult and the scrap will become slightly less valuable. Materials selection and design features could help to alleviate this problem but presently, there is little incentive to do so.

Tires are a major recycling problem, particularly the steel-belted variety. The following approaches are in various stages of development, but none appears yet to be a clearly economical solution:

- burning to produce thermal energy;
- cryogenic, shredding, or other processes to recover the rubber for subsequent use (e. g., as an asphalt extender);
- conversion to carbon black, and
- processing to produce a form of synthetic liquid fuel.

AUTOMOBILE TECHNOLOGY BEYOND 1985

In the period from **1985** to **2000,** it is expected that technological development will proceed along three lines. First will be efforts to develop and commercialize advanced engines capable of operating at much higher efficiency than the 25 percent typical of the best engines of today.[25] A four-passenger vehicle equipped with such a propulsion system could have a operational fuel economy of 60 mpg or more.[26] A second line of development will be improvement of other automobile components to provide even greater fuel economy. It is anticipated that efforts will concentrate on continuously variable transmissions, low-friction tires, and improved aerodynamics. The need for, and emphasis on, more efficient vehicles will be partly determined by success in a third area of development—alternate energy sources. It is expected that the technology to produce fuels from sources other than petroleum and to use electrical energy could reach a high state of refinement. If so, the pressure for greater automotive fuel economy would be correspondingly less. This section of the report examines some of these potential advances in auto and fuel technology and assesses the outlook and the problems associated with their development and use.

Propulsion Systems

New engines or power sources that are under development for automotive applications include: Brayton (or gas turbine); Stirling; diesel: Otto- diesel hybrid; adiabatic diesel; stratified charge; various rotaries (including Wankel); Rankine; battery; fuel cell; and other energy storage devices, such as flywheel and thermal sink.

It is also possible to add "upstream" systems such as superchargers, turbochargers, Comprex "superchargers," and regenerators (heat exchangers). Also a great variety of fuels from different sources could be used. They include gasoline, diesel, liquefied petroleum gas, liquefied natural gas, petroleum natural gas, hydrogen, alcohol, ammonia, ether, and hydrazine. Finally, compounding, or combining two or more different engine types, adds new possibilities.

The list of concepts which have been Formulated is extremely ions, but it is unlikely that more than a few will make their way into passenger-car use by **2000.** A qualitative evaluation of the relative merits of the basic types of engines in terms of their key characteristics *is* given in figure 63.

Research and development programs for advanced heat engines are being conducted by both Government and industry. The Department of Energy, acting under the Energy Reorganization Act of 1974 and the Federal Non-Nuclear Energy Research and Development Act of 1974, has been pursuing the development of the gas turbine and Stirling engines for passenger-car application. More recent legislation, the Automotive Propulsion Research and Development Act of 1978, directs DOE to support research and development t that would lead to introduction of alternate automobile propulsion systems with in the next decade. The Act also calls for dissemination of technical information on advanced engines. The intent of the Act is to supplement the research and development efforts of private industry and to encourage and facilitate competition in developing alternate engines. Although little has yet been accomplished under the Act, it does provide the basis for unifying and focusing the Government efforts in assisting R&D on alternate automotive propulsion systems.

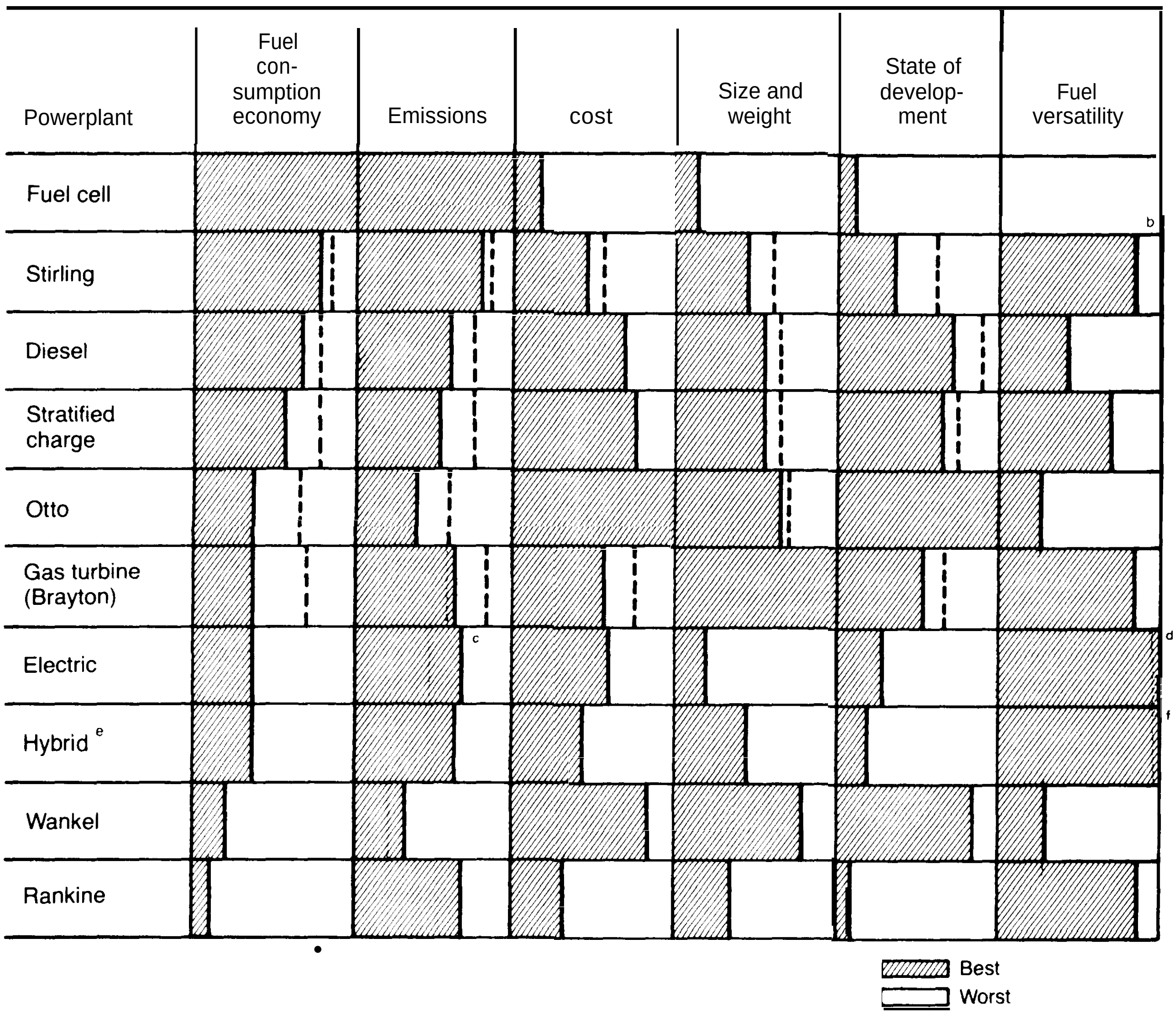
Stirling Engines

The Stirling engine converts heat energy from the burning air/fuel mixture to mechanical energy through the alternative compression and expansion of a confined working fluid. The working fluid (normally a small quantity of high-pressure hydrogen or helium) is cooled during the compression stage and heated during the expansion stage. Residual heat energy is recycled through a heat exchanger that stores a

[25] Engine efficiency is simply the energy output of an engine divided by the input energy (that contained in the fuel). The adiabatic turbocompound diesel has been tested at 48 percent efficiency. Adding a bottoming cycle was calculated to raise the efficiency to 63 percent. Improvements are expected in other engine cycles, particularly the Stirling and Brayton whose efficiencies are now about 40 percent. SRI Supplement.

[26] The turbocharged VW diesel Rabbit has registered 60 mpg in the combined EPA mileage rating. U.S. Department of Transportation, Office of Public Affairs, *Fact Sheet: Volkswagen Integrated Research Vehicle*, June 28, 1977.

Figure 63.—Characteristics of Automotive Propulsion Systems'



' **Passenger car application.**
[b]**D!fferent fuel cells use different fuels, but a fuel cell will only use the fuel for which it was designed.**
[c]Depends on extent of emissions from electric-generating plant and the Importance of point versus dispersed emıssıons
[d]Can use any fuel used to generate electricity.
[e]Typically, an internal combustion engine plus battery or flywheel.
[f]Can use any fuel used to generate electricity, and those usable in the secondary **power plant.**

SOURCE" SRI, p. V-44, and OTA.

large portion of the heat of the working fluid after expansion and returns it to the working fluid after compression.

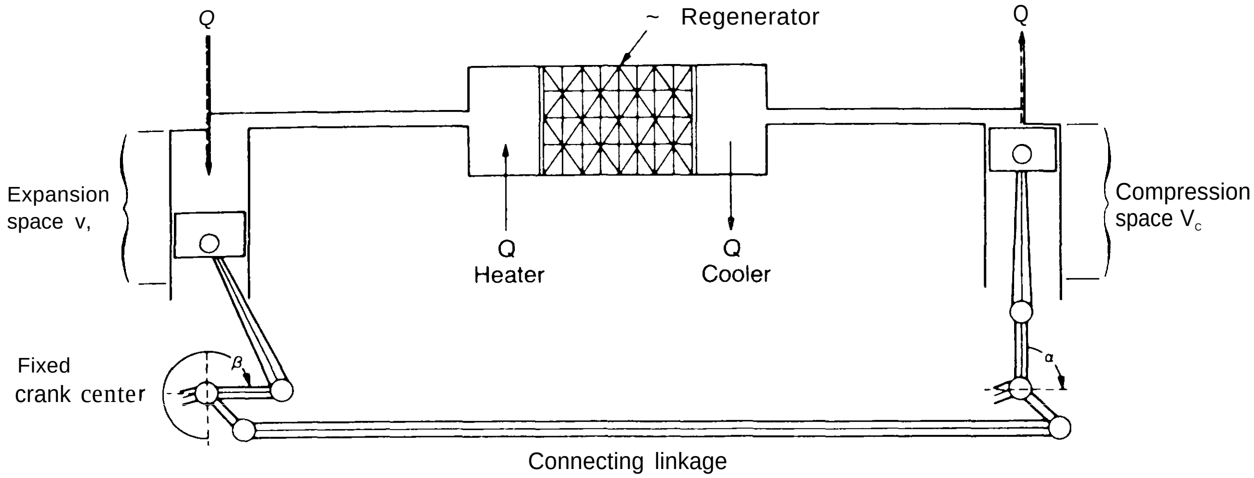
A sequence of four events occurs during a full work cycle of the engine:

- The working fluid is transferred from the hot space through the heater, regenerator, and cooler to the cold space. This occurs with a relatively small change in total working space volume.
- A compression process occurs when the working fluid is located primarily within the cold space and the adjacent cooler.
- The working fluid is transferred from the cold space through the cooler, regenerator, and heater to the hot space, with a relatively small change in total working space volume.
- The working fluid expands when it is

located primarily within the hot space and the adjacent heater.

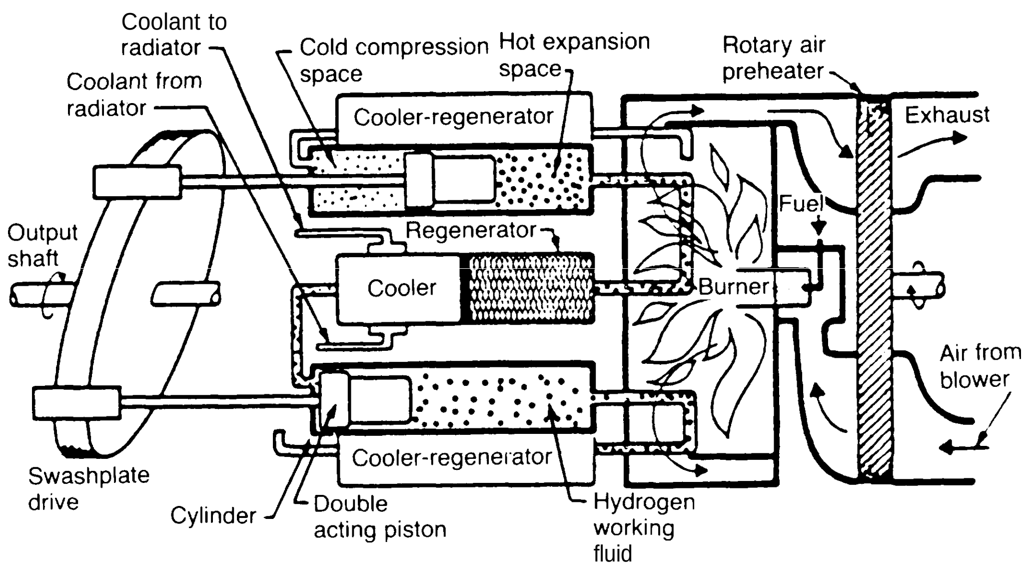
The expansion and compression spaces are phased so that the working fluid is located in the hot space of the engine as total working space volume increases. As total working volume decreases, the working fluid is found mainly in the cold space of the engine. The four processes are repeated for each revolution of the crankshaft. The motions of the mechanism and the gas flow can best be understood by examining the two-piston analogous mechanism and its volume crank angle diagram shown in figure 64. This configuration is not currently used as a Stirling engine, but is useful in illustrating the principle. A schematic drawing of the double-acting, swash plate, piston-type Stirling (which is an operating engine) is shown in figure 65.

Figure 64.—Principle of the Stirling Engine



SOURCE SRI

Figure 65.—Stirling Engine With Swash Plate



SOURCE” *SydecEEA,* p II-21

The other common type of Stirling has a rhombic-drive, inline piston displacer configuration. However, Wankel expanders, valved versions, and similar variants are under study.

The Stirling engine shows significant potential when compared to the conventional internal combustion engine. It has lower noise levels because of the continuous burning process and reduced emissions. The Stirling can burn a variety of fuels. Its operation is smooth and without vibration. Finally, the engine has cycle efficiencies approaching 40 percent.

The problems in the development of the Stirling are all technical or cost-related, They may never be overcome on a cost-competitive basis. These problems include:

- high temperatures with attendant problems of materials, sealing, thermal cycling, etc.;
- high-pressure areas and the basic technological difficulties concerning the sealing so that gas does not leak out of the engine or into other parts of the system (efficiency improves with system pressure and units have been run at well over 3,000 psi);
- cost, complexity, and availability constraints centering on the use of sophisticated electronic controls, ceramic components for the heat exchanger, and extensive stainless steel tubing required to withstand the very high pressures and temperatures inside the engine;
- uncertainty regarding the feasibility of producing many of the engine components which are new and have never before been mass-produced (the production processes of engine manufacturers and component vendors would have to be refined before cost-effective mass production could take place);
- need for large, high-capacity radiators and the severe loss in efficiency when the heat is rejected to high ambient temperatures (e. g., 100°F or greater);
- complexity and low efficiency of the gas volume control system and slow response to changes in speed and load demand;
- uncertainty regarding engine durability and the feasibility of producing engines in different sizes; and
- fuel economy actually attained to date for the complete powerplant (with accessories) is about that of a conventional Otto-cycle engine.

