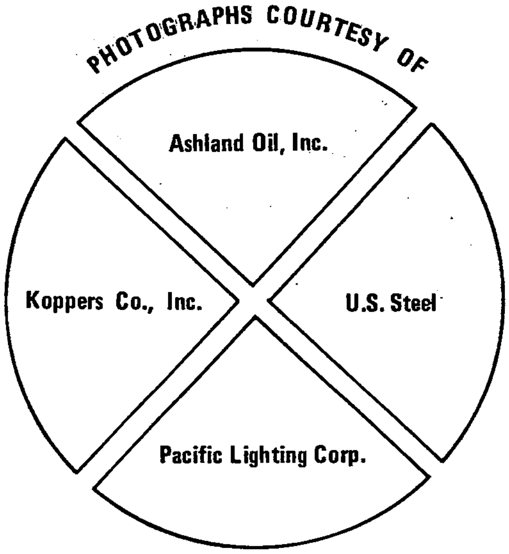
Potential for ENERGY CONSERVATION in the United States: 1974-1978

A Report of the National Petroleum Council

TRANSPORTATION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POTENTIAL FOR ENERGY CONSERVATION
IN THE
UNITED STATES: 1974-1978
TRANSPORTATION

A Report of the
Transportation Task Group
E. R. Heydinger, Chairman

Prepared for the
Committee on Energy Conservation of the
National Petroleum Council
Maurice F. Granville, Chairman

With the assistance of the
Coordinating Subcommittee
Robert C. McCay, Chairman

September 10, 1974

NATIONAL PETROLEUM COUNCIL

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PREFACE

The Transportation Task Group was organized under the National Petroleum Council's Committee on Energy Conservation in November 1973. In response to the charge of the Coordinating Subcommittee, based on the study request letter from the Secretary of the Interior (see Appendix A), the Transportation Task Group prepared an appraisal of short-term, 1974-1978, energy conservation measures applicable to the six basic modes as well as the miscellaneous energy usage of the transportation sector. The modes evaluated account for all of the energy consumed in the transportation sector. This report represents the detailed work which served as the basis for Chapter Four of the National Petroleum Council's report, *Potential for Energy Conservation in the United States: 1974-1978*, published September 10, 1974.

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INTRODUCTION

In the United States during 1972, energy consumed in the transportation sector was equivalent to about 9 million barrels per day of petroleum products or about 17.8 quadrillion British Thermal Units (BTU's) of energy on an annual basis. This consumption represents nearly one-fourth of the Nation's total energy requirement.

The importance of transportation is evidenced in that approximately 20 percent of national expenditures [Gross National Product (GNP)], 16 percent of the taxes, 10 percent of the investment and 12 percent of the Nation's employment are provided directly by this sector. Transportation both supports and is dependent on the industrial sector, consuming 75 percent of the rubber output, 67 percent of the lead, 36 percent of the zinc, 27 percent of the cement, 24 percent of the steel and 21 percent of the aluminum.

Future transportation energy requirements were expected to grow to about 11 million barrels per day (21.8 quadrillion BTU's) by 1978 under a Past Trends-Continue case which would assume no change in real energy costs from the 1972 level. This scenario was used as a base case for measuring the impact of energy conservation possibilities.

This report discusses the possibilities of improving the efficiency of energy use and other ways of reducing energy consumption in the transportation sector, focusing on conservation measures that could be implemented by 1978.

For purposes of analysis, the entire sector has been categorized into six basic modes:

- Highways
- Airways
- Railways
- Waterways
- Urban Public Transit
- Pipelines.

Figure 1 diagrams the breakdown of transportation energy use among these modes and shows the dominance of the "highway" category.

The highway mode accounted for 75 percent of 1972 transportation energy consumption and most of this was used in cars and light trucks. Clearly, this category is the dominant area of energy conservation potential within the transportation sector. Table 1 shows the detailed breakdown of energy consumption within the transportation sector for 1972. Also shown on this table is a "miscel-

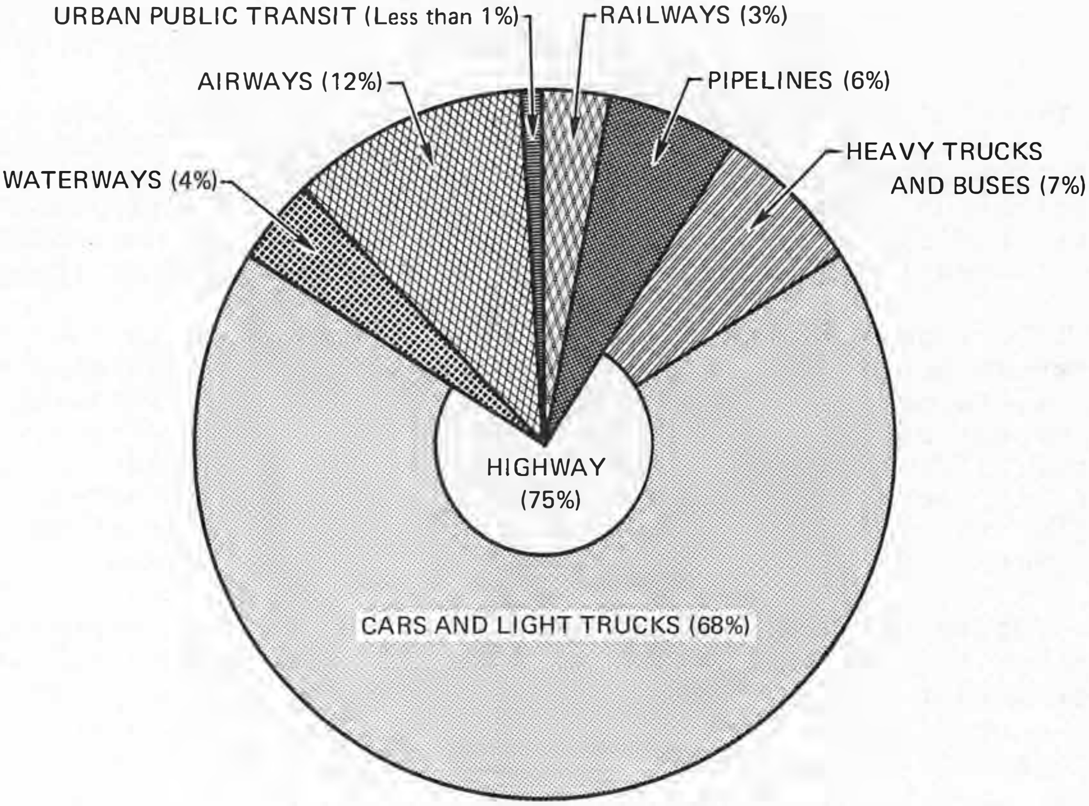

Figure 1. Components of Transportation Energy--1972.

laneous" category which includes energy consumption in such areas as farm and construction equipment. Although the discussion of conservation possibilities in the miscellaneous area is covered in this transportation report, the consumption volume has been included in the Industrial Task Group report.

There are large differences in energy efficiency among the various modes of transportation; however, the desire for ever greater speed and flexibility has generally directed utilization toward the less efficient modes. A number of other factors such as the relatively low cost of energy, growth in suburban living, emission controls, and the simultaneous demand for increased mobility have jointly resulted in a rapid rise in energy consumption. A vast array of problems will be encountered in any attempt to modify the transportation system, requiring utmost coordination and cooperation among government, business, and the general public. The national economy and existing life-styles were created, in part, through utilization of a flexible, multi-faceted transportation system and the far-reaching impact of any changes imposed on that system must be carefully balanced with the objectives of energy conservation.