Until recently, most experience with the Stirling engine has been in the research laboratory. The only commercial application of the Stirling cycle to date has been in a cryogenic machine for producing liquid air. However, some development work has been done on potential application of the Stirling in heavy-duty trucks, and there has been minor production for military hardware. Work on the feasibility of a four-cylinder 170 horsepower (hp) Stirling for automobiles was conducted by Ford and the Department of Energy (DOE) under a licensing agreement with N.V. Phillips Gloeilampenfabriken of the Netherlands. Laboratory testing of the engine was completed in 1976. The second phase sought to improve engine durability and performance in road tests, to determine potential feasibility, to assess the potential for engine size modification, and to initiate R&D work with other firms. Table 146 shows some features of the Stirling engine compared with the baseline standard engine.

Ford recently completed a feasibility study, funded by DOE, involving the conceptual design and evaluation of an 80 to 100 hp Stirling engine for use in a passenger car of the 2,500- to 3,000-pound weight class. Subsequently, Ford announced its withdrawal from the DOE Stirling engine program.

DOE is also funding Mechanical Technology, Inc., United Stirling of Sweden, and AM General Corporation in a joint effort to develop three generations of engines in the 55 to 130 hp range. The first portion of this work was to demonstrate a Stirling engine in an Opel Rekord. Installation was completed, and road testing was begun in the summer of 1978. Preliminary test results are encouraging. The Stirling Opel equaled a diesel-powered Opel in fuel economy and easily met the future statutory emissions standards.

Even if all performances projections are realized and durability is demonstrated, the market

Table 146.—Stirling and Baseline Engine Data[a]

	"4-21 5" Stirling[b]	351-2V V-8 Baseline	Clean Air Act'
Emissions (g/mi)			
Hydrocarbons	0.04	0.49	0.41
Carbon monoxide	1.98	6.05	3.40
Oxides of nitrogen	0.39	1.35	0.4
Fuel economy (mpg)			
City	13.5	11.0	
Highway	18.7	16.0	
Metro-highway	15.5	13.0	
Performance (sec.)			
0-60 mph	12.6	15.8	
25-60 mph	10.2	11.2	
50-80 mph	12.8	18.5	

[a]Stirling engine used was 4-215 170 hp engine. Baseline computed using 351-2V V-8 1975 Torino with California calibration.
[b]Projected from dynamometer and test rig data.
[c]Statutory emission standard before the 1977 Amendment.
SOURCE: Ford Powertrain Research Office, "Stirling Engine Program," *Fourth International Symposium on Automotive Propulsion Systems*, Apr. 20, 1977.

for the Stirling engine will probably be limited by cost, availability of materials, and technical considerations. The long leadtimes required to modify existing engine plants and to introduce new processes for the production of new engine parts make the commercialization of the Stirling engine unlikely until 1990 to 2000. The lag is likely to persist despite the fact the Government support doubled in 1978.

Brayton Cycle Engines

A gas turbine (or Brayton cycle engine) is usually a continuous combustion powerplant in which the burning takes place in the working fluid. The main elements of the most common and simplest configuration are a compressor, a burner, and an expander (or turbine), with the entire gas stream proceeding through each. The compressor and turbine are usually on a common main shaft.

The combustion energy drives the turbine which, in turn, drives the compressor. This permits the extraction of power in the form of jet thrust, or shaft power, taken from the main shaft or from a separate power turbine in the exhaust gas stream. Many other types of compressors and expanders (rotary, reciprocating, lobe, screw, and vane) have been developed. However, only the axial, centrifugal, mixed-flow, or radial-inflow elements have found wide acceptance.

Present design practice for ground vehicle gas turbines favors the single-stage compressor and turbine on a common shaft, with a power turbine in the exhaust stream on a second shaft, and a regenerator (moving element heat exchanger) or recuperator (fixed element heat exchanger) to bring some of the exhaust waste heat back with the inlet air. Movable turbine nozzle vanes or a power transfer system are also included to improve part-load fuel economy. Recently, there has also been increased interest in small single-shaft designs operating at high speeds, high-pressure ratios, and without regeneration.

Turbine efficiency is a function of inlet air temperature, compression ratio, and turbine inlet temperature. Efficiency is also limited by the strength of the turbine blades at the high-operating temperatures typical of Brayton cycle engines. Blade cooling can allow slightly higher gas temperatures, but it is complex and costly, especially in the relatively small engines suitable for passenger cars. A very high overall air/fuel ratio (up to 40 to 1) is used to reduce the temperature of the burner and turbine wheel.

Maximum efficiency of the best recuperative versions of large-size turbines (400 hp) is nearly 40 percent. It is presently believed that all-ceramic engines with high-performance regenerators (or recuperators) may be able to achieve 38-

percent efficiency in the 100 hp size range.[27] It is more difficult to achieve high efficiency in a small gas turbine than in a large one; surface friction in a narrower flow path affects a greater portion of the total air flow and clearances between the moving parts and the housing account for a higher percentage of losses.

The power output of a single-shaft turbine decreases to nearly zero as engine speed drops by 50 percent. Thus, this turbine must operate over a much narrower speed range than most other engine types to maintain high efficiency. This requires the use of a wide-range continuously variable transmission (CVT) in order to match the narrow speed range of the engine to the variable speeds needed for operation of an automobile. Such transmissions are under development. The two-shaft configuration, or "free turbine" allows use of the standard automatic transmission employed in existing automobile designs, since the second turbine is able to operate at speeds considerably different from those of the main shaft.

The technical and performance potential of the gas turbine is attractive for the following reasons:

- There is the potential for high thermal efficiency, and thus good fuel economy (although this has not been realized to date).
- Gas turbines can be designed for a very wide range of gaseous or liquid fuels (multifuel capability).
- The turbine exhaust has substantially lower HC and CO emissions due to the more complete combustion associated with longer burning duration at higher temperatures. Also there is considerable research activity directed at achieving a "low NO_x" burner which should meet 0.4 gram per mile NO_x—the original statutory standard and the 1982 California requirement.
- The turbine has low weight and smooth operation, as well as a long life and reduced maintenance costs.

In order to realize the potential for high thermal efficiency, the turbine inlet temperatures need to approach 2,5000 F. Thus, the hot parts of the burner, ducting, nozzle ring, and turbine wheels require highly temperature-resistant materials. These can be sheet, forged, or cast "super alloy s," or ceramics. Ceramics would offer the best temperature resistance, long life, and lower production costs if the technology could be perfected.

One of the main limitations to ceramic materials is random undetectable defects in the crystal structure. As a result, conservative design practice requires use of stress levels of about one-quarter of those possible with a "perfect" material. A breakthrough in understanding the fundamental properties of ceramics with regard to their uniformity and freedom from random defects would enhance the gas turbine's competitive position.

Another problem with the ground vehicle turbine is the inability to achieve good fuel economy under partial load conditions and in acceleration and deceleration modes. Efforts to increase the fuel economy of the turbine are being made through redesign of the combustion chamber, compressor, and turbine. Most of the turbine engines presently being road tested use two shafts (the "free turbine"), fixed geometry combustors, and continuous fuel injection systems. In order to reduce fuel consumption when operating at less than full torque requirements, experiments are being conducted with intermittent fuel injection that varies with vehicle speed and with variable air-orifice geometry in the combustion chamber.

Gas turbines are not yet on the market, although both GM and Ford were close to offering large turbines in trucks and buses several years ago. The present GM turbine development program for both cars and trucks is quite active. However, Ford has essentially halted its truck turbine program. A consortium of AiResearch/Mack/KHD has also begun development of a large-truck turbine and could be the first with commercial sales.

The use of turbines in passenger cars is uncertain in the near future, but breakthroughs in ceramics could enhance their potential. The DOE/Chrysler target date for a competitive automobile turbine is 1983. GM has an ongoing development program, but its time frame is unknown. It is possible that GM is further along in

[27]Discussion with Garret Research Corporation.

development than Chrysler/DOE; GM is not relying on ceramic materials at this time.

United Turbine A. B., a subdivision of Volvo, has developed a three-shaft turbine (the KIT) which it claims is competitive in fuel economy with its current ICE-powered automobile.[28] Volkswagen, Nissan, and Toyota are also active in turbine development.

Once turbine engines are fully developed, their costs could be attractive for the consumer, largely due to long life and reduced maintenance. Initial costs and fuel economy need to be brought to a competitive level, however, and high-temperature materials at low cost are required.

Diesels

The use of diesels through 1985 was discussed at length earlier in this chapter. As interest in passenger car diesels grows, many other concepts for improving the engine will be explored in greater depth. Most improvements will probably occur after 1985. Some of these developments are:

- variable compression ratio to improve starting and optimize operation over a wide range of conditions;
- positive timing of ignition (e.g., via spark plug);
- throttling to reduce smoke;
- modulated or pilot fuel injection to minimize need for indirect injection and/or massive construction;
- use of valve selector to cut out unneeded cylinders;
- various forms of capturing the waste energy in the exhaust of a conventional diesel (e.g., Rankine bottoming cycle—a small closed-cycle steam turbine coupled to the crankshaft—or Comprex "supercharging");
- innovative, very low-fuel-consumption concepts, such as the Cummins/TARADCOM adiabatic turbocompound diesel; and
- friction-reducing features such as an "air bearing" between piston and cylinder wall.

In view of the abundance of technological options, the relative emphasis on diesel versus gasoline engines may well hinge on the manufacturers' broad strategy considerations about the merits of developing two kinds of engines when either one would do the job. At the same time, diesel and gasoline engine technologies are tending to grow closer together (the Texaco TCCS concept and a "spark-timed" diesel concept are almost identical) and could conceivably merge. This potential merging has major competitive implications for the diesel engine industry and for the automobile manufacturers.

The adiabatic turbocompound diesel may provide thermal efficiency comparable to or higher than the Stirling in about the same time frame. The Cummins/TARADCOM program is exploring various changes to the diesel; by 1979, a test engine incorporating these changes should produce a thermal efficiency of 56 percent.[29] Thermal efficiency of up to 48 percent has already been achieved but the developmental engines, and even production versions, may be quite difficult to adapt to passenger car applications.

The major gain in efficiency is obtained by completely removing any form of cooling of the pistons and combustion chamber and by insulating the engine against radiant heat loss. Thus, the interior cylinder wall temperature of the engine is extremely hot in operation (above 2,000° F, compared to about 5000 F for a conventional diesel), and essentially all the waste heat goes out the exhaust. This high-energy exhaust stream is first used to drive a turbocharger and then to drive a power recovery turbine that is coupled to the crankshaft. The Wright Cyclone R3350 aircraft engine of the 1950's (using aviation gasoline) used this same turbocompound principle and achieved thermal efficiencies of over 40 percent in commercial service. It is conceivable that further compounding (e. g., addition of a Rankine unit) could raise the overall efficiency to greater than 60 percent.

The extreme temperatures of the power section require the use of ceramic pistons and unusual combinations of piston rings, cylinder wall, and lubricants. However, these problems are being worked out. The basic engine, plus compounding, could have 25 percent less vol-

[28] S. O. Kronogard, "Advances in Automotive Gas Turbines," Mechanical *Engineering*, October 1977, pp. 38-43.

[29] SRI, p. V-52

ume than a naturally aspirated engine but the amount of hot ducts and thermal insulation would add appreciably to the effective engine volume. The cost of early engines would be several times that of existing engines and even in high production, costs would probably never drop below double. Also, it would take many years to arrive at a passenger car production version.

Fuel Cells

Fuel cells generate electricity from chemical energy through an electrochemical process. They have four primary ingredients: an electrolyte (conducive to ions such as hydrogen or oxygen); two electrodes per cell; a case for the cell or combinations of cells; and tanks for containment of fuel and oxident (if needed). Many fuel cells, especially those operating at or near room temperature require a catalytic agent, often platinum, in very small amounts on the electrode.

Many combinations of different types of the ingredients can be made into fuel cells. Some of the fuels used are hydrogen, methanol, hydrazine, ammonia, metallic fuels (e.g., zinc/air), and biological fuel. Some operate at a range of temperatures from room temperature up to 1,0000 Centigrade and higher.

Fuel cells have received most recent and widespread visibility by virtue of their use in satellites to produce electrical power. The process is inherently much quieter, cleaner, and more efficient than conventional power-generating equipment. The higher efficiency capability is a result of the fact that the fuel cell does not involve conversion of heat to mechanical energy, thus avoiding thermodynamic lower limits on efficiency.

Practical, cost-effective fuel cells are not yet available, and it is difficult to predict when such systems might be developed. Current costs of fuel cells are much higher than other practical energy conversion systems. Yet, the potential of fuel cells, both for stationary electric generation and to power vehicles, should not be underestimated or overlooked. 30

[30] G Sandstede, ed., from *Electrocatalysis to Fuel Cc//s* (Seattle: University of Washington Press for Battelle Seattle Research Center, 1972).

Drivetrain and Tires

Ongoing improvements n transmission and drivetrain-related equipment are expected to be in production by the mid-1980's. A practical CVT will require a much longer time frame and, in light of other improved transmissions, may be limited in application.

In addition to the reduced rolling resistance associated with belted radial tires and the weight savings possible from using a "compact" spare (or eliminating the spare through a run-flat system), another tire innovation holds considerable promise. This is a cast, all-plastic tire with no cord or bead of any sort. One concept uses a fully closed torroidal form (liker-tube) mounted on a two-piece wheel. Another uses an integral plastic tire and wheel. Still another uses a conventional tire cross-section with a steel bead. Compared with current tires, these concepts have the promise of achieving simultaneously:

- equal durability with equal wet and dry traction,
- 50-percent weight reduction,
- reduced hysteresis (rolling friction),
- complete recyclability, and
- lower first cost [31]

However, the technical problems of noise, durability, heat buildup, etc., for these concepts are much the same as those of conventional tires.

The captive nature of the tire industry, the major shift that would be required in facilities and materials sources, the great reduction in required labor, and related institutional problems may slow the development of the all-plastic tire.

Vehicle Design and Manufacture

Post-1985 vehicle design and manufacturing changes could be motivated by several factors. These include the need to reduce the weight of vehicles further for improved fuel economy, the need to enhance the safety characteristics of vehicles, particularly in light of the reduction in

"SRI Supplement.

size and weight of cars, and the need for more durable, longer lasting vehicle structures that are more corrosion-resistant. The limiting factors may be the engineering and design techniques and the availability of high-strength, lightweight durable materials to accomplish all of these objectives simultaneously.

Research in this area thus far has shown some promising results. For instance, smaller, lighter vehicles need not have a safety disadvantage. The creative use of lightweight materials (such as high-strength low-alloy steels, aluminum, composite structural plastics, and plastics, foams, and integrated foam-filled structures) has been demonstrated in the design of lightweight, sturdy vehicles.

The primary difficulty in new materials applications is in developing manufacturing processes that are competitive with steel forging, iron casting, and stamping in terms of manpower and time. Significant progress is being made with aluminum stamping, bonding plastics to metals, and molding large shapes of plastic. Such advances will encourage the use of these materials.

Durability, Corrosion, and Recycling

Durability and corrosion resistance depend on the materials used, the quality of vehicular components, and the ease of repairing or replacing those parts that are expected to wear. The plastic and aluminum parts will not rust, although the plastic may deteriorate over time, and aluminum will oxidize somewhat. Corrosion of steel parts can be controlled to a greater degree than at present by modifying design to limit the areas where salt and mud collect, by improving metal coatings (paints), by use of galvanized (zinc-coated) metals, and by improving sealing materials (undercoating). Progress is being made in these areas.

It is relatively easy to design stronger, and hence more durable, automobile parts. However, this generally entails added cost and increased weight. An overall saving in materials and in production energy might result. However, the cost-effectiveness of this approach requires careful study. Increased durability could lead to a fleet of older vehicles, made to earlier design standards, and possibly in poorer repair.

Recycling is now a well-established industry; its continuation and expansion depend more on will and economics than on technology. The increased use of plastics will require more attention to the recycling of these parts. Separation of plastics from metals will become increasingly difficult. Sorting of plastics for recycling is an almost insurmountable problem; a cost-effective solution will be difficult to find. Plastics that cannot be reclaimed pose a solid waste problem, since they do not decompose naturally.

Safety

There are a number of safety technology concepts in the automobile transportation system relating to vehicles, highways, and driver performance. Many of these concepts can be applied to crash avoidance or crash severity reduction, or to both in some cases. The following is a listing of some of these concepts:

- improved vehicle structural engineering / design / materials;
- advanced restraint systems;
- interior design concepts for safety;
- antilock and radar brakes;
- fuel systems and fuel tanks with reduced flammability;
- vehicle control augmentation;
- vehicle exteriors that minimize injury to pedestrian and pedacycle riders; and
- modal mix considerations (truck underride guard, for example).

Vehicle crashworthiness has two underlying objectives —maintaining occupant compartment integrity in the crash, and controlling the accelerations of the vehicle and the occupants throughout the event. By controlling the acceleration and spreading it out over time, the peak accelerations and overall level of accelerations on the vehicle occupants are reduced, Designs that can achieve higher levels of crashworthiness require application of known basic design principles. Computer-aided finite element analysis in vehicle design offers the capability for detailed examination of vehicle structural response characteristics. Also, routine application of engineering principles applied to crashworthiness criteria could produce vehicles of extremely high structural integrity.

Advanced restraint systems and interior design considerations for safety are an integral part of the occupant protection concept.[32] Considerable progress has been made in these areas and more improvements are expected.

Exterior designs that can lessen injuries in collisions with pedestrians, cyclists, and motorcyclists have not been fully explored yet. One approach to this concept has been a soft front-end design which tends to soften the initial blow and guide a struck pedestrian onto the hood of the vehicle. The efficacy and applicability of these ideas need further study. Certain features, such as breakaway or hinged outside mirrors and hinged hood ornaments, are already commonplace on vehicles.

Brakes

Several concepts regarding improved brakes are under consideration for 1985 and beyond. These include antiskid brakes and radar brakes.

Antiskid brakes have been developed for passenger cars. However, marketing of the early systems (which were developed without regulatory pressure or other incentives) was not very successful. Operating experience with such units has been quite satisfactory, despite early problems with the more complex units used on trucks. Technologically, such systems are quite feasible, but users have not viewed the benefits as being worth the added cost. A number of new antiskid braking concepts are under development. They could result in up to 10 percent less stopping distance in many cases, and several times that in a few severe conditions. More importantly, they essentially eliminate loss of directional control in emergency stops.

Since diesel engines have no engine vacuum, the Oldsmobile diesel uses a hydraulic booster to power the brakes. The hydraulic boost consists of using the power-steering pump for this second function. When antiskid systems are used, it probably will be preferable to use this form of power assist (rather than vacuum) for spark-ignition engines as well as diesel because of the much smaller actuators required.

Radar-assisted brakes are also under development. Their purpose is to perceive an inevitable collision event and respond faster than the human operator in applying the brakes. The system is not necessarily designed to avoid collisions, but to reduce the impact speed and thus the severity of a crash. Minicars, Inc., has developed such a system in conjunction with its work on the Research Safety Vehicle Program. They calculated a 60- to 90-percent reduction in collision energy at 50 mph compared with operator-actuated brakes, using a perceived hazard distance of 80 feet.[33] However, there is some concern that the widespread use of radar equipment may present a microwave radiation hazard.

Fuel Systems

Over 17,000 fires occur annually in the United States as a result of motor vehicle crashes.[34] In 1975, there were 55,000 vehicles involved in fatal crashes; more than 1,200 fires occurred.[35] The current FMVSS 301 standard on fuel system integrity considerably reduces the allowable fuel loss in 30 mph front, rear, and side collisions. The RSV program specifications, however, call for no fuel loss under much more severe test conditions. The technology for secure fuel systems is available. Bladder tanks, compartmentalized tanks, resealing tanks, foam filler blocks, and the like have been used extensively in aircraft and racing cars to reduce fire hazards. All of this technology is easily transferable to passenger cars at some modest increase in cost.

Another approach to minimizing problems with fires is to identify and eliminate the ignition source(s). An inertial switch is available which shuts off the electrical system in a crash. The electrical system has long been suspected to be a primary source of ignition in collision, fires.

[32] John D. States, "Static Passive Occupant Restraint Systems, Without Airbags and Without Belts, Is It Possible?," *Fifth International Congress on Automotive Safety-Proceedings*, Cambridge, Mass., July 11-13, 1977, pp. 419-426.

[33] Rudolf Limpert, "Minicars RSV Brake System," *Fifth International Congress on Automotive Safety-Proceedings*, Cambridge, Mass., July 11-13, 1977, pp. 773-802.

[34] John Hubbard, Virginia Kelley, Russell Shew, "Fuel-Fed Vehicle Fires," *Trial*, January 1978.

[35] U.S. Department of Transportation, *Fatal Accident Reporting System, 1975 Report*,

Program and Concept Cars

Concept cars have been used as a means of corporate advertising, exploring public interests and tastes, and checking feasibility of new engineering and production concepts. More recently, concept cars have been used to investigate and stimulate innovative technical approaches that address national needs. The major auto companies routinely build such vehicles; the prototypes from small auto companies and inventors attempting to break into the automotive world can be viewed in this same category.

This class of vehicles includes the Chrysler gas turbine cars, the GM XP898 "all plastic" car, the Bricklin and DeLorean cars, the wide variety of cars used to explain new engines and/or fuels, electrics and hybrids and, finally, the series of safety cars. The safety car program started with the Liberty Mutual/New York State car of the 1960's. It progressed through the NHTSA Experimental Safety Vehicle (ESV) Program of the early 1970's to the present RSV (Research Safety Vehicle) Program, which attempts to integrate emission control and fuel-economy goals with the primary safety concepts.

As a parallel aspect of the ESV program, the major auto companies built their own versions of ESVs. These cars provided major improvements in meeting safety criteria, but retained much of the conventional full-size passenger car design, materials, styling, and production features. The ESVs, designed and built by nonautomotive developers, were not based on existing vehicles and had little in common with the conventional auto designs.

The current RSV program includes a very unconventional car from Minicars, Inc., as well as the Calspan/Chrysler vehicle, which is based on a modified Lightweight production sedan. At the same time, VW has developed a safety car version of their Rabbit model that achieves excellent fuel economy, emissions levels, and performance. The major U.S. auto manufacturers have not publicized any in-house integrated safety car efforts comparable to their earlier ESVs.

The information gained from the present RSV and parallel activities will probably provide both a basis for some of the future safety regulation and a fund of data and experience that will be extremely useful to the major auto producers. As an example, the VW safety car, which is a modified version of the Rabbit, weighs about 200 pounds more and is powered by a four-cylinder, turbocharged diesel. It obtains 60 mpg (composite), accelerates from O to 60 mph in less than 14 seconds, meets 1983 emissions standards, and provides 40 mph barrier (and 30 mph pole) crash survivability without serious injury. It is claimed that this car could be in production in 3 years.

Electric and Hybrid Vehicles

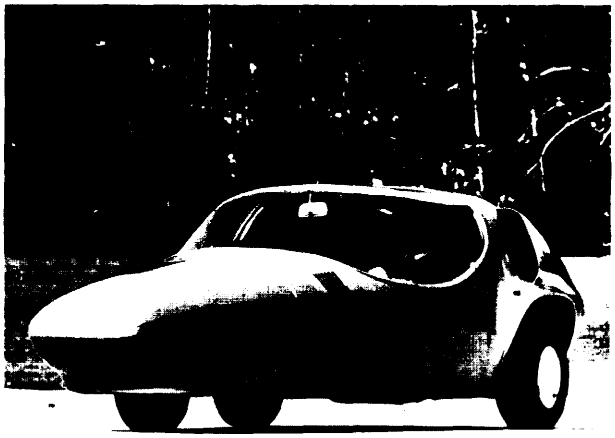
In the present environment of low-cost and plentiful gasoline, electric vehicles must be viewed as an alternative that is competitive in only very limited applications or under conditions of Government subsidy. In view of the inevitable depletion of petroleum resources and the continued problem of air pollution with petroleum fuels, Federal encouragement and subsidy of EVS is proceeding. The program has the dual objectives of conserving petroleum and assuring that the necessary technology and experience are in place before the need becomes urgent, since EVS can derive their energy from coal-fired or nuclear-generating systems.

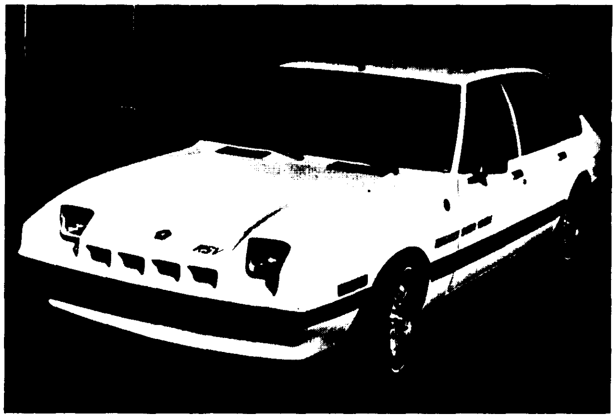
Many individual inventors, large corporations, and major auto manufacturers have been pursuing EV development programs, partly in the hope of providing a viable, currently competitive vehicle, and partly to be ready earlier than their competitors where EVs eventually become economically competitive. Present EV technology generally provides vehicles of such limited performance that public acceptance has been extremely low. For example, the only EVs commercially available are limited to about 35 mph, speed drops drastically on minor grades, and performance is much poorer near the end of the battery charge. Also, there is insufficient energy storage to include provisions for heater, defroster, air-conditioner, and similar features.

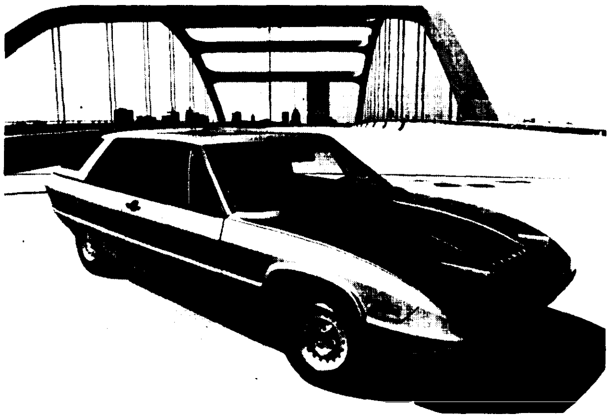
A typical electric-vehicle power train consists of storage batteries, provision for recharging from household or similar 110/220 volt sources, a controller to adjust speed and acceleration, and an electric motor that drives the road

Experimental Vehicle Designs

Pholo Credit U S Department of Transportation







wheels. The EV *may* also include regenerative braking, as well as a load-leveling device such as a flywheel to increase vehicle range.

The EV concept extends to a number of vehicles including delivery vans, urban passenger cars, buses, agricultural equipment, industrial lift trucks, and golf carts. Current research is focused on batteries, controls, and vehicles for personal transportation and light-duty commercial use.

The extremely limited energy storage capability of present day battery systems has led to the concept of combining a battery or similar energy storage system with a combustion engine system. This combination is known as a hybrid powerplant. Two hybrid concepts have been predominant—an internal combustion engine with a battery system, and an internal combustion engine with a flywheel energy-storage system.

Since the hybrid vehicle currently offers certain performance characteristics superior to EVs, it may provide a more acceptable alternative and may encourage the development and introduction of more advanced electric-vehicle systems. Flywheel and other energy storage systems currently under development may provide both electric and hybrid vehicles the performance and economy needed to improve their public acceptance.

Benefits

The successful development of an electric- or hybrid-vehicle power system (i.e., battery and power train technology) can provide a variety of benefits in the future. To the extent that electricity is generated from nonpetroleum sources and to the extent that electric- and/or hybrid-vehicle use replaces petroleum-vehicle use, the electric vehicle offers a means for substantial savings of petroleum.

Another benefit could be the virtual elimination of air emissions in urban areas. This benefit needs further examination because the emissions would be shifted to the utility. The ultimate impact would depend on the plants' locations as well as emission characteristics. However, unless emphasis is placed on vehicle safety, the increased use of small, lightweight vehicles may have an adverse effect on traffic safety.

Constraints

Consumer preferences may represent strong barriers to early sales of urban EVs and hybrids. The average range of a current EV is only about **50** miles, a major disadvantage for consumers. Although the hybrid vehicle does not suffer from the range limitations of the electric vehicle, it requires a more complex and expensive engine power train design and needs two energy sources.

Few EVs are currently equipped with the powerful motors and associated controls needed to match the acceleration of ICE-powered vehicles. Electric-vehicle users must adjust to lower speeds and reduced performance. Hybrids are not expected to perform much differently than EVs in this regard.

Many or most of the amenities that are commonplace in current ICE-powered vehicles are not expected on EVs or hybrids. Such equipment includes power steering, power brakes, extra interior space, and air-conditioning. However, in a serious energy shortage, this equipment would probably be discarded on ICE-powered automobiles as well.

Systems for servicing EVs or hybrids do not exist yet. Parts availability, maintenance know-how, and repair availability and costs are unknown.

State of the Art

In **1970,** the Edison Electric Institute defined the minimum desirable characteristics of electric vehicles for use by utility companies. (See table 147.) The purpose of the program was to encourage the manufacture and test operation of a significant number of special purpose electric vehicles.

The U.S. Postal Service is currently conducting a comprehensive electric-vehicle program. During the project, a set of technical goals for electric vehicles was developed. Except for the 4-year battery life, the technical goals of the postal electric vehicles (table 148) have been met by approximately **380** vehicles. A number of battery and control system failures were experienced by these vehicles. Preliminary results indicate that improved vehicle acceleration is desirable.