TABLE 1

TRANSPORTATION ENERGY AND RELATED CONSUMPTION BY MODE AND PURPOSE*—1972

	Thousand Barrels Per Day			Quadrillion BTU's	Percent of Total Transportation Energy
	Gasoline	Distillate†	Other		
Highway					
Passenger Cars					
Private (Personal Use)	3,886.0	–	–	7.46	42.96
Commercial and Other	870.8	–	–	1.67	9.63
Total	**4,756.8‡**	–	–	**9.13**	**52.59**
Single Unit (Light Trucks)					
Private (Personal Use)	669.1			1.29	7.40
Commercial§	705.3	31.9	–	1.42	8.15
Government	32.9	.2	–	.06	.36
Total	**1,407.3**	**32.1**	–	**2.77**	**15.91**
Combination (Heavy) Trucks					
Commercial§	69.4	483.0	–	1.16	6.11
Government	.9	6.2	–	.01	.07
Total	**70.3**	**489.2**	–	**1.17**	**6.18**
Buses					
School	20.4	.4	–	.04	.23
Urban	2.0	18.8	1.6‖	.05	.25
Intercity	3.0	12.1	–	.03	.16
Total	**24.4**	**31.3**	–	**.12**	**.64**
Motorcycles	22.3	–	–	.04	.25
Total Highways	6,281.0	552.6	1.6		
	6,835.1			**13.23**	**75.57**
Airways					
Airlines					
Scheduled	–	670.0	–	1.39	7.41
Supplemental	–	6.0	–	.01	.07
Total	–	**676.0**	–	**1.40**	**7.48**
General Aviatior	46.0	37.0	–	.17	.92
Military	–	288.0#	–	.57	3.18
Factory and Miscellaneous	–	20.0	–	.04	.22
Total Airways	46.0	1,021.0	–		
	1,067.0			**2.18**	**11.80**
Railways	–	247.3	3.1**	.53	2.77
	–	.8††	–	–	.01
Total Railways	–	248.1	3.1		
		251.2		**.53**	**2.78**

TABLE 1 (Cont'd)

TRANSPORTATION ENERGY AND RELATED CONSUMPTION BY MODE AND PURPOSE*—1972

	Thousand Barrels Per Day			Quadrillion BTU's/Year	Percent of Total Transportation Energy
	Gasoline	Distillate†	Other		
Waterways					
Private and Commercial	44.8	65.9	—	.23	1.22
Commercial					
At Port	—	—	41.0	.09	.45
At Sea	—	—	196.0	.45	2.18
Total Waterways	44.8	65.9	237.7	—	—
		348.4		.77	3.85
Urban Public Transit (Nonhighway)††					
Rapid Transit	—	—	3.4	.01	.04
Surface Railway	—	—	.2	—	—
Trolley Coach	—	—	.2	—	—
Total UPT	—	—	3.9	.01	.04
Pipeline					
Total Pipeline	—	167.9‡‡	371.0§§	—	
			538.9	1.15	5.96
Total Transportation Energy	6,371.8	2,055.5	617.3		
		9,044.6		17.86	100.00
Miscellaneous					
Farm Equipment‖‖	134.0	144.0	—	.56	—
Construction Equipment	45.0	281.0	—	.69	—
Utility Engines##	22.0	—	—	.04	—
Snowmobiles	5.0	—	—	.01	—
Race Cars	.5	—	—	—	—
Total Miscellaneous	206.5	425.0	—		—
		631.5		1.30	
GRAND TOTAL	6,578.3	2,480.5	617.3		—
		9,676.1		19.16	

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*Data may not agree with Bureau of Mines data as some volumes are estimated and some are based on Federal Highway Administration or tax data which could include changes in secondary inventories.

†Distillate as used includes the full range of middle distillate oils including diesel fuels, kerosine jet fuel, marine diesel and also naphtha jet fuel.

‡Due to the necessity of using data as described in footnote (*), this volume and the respective BTU value does not precisely agree with the values shown by the Patterns of Consumption/Energy Demand Task Group.

§Private business and for hire.

‖Propane.

#242,000 barrels per day naphtha jet fuel; 46,000 barrels per day kerosine jet fuel.

**Residual oil.

††Electricity converted to distillate equivalent.

‡‡Liquids pipeline fuels converted to distillate equivalent.

§§Natural gas pipeline fuels converted to distillate equivalent.

‖‖Fuel for motive purposes.

##Small horsepower engines, lawnmowers, tillers, etc.

SUMMARY OF SHORT-TERM CONSERVATION POTENTIALS

In order to evaluate the energy conservation potentials in each transportation mode, various conservation measures are appraised in terms of the savings potential, factors of implementation (methods, incentives, relative time and costs), impact (social, economic, political, and environmental), public acceptance and overall feasibility. The volumes of energy savings potentials, based on many assumptions, are estimated for 1974 and 1978 for each measure. An overall assessment of the potentials that have been identified is shown on Table 2. It is very important to caution that *these potentials are not additive* and more often result in interaction or even competition and duplication. For example, even if vehicles are rendered more efficient, the gain would be offset where there is a transfer of load (people or goods) to a different means of transportation. Since the load can only be transferred to one other means at a given time, the savings will not accrue in duplicate.

In considering transportation conservation options, this report does not attempt to select or recommend the implementation of particular measures. The intent is to identify and discuss the possibilities that exist and to present them in a framework which allows informed judgments by others.

While the reader is cautioned that the potential savings identified under each of the various modes cannot be totalled, the study has identified a large number of energy conservation measures. An examination of these options, as summarized in Table 2, discloses that there are six specific actions that offer the major share of conservation potential in the transportation sector:

- More small cars
- Increased car-pooling
- Modified exhaust emissions and gasoline lead regulations
- Improved auto design
- Reduced speed limits
- Improved vehicle maintenance.

One of the difficult aspects of the analysis is that of distinguishing between energy-conserving actions (more accurately "reactions") that could or will result from increased energy costs and those attributable to non-cost causes. In this regard, energy conservation can result from one or a combination of the following actions:

- Higher costs, resulting in energy-saving actions
- Direct conservation actions, regulatory or voluntary.

TABLE 2

CONSERVATION MEASURE EVALUATION MATRIX

Mode	Conservation Measure	1972 Base Consumption	Potential Savings Volumes* 1974	Potential Savings Volumes* 1978	Implementation Values: Methods & Incentives	Implementation Values: Relative Time†	Implementation Values: Relative Costs‡	Impact Factors & Relative Values§: Social	Impact Factors & Relative Values§: Economic	Impact Factors & Relative Values§: Political	Impact Factors & Relative Values§: Environment	Relative Public Acceptance	Feasibility Factor —Overall—‖
		(Thousand Barrels per day)											
I. Highway													
A. Passenger Cars													
	1. Car-pooling (To & From Work)	1,832	92	325	Priority parking, reduced tolls, tax deductions, insurance discounts, employer subsidies, etc.	Reasonably short 3	Low 3	Loss of independence, privacy, flexibility, status, etc. 1	Longer commuting time; loss of revenue to business and government; lower auto sales; lower commuting costs. 2	Negligible 2	Less pollution, congestion, & noise; reduced land requirements for roads & parking lots. 4	1	16
	2. Travel Characteristics												
	a. Driving Restrictions	3,593	38	46	Auto use restrictions as auto free zones; reduced parking; higher parking rate & tolls; special permits, etc.	Moderate 2	Low 3	Arbitrary nature—loss of personal freedom, discriminatory; changed locations of work & shopping centers. 1	Shift of sales patterns; higher motoring costs; increased government revenues (tolls, taxes, etc.); reduces low efficiency city driving. 2	Requires legislative action 1	Cleaner & less congested cities. Causes more urban sprawl 2	1	12
	b. Four-Day Work Week	2,267	102	125	Employer Options	Reasonably Short 3	Low 3	More leisure time 3	Increased sales of recreational equipment. 2	Negligible 2	Reduced congestion & pollution; greater demands on recreational areas. 2	2	17
	c. Walking & Bicycling	850	2	40	Auto disincentives and creation of bicycle & walkways.	Substantial 1	Moderate 2	Improved health; increased local awareness; higher accident potential 3	More or less travel time depending on distance & congestion; limited hauling capacity; lower demand for cars. 2	Significant implementation requires legislation. 2	Reduced pollution & congestion. 3	3	16
	d. Driver Behavior	5,425	57	70	Driver education & efficiency monitoring devices	Moderate 2	Low 3	Negligible 2	Negligible 2	Government programs & encouragement would be helpful 2	Negligible 2	2	15
	3. Speed Limits	5,425	168	190	Government Mandate	Immediate 3	Moderate 2	Balance of safety factors—longer driving time vs. lower fatality & injury rates 2	Cost in terms of lost time vs. lower driving costs and lower costs associated with reduced fatality & injury rates 2	Unclear 2	Negligible 2	1	14
	4. Auto Design	4,757	0	236	Economic incentives or mandate	Moderate 2	Moderate 2	Negligible 2	Lower driving costs; higher cost of cars 2	Legislative action might be required 2	Negligible 2	3	15
	5. Vehicle Maintenance	5,425	142	174	Mandatory requirements or educational programs	Immediate 3	High 1	Discriminates against low income group; Possible safety improvement 1	Higher maintenance cost vs. lower fuel consumption; Increased revenues for auto maintenance industry 2	Legislative action might be required 1	Less pollution 3	1	12
	6. Vehicle Changes (Small Cars)	4,757	73	361	Economic incentives; efficiency or fuel taxation; educational programs	Moderate 2	Moderate 2	Reduced safety 2	Lower driving costs; improve balance of payments; employment and production curtailment during conversion 2	Legislative action might be required. 2	Less pollution; lower resource requirements 3	3	16
	7. Emission Standards and Lead Phasedown	6,164	0	280	Government Mandate	Immediate 3	Negligible 3	Possible adverse health impact 2	Lower driving cost via improved fuel efficiency; lower refining investment & costs; lower cost cars; Higher costs due to pollution 3	Requires legislative action 2	Higher initial levels of pollution 1	2	16