Table 147.—Desirable Minimum Characteristics— Electric Work Vehicle

Range	64 km (40 mi.)
Cruising speed	48 km/hr (30 mph)
Maximum speed	80-97 km/hr (50-60 mph) for emergency requirements
Acceleration to	48 km/hr (30 mph) in 10 seconds or less
Seats	Driver and passenger
Plus payload	227 kg (500 lbs.)
Stops per day	150-200 (not required to reach 48 km/hr (30 mph) after each stop)

SOURCE E A Campbell, *Analysis of On-Road Electric Vehicle Experience of 62 U S. Utilities*, SAE Paper 760074, 1976

Table 148.—Technical Goals of U.S. Postal Service Electric Delivery Vehicle

Range	32 km (20 mi.)
Maximum speed	53 km/hr (33 mph)
Acceleration to	48 km/hr (30 mph) in 20 seconds
Grade	10% at 16 km/hr (10 mph)—122 m (400 ft.)
Battery life	4 years

SOURCE. D P Crane and J.R Broman, "United States Postal Service Electric Vehicle Program," *Fourth International Electric Vehicle Symposium*, Dusseldorf, Germany, 1976

The Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976 (Public Law 94-413) included a provision to "demonstrate the economic and technological practicability of electric and hybrid vehicles for personal and commercial use in urban areas and for agricultural and personal use in rural areas . . ."[36] The Administrator of ERDA (now DOE) was required to "promulgate rules establishing performance standards for electric and hybrid vehicles to be purchased or leased. . ."[37] within 15 months of enactment. The 1976 Act originally called for the procurement of 2,500 EVs by December 17, 1979. Through an amendment in the law, the number has been reduced to 200 for the first year and 600 and 1,700 in the following 2 years. In all, an EV fleet of 7,500 vehicles will be on the road for test and demonstration in the 1981-84 period. It is important that this test fleet be viewed as a success or the future acceptance of EVs will be seriously jeopardized.

The DOE electric vehicle program has concentrated on the development of six components. They include the battery, charger, motor, controller, transmission, and body/chassis. Table 149 lists the components and characterizes a few typical design alternatives. Figure 66 shows two EV unit configurations with different charger systems. The onboard charger option would most likely be used for personal two- and four-passenger vehicles; the batteries of these vehicles would be charged at individual residences. Small commercial delivery vans might find it more convenient to utilize high-voltage offboard charging systems.

The key to a successful electric vehicle is the development of an improved battery with greater storage capacity, higher power density, and greater recycling capability at minimal cost increases. A number of electric-vehicle prototypes are currently being produced in the United States, Europe, and Japan. These generally incorporate state-of-the-art lead-acid battery technology. Such vehicles are typically limited to an operating range of about 25 to 30 miles between recharges; they generally have speed limitations of less than 50 mph because of low specific power. Also, the already-poor specific energy characteristics (28 to 32 watt-hour per kilogram) of lead-acid batteries degrade further when power demand is increased to maintain high acceleration and operating speeds.

[36] *Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976*, P.L. 94-413, 94th Congress.
[37] Ibid.

Table 149.—Typical Electric Vehicle Component Design Alternatives

Component	Type
Battery.	Lead-acid (current)
	Lead-acid (Advanced)
	Nickel-iron
	Iron-air
	Zinc-air
	Zinc-chlorine
	Sodium-sulfur
	Lithium-metal sulfide
Charger	Onboard
	Offboard
	Offboard, battery exchange
Motor	DC traction (series wound)
	DC separately excited (shunt)
	AC induction
	Others
Controller	Silicon controlled rectifier (SCR) chopper
	Inverter
	Variable resistance (Rheostat)
Transmission	Typical: 3-speed automatic with torque converter
	Continuously variable transmission
	Manual
	None
Body/chassis	Fiber reinforced plastics (fiberglass)
	Lightweight metals
Axles	Typical
Springs	Typical leaf layer coil
Brakes	Typical Self-adjusting hydraulic
	Regenerative
Tires.	Typical
Auxiliary power	Battery and charger
	AC/DC converter
Accessories	Gasoline heater
	Thermal storage heater
	Air-conditioner

SOURCE US Energy Research and Development Administration Transportation Energy Conservation Division, *Environmental Development Plan*, September 1977

Europe and Japan are moving ahead in EV development. Japan has demonstrated an EV with a range of nearly 300 miles[38] and England has had a successful delivery fleet in operation for several years.

There are several types of lead-acid battery cars on the market. They suffer from the problems of short range, low speed, low performance, and flimsy vehicle structure and they have not sold well. General Motors has announced the possibility of marketing a delivery-type vehicle or small urban passenger car in the 1980's. GM will also provide a number of the electric vans in the DOE demonstration program.

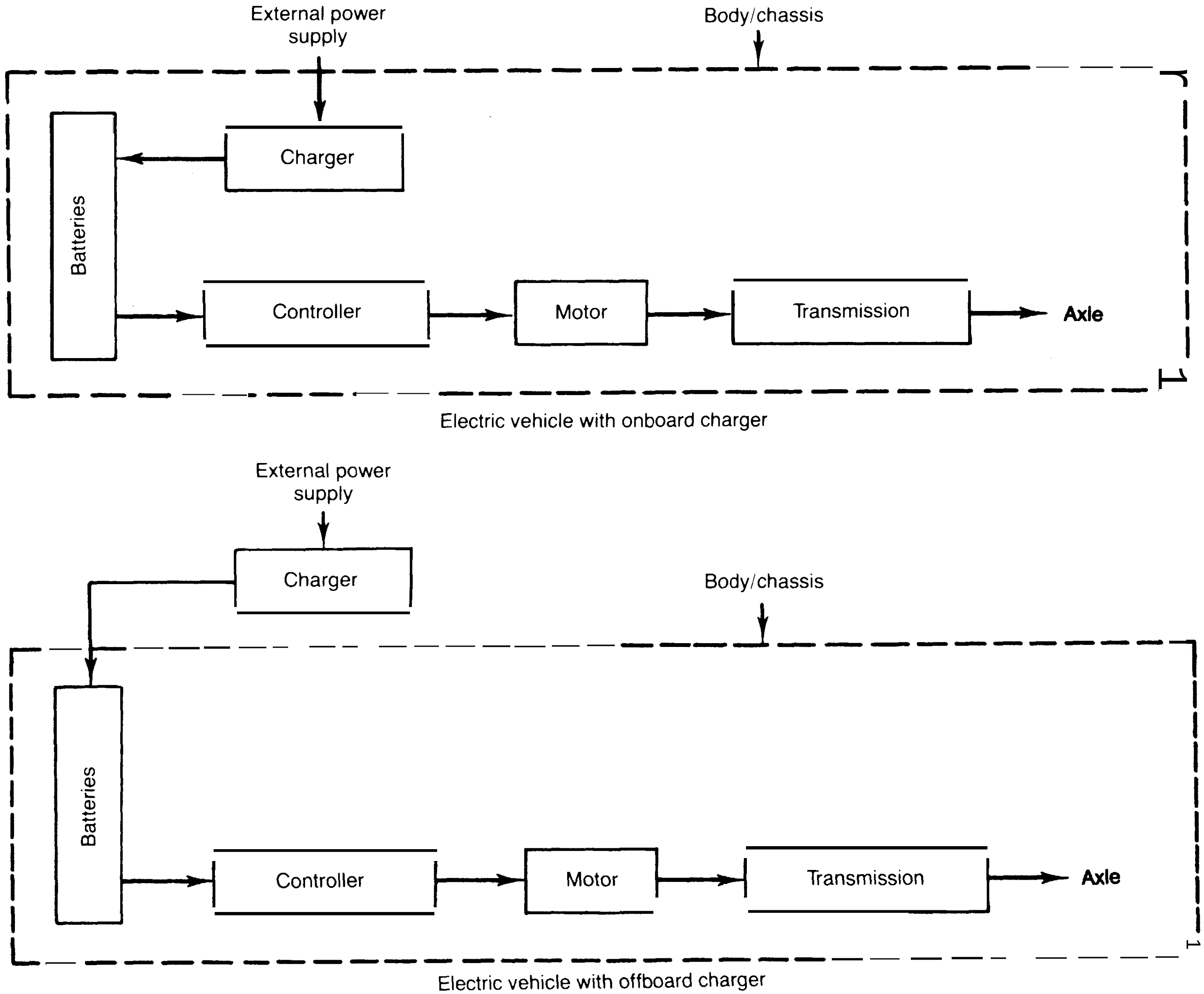
"Briefing by the U.S. Department of Energy, September 1977.

Electric Vehicle Components

The propulsion system of the EV is made up of the electric drive motor, the controller, and the drivetrain. The drive motor may be either a DC or AC induction motor. Both systems may incorporate regenerative electric braking. The potential advantages ascribed to the AC induction motor relative to the DC drive include lower maintenance requirements, lower cost, better control of speed and torque, greater reliability, and better performance in rugged terrain. For either system, required battery voltages are in the range of 80 to 150 volts.

Attempts are being made to reduce overall vehicle weight and aerodynamic drag to improve performance. These goals can be attained

Figure 66.—Electric Vehicle Configurations



SOURCE: U.S. Energy, Research, and Development Administration, Transportation Energy Conservation Division, *Environmental Development Plan*, September 1977.

by constructing the body and suspension of special lightweight but high-strength materials (aluminum, plastics, composites) and by suitably streamlining the configuration.

Hybrid Systems

Hybrids using internal combustion engines can be of the series or parallel type as well as other arran~ements. (See figure **67.**) In the series configurate ion, the ICE is used to maintain the energy storage system at optimum operating conditions. The storage system is geared directly to the drive wheels to provide propulsion. In the parallel configuration, either the ICE or the energy storage system can supply power to the wheels, with each system operating as close to optimum as possible. In both configurations, the energy storage device is generally reversible and capable of accepting energy from regenerative braking systems.

The major subsystems of hybrid vehicles are shown in table 150. The number of possible permutations is quite large; however, preliminary investigations have indicated greater potential for certain configurations.

Reliable data on hybrid vehicles are unavailable because few vehicles have been built. However, extrapolation of certain characteristics suggests that a relatively small ICE (for highway cruising) combined with an electric drive (for urban driving) may prove to be a successful alternative to the severely limited range of purely electric vehicles.

Table 150.—Hybrid Vehicle Subsystem Typical Design Alternatives

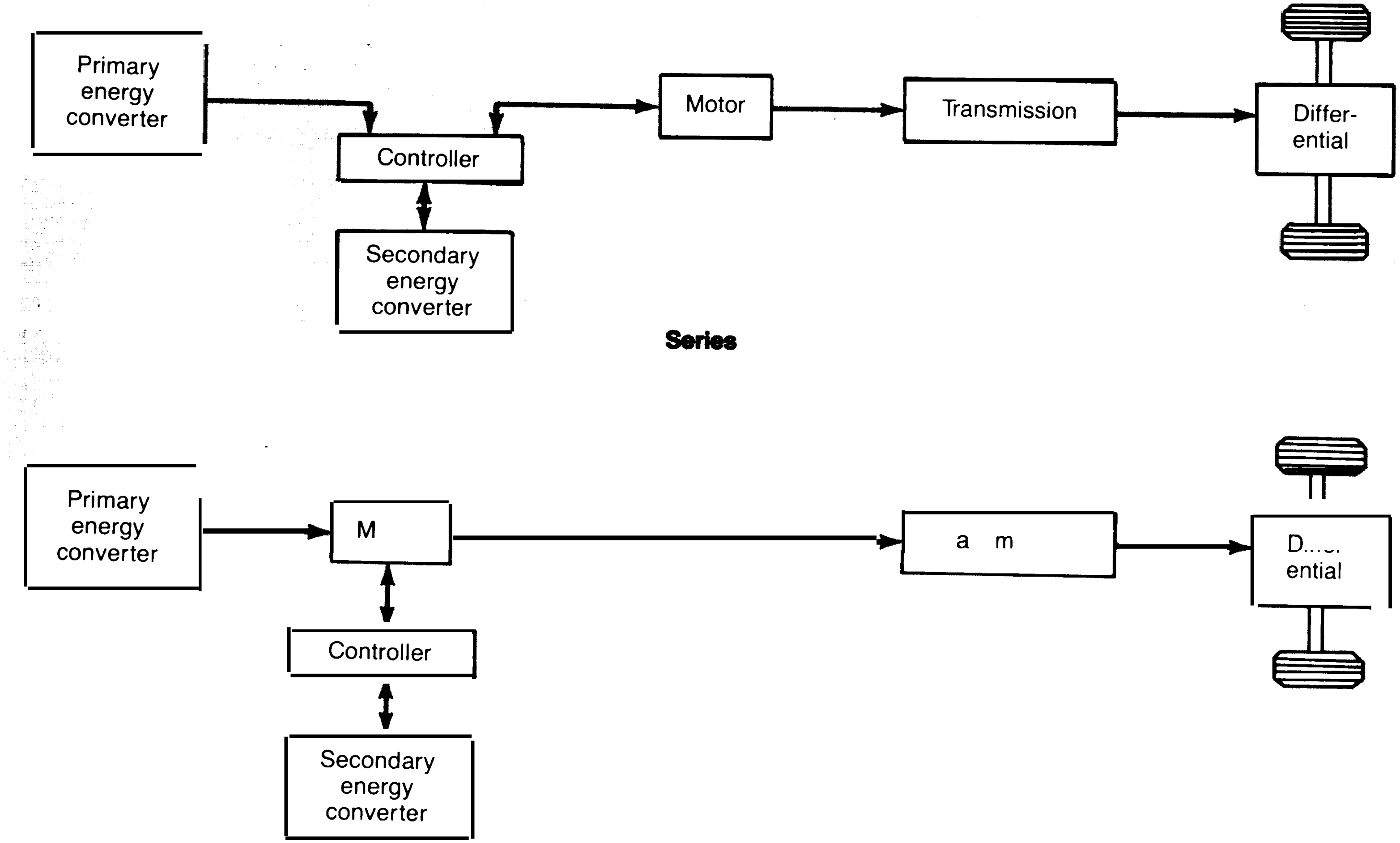
Vehicle subsystem	Alternative hardware
Primary energy converter	Heat engine Conventional (Otto cycle) Diesel Gas turbine Rankine Stirling Battery[a] Fuel cells
Secondary energy converter	Heat engine Flywheel Battery Fuel cell Hydraulic accumulator Pneumatic pressure vessel[b] Elastic storage (e.g., spring)
Motor/generator	AC DC
Controller	Inverter Cycloconverter Relays, switches Chopper
Transmission	Typical: a) 3-speed automatic with torque converter; b) manual Continuously variable transmission
Chasis	
Body	Fiber-reinforced plastics (fiberglass) Lightweight metals
Axles	Typical
Springs	
Brakes	Typical: Self-adjusting hydraulic Regenerative
Tires	Typical

[a]Battery flywheel and other such configurations that use a sing le energy source (e g elect ricity) are considered electric vehicles

[b]Can also be used as auxiliary storage for regenerative braking m a 3 part energy storage system

SOURCE U S Energy Research and Development Administration Transportation Energy Conservation Division *Environmental Development Plan* September 1977

Figure 67.—Hybrid Vehicle Power Systems



SOURCE: U.S. Energy Research, and Development Administration, Transportation Energy Conservation Division *Environmental Development Plan*, September 1977.

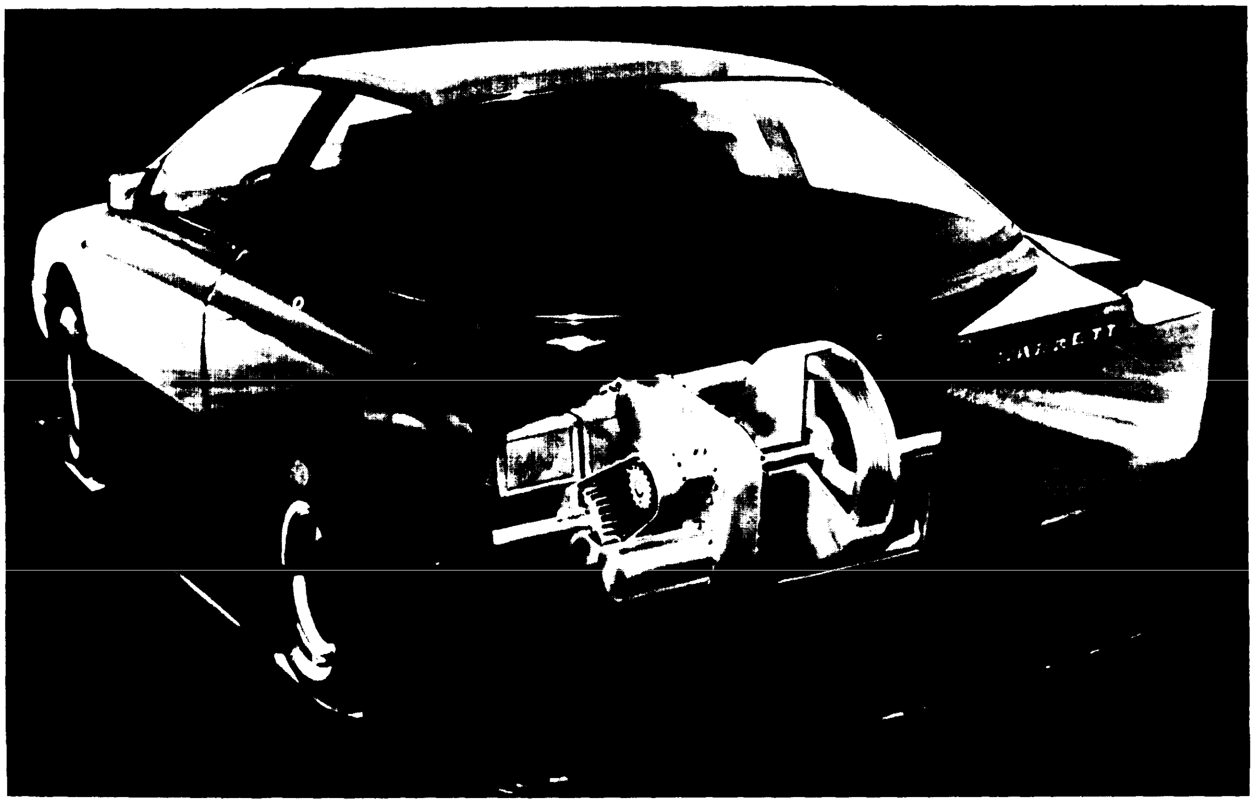


Photo Credit A iResearch Manufacturing Company

Both the electric-vehicle and hybrid-vehicle designs are in their infancy. Therefore, a wide range of developments are being considered and many of these are being pursued. Research efforts are continuing in the development of batteries with greater energy densities, longer life, and shorter recharging requirements. Flywheel development work has established objectives for energy density for 1980 and 1985. Supporting research is also being conducted on electrical components and materials. The NASA Lewis Laboratory (under contract to DOE) is trying to evaluate the more promising vehicle propulsion system configurations.

Investment and Costs

Current investment by the DOE for the EV and Hybrid Program is about $30 million for fiscal year 1978 and $37.5 million is requested for fiscal year 1979. The extent of private funding for research in the area is unknown at this time, although it is thought to be fairly sizable.

Electric-vehicle costs are hard to project because of the scarcity of data. A number of factors, including improvement of vehicle design, advancement in battery technology, and development of production economies of scale, will influence future costs of electric vehicles. In a study for DOE, General Research Corporation developed costs for near-term (1980) two- and four-passenger electric vehicles powered by lead-acid batteries. (See table 151,) A comparison of initial price shows a wide disparity between two- and four-passenger EVs, and conventional **(1976)** ICES. Four-passenger EVs cost about 20 percent more than conventional ICE compacts. The primary reason for the disparity lies in the cost of the lead-acid battery, which accounts for up to 22 percent of the total price of the EV. Four-passenger EVs are almost twice as expensive as two-passenger EVs. Because of greater size and weight characteristics, the four-passenger EV requires a larger (and, therefore, more expensive) battery power pack than that needed by the two-passenger EV. Two-passenger EVs cost about 25 percent less than conventional 1976 subcompacts. Again, the difference is primarily due to the smaller weight of the two-passenger EV.

Operating costs for electric vehicles will depend largely on improvements in the energy ef-

Table 151 .—Comparison of Costs for Electric and Conventional Cars (initial price, 1976 dollars)

Vehicle type	Base price	Battery cost	Total
2-passenger EV.	$1,901	$ 374	$2,275
4-passenger EV.	3,518	1,020	4,538
Conventional compact.	3,780	—	3,780
Conventional subcompact	3,060	—	3,060

SOURCE General Research Corporation. *Potential Applicability of a Lead-Acid Battery-Powered TwoPassenger Electric Car*, June 1976.

ficiency of the battery, battery life, and the battery-charging system. The rate of growth in the price of electricity will also be a factor. Maintenance costs for electric vehicles are expected to be less than those for conventional ICES simply because EVs have fewer mechanical working parts. The overall operating cost spread between ICES and EVs will also be influenced by the rate of improvement in ICE fuel economy and the rate of growth in the price of gas, An important addition to routine operating costs of a lead-acid battery system will occur about every 2 years. This is the replacement of the entire battery pack at a cost of about $500 to $1,000.

The costs of owning and operating hybrid vehicles are even less certain than for EVs. The initial cost is anticipated to be higher than that of an EV, since two propulsion systems are included. Operating costs are dependent on many of the same factors as the EV and also on the cost of the secondary fuel source.

ALTERNATE FUELS

The liquid and gaseous fuels that could be used in conventional and potential future automobile powerplants can come from a variety of sources and in numerous forms. Fuels which have been tried include: gasoline, diesel fuel, broadcut fuels, lower alcohols (ethanol and methanol), higher alcohols, ether, ammonia, liquid natural gas, propane, methane, hydrogen, and hydrazine. Any of these fuels can be used in pure form, and some can be blended or mixed with other fuels.

The sources of fuels are nearly as varied as the type of products. Coal, oil shale, tar sands, biomass (including municipal and agricultural waste as well as agricultural products), and water (for hydrogen), are considered likely alternate sources for fuel in the intermediate and long term. This section deals with the technical aspects of some of these sources, the end products, and their use in propulsion systems for automobiles.

Oil Shale

The oil in oil shale is contained in kerogen, a complex, high molecular weight organic substance composed of carbon, hydrogen, oxygen, sulfur, and nitrogen, intimately mixed with inorganic silt particles. Separation of the oil requires that heat be applied to the shale. This causes the kerogen molecules to break up, releasing liquid hydrocarbons, some combustible gases, and water from the inorganic spent shale residue. The liquid hydrocarbon mixture (crude shale oil) is then upgraded to syncrude to make it acceptable as a conventional petroleum refinery feedstock.

The use of substitute automotive fuels derived from oil shale does not require new engine technology. Oil shale products could supplement supplies of petroleum available to the auto sector. They could also be used as feedstocks for the petrochemicals industry, thereby allowing greater use of available petroleum supplies by the automotive sector.

Two basic processes for recovering the oil from oil shale are being developed: the above-ground process, and in situ processing. Above-ground shale processing consists of four basic steps: mining the shale; crushing it to the size necessary for the retorting vessel; retorting the shale through the application of heat; and upgrading the raw shale oil through the removal of contaminants (excess nitrogen and oxygen) to make it acceptable as a refinery feedstock. There are several above-ground shale oil processing methods, characterized primarily by different procedures used in heating and retorting the oil shale.

In situ recovery of oil shale differs from aboveground recovery in that the oil is recovered from directly within the bed of shale. The shale is fractured by explosives and then ignited by a flame from compressed air and a combustible gas pumped into the shale bed. The gases heat and retort the shale, producing an oily vapor. The vapor condenses to a liquid at the base of the in situ retort and is pumped to the surface for upgrading to the level of refinery feedstock quality. A "modified" in situ process is being developed in which a portion of the shale bed is first mined by conventional methods and retorted on the surface. The remaining shale is retorted underground. This process has been developed and is being tested by Occidental Petroleum Corporation with marginal success.

Oil shale production is constrained primarily by technology, production *cost,* and environmental impacts. The existing processes have yet to be implemented on a commercial scale in the United States. It is unclear whether full-scale production will entail changes or modifications in existing technology.

The existence of high Ievels of nitrogen, arsenic, and oxygen and high carbon-to-hydrocarbon ratios in oil shale necessitates fairly substantial upgrading to improve the quality of oil shale syncrude. This processing is one of the cost factors that makes oil shale noncompetitive with crude petroleum at current prices.

A major environmental constraint involving above-ground oil shale production is the problem of spent shale. Only about 12 percent (by weight) of oil shale can be converted to oil. (This figure varies depending on the quality of the deposit.) The remaining 88 percent is relatively useless. It has been estimated that a 1-million-barrel-a-day (bbls / day) shale industry using high-grade (3o gallons per ton) shale will generate 1.5 million tons of spent shale a day. This is after mining, crushing, and retorting. Crushing the rock and retorting causes the total volume to increase. Thus, all of the spent shale cannot be put back where it came from. The problem of disposing of this shale in an environmentally and economically acceptable fashion is a major constraint to the success of the oil shale industry. Dust can also be a problem, particularly if the processing reduces the shale to a fine powder.

In situ processing has some different environmental impacts from those of surface retorting of sha!e. Aboveground processing is characterized by problems such as significant land disturbance due to mining, large volumes of spent shale, relatively high water use, and air and water emissions from retort operations. In situ processing reduces some of these impacts but increases the potential for ground water contamination, aquifer disruption, and subsidence or uplifting at the surface. Modified in situ processing has a combination of the surface and underground impacts.

Primary air pollutants associated with oil shale processing include sulfur dioxide, hydrocarbons, nitrogen oxides, and particulate. Other pollutants that can occur include ammonia, carbon monoxide, hydrogen sulfide trace elements, and toxic substances. Conventional control systems are available for some of these pollutants, but their removal efficiency and dependability in these specific applications have not been demonstrated. These air pollutants are off-gas emissions and are associated with both the surface and in situ retorting processes, The effectiveness of in situ methods in reducing gaseous pollutant formation, and containing and treating them, will not be known until the technology has undergone additional field testing. The upgrading, refinement, and storage of the product are common steps to both processes, and similar impacts will occur.

The water use requirements of shale process-

Photo Credit: U.S. Department of Energy

In situ oil shale retorting

ing may constrain the development and use of major oil shale deposits in arid regions. The principal deposits of oil shale are found in Colorado, Utah, and Wyoming, where water supplies are limited. Extensive development of these deposits, using existing mining and surface retorting methods, could cause unacceptable burdens on water use in the area and cause economic hardships for farmers and industries using the available water in these areas. In situ processing requires less water for shale processing than current surface retorting and refining.

A major environmental impact which may occur with in situ processing is geological disturbance. Mining, hydraulic and explosive fracturing, and in situ retorting cause physical disruption and cracking of strata. They may also result in the severe disruption of adjacent ground-water-bearing aquifers and cause subsidence or uplifting at the surface. Depending on the proximity and structure of aquifers, ground water supplies may be contaminated and aquifer flow and storage characteristics may be changed. Subsidence at the surface, which may not occur immediately, can damage buildings and roadways or affect options for subsequent land use. Finally, since oil shale is concentrated principally in Colorado, Utah, and Wyoming, the effect of "boomtown" development and accompanying social problems could be considerable.

At the present time, no oil shale plants have been constructed or operated in the United States on a large-scale commercial basis. The technology is at the bench-scale to pilot-plant stage of evolution. Both Government and privately sponsored projects involving R&D of oil shale recovery processes have been underway since the 1920's. Both above-ground (conventional) shale processing and in situ shale processing are under development.

Several types of surface shale oil retorting methods are reportedly near the state of commercial application. Union Oil Company has announced plans to construct a 10,000-bbl-per-day oil shale plant in Colorado, providing they receive a proposed $3 per barrel tax credit. The Paraho Development Corporation is scheduled to produce a total of 100,000 barrels of shale oil for test purposes at its plant at Anvil Points, Colo., under joint Navy/DOE financing. Paraho has also proposed to build an 11,500-ton-a-day commercial-scale module. The TOSCO Corporation, in conjunction with Colony Development Corporation has recently designed a commerical-sized plant to produce 47,000 bbls per day of shale oil and 4,300 bbls per day of liquefied petroleum gas.

Additional research in aboveground oil shale conversion has been carried out by Union Oil Company, the Institute of Gas Technology, and the Superior Oil Company.

Several in situ processes have also been tested. Occidental Petroleum Corporation has been conducting a series of field tests since 1972. It has constructed three commercial-sized, modified in situ retorts. One of these produced 27,500 barrels of oil in 6 months from shale containing 17 gallons per ton. In addition, work is also being done at the Lawrence Livermore Laboratory and DOE's Laramie Energy Technology Center on variants of in situ oil shale recovery.

Estimates of commercialization of fuels from oil shale are subject to considerable speculation; a small amount of production could begin in the late 1980's or 1990's. However, it will be many years before the maximum economic recovery rate (commensurate with competing petroleum prices) will be attained. Current indications are that oil shale derived fuels will not be widely used by the auto sector before the year 2000, primarily because of cost considerations. Over the next 20 to 25 years, the likelihood of commercially available fuel from shale oil will increase as the price of petroleum increases.

Due to the continued uncertainty on such factors as oil shale technology, environmental requirements, disposal of spent shale, and problems of operating on a large scale, investment costs of oil shale plants are difficult to estimate with accuracy. The interplay of institutional, environmental, economic, and technological factors will have significant impact on capital and operating costs. Current estimates call for a $1 billion to $1.2 billion investment for a 50,000-barrel-a-day surface retort facility and at least $750 million for a similar size modified in situ operation.

For the same reasons, the projected retail price of shale oil is uncertain. Occidental Petroleum claims that it can produce oil from oil shale at a total cost of $12 a barrel.[39] However, another source (Continental Oil Company) claims that the addition of environmental costs and syncrude upgrading costs raises the per-barrel cost of oil shale to $16 to $26, a figure well above the current world crude price of about $13.50 a barrel.

Tar Sands

Tar sands (or bituminous sands) occur throughout the world in various types of deposits of varying viscosity. The bitumen in the sand ranges from 5 to 13 percent by weight. The best deposits are in Canada and South America, totaling 98 percent of the estimated 1,680 billion barrels of world reserves. The United States has less than 2 percent of world reserves and considerably less in tar sands than oil shale reserves. Consequently, tar sands are not considered a major domestic energy resource. Utah contains 93 percent of the estimated 27 billion barrels of oil in tar sand deposits in the United States.

The recovery process of tar sands is of two types: mining followed by surface extraction, and in situ extraction. Surface extraction processes are many:

- hot water (the only one used commercially),
- cold water,
- solvent extraction,
- mechanical extraction, and
- spherical agglomeration.

[39] *Business Week*, Jan. 30, 1978

The types of in situ extraction that can be used are thermal stimulation and solvent extraction. The thermal stimulation technique has several approaches involving steam injection or flame propagation.