TABLE 2 (Cont'd)

CONSERVATION MEASURE EVALUATION MATRIX

Mode	Conservation Measure	1972 Base Consumption (Thousand Barrels per day)	Potential Savings Volumes* 1974	Potential Savings Volumes* 1978	Implementation Values: Methods & Incentives	Implementation Values: Relative Time†	Implementation Values: Relative Costs‡	Impact Factors & Relative Values§: Social	Impact Factors & Relative Values§: Economic	Impact Factors & Relative Values§: Political	Impact Factors & Relative Values§: Environment	Relative Public Acceptance	Feasibility Factor —Overall—‖
	8. a. Mode Shifts (From Cars)												
	1. Urban Bus	4,757	0	33	Auto disincentives; bus lanes; encouragement of greater bus production and scheduling improvements; government subsidies.	Moderate 2	High 1	Loss of independence & flexibility, privacy, status, etc.—greater safety. 2	Longer commuter time & lower costs; lower auto sales; loss of revenues to business & government. 2	Subsidies and operating priorities (bus lanes) would require legislation. 3	Less pollution, congestion & lower parking needs 4	1	15
	b. Intercity: Bus Train Air		0 0 0	31 15 38	Government policies for encouragement and subsidies, especially for train service, auto disincentives (tolls & taxes), improved service.	Bus - Moderate 2 Train - Long 1 Plane - Short 3	Bus - Moderate 2 Train - High 1 Plane - Low 3	Increased safety; loss of convenience & flexibility on arrival. 2	Loss of time (except air); expansion would create jobs; lower car sales & associated revenues. 3	Subsidies & disincentives require legislation. 2	Less pollution, congestion 3	Bus 2 Train 1 Air 2	Bus 16 Train 13 Air 18
B.	Commercial Trucking	1,289											
	1. Speed Limits (Intercity)	609	18	22	Government Mandate	Immediate 3	Moderate 2	Balance of safety facto's-longer driving time vs. lower fatality rate; time away from family. 1	Overall productivity loss. 0	Unclear 2	Negligible 2	2	12
	2. Design	559	6	7	Economic incentives or mandate.	Moderate 2	Low 3	Negligible 2	Negligible 2	Negligible 2	Negligible 2	2	15
	3. Weight (Heavy Trucks)	559	0	24	Government Mandate	Reasonably Short 3	Low 3	Negligible 2	Increased productivity & lower operating costs. Greater roadway wear. 3	Negligible 2	Reduced trips & less pollution & congestion. 3	2	18
	4. Maintenance & Operating Procedure	559	20	37	Economic Incentives	Immediate 3	Low 3	Negligible 2	Lower operating costs. 3	Negligible 2	Negligible 2	2	17
	5. Mode Shifts (From Trucks)	296	25	30	Economic incentive, subsidies to rail to improve service	Moderate 2	High 1	Negligible 2	Lower Shipping costs. 3	Questionable cost-value judgement. 1	Less rural congestion, more urban congestion & pollution 1	2	12
C.	Intercity Buses												
	1. Expanded Utilization (See I. A. 8. b.)												
	2. Operating Efficiencies		– Insignificant –										
D.	Roadway Improvements		– Insignificant –										
II.	Airways												
A.	Operating Efficiencies	1,067	41	55	Reduced cruise speeds; improved traffic control; switch training to simulation	Reasonably short 3	Low 3	Negligible 2	Increased efficiency 3	Negligible 2	Less noise & pollution 3	2	18
B.	Flight Reductions	1,067	104	Unclear	Reduced flights via increased load factors; economic incentives	Immediate 3	Low 3	Travel Difficulties 1	Reduce employment; increased unit costs; idle aircraft; less ability to absorb higher costs. 1	Negligible 2	Less noise, pollution & airport congestion. 3	1	14
III.	Railways												
	Operating Efficiencies	251	15	20	Improved fuel management and maintenance; computerized control techniques; —economic incentives	Reasonably short 3	Low 3	Negligible 2	Increased Efficiency 3	Negligible 2	Negligible 2	2	17
IV.	Waterways												
A.	Operating Efficiencies	348	23	25	Speed reductions; improved turnaround; economic incentives.	Reasonably short 3	Low 3	Negligible 2	Increased Efficiency 3	Negligible 2	Negligible 2	2	17
B.	Mode Shifts (To Water)	–	0	3	Expanded use of St. Lawrence Seaway to maximize Great Lakes. Economic incentives thru change in freight rate schedules.	Moderate 2	Low 3	Negligible 2	Shift of revenues among carriers & ports; increased efficiency via lower transportation cost. 3	Requires legislation 1	Improved balance for water and land freight traffic. 3	2	16

TABLE 2 (Cont'd)

CONSERVATION MEASURE EVALUATION MATRIX

Mode	Conservation Measure	1972 Base Consumption	Potential Savings Volumes*		Implementation Values			Impact Factors & Relative Values§				Relative Public Acceptance	Feasibility Factor —Overall—‖
		(Thousand Barrels per day)	1974	1978	Methods & Incentives	Relative Time†	Relative Costs‡	Social	Economic	Political	Environment		
V. Urban Public Transit													
	A. Increased peak hour ridership	1,832	14	14	Auto disincentives; Improved scheduling; bus lanes	Immediate 3	Negligible 3	Greater safety; loss of independence, flexibility, privacy, status, etc., increased crowding, standing, & discomfort 1	Longer commuter time; lower commuter costs; lower auto sales; loss of revenues to business and government 2	Operating priorities (bus lanes) and auto disincentives would require legislation 2	Less pollution, congestion, & lower parking needs 3	1	15
	B. Spreading peak hour ridership	1,832	0	69	Staggering of work hours; Employer option	Reasonably short 3	Low 3	Inconvenience to employees and their families 1	Disruption to normal business patterns 1	Negligible 2	Less congestion 3	1	14
	C. Improved bus load factor	(Unclear)	0	19	Off-peak utilization through improved service and subsidies	Reasonably short 3	Moderate 2	Greater safety; loss of independence, flexibility, privacy, status, etc. 2	Longer travel time; lower travel costs; lower auto sales; loss of revenues to business and government 2	Subsidies would require legislation 2	Less pollution; congestion & lower parking needs 3	1	15
	D. Additional urban buses		0	33	(See Highway Mode Shifts, I. A. 8. a.)								
	E. Mini-bus commuting system	1,832	0	8	Employer subsidies & incentives; Auto disincentives; Changes in laws and regulations	Moderate 2	Moderate 2	Greater safety; loss of independence, flexibility, privacy, status, etc. 2	Longer commuter time; lower commuter costs; lower auto sales vs. increased van sales 2	Changes in laws & regulations and disincentives would require legislation 3	Less pollution, congestion & lower parking needs 3	2	16
VI. Pipelines		539	5	6	Improved efficiency of pumping units dependent on overall economics of operation	Moderate 2	High 1	Negligible 2	Negilgible 2	Negligible 2	Negligible 2	2	13
VII. Miscellaneous		632											
	A. Farm Equipment	278	20	23	Improved energy management and reduced tillage; education & economic incentives.	Moderate 2	Low 3	Negligible 2	Reduced operating costs. 3	Negligible 2	Improved soil conservation. 3	2	17
	B. Construction Equip.	326	(Insignificant)										
	C. Utility Engines	22											
	D. Snowmobiles	5											
	E. Race Cars	.5											