In situ and underground mining processes are critical to tar sand development since only 10 percent of the U.S. and Canadian tar sand can actually be surface-mined for extraction. The product is a heavy synthetic feedstock, high in sulfur (up to 5 percent) and relatively low in nitrogen (less than 1 percent), which can be cracked to synthetic crude oil and then refined. The mining, extraction, and in situ processes of tar sand have all of the problems of oil shale mining and extraction. There are various R&D projects ongoing in the United States. In Canada, there is a successful commercial tar sands plant producing **50,000** barrels per day of high-quality synthetic crude oil. Several others are scheduled for operation in the 1980's.[40]

Coal Liquids

Liquid hydrocarbons can be produced from coal by four categories of processes—solvent hydrogenation, pyrolysis, hydrocarbonization, and indirect liquefaction. During these processes, the coal is broken into smaller molecules, contaminants such as ash and sulfur are removed, and the proportion of hydrogen in the molecular structure is increased. Synthetic crude oil, premium fuels, feedstocks, or low-ash, low-sulfur boiler fuels are produced.

Indirect liquefaction (e.g., Fischer Tropsch synthesis) involves the gasification of coal in the presence of oxygen and hydrogen. The gas is then purified and passed over a catalyst, yielding liquid products ranging from methanol to heavy hydrocarbons. The process can be directed towards the production of motor fuel and substitute natural gas. This process is currently employed in a State-owned plant (SASOL) in South Africa.

In solvent hydrogenation processes, the coal is dissolved in process-derived solvent, and molecular hydrogen is added directly or in-

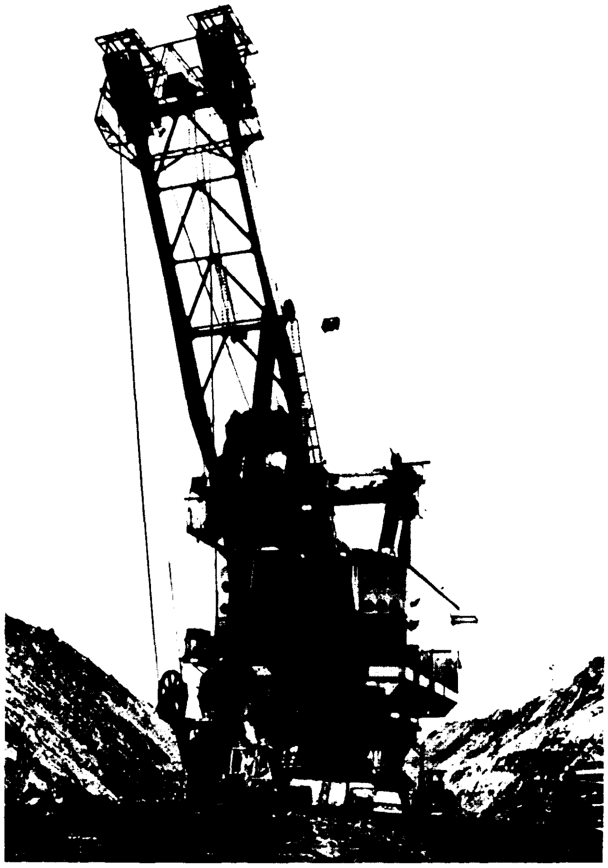


Photo Credit U S Department of Energy

Mining for coal

directly via a hydrogen donor solvent. Solvent hydrogenation processes can be either catalytic or noncatalytic. Catalytic processes are further classified as fixed or ebullating bed reactors to describe how the coal, solvent, and hydrogen mixtures contact the catalysts. Pressure in the solvent hydrogenation reactor ranges from 1,000 to 4,000 psi and temperature ranges from 7500 to 9000 F.

Pyrolysis is similar to coal coking in that the coal is heated to remove tars, gas, and other volatiles, leaving a coal char that is largely carbon. Coal pyrolysis processes usually operate at low pressure (**2o** to **50** psi) and moderately high temperature (1,600 °F), and are noncatalytic.

Hydrocarbonization is a refinement of the coal pyrolysis process and entails noncatalytic carbonization of the coal and thermal cracking of the heavy coal liquids in a hydrogen atmosphere to produce fuel oil, distillates, and gaseous fuels. Hydrocarbonization operates at

[40] U.S. Department of the Navy, Energy and Natural Resources, Research and Development Office, *Energy Fact Book 1977* TT-A-64277-306, April 1977, pp. VII-1 to VII-20.

rnoderate pressure (500 psi) and temperature (1,000° F). Most of the research in the United States is on the direct liquefaction process (the latter three described).

The conversion of coal to a liquid product requires increasing the proportion of hydrogen, either by adding hydrogen or removing carbon. (The hydrogen-to-carbon ratio in coal is 0.9 to 1; in oil it is 1.75 to 1.) The hydrogen for the process can be derived from a catalytic reaction of steam and a light hydrocarbon (usually methane or naptha), a partial oxidation of heavier oil or coal, or an endothermic reaction involving carbon and steam. For the economics of the conversion to be favorable, the energy for hydrogen production must come from the coal itself. A major influence on the cost is the 1imited ability to produce a sufficient supply of hydrogen from the coal-generated energy to maximize the conversion of coal to hydrocarbons.

The use of substitute automotive fuels derived from coal would not require new engine technology. However, new engine technology could reduce fuel quality requirements, and thus fuel cost. Coal liquids could supplement supplies of petroleum available to the automotive sector. In addition, the use of coal liquids as feedstocks for the petrochemicals industry could allow greater use of available petroleum supplies by the automotive sector.

Major constraints to the development and use of coal liquids center on technology, economics, and environmental impacts. Since none of the coal liquefaction processes have been demonstrated in the United States on a commercial scale, it is not clear which process will prove to be the most energy-efficient and cost-effective. As a result, there is uncertainty about investment, operating costs, and production levels.

Coal liquefaction processes generally require high pressures, carefully controlled temperatures, and large reactors for coal conversion. This, in turn, requires specialized equipment that can withstand the corrosive and fouling effects of coal and can adequately control the flow of materials and heat in the reactors. Research is continuing into the development of equipment for commercial-scale application. However, as a result of these specialized equipment needs, the processes are highly capital-intensive.

Before coal liquids can be refined, ash particulate and unreacted solids must be separated and removed. Several processes for ash and solids removal have been developed and are being tested. A major goal is to eliminate excessive char buildup and clogging of feed 1ines and reactor equipment.

Unless heavily upgraded, crude oil derived from coal is generally inferior to natural crude oil because greater quantities of bound nitrogen are present in the synthetic crude. In addition, liquids from coal may be less stable than petroleum liquids. Although processes have been developed to upgrade the quality of coal-derived syncrude, they involve additional costs that hinder the competitiveness of coal liquids.

The price of available conventional fuel supplies (gas and oil) is also an important factor. Given current technology, coal liquids cannot be produced or sold (except at a loss) at current levels of petroleum import prices. Thus, the import price of crude oil must rise before investments in coal liquefaction become attractive, Crude oil prices will rise as existing world supplies of conventional fuels are depleted and/or as a result of a price hike by the OPEC cartel. Both of these mechanisms are largely beyond the control of the United States. Therefore, uncertainty with respect to the price and rate of depletion of existing fuels contributes to uncertainty with respect to the economics of investment in a coal liquefaction industry. Even if the cost of coal liquefaction becomes competitive with petroleum production, factors relating to risk acceptability and capital cost may delay the commercialization of coal liquids. Not only are production processes untested at the commercial level (with the notable exception of SASOL in South Africa), but also the substitution of coal liquids for conventional fuels is relatively untested. However, it is believed that any such changeover will be simple and straightforward.

In addition, few companies have immediate access to the large amounts of capital required for plant construction. Therefore, the rate at which capital can be mobilized (i. e., through the formation of joint ventures or consortia) will have an impact on the level and timing of coal liquids' commercialization.

Other drawbacks involve environmental considerations. Large-scale deployment of coal liquefaction processes could have significant impacts on the air and water quality of the regions in which they are developed. Sources of process emissions are known and conventional techniques are available for emissions control. However, the exact quantities of air and waste-water pollution are not well-known, nor have the overall cost effectiveness and dependability of conventional control techniques been demonstrated for large-scale coal liquefaction plants.

Two other environmental characteristics of liquefaction are of particular concern—the inherently hazardous nature of some organic compounds generated in this process, and the environmental impacts specific to the use of the product coal liquids. Great care must be taken to avoid hazardous exposures to process streams, products, and waste streams. The dangerous organic compounds that exist in air emissions, water effluents, and solid waste can be eliminated through oxidation and decomposition.

Many of the organic liquids derived from coal are both carcinogenic and toxic (as is natural crude oil) and it is not expected that the products of liquefaction will be rendered inert. One example relates to the benzene content of coal-derived liquids. Benzene has been recently recognized as a carcinogen, and both the Environmental Protection Administration and the Occupational Safety and Health Administration are stepping up their regulatory program accordingly. Regulations applicable to petroleum refining and gasoline handling are expected. Gasoline has about 2 percent benzene. Coal-derived gasoline will require greater control than conventional gasoline, since coal liquids have 5- to lo-percent benzene content.

Liquefaction produces a low-ash, low-sulfur fuel, but does little to reduce the nitrogen content of the fuel. To avoid damaging the catalysts in the refinery, most of this nitrogen must be removed before the fuel is refined to gasoline. Use of coal-derived gasoline can result in higher emissions of nitrogen oxide than use of petroleum-refined gasoline, unless the denitrification of the coal-based fuel reduces fuel-bound nitrogen below the level found in petroleum. In addition, coal-derived fuels contain proportionately larger amounts of aromatics and ring-structure compounds. Research is underway to test the effects of these differences in fuel chemical composition on engine exhaust emissions and combustion characteristics.

Still, the greatest technological barriers to coal liquids utilization lie in the production area. The major thrust of present Government and private research is on the development and improvement of coal liquefaction production technology. DOE is currently sponsoring the development of several conversion processes that are in the pilot-plant stage. In fiscal year 1977, $73 million had been spent on R&D for coal liquefaction. Among the chief efforts are the Solvent Refined Coal Process pilot plant at Fort Lewis, Wash.; the H-Coal Process pilot plant at Catlettsburg, Ky.; and Hydrocarbon Research, Inc.

Other projects include the Donor Solvent Liquefaction Process, being developed by EXXON Research and Engineering Company. The production of clean industrial and transportation fuels from coal is being investigated by the Lummus Company through the use of a bench-scale pilot plant.

While significant experimentation has been conducted to determine the optimum operating conditions for coal conversion processes, there has also been extensive research and testing of the ability of coal handling and feeding systems to withstand the corrosive and fouling effects of coal and coal products in the conversion process. Separation of ash and unreacted coal from the viscous coal liquids is a difficult problem common to all liquefaction processes and has also been the focus of considerable development effort. Many techniques are being investigated, including filtration, centrifugation, fractionation, and magnetic and solvent separation.

The time frame for commercialization of coal liquids is long term. As mentioned previously, the rate and extent of market penetration will depend on the price and availability of conventional fuels and the cost (relative to existing fuels) of producing and using coal liquids. In a study for DOE, Energy and Environmental Analysis, Inc., estimated that coal liquefaction plants will first become commercially profitable between 1988 and 2005.[4] Some industry

[4]Energy and Environmental Analysis, Inc., *Integration of Uncertainty in to Industrial Evaluations of Fossil Energy Technologies*, February 1977.

sources predict that synthetic fuels could be available at approximately double the cost of producing liquid fuels from crude oil at current rates. On this basis and assuming assuming a 3-percent-per-year real increase in the current price of imported crude, (about $13 a barrel) coal liquids r-night become profitable around **2000.**

Estimates of capital costs for coal liquefaction plants with 50,000 -bbl-per-day capacity range from $650 million to $850 million." These figures should be regarded with caution. Changes in institutional, environmental, economic, and technological factors could have significant effects on investment and funding levels. Moreover, few firms may be willing to invest in large-scale liquefaction plants until pilot plants have been successfully built and operated. This itself is a lengthy and expensive process, requiring at least 4 years and (depending on pilot plant size), **$50** million to **$200** million.[43]

Alcohol Fuel and Alcohol= Gasoline Blends

Alcohol fuels generally involve the use of either ethanol or methanol, although higher alcohols and ether are potential, but less likely, candidates. Ethanol (grain alcohol) can be manufactured by fermentation from biomass (i. e., municipal and agricultural wastes, plants, grain, etc.).

Methanol is currently produced from natural gas, heavy residuals, or naphtha. Recent research on synthetic fuels has also illustrated the potential for producing methanol from coal. Methanol can also be produced from biomass, but not as readily as ethanol.

Alcohol can be used as an automotive fuel in two ways. It can be blended with regular gasoline in concentrations of up to 20 to 30 percent by volume with only minor changes in automobile engines and fuel systems. Pure (neat) methanol or ethanol can be used only if the engine and fuel system are modified.

The high octane rating of alcohol allows for an increased compression ratio, which in turn provides better thermal efficiency. Thus, although the Btu content per unit volume of alcohol is only about half that of gasoline, it offers potential energy efficiency improvements of 3 to 10 percent relative to gasoline on a weight basis. "

Problems associated with the use of neat methanol include corrosion, cold starting, and vaporlock. However, such problems are routinely solved during the development phase of various gasoline engine changes, and demonstration vehicles burning neat methanol have been successful.

The costs of modifying engine carburetion and fuel feed systems for the use of alcohol-gasoline blends are minor. In many cases, all that is required is carburetor adjustment. In these terms, the potential for the use of alcohol blends is greater than that for neat alcohol. Alcohol fuels can also be used in gas turbines, in external combustion engines such as the Stirling, and in boiler heating applications.

The emission characteristics of engines burning alcohol fuels compare favorably with gasoline-powered engines. In general, pure alcohol fuel shows a reduction in hydrocarbons, carbon monoxide, and nitrogen oxides, although the data are not perfectly uniform or consistent. Emissions tests using pure methanol have shown reductions in NO_x by a factor of two to three over similar tests with gasoline. Ethanol does not appear to offer **as** much of a reduction in regulated pollutants as methanol. Alcohol-gasoline blends seem to alter the emissions in proportion to the amount of alcohol in the blend.

Potential problems could exist with respect to the level of the presently unregulated unburned fuel (UBF) emissions of methanol engines. UBF emissions with methanol are as much as 5 times those of gasoline. Less than 2 percent of the UBF emissions are hydrocarbons; the remainder consist mainly of methanol and aldehydes. These emissions are currently unregulated; their air pollution significance in terms of reactivity and toxicity is not well-understood. If further study

[42] S. Katell and L.G. White, "Clean Fuels from Coal are Expensive," *Hydrocarbon Processing*, July 1976.

[43] Energy and Environmental Analysis, Inc., *Integration of Uncertainty into Industrial Evaluations of Fossil Energy Technologies*.

[44] R.R. Adt et al., "The Effects of Blending Methanol with Gasoline on Geometric Distribution," *Fourth International Symposium on Automotive Propulsion Systems*, April 1977.

demonstrates undesirable impacts caused by aldehyde emissions (such as formaldehyde, which is an irritant) the potential for use of methanol in automotive engines could be limited. This potential problem does not appear to be as serious with ethanol fuel.

Storage and distribution is somewhat more difficult with alcohol. Part of the problem is that alcohol has only about half as much energy per gallon as gasoline; thus storage facilities must be larger to hold gasoline-equivalent amounts of energy. Alcohol and water are miscible, To keep the fuel pure, water contamination in shipping and storing must be prevented. Current gasoline shipping and storage facilities permit water contamination, since the two liquids do not mix and the water can be drained off easily. In the use of alcohol blends, water contamination will cause the two fuels to separate into their respective phases. Ethanol is slightly less subject to water absorption and phase separation than methanol, and may be more attractive in that respect. [45]

The potential availability of alcohol depends upon the costs of producing it relative to the cost of gasoline production from petroleum or other sources. Although methanol can be produced now from natural gas or petroleum, its value as an alternative automotive fuel will presumably rise only if it is produced from nonpetroleum sources.

The use of ethanol produced from organic wastes could become significant in a local or regional area where agricultural wastes are readily available. The use of methanol could be effective on a national scale if it is found to be an energy-efficient, cost-efficient coal conversion product,

Manufacturers can currently produce vehicles that will operate satisfactorily with either methanol or ethanol blends. Autos in Brazil have been operating routinely on 20 percent (and even up to 30 percent) ethanol blends for several years. Volkswagenwerk AG and General Motors have been engaged in prototype testing of methanol-fueled vehicles. [46] Volkswagen's test fleet of 45 methanol-blend test vehicles accumulated nearly 1.8 million kilometers. The only major, practical problem encountered was some corrosion of materials used for some components that came in contact with the methanol blend. Minor adjustments in carburetion are necessary to improve vehicle driveability.

Thus, the experience of test programs and the real experience in Brazil indicate that methanol or ethanol blends could be widely used with little or no problem. However, the production of alcohol fuels in large quantities will probably not be commercially feasible until beyond **1985.**

Research on the use of neat methanol indicates that driveability is presently unsatisfactory in the cold-start and warmup phase of engine operation. Volkswagen is studying the potential for improving driveability by mixing additives with the alcohol fuel or by using an auxiliary fuel during the cold-start phase. General Motors has found the driveability of neat methanol-fueled vehicles to be enhanced through the use of electronic fuel injection systems rather than carburetors. In addition, GM's research has shown that achievement of acceptable driveability requires redesign of the fuel intake system to provide the approximately nine-times-greater mixture heating needed for satisfactory fuel vaporization. Research is continuing in the study of various combinations of air-fuel ratios, ignition timing, and engine compression ratios to obtain the most acceptable compromise among driveability, fuel economy, and exhaust emissions with methanol. Preliminary development of corrosion-resistant automotive and fuel tank storage parts necessary for long-term methanol handling has been completed. In addition, much experience has been gained from the use of methanol in racing cars.

The production of methanol from coal essentially requires the gasification of coal in the presence of hydrogen under high pressure and very high heat. Estimates of costs for coal

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[45] U S. Department of Transportation, Office of the Secretary, *Fuels and Materials Resources for Automobiles in the 1980-1990 Decade*, Report of a Panel of the Interagency Task Force on Motor Vehicle Goals Beyond 1980, March 1976.

[46] N.D. Brinkman, "Vehicle Evaluation of Methanol-Compromises Among Exhaust Emissions, Fuel Economy and Driveability," *Fourth International Symposium on Automotive Propulsion Systems*, April 1977; General Motors Corporation, *1975 General Motors Report on Programs of Public Interest*, J. Van de Weide et al., "Alternative Fuels with Regard to LPG and Methanol, " *Fourth International Symposium on Automotive Propulsion Systems*, April 1977.

FUELS FROM BIOMASS

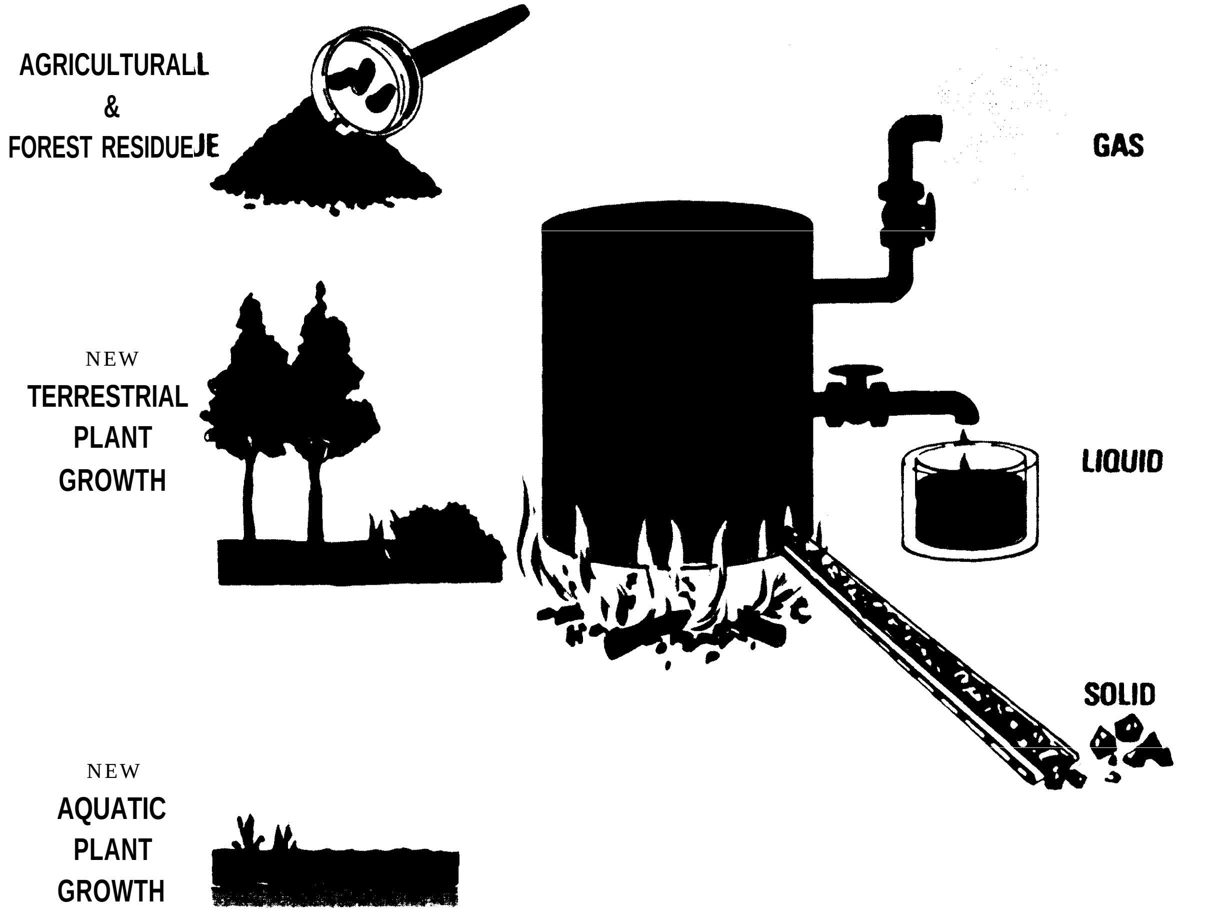

Photo Credit U S Department of Energy

gasification vary with assumptions regarding environmental regulations, coal prices, capital costs, and the commercial application of alternative conversion processes. The fact that there are no coal gasification plants in commercial-scale operation in the United States heightens the risk and cost for potential investors. One estimate of capital costs for the Synthane coal gasification process showed capital investment figures ranging from $420 million to $737.5 million for a 250 million standard-cubic-feet-per-day gas plant [47].

The production of ethanol requires construction of fermentation and distillation facilities that are much different than those currently used. The ability to produce ethanol on a smaller scale, with a local or regional resource and market base, may offer a production advantage over methanol from the standpoint of facility size requirements, startup time, and capital.

In 1974 through 1977, the Nebraska Agricultural Products Industrial Utilization Committee conducted a fleet test with 45 vehicles using a 10-percent ethanol blend. The vehicles traveled over 2 million miles, and no problems were reported with the use of gasohol. The Committee is now involved in facility site selection for ethyl alcohol plants in Nebraska.

In an effort to stimulate the development of alcohol production facilities, the California legislature recently approved a $1.00 per gallon investment tax credit on ethanol sold as a blend with gasoline. Gasohol is also available in Iowa and Illinois in limited quantities. The Colorado legislature recently approved a gasohol program for that State, reportedly because they believe that the use of gasohol in motor vehicles will

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[47] Katell and White.

significantly relieve the air pollution problem in the Denver area.

Current Federal policy consists of subsidizing R&D for coal gasification and liquefaction. A more active Federal policy might consist of price supports and subsidies for the capital and operating costs of producing methanol from coal, Biomass conversion to ethanol or methanol has the inherent advantage of recycling waste products of many types; support in developing these processes would accelerate development in this area.

The Mobil Process: Methanol to Gasoline

Mobil Oil Corporation recently reported the development of a process to convert methanol to gasoline. The process, using a zeolite catalyst, basically dehydrates the methanol. 'i-he end products from pure methanol are gasoline (about 38 percent), water (56 percent), and a small amount of liquid petroleum gas and fuel oil. The gasoline has no sulfur or nitrogen, and has a fairly high octane rating.

It is reported that, to obtain 1 gallon of gasoline, 2.4 gallons of methanol are required, plus $0.10 per gallon refinery costs. Thus the feasibility of commercializing this process depends heavily on the relative costs of methanol versus conventional gasoline. The advantages of this product are that no alterations are required in engines, shipping, or storage facilities. The purity of the product and high octane rating would also be beneficial. [48]

[48] Presentation by William T. Koehl, Mobile Oil Corporation at the Symposium on Alternative Fuels Utilization, University of Santa Clara, Santa Clara, Cant., June 18-23, 1978.

Hydrogen

In recent years, there has been considerable interest in hydrogen as a replacement for petroleum-based fuels. Hydrogen has a high energy content and, if burned with oxygen, is basically emission free. If burned with air in an internal combustion engine, H_2 has potential of greatly reduced emissions, although some NO_x is formed and there are problems with pre-ignition and explosions back through the intake system. Hydrogen is very compatible with alternative heat engines such as the gas turbine and the Stirling engine.

Other problems with hydrogen as a fuel for ground vehicles are centered around storage and the fueling infrastructure. Hydrogen is of very low density as a gas (the lowest of all elements) and would have to be stored and transported under extreme pressure. As a liquid, hydrogen is cryogenic, and the thermal insulation and special handling required would mean that the general use of hydrogen would be costly. Several developments are in progress for storing hydrogen as a metal hydride; they show some promise, but are a long way from practical application. Since hydrogen molecules are small, leakage would always be a problem. Because hydrogen is colorless and odorless, leaks cannot be easily detected or traced.

The potential for hydrogen use exists, but general use is not expected until many problems are solved. In addition, an adequate supply would probably not be available until a cheap, effective method of extracting hydrogen from water is developed.

GLOSSARY

GLOSSARY

Acronyms and Abbreviations

ACRS	Air Cushion Restraint System (commonly called Air Bag)
AGT	Automated Guideway Transit
AMC	American Motors Corporation
AQCR	Air Quality Control Region
BLS	Bureau of Labor Statistics
Btu	British thermal unit
CAFE	Corporate average fuel economy
CBD	Central Business District
CEQ	Council on Environmental Quality
CID	cubic inch displacement
CO	carbon monoxide
CPI	Consumer Price Index
CVCC	compound vortex controlled combustion
CVT	continuous variable transmission
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPI	disposable personal income
DPM	downtown people mover
EGR	exhaust gas recirculation
EPA	U.S. Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
ERDA	Energy Research and Development Administration
FHWA	Federal Highway Administration
FMVSS	Federal Motor Vehicle Safety Standard(s)
FTC	Federal Trade Commission
GMC	General Motors Corporation
GNP	Gross National Product
GRT	group rapid transit
HC	hydrocarbons
HEW	U.S. Department of Health, Education, and Welfare
ICE	internal combustion engine
LARPP	Los Angeles Reactive Pollutant Program
LDV	light duty vehicle
MMBD	million barrels per day
mpg	miles per gallon
MVMA	Motor Vehicle Manufacturers Association
NAAQS	National Ambient Air Quality Standards
NAS NAE	Natural Academy of Sciences and National Academy of Engineers
NEPA	National Environmental Policy Act of 1969
NHTSA	National Highway Traffic Safety Administration
NO_x	nitrogen oxides
OCS	Outer Continental Shelf
OPEC	Organization of Petroleum Exporting Countries
OSHA	Occupational Safety and Health Administration
PIES	Project Independence Evaluation
PL	Public Law
PMT	passenger miles traveled
PMVI	Periodical Motor Vehicle Inspection
PRT	personal rapid transit
RSV	research safety vehicle
SEC	Securities and Exchange Commission
SIE	spark ignition engine
SLT	shuttle-loop transit
SMSA	Standard Metropolitan Statistical Area
SRI	Stanford Research Institute
Sydec	System Design Concepts, Inc.
TCP	transportation control plan
TSM	transportation system management
UMTA	Urban Mass Transportation Administration
U.S.C	United States Code
VMT	vehicle miles traveled
WAES	Workshop on Alternate Energy Strategies
WOCA	World Outside Communist Area

Definitions

Adiabatic—Occurring without loss or gain of heat; in automotive engines, a design that incorporates thermal shielding to prevent radiant heat loss-thereby increasing thermal efficiency and allowing recapture of heat from the exhaust stream.

Air Cushion Restraint System (ACRS)—An automotive safety device in which a sensor, activated by the rapid deceleration caused by impact with another vehicle or a fixed object, triggers a mechanism that inflates air bags in front of the driver and front-seat passengers. The driver bag is housed in the steering wheel hub. The passenger bag is in the area typically used for a glove compartment.

Air Quality Control Region (AQCR)—A geographic area, designated by the Federal Government, where two or more communities either in the same or different States have the same air quality or share a common air pollution problem. ACQRS were established by the Clean Air Act of 1963 as the areas in which attainment of National Ambient Air Quality Standards is to be measured. Currently there are 247 such regions in the United States and its territories.

Air Quality Standards—The prescribed level of pollutants in the outside air that cannot be exceeded legally during a specified time in a specified geographic area. (Also called National Ambient Air Quality Standards.)

Allocation—An administrative distribution of funds by the Federal Government among the States (performed for funds that do not have legislatively mandated distribution formulas).

Appropriation—A legislative action that makes funds available for expenditure with specific limitations as to amount, purpose, and duration. In most cases, an appropriation act permits money previously authorized by substantive legislation to be obligated and payments to be made. In the highway program, appropriations specify the amount of funds which Congress will make available to liquidate prior obligations; that is, the sum of all payments of vouchers to be submitted during a given fiscal year. Highway appropriations permit the payment of obligations incurred in previous years.

Arterial—A highway primarily for through traffic, usually a continuous route.

Authorization—Substantive legislation that empowers an agency to implement a particular program and, in many cases, establishes an upper limit on the amount of funds that can be appropriated for that program.

Automated Guideway Transit (AGT)—A class of transportation systems in which unmanned vehicles are operated on fixed guideways along an exclusive right-of-way. Commonly, AGT systems are divided into three classes: Shuttle-Loop Transit, Group Rapid Transit, Personal Rapid Transit.