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*Most likely; Numbers in these columns are not additive. (See Transportation Task Group Report for basis of determination.)

†Relative time factors: 1 = greater than 4 yrs; 2 = less than 4 yrs; 3 = less than 2 yrs.

‡Relative cost factors: 1 = high; 2 = moderate; 3 = low.

§0 = intolerable; 4 = excellent.

‖Sum of arbitrary values: higher values indicate greater feasibility; total of 14 would be neutral.

The effect of higher energy costs on demand is discussed in greater detail in the Patterns of Consumption/Energy Demand Chapter of *Potential for Energy Conservation in the United States: 1974-1978*. For transportation, it is estimated that a 6-8 percent reduction in demand, equivalent to 660 and 880 thousand barrels of oil per day (1.3 and 1.8 quadrillion BTU's on an annual basis) by 1978, would result from primary energy cost increases of 100 percent and 150 percent, respectively, over 1972 cost levels--*at the wellhead, minemouth or other primary level*. The former cost increase has already occurred.

A wide range of possible changes in existing regulations or new regulations are also discussed in this report. Similarly, a number of voluntary actions by industry or consumers are identified. Most of the energy conservation measures can be largely segregated into one of the two categories--cost stimulated, or direct conservation actions--although it is obvious that the categorization is not distinct or clear-cut. Considering small cars, for example, rising energy costs, which will result in higher automobile prices and higher gasoline prices, will be the primary driving force toward consumers' buying more small cars. Other actions, such as savings attributable to reduced speed limits, are clearly regulatory. Figure 2 gives a pictorial view of the possibilities for energy conservation in the transportation sector through 1978, where the major actions identified are subdivided between those which are largely energy cost-oriented and those which are largely dependent upon regulatory or voluntary action.

The aspect of rationing was considered for discussion in this report. However, rationing as a concept is viewed as a means of allocating available supply and not as conservation in the strict sense of the word.

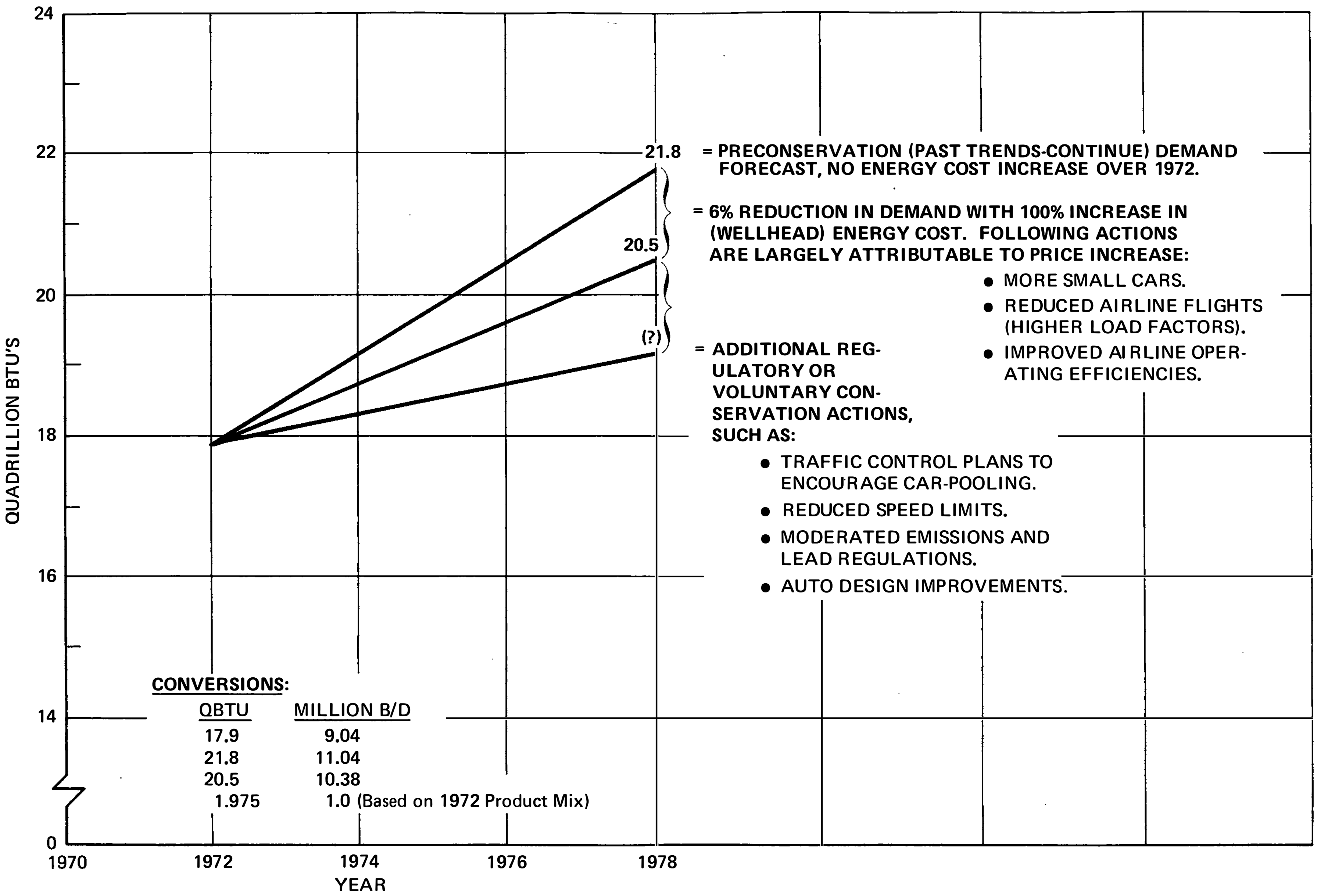

Figure 2. Energy Conservation in the Transportation Sector--(100-Percent Increase in Primary Energy Cost over 1972).

Chapter One

HIGHWAYS

INTRODUCTION

The highway mode of transportation, including cars, trucks, buses and motorcycles carried about 88 percent of the Nation's passenger movement, essentially all local shipments of goods, and 23 percent of the inter-city movement of freight during 1972. The inherent door-to-door flexibility of the highway system has provided impetus for higher levels of economic growth than would have been achieved in its absence.

In accomplishing this task, fuel consumption in the highway mode reached 6,835 thousand barrels per day in 1972 and directly accounted for 75.6 percent of the energy consumed by all forms of transportation. By virtue of its size, the highway mode also presents the largest potential for energy savings and has become the primary objective of conservation strategies.

In the highway mode, the discussion of energy conservation will focus on measures that could be implemented to reduce the present high level of energy intensity. However, a high degree of economic, social, political and environmental uncertainty exists with regard to the implementation and achievement of any conservation goals. Therefore, some discussion will be presented as to the impact in terms of public acceptability and life-style along with the evaluation of overall feasibility of the means during the next 4 years.

The full impact of all conservation measures listed under the highway mode would present a substantial reduction in consumption. However, it must be recognized that significant interaction or potential competition exists between many of these conservation options which requires considerable caution in an attempt to isolate particular cause/effect relationships (e.g., a commuter diverted from his auto cannot carpool and use the bus simultaneously). Moreover, it is likely that conservation measures will be relaxed when an adequate level of transportation energy is achieved. Assuming continued growth in disposable incomes, there could be a large potential demand overhanging the market that could easily reinstate a shortage position, unless the turn from conservation is gradually employed.

PART ONE: PASSENGER CARS AND LIGHT TRUCKS

The Nation's passenger cars and light trucks (for private, non-commercial use) together consumed 5,425 thousand barrels per day or 60.0 percent of total transportation energy and 79.4 percent of the fuel consumed on highways during 1972. As previously mentioned, these vehicles have provided a flexibility and utility of transportation which is responsible, in large measure, for the present style of living. To suggest, as some, that the people's affection for these vehicles has ended, or that the desire for this flexibility is no longer important, would be naive. Individuality in transportation is important and it probably will be maintained in the future, albeit, in different forms and for selected purposes.

Because cars and light trucks consume such large quantities of energy, and by virtue of their use characteristics are relatively inefficient, they have become an obvious target for lowering consumption through any number of means. If individual transportation methods are to be maintained, some compromise must be effected whereby the individual vehicle becomes more efficient and more careful choice is exercised in terms of utilization. For example, one person may prefer to carpool or ride the bus to work in order to retain greater flexibility in the use of his car at other times. Another may choose very small cars or motorcycles in order to maintain freedom of choice.

This section of the study relates a number of measures for energy conservation as they pertain specifically to passenger cars and light trucks. In some cases, these vehicles must be considered jointly due to: (1) the lack of reliable end-use data for light trucks, i.e., substitute for second car, camper hauling, urban delivery, farm vehicle, etc., and (2) that virtually all light trucks of this type use gasoline; whereby, steps aimed at conserving gasoline can, to some extent, be applied to both vehicle types.

The assumed projections of vehicle gasoline efficiencies [miles per gallon (MPG)] used throughout this report to determine conservation potentials are deemed, at this writing, to be the most probable future levels. The efficiency values employed essentially agree with those appearing in the NPC interim report entitled, *Energy Conservation in the United States--Short Term Potential 1974-1978*, and reflect to the extent practicable some changes in the composition of future car fleets, the effects of vehicle emission control systems, more intensive energy conservation practices and other intangible factors. They differ from the efficiency levels identified by the Patterns of Consumption/Energy Demand Task Group in their Past Trends-Continue case because that projection was intended to serve as a base case consistent with the projections found in the NPC *U.S. Energy Outlook--A Report of the National Petroleum Council's Committee on U.S. Energy Outlook*. As reported by that Task Group, the events occurring since 1972 have probably rendered the Past Trends-Continue projections obsolete.

The conservation potentials achievable, through actions affecting cars and light trucks, are summarized in Table 3, but it must be

TABLE 3

HIGHWAY FUEL CONSERVATION POTENTIAL–PASSENGER CARS AND LIGHT TRUCKS
(Thousand Barrels Per Day)

Measure	Savings 1974	Savings 1978
Car-pooling (Work Commuting)	92	325
Travel Characteristics		
• Driving Restrictions	38	46
• Four-Day Workweek	102	125
• Walking & Bicycling	2	40
• Driver Behavior Change	57	70
Speed Limits (55 MPH)	168	190
Auto Design Changes	–	236
Vehicle Maintenance	142	174
Vehicle Changes (Smaller Cars)	73	361
Emission Standard Changes	–	280
Mode Shifts to:		
• Urban Bus	–	33
• Intercity		
– Bus	–	31
– Train	–	15
– Air	–	38

re-emphasized that interaction and competition exist between these measures. Moreover, the significance of the impact resulting from adoption of these measures must be balanced carefully against the level of conservation to be attained.

CAR-POOLING (WORK COMMUTING)

Car-pooling has a very high potential for immediate conservation due to the short time required for implementation and lack of significant capital requirements. It is difficult to precisely estimate the savings potential of car-pooling due to the variation in geographic locations, residential densities and sizes of metropolitan areas. Nevertheless, an appraisal can be made based on 1970 U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) surveys covering trip purpose and automobile occupancy rates (load factors).

At the present time, approximately one-third of all passenger car travel is to and from work, and only about 25 percent of these auto commuters pool rides with any regularity. While this limited amount of pooling leaves ample capacity for expansion, it has the effect of increasing the commuter load factor from unity to about 1.6 person miles per vehicle mile.

In order to measure the quantity of fuel that might be saved through increased car-pooling, the physical limit of auto occupancy of 4.8 person miles per vehicle mile is based on a weighted average of U.S. fleet passenger car seating capacities. Of course, the practical limit must be lower since some workers could not participate due to hours of work, origin or destination of trip and vagaries of auto business use. For the purpose of establishing a realistic scenario of the immediate saving potential, it is estimated that half of the auto commuters cannot carpool. The remainder of the commuters, voluntarily or through incentives or disincentives, could form carpools containing an average of three persons, thereby raising the overall load factor to 2.0 person miles per vehicle mile (see Appendix C, Exhibit I).

Since the carpool eliminates one vehicle trip for each member but the driver, it is assumed that those trips eliminated are of equal length to that of the average lone driver. However, the length of the carpool trip increases in most cases due to the dissimilar origin and destination of passengers. Thus, the savings in vehicle mileage due to car-pooling equals the trips eliminated less the extra mileage of carpool trips caused by circuity. This saving equals 36 percent and implies that car-pooling activity in 1972 saved an estimated 942 thousand barrels per day. Intensified car-pooling over the 1972 level could result in the consumption reductions shown in Table 4.

TABLE 4

POTENTIAL FUEL SAVINGS FROM CAR-POOLING

	Implied Savings Through Carpools	Additional Savings Over 1972	
Variables	1972	1974	1978
Carpool Load Factor	1.6	1.7	2.0
Miles Per Gallon	13.4	13.2	12.9
Potential Savings (Thousand Barrels Per Day)	942	92	325

Although these reductions are based on the most likely condition for the variables of load factor (passenger miles per vehicle mile) and miles per gallon (MPG), it must be recognized that a significant interaction will undoubtedly occur. The already apparent shift to smaller, lighter cars with inherently greater fuel efficiency (MPG) reduces the increment of available savings potential from car-pooling at a given load factor (see Appendix C, Exhibit I, Figure 3). Moreover, the maximum load factor of the smaller car will be lower, thereby reducing pooling capacity and ultimate savings potential.

Concurrently, the greater efficiency (MPG) of the smaller vehicle would have the potential to counteract the other forces. For example, at a load factor of 2.2 (a probable value for smaller cars), the saving potential is 16 thousand barrels per day less at 18 MPG than at 13 MPG. However, only about 1.5 percent of the base level of commuter vehicle mileage would need to be driven in the 18 MPG car to fully compensate for this lesser saving potential at the same load factor. Inversely, a much greater saturation of 18 MPG cars would offer increased fuel savings even with somewhat lower load factors.

The degree of impact associated with car-pooling is dependent, as in the case of many other measures, on the incentives used for encouragement. Attainment of a high level of car-pooling is unlikely on a purely voluntary basis as it impinges heavily on personal freedom and flexibility. Car-pooling would result in somewhat longer commuting time, loss of independence, privacy, flexibility and in some cases, status for the individual. In direct proportion to the dollar savings by carpoolers would be the loss of revenue to business and government agencies that benefit from the sale of products, services or taxes generated. The possibility exists that reduced vehicle mileage, through less use in car-pooling, could encourage longer retention of cars and/or a reduction in multi-car ownership. Any resulting lower level of new car sales would impose economic penalties, since 1 in 6 persons are employed in auto-associated industries.

In terms of advantages, car-pooling would offer reductions in air pollution, noise levels, and congestion on the highway. Commuting expense for the average carpooler could be reduced by $100 to $250 per year, dependent on the number of persons per pool; in addition to the possibility of eliminating the ownership costs of one or more cars in multi-car households. Carpools are also feasible for suburban and rural residents for whom urban-type transit service could never be justified. Finally, attendant reductions in land requirements for roadways and parking would be aesthetically pleasing and may possibly allow some reallocation of tax monies.

Some increased propensity to carpool has been noted due to fuel shortages and higher fuel prices, but the exact coefficients of dependency on these variables can only be determined through extensive research. The implementation of car-pooling, on a voluntary basis, could develop in a matter of months in response to fuel shortages. Insignificant capital costs and ease of institution have given rise to the present level of car-pooling, but it is obvious that the maximum practical benefits will only be attained through additional incentives. Preferential treatment of carpoolers in the form of priority parking, reduced tolls, tax deductions, insurance discounts and possibly employer subsidies (work schedule variation to allow off-peak hour travel, purchase assistance for pool vehicles, and/or operating cost assistance) would aid in promoting the cause. Disincentives, such as higher-than-normal tolls for the one occupant car, could tend to discourage the lone driver.

Certain of these actions would require legislative and institutional changes, indicating implementation delays of several years.

Moreover, the reduction of congestion, pollution, and parking problems would tend to make lone driving more attractive. As indicated in the introduction of this section, when sufficient quantities of fuel are conserved through car-pooling, in combination with other measures, the saving could be consumed in other automobile uses. The implied option of free choice in using any surplus fuel attained through conservation efforts suggests this psychological impact as one type of incentive for encouraging conservation but communication of the concept is dubious at best.

Despite the obstacles and disadvantages of car-pooling, it offers reasonably short implementation time at a small cost and significant fuel savings. Voluntary achievements in car-pooling are presently considered insufficient and mandatory requirements would be nearly impossible to formulate or enforce. The extent of conservation attainable through this means will be largely dependent on the incentives provided.

TRAVEL CHARACTERISTICS

As a means of energy conservation, changes in concepts of travel characteristics or habits can assume many forms. Although the greatest savings potential and effort to conserve would undoubtedly be in the area of reducing vehicle miles of travel, additional benefit could be derived from changes in operating skills and driving habits. Proposals for the reduction of vehicle mileage range from complete driving bans, restrictions on vacation and recreational travel, trip consolidation or elimination, to promotion of walking and bicycle transportation. Greater efficiencies can also be attained through the manner in which the driver operates his vehicle in terms of acceleration, warm-up, idling and steadiness of cruising speed.

The institution of many of these concepts is simply not feasible in the short term (1974-1978) due to physical limitations of alternate transport modes and, primarily, to the probable lack of public acceptance. While solid data is not available to substantiate a firm hypothesis for many of these areas, estimates have been developed from government statistics to depict some parameters of vehicle trips and the purposes for which fuel was consumed.

The three major purpose-of-trip categories and areas of fuel consumption are earning a living, family business and social-recreational (see Appendix C, Exhibit II, Table 29). Within these broad areas, the categories of getting to and from work, visits to relatives and friends, and shopping trips account for over half of the fuel consumed, but more than 25 percent of the usage cannot be defined as to purpose. Moreover, there appears to be a considerable amount of regional variation as to mileage accumulated and fuel consumed in the pursuit of these activities. The significant point to be observed from this data is that vacations, pleasure riding and educational-civic-religious consumption of fuel probably accounts for less than 12 percent of the total. As affected by other conservation measures (speed limits, etc.), a savings will undoubtedly occur, but because of the small percentage of use, restrictions directed specifically at these "private" consumption areas would have minimal effects on the total transportation picture. Moreover, they would be less acceptable due to their arbitrary nature and infringement upon personal freedom. To avoid these enforcement handicaps, conservation proposals to reduce vehicle use must be of broader nature and universally effective. In this framework, efforts to conserve fuel could fall into three general categories: auto-free zones, indirect use restrictions and direct use restrictions. This section will discuss some options to embrace these alternatives, but quantifications will be very subjective. Values will be suggested only in vague terms as there is an obvious intermodal overlap between auto restriction and shifts to other modes of travel. The discussion will also include the conservation benefits of promoting bicycling (as it does not require the direct use of or shift to other fuels) and improving the driver's operating habits.

Driving Restrictions

Some experimentation is already under way in the United States and Europe to reduce the number of automobiles operating within, or in parts of, cities through strategies such as total or partial bans from selected streets and areas. *Auto-free zone* proposals usually involve the prohibition of motor vehicles in relatively small areas, such as several square blocks in the heart of the business district. They may consist of complete prohibition at any time; use limited to buses and/or delivery vehicles; or prohibition only at specified times. While this type of restriction may serve aesthetic values, reduce noise, and improve air quality in the immediate area, it is not likely to cause any appreciable reduction in vehicle usage. The only perceivable impacts are on the merchants in the affected area, as this system tends to introduce some of the features of a regional shopping center into the downtown area.

Indirect auto-use restrictions generally consist of efforts to reduce auto-use in areas larger than those affected by auto-free zones. Such strategies usually fall short of actual prohibition on vehicle-use and often promote options such as: improved public transportation to attract motorists from their cars; reduction of parking spaces to discourage auto use; increased parking fees or parking rates that escalate with longer times to discourage all-day parking; and "road-pricing" policies which impose or increase tolls at all times or during peak traffic periods, especially on roads where reduced vehicle travel is deemed desirable.

Of the foregoing options, many studies indicate that minor improvements in public transport will not create any diversion from cars and there is serious doubt whether major improvements would have any short-run impact on automobile usage or ownership. This does not suggest that such improvements should not be made, but only that to be effective they should be combined with automobile restraints.

Until recent years, a primary concern was the availability of sufficient parking spaces at reasonable prices to assure or promote the central business district. Now that a reverse policy is being considered in some areas, it may develop that subsidies will be needed to relieve the hardship placed on merchants and building owners in the larger metropolitan areas. As an example, the motorist who travels to the city for other than work is more likely to select a destination where he can park to accomplish his objective, rather than to shift modes of transportation. In the long term, parking difficulties may encourage further acceleration of business development on the city periphery, resulting in minimal impact on vehicle miles traveled.

Imposition or increase of tolls is not a new method of paying for specialized facilities such as bridges, tunnels, etc.; however, a new dimension is added when the purpose would be to discourage vehicle use in particular areas. Proposals have been made to increase the price of using streets in highly congested areas either by imposing new tolls for entrance or exit and by the more elaborate use of scanning systems (similar to the units used by railroads for car identification) which could record and, through central computerization, bill car owners for the use of roads where travel reductions are desired. A version of such a system is now employed for buses in the New York City area.

A recent doubling of tolls on certain bridges into Manhattan has increased revenue considerably but had very minor impact on the number of vehicles entering. Some shifting from toll to free crossings was detected, which indicates a probable increase in vehicular travel rather than the sought after reduction.

Theoretically, there is a point where the increase of tolls will result in diminished travel, but the problem is similar to that of parking; the motorist who has a choice is more likely to change his destination than his mode of travel. Moreover, the toll approach may also further the relocation of business to the periphery of the city. Thus, it seems very unlikely that higher tolls will be widely employed for conservation purposes during the next decade. The cost of the more equitable scanner system would be enormous for key roads alone; and, the unique identification and recording procedure could constitute invasion of privacy through knowledge of vehicle location (it could also help locate stolen cars). Overall, the negative impact of indirect restrictions and the inability to control the options of driver destination hold little promise for reduction in vehicle miles.

Direct restrictions on automobile use take a form similar to auto-free zones, but the areas involved are generally much larger. The techniques considered in this phase include restriction of vehicle movement in order that "through" vehicles bypass the congested areas; preferential treatment for multiple-occupant vehicles; special stickers or licenses to enter critical areas at all or certain times of day; or complete prohibition of vehicle use.

Elimination of through-traffic is a concept which is already employed in many cities; however, the effect on overall vehicle mileage is marginal. The area of largest perceivable saving would result from elimination of the "stop and go" city traffic for the "through" vehicle.

Preferential treatment for multi-occupant vehicles or carpools such as lower toll costs and reserved lanes during rush hours provide an additional incentive to participate in that concept. The degree to which it reduces vehicle mileage and conserves fuel are covered in the car-pooling discussion.

A variant of toll system approach would be the issuance of special licenses or permits which, for a price, might be available to anyone or available only to "qualified" persons. This scheme could limit access to the central business district, but would generally have the same impacts as tolls or parking reduction with the added implication of discrimination against either low income people or those lacking the "qualified" status.

Complete prohibition in the strict sense is deemed totally infeasible during the period covered by the Phase I study (1974-1978) because the alternate methods of transport will simply be inadequate. Auto-free zones will undoubtedly be created in many cities in the future years and other efforts will be made to reduce vehicle travel and congestion through the various schemes discussed. However, the barriers against implementation tend to suggest that none of these devices will be used to a significant degree. Based on this premise, Table 5 (based on Appendix C, Exhibit II, Table 29) depicts the volume of fuel that could be conserved by a combination of all types of restrictions if they were to achieve a 1 percent reduction in the fuel consumed by specific trip purpose.

Based on consistent driving patterns through 1978, the potential fuel savings through driving restrictions are estimated at 46 thousand barrels daily in that year.

Four-Day Work Week

The 4-day work week is another concept which could have considerable impact on travel characteristics as they pertain to work commuting trips. It is recognized that many industrial operations, especially those on a 2- or 3-shift basis, could not practically convert to a 4-day, 10-hour schedule. Moreover, many public service functions such as restaurants, utilities, transportation, and others must maintain a 7-day operational procedure which effectively reduces the conversion potential.

The largest opportunity for this alternative work schedule lies with the white-collar or office type work force where a skeleton group of employees might serve to maintain communication and other essential business services on non-working days. Thus, if it is assumed that 25 percent of those commuting to and from work by car could be placed on a 4-day schedule, it is calculated (see Appendix C, Exhibit II) that nearly 100 thousand barrels per day of fuel could be conserved (based on 1972 data) with full implementa-

TABLE 5

FUEL CONSERVED BY DRIVING RESTRICTION--1972
(Thousand Barrels Per Day)

Purpose of Trip	Fuel Consumed	Fuel Saved
To and From Work	*	*
Related Business	435	4
Medical and Dental	83	1
Shopping	410	4
Other Family Business	528	5
Vacations	201	2
Visits to Relatives, etc.	617	6
Pleasure Rides	168	2
Other Social	889	9
Education, Civic, Religious	262	3
Total	3,593	36

Note: Based on consistent driving patterns through 1978, the potential fuel savings through driving restrictions are estimated at 46 thousand barrels daily in that year.

* See Table 4, "Potential Fuel Savings from Car-Pooling."

tion or 125 thousand barrels daily in 1978. This savings value undoubtedly would be moderated by an added amount of personal driving stemming from the availability of additional leisure time. Public transit will only be affected to the extent of reduced peak-hour congestion, as the remaining majority of persons on 5-day schedules must continue to receive accommodation.

Aside from the aspects of fatigue that may result from 10-hour work days, the social and environmental impact of this schedule can be favorably qualified in terms of reduced traffic congestion, lower levels of auto emissions, and additional time to pursue self-interest activities. The latter feature should provide economic gains through greater sales of leisure-time equipment and do-it-yourself commodities. The direct effect on participating businesses would involve communication difficulties, but, systems of staggered days-off could rectify the major problems.

Public and worker acceptance of the concept is presently unclear as experience has been very limited and reactions noted are of wide range. Implementation of the concept is primarily dependent on the attitudes of employers who would have to evaluate the costs of any change in worker efficiency. The question of degree and timing of implementation will depend largely on the success or failures of the initiators. Nevertheless, the potential for fuel conservation is of sufficient magnitude that the concept warrants serious experimentation to discern its feasibility.

Walking and Bicycling

Walking and bicycling are considered under this section of the report because any shift that might occur is not dependent on primary fuels as a power source nor is there a fuel transfer effect. If it is assumed that bicycling and walking could, in some cases, be substituted for the automobile, the primary constraints of change would be the distance covered and the consideration of the bulk to be transported (groceries, etc.). Of course, the shorter the trip, the greater would be the propensity to walk or use the bicycle and the shorter trip correlates positively with lower auto efficiencies in terms of miles per gallon.

Recent studies indicate that 62.4 percent of all auto trips are less than 5.5 miles in one direction. However, as displayed on Table 6, these trips represent only 15.7 percent of all vehicle miles and present a small universe for extraction of savings.

TABLE 6

VEHICLE TRIPS AND VEHICLE MILES
(Percent by Length of Trip)

Trip Length (Miles, One-Way)	Percent of Trips	Percent of Vehicle Miles
Less than 1.5	24.5	1.7
1.5-2.4	13.0	3.1
2.5-3.4	10.0	3.4
3.5-4.4	6.5	2.8
4.5-5.4	8.3	4.7
Total	62.3	15.7

Based on methodology shown in Appendix C, Exhibit II, the calculations for estimating potential fuel savings as determined by trip lengths for 1974 and 1978 are explained on Table 7.

For round trip estimates the values shown would be doubled. The likely savings total of about 40 thousand barrels per day for 1978 makes the reasonable assumption that the proportion of short trips will remain constant over time.

Despite the small amount of conservation attainable, the favorable aspects of possible health improvements through exercise, the modest reduction of air and noise pollution, and the potential for reduction of parking areas are benefits that should weigh heavily in terms of promotion. Public acceptance would be dependent on physical ability to participate, purpose of trip (load to be carried), climate, safety aspects, and customary social norms.

While a time of travel factor is also involved, it could be more or less depending on distances and traffic density. Increased

TABLE 7

FUEL SAVING POTENTIAL THROUGH DIVERSION OF TRIPS TO BICYCLE AND WALKING

	1974					1978				
Trip Length (Miles, One-Way	Total Vehicle Miles	Percent of Vehicle Miles	Percent Diverted	Miles Per Gallon	Fuel Saved (MB/D)	Total Vehicle Miles	Percent of Vehicle Miles	Percent Diverted	Miles Per Gallon	Fuel Saved (MB/D)
Less than 1.5	-	1.7	.5	7.0	.9	-	1.7	5.0	8.0	8.9
1.5-2.4	-	3.1	.1	7.5	.3	-	3.1	2.0	8.5	6.1
2.5-3.4	-	3.4	-	-	-	-	3.4	1.0	9.0	3.2
3.5-4.4	-	2.8	-	-	-	-	2.8	0.5	9.5	1.2
4.5-5.4	-	4.7	-	-	-	-	4.7	0.1	10.0	.4
Total	1,167 x 10^9	15.7	-	-	1.2	1,288 x 10^9	15.7	-	-	19.8

participation in these activities certainly would increase the incidence of pedestrian and cycle accidents due to lack of adequate walking space and/or bicycle paths. Expanded usage of bicycles would add further pressure to manufacturing facilities which are currently strained by the demand. The foul weather factor associated with these options adds another variable to the prediction of peak demands for local bus service and mass transit.

Many of the auto driving/parking restrictions already covered would serve as incentives to walk or bicycle. The construction of specialized facilities and funding thereof is deemed the controlling implementation factor. Some achievement could be made through the use of existing parking lanes and creation or set-aside of special bicycle streets. New facilities, requiring legislative action, are most likely a decade away.

Driver Behavior

Driver behavior directly affects the rate of fuel consumption, and the degree to which the proper habits can be acquired offers an area of potential conservation. The driver who allows excessive vehicle warm-up or idle time (zero miles per gallon), accelerates more rapidly than necessary, drives with erratic throttle control, or at high rates of speed wastes a considerable amount of fuel.

The conservation of fuel that could be generated through driver education and cooperation is highly speculative. The basic requirement would be the installation of a device or gauge to continually monitor fuel economy and report it to the driver in simple terms, e.g., miles per gallon. Several units of this type are currently on the market and these could be readily made available for a retrofit program as well as for installation on new cars. Of course, the adaptation of an economy monitoring device does not imply that the driver will necessarily heed its warning and react to achieve greater efficiency.

Quantifying the savings that might be obtained is limited to estimation. Urban driving with its inherent stop and go patterns results in high levels of consumption, while speed is the major factor under expressway driving conditions (the latter being covered under the analysis of speed limit section). It is generally acknowledged that rapid acceleration can increase consumption by 15 to 20 percent. Assuming that 80 percent of the drivers already are refraining from such practices; that 55 percent of the vehicle mileage is accumulated under these urban conditions; and that possibly half of the drivers might make concerted effort to improve their driving habits, it follows that 1 percent of national auto driving consumption or 54 thousand barrels per day might have been saved in 1972 through improved driver technique. On this basis, the savings potential would amount to 57 thousand barrels per day in 1974 and 70 thousand barrels per day in 1978.

The impact of gauge installation will be totally dependent on the mandate; however, objection would undoubtedly be encountered from the owners of older cars if a retrofit program is initiated. The actual use of such a fuel economy measuring device, if not too expensive, is more likely to result from higher fuel prices and/or future fuel shortages.

SPEED LIMITS

In an effort to reduce fuel consumption on the Nation's highways, a maximum speed limit of 55 MPH was enacted on January 2, 1974. While it is an accepted fact that automobiles operating at higher speeds use more fuel than those operating at lower speeds, data on the concept remains vague and elusive. Moreover, trip length, vehicle condition, weather, wind, road surface condition and other factors all have direct bearing on fuel economy at given rates of speed.

The trend of average highway speed has advanced steadily since a war-time low of 1942 and according to government survey, passenger cars reached an average speed of 62 MPH on main rural roads during 1971. New highways (especially the Interstate System) and vehicles have been designed for 70-75 MPH cruising speeds. Experiments and observation reveal that because of these factors, speed limitations are often exceeded when drivers intuitively feel a safe capability for higher speeds, thereby raising questions about enforcement and/or compliance with lower limits. For example, the desire for conservation and the difficulty in obtaining fuel during the early months of 1974 was generally observed to have had a lowering effect on average rural driving speeds. Although these conditions cannot be readily proven, it now appears that average driving speeds have accelerated to beyond the posted limits and the degree of compliance with these limits can only be guessed, lacking extensive research.

A government (DOT) study was conducted in an effort to derive the relationship of the speed and fuel economy variables. In this study, the results cannot be described as typical because the sample was very small (12 cars, air conditioning off; 9 cars, air conditioning on) and the test runs were conducted at uninterrupted, constant speeds, on straight, level roads and in the absence of congestion or situations that might arise under normal operation.

Despite these shortcomings, the observed data for all cars in the sample show, without exception, a declining trend in MPG at speeds in excess of 50 MPH. For example, on cars with air conditioning off, changes in speed from 50 to 60 MPH revealed a simple average increase in consumption of 11.31 percent, while changes from 60 to 70 MPH averaged 17.28 percent increase in consumption. With air conditioning in use, the average changes in consumption were: 50 to 60 MPH, +9.47 percent; 60 to 70 MPH, +13.90 percent. Although not at issue in this case, the lower rates of change when using air conditioning are undoubtedly due to the greater engine base load imposed at all speeds; while requiring a decreasing percent of engine output as the engine and car speed increase.

The data derived by the study are based on a sample of insufficient size to provide a high degree of reliability. A simple average of change in consumption may not produce the same trend rate as an average weighted by the fleet of cars in actual operation. Nevertheless, the general trend is deemed realistic and must be accepted for lack of other substantive data.

Another factor, often overlooked, is that speed limits only have a significant bearing on fuel economy where rural driving is involved. Applying the efficiency changes developed from the DOT study to rural driving, modified by a variance in driver compliance with lower speed limits, the estimated fuel conservation potential from this measure amounts to 168 thousand barrels per day in 1974 and 190 thousand barrels per day in 1978 (see Appendix C, Exhibit III).

Since implementation has already taken place, a discussion of methodology, timing and cost is less relevant but, since the full impact has not yet become apparent, some discussion is appropriate. The most obvious impact of reduced speeds is the additional time required for travel and the associated cost in terms of lost time. For example, if time is valued at the new minimum wage of $2.00 per hour, the cost of reduced speed (62.5 to 55 MPH) in 1974, at 90 percent compliance and based on the mileage affected, would amount to nearly $2.5 billion. Although this comparison is largely fictitious because the value of travel time is often questionable, it is interesting because the cost of this time far exceeds the cost of fuel saved ($1.668 billion at $0.55 per gallon) in that year, not to mention whatever personal inconveniences might occur through lost or prolonged travel.

While lower speeds also present the consumer with an opportunity to save money through lower fuel costs, the increased time requirements may divert some drivers to air travel at higher energy costs, if additional flights are required.

Injuries and property damage from accidents could be expected to diminish at the lower rates of speeds, provided compliance is high. Since driver behavior is difficult to predict, a significant part of the drivers may not cooperate and the propensity toward accidents could rise as a result of increased variance in travel speeds among vehicles.

Because of the cost of time, the cost of changing speed limit signs (estimated as high as $20 million), the dubious nature of compliance, and the high cost of rigorous enforcement of lower speed limits, the change must be justified by the need to conserve fuel. From a realistic and practical standpoint, the change really requires a different driver attitude. Although the 1974 demand for fuel has been lower than in the previous year with higher speed limits, concurrent changes in fuel availability and higher prices undoubtedly have had some impact. Until some of these variables stabilize, it will be most difficult to isolate exact cause/effect relationships.

AUTO DESIGN

Nearly all of the other discussion in the highway section of this report pertains to conservation opportunities that are predominantly influenced by the vehicle operator, in terms of how, when, where, or what kind of vehicle he drives. In the realm of auto design, the inherent efficiency parameters of the vehicle are of primary importance and are the elements over which the driver/consumer has the least amount of control. Consumer preference expressed in the marketplace, has a definite impact on type or style of the vehicle, but the flexibility of the vehicle manufacturing industry is essentially restricted to moderate changes on an annual basis and complete revisions only every 4 or 5 years, due to large investments in tooling and many other composite intricacies of producing 10 million vehicles per year.

Although exceptions exist, design changes generally stem from an evolutionary process of technological advancement covering factors such as vehicle weight, drive line components (transmission type and rear axle ratio), engine design parameters, rolling resistance, aerodynamic drag, and accessories--particularly air conditioning, power steering, and electrical components. Improvements generally involve considerable lead time for incorporation, higher production costs and elements of risk during the developmental stages.

Despite these problems, the automobile industry is concentrating its efforts to improve the fuel economy of future new car production. This means that designers are frequently faced with a host of problems that often present conflicting requirements. The automobile must appeal to the public offering style, performance, durability, and fuel economy at a reasonable selling price. More recent requirements to be satisfied include safety and emission standards, all of which realistically mean that the future automobile will be a result of compromise in determining the "optimum" balance of all alternatives.

In terms of conservation potential, it is not a simple matter to achieve the best design balance since fuel economy is the net effect of complex design interaction and few changes can be considered independently. For example, engine design, transmission and rear axle ratio must be carefully matched to form an integral, interdependent mechanism for vehicle motion. The following discussion and Table 8 relate conservation volumes to the changes in design parameters that could reasonably be expected during the period through 1978. Although the various conservation possibilities are discussed individually, it would not be appropriate to add the savings values because of the interdependence of the design variables. Moreover, if all the indicated design changes were incorporated in unison, the driveability of the vehicle