Automobile—As used in this study, a four-wheeled vehicle, with a gross weight of less than 6,000 pounds, designed primarily for use as a passenger car. Coupes, sedans, and station wagons of all sizes are considered automobiles. Light-duty trucks and vans, even though used as passenger vehicles, are not classed as automobiles. Motorcycles and mopeds are also excluded.

Barrel—A measure of petroleum or petroleum products, equivalent to 42 U.S. gallons.

Brayton Cycle Engine—A high-speed, external combustion engine in which expanding gases from continuously burning fuel are used to drive a turbine. Most of the turbine output is used as motive power, but some is used to drive a compressor to provide air for the combustion process. (Also known as Gas Turbine Engine.)

British Thermal Unit (Btu)—The quantity of heat required to raise the temperature of 1 pound of water 1 degree Fahrenheit at or near 39.2 F. (used as a measure of the energy content of fuels).

Corporate Average Fuel Economy (CAFE)–The sales-weighted average fuel consumption (in mpg) for all passenger vehicles sold by an automotive manufacturer in a given model year.

Capacity (Highway)—The maximum number of vehicles that can pass over a given section of a lane or roadway in one direction (or in both directions for a two-lane or three-lane highway) during a given time period under prevailing roadway and traffic conditions.

Categorical Grant—As applied to highway financing, funding from a higher level of government (Federal or State) that is earmarked for expenditure for particular purposes.

Central Business District (CBD)—Usually the downtown retail trade area of a city, or generally an area of very high land valuation, traffic flow, and concentration of retail business offices, theaters, hotels, and service businesses.

Cetane Number—A measure of the ignition value of a diesel fuel, representing the percentage by volume of cetane in a mixture with methylnaphthalene that gives the same ignition lag as the fuel being tested (also called "cetane rating"). For gasoline, the equivalent measure is octane number.

Chassis—The frame, wheels, and machinery of a motor vehicle, on which the body is supported.

Civilian Labor Force—The total number of persons 16 years old and over who are employed and those who are unemployed and seeking work, excluding members of the Armed Forces and institutionalized persons.

Collector (Collector/Distributor)—A free access road that provides the link between arterials and local access streets.

Compact-Size Car—A pre-1975 automobile industry designation for cars with a wheelbase between 101 and 111 inches. After 1975 these cars are included in the **small** category. (See Vehicle Size Class.)

Consumer Price Index (CPI)—The index issued by the U.S. Department of Labor, Bureau of Labor Statistics, as a measure of average changes in the retail prices of goods and services usually bought by the families of wage earners and clerical workers living in cities.

Contract Authority—A form of budget authority that permits obligations to be made for the full amount of the authorization (i.e., the empowerment to enter into contracts in advance of appropriations). The Federal-Aid Highway Program utilizes contract authority.

Conventional Transit—A system or organization providing intraurban common-carrier passenger service by vehicles carrying 12 or more seated passengers over at least one regular fixed route with a published time schedule (does not include variable-route service, unscheduled service, or interurban service).

Crash **Avoidance (Systems)**—Motor vehicle systems designed to avoid collisions or to reduce the impact velocities of collisions that cannot be avoided. They are intended to overcome:

- failure or inability of the driver to see or otherwise perceive a hazardous circumstance soon enough,
- inability of the driver to respond quickly enough once an impending crash circumstance is recognized, and
- inadequate response of the vehicle to appropriate or typical driver inputs.

Crashworthiness—Motor vehicle design features (vehicle structure and occupant restraint systems) that reduce the severity of injuries to vehicle occupants and damage to the vehicle when a collision occurs. (See also Vehicle Damage Protection.)

Curb Weight—The weight of the empty vehicle (including fuel). (See also Gross Vehicle Weight.)

Diesel **Engine**—An internal-combustion engine in which the fuel is injected into the cylinder near the completion of the compression stroke and is ignited by the heat of the compressed air in the cylinder. No spark plug or carburetor is needed.

Diesel **Fuel**—The middle distillate petroleum fraction used as a fuel in diesel or compression ignition engines. (Most diesel fuels have a cetane number in the range of 30 to 65.)

Disposable Personal Income (DPI)—The income remaining to individuals after deduction of all personal taxes and all nontax payments to governments.

Drivetrain—The combination of gears, clutches, shafts, etc. that transmit energy from the engine to the wheels.

Emissions—All substances discharged into the air from a stack, vent, tail pipe, carburetor, or other source.

Emission Standards—The maximum amount of a pollutant that can legally be discharged from a single source, either mobile or stationary.

Ethanol—A colorless, volatile, inflammable liquid (C_2H_6O); any of various compounds that are analogous to ethyl alcohol in constitution and that are hydroxl derivatives of hydrocarbons. (Also called ethyl alcohol.)

Expressway—(See Freeway.)

Fatality—As applied to automobile safety, a death that occurs within 1 year as the result of an automobile accident.

Federal-Aid Highway Program—Those programs that apportion Federal funds to the States, with a requirement for State matching funds, for the Interstate, primary, secondary, and urban systems and for the urban extensions of the primary and secondary systems. Other Federally supported programs, such as Forest Highways, Highway Beautification, etc., are not included under this term.

Federal-Aid Highway Systems—The four categories of roads eligible for Federal funds:

1. *Federal-Aid Primary System*—a system of connected main highways within each State.
2. *Federal-Aid Secondary System*—A system of secondary roads including farm-to-market roads, rural mail routes, public school routes, local rural roads, access roads to airports, county roads, and township roads.

3. Interstate System-Technically The National System of Interstate and Defense Highways; a system of freeways established by the Federal Government in 1944 to connect principal cities and industrial areas.
4. ***Federal-Aid Urban*** System/-A system of roads, including some extensions of the Interstate System, that serves major urban activity centers and includes high-volume arterial and collector routes and access roads to terminals of other transportation modes.

Fleet—The total stock of vehicles in use in the country.

Freeway (Expressway)—A divided arterial highway designed for the safe unimpeded movement of large volumes of traffic, with full control of access and grade separations at intersections.

Fuel Cell—An electrical power source in which fuel and oxidant are fed continuously to the electrodes, converting chemical energy into electrical energy directly, without the need to recharge an electrical outlet.

Gross National Product (GNP)—The market value of all goods and services produced by the Nation's economy. As calculated quarterly by the Department of Commerce, gross national product is the broadest available measure of the level of economic activity.

Gross Vehicle Weight—The weight of the empty vehicle plus the weight of the maximum anticipated load. (See also Curb Weight.)

Highway Trust Fund—A trust fund established by Congress in 1956 to finance construction of the 45,000-mile National System of Interstate and Defense Highways. Trust Fund revenues accrue from highway user taxes.

Household—All persons occupying a housing unit.

Household Formation—The establishment of new households (individuals, couples, or families); the consumer unit that rents or buys and occupies housing units. New households are formed by marriage, divorce or separation, children moving from their parents' homes to their own dwelling units, or movement from group quarters to individual dwelling units.

Hybrid Vehicle—A vehicle with two propulsion systems that use different sources of energy—typically an energy storage system (battery or flywheel) and an internal-combustion engine to provide auxiliary power for periods of heavy load, such as during acceleration or high-speed cruise.

Hydrocarbon—An organic compound made up entirely of carbon and hydrogen.

Hydrocarbon Fuels—Fuels that contain an organic chemical compound of hydrogen and carbon.

Intermediate-Size Car—A pre-1975 automobile industry designation for cars with a wheelbase between 112 and 118 inches. (See Vehicle Size Class.)

Internal Combusiton Engine (ICE)—Any engine, either reciprocating or rotary, in which the fuel is burned inside of the engine.

Interstate Highway System—(See National System of Interstate and Defense Highways.)

Jitney–A car or small bus that carries passengers over a regular route according to a flexible schedule.

Lead —Tetraethyl lead or any other organo-metallic lead compound added to gasoline to prevent engine knock.

Light-Duty Vehicle (LDV)—Any motor vehicle either designed primarily for transportation of goods and rated at 6,000 pounds gross vehicle weight (GVW) or less, or designed primarily for transportation of persons and having a capacity of 12 persons or less.

Light Truck—A truck with a gross vehicle weight of 10,000 pounds or less.

Local Street—A street intended only to provide access to abutting properties.

Mass Transit—For-hire, common-carrier, ground passenger transportation service provided for travel within communities or metropolitan areas. Included are all forms of surface, elevated and subsurface modes that use fixed guideways or operate on streets, highways or waterways. All air transportation modes are excluded.

Methanol—A light, volatile, poisonous liquid alcohol (CH_40) formed in the destructive distillation of wood or made synthetically.

Middle Distillates—A category of petroleum fuel that includes home heating oil and the diesel fuels burned by surface transportation carriers.

Mobility—The satisfaction of travel demand. The parameters of mobility are number of trips, trip length, number of persons served, and the mode of transportation.

Modal Split—The distribution of person trips by mode of travel.

Motor Bus—A rubber-tired, self-propelled, manually steered transit vehicle with fuel supply carried on board.

National Ambient Air Quality Standards (NAAQS)—The prescribed levels of atmospheric pollutants that cannot be exceeded legally during a specified time in a specified geographic area. NAAQSS are established by EPA under the authority of the Clean Air Act of 1970.

National System of Interstate and Defense Highways—A system of freeways established in 1944 to connect principal cities and industrial areas. It was later expanded to include mileage within urban areas. Dedicated construction funding is provided through the Highway Trust Fund for the planned 42,500-mile system.

Nitrosamines—Any of various neutral compounds that are characterized by the grouping NNO, some of which are powerful carcinogens.

No-Fault Insurance—A motor vehicle insurance plan under which an accident victim is compensated, usually up to a stipulated limit, for actual losses (as medical bills and lost wages) but not for claims of pain and suffering, by his own insurance company regardless of who is responsible for the accident.

Obligations—Commitments made by Federal agencies to pay out money, as distinct from the actual payments, which are "outlays." Generally, obligations are incurred after the enactment of budget authority. However, since budget authority in the highway program is in the form of contract authority, obligations are permitted to be incurred immediately after apportionment.

Octane Number—A number that is used to measure the antiknock properties of liquid motor fuel.

Oil Shale—A finely grained sedimentary rock composed mostly of clay that contains an organic material called kerogen, which can be refined into a product with properties similar to petroleum fuels.

Organization of Petroleum Exporting Countries (OPEC)—The Association of the world's largest oil producing and exporting countries. There are 12 full members: Abu Dhabi, Algeria, Ecuador, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, and Venezuela. Gabon is an associate member.

Otto Cycle Engine—A spark-ignition, internal combustion engine, fueled by a mixture of gasoline and air that is introduced in a cylinder and ignited by an electrical spark. Also called four-stroke cycle since two revolutions per cylinder or four piston strokes are required: intake, compression, power, exhaust.

Paratransit—Forms of public transportation that provide modes of service between that of the private automobile and conventional transit. Paratransit can be grouped into three categories: hire and drive, hail or phone, and prearranged shared use.

Particulates—Any material, except uncombined water, that exists as a solid or liquid in the atmosphere or in a gas stream at standard conditions. The particulate matter in automobile exhaust is made up of several organic substances, including lead.

Passenger Miles Traveled (PMT)—One passenger traveling one mile. As a measure of transportation, the aggregate of the miles traveled by all passengers on all trips for a given time period for a specified area.

Passive Restraint—A device, requiring no prior action by the user, that restrains motor vehicle occupants from possible injury-producing movements during a collision.

Performance (Automobile)—The capability of the automobile to accelerate, to perform passing maneuvers, and to climb grades. One measure is the time required to accelerate from 0 to 60 mph.

Personal Consumption Expenditures.—The market value of purchases of goods and services by individuals and nonprofit institutions and the value of food, clothing, housing, and financial services received by them as income in kind. It includes the rental value of owner-occupied houses, but excludes purchases of dwellings, which are classified as capital goods (investment).

Pickup Truck—A vehicle with an enclosed cab for the driver and an open-topped metal box over the rear wheels.

Public Transit—(See Mass Transit.)

Public Transportation—(See Mass Transit.)

Rail Rapid Transit—A mode of urban transportation in which transit vehicles operate on a fixed rail guideway.

Rankine Cycle Engine—An external-combustion engine in which a working fluid is expanded and contracted to transform chemical energy into mechanical energy.

Revenue Passenger Mile—One revenue-paying passenger traveling one mile. As an aggregate, revenue passenger miles represent the total distance traveled by all transit passengers.

Revenue Vehicle-Mile—One transit vehicle (bus, trolley car, subway car, etc.) traveling one mile while in revenue service. Revenue vehicle-miles represent the total mileage traveled by vehicles in scheduled or unscheduled revenue-producing services.

Spark-Ignition Engine—An engine employing an electrical device to create a spark to initiate combustion of the fuel-air mixture.

Standard-Size Car—A pre-1975 automobile industry designation for cars with a wheelbase of 119 inches or more. (See Vehicle Size Class.)

Stirling Cycle Engine—An external-combustion engine in which heat from burning fuel is used to expand a confined working fluid (usually helium or hydrogen) that drives a piston. The expanded (and thus cooled) working fluid is compressed and reheated for another piston stroke.

Stratified-Charge Engine—A slightly modified Otto cycle engine in which fuel is fed into the cylinders in a way that produces a rich fuel-air mixture near the spark plug and a lean mixture elsewhere. The spark plug ignites the rich mixture which, in turn, ignites the lean mixture, producing a more complete burn and in some designs, a more efficient use of fuel.

Subcompact Car—A pre-1975 automobile industry designation for cars with a wheelbase of 100 inches or less. After 1975 these cars are included in the small category. (See Vehicle Size Class.)

Synthetic Fuel (Synfuel)—A fuel that does not exist in nature, but can be manufactured or synthesized from natural materials. Generally, synthetic fuels are derived from other forms of fossil fuels that are less convenient for consumer use. Synthetic liquid fuels are produced from coal, shale, and tar sands.

Tar sands—Geological deposits of sand and clay that are heavily impregnated with oil.

Three-Way Catalyst—A treatment system for automobile exhaust that employs platinum or rhodium as the active noble metal catalyst for conversion of HC, CO, and NO_x. The device derives its name from the fact that it acts on the three major atmospheric pollutants in automobile exhaust.

Transit—(See Mass Transit.)

Truck—A motor vehicle designed primarily for goods movement which is used on public highways and streets.

Turbocharger—An air compressor driven by exhaust gases from an engine and used to force the fuel-air mixture into the cylinders at greater than atmospheric pressure, thereby boosting the power of the engine.

Vehicle Damage Protection—Vehicle design features intended to reduce the cost of damage to the vehicle in low-speed collisions. These features have no effect on death or injury to vehicle occupants. (See also Crashworthiness.)

Vehicle Miles Traveled (VMT)—One vehicle traveling one mile. As an aggregate measure, VMT represents the travel by all vehicles on a given roadway or on all roadways in a specified geographic area during a given time period.

Vehicle Size Class—A classification of motor vehicles by length. Pre-1975 and post-1975 size classes are shown in the following table:

Pre-1975	Post-1975
Subcompact (100” or less)	Small (less than 100”)
Compact (101” -111“)	Medium (100” - 112”)
Intermediate (112” - 118”)	Large (over 112”)
Standard (119” or over)	

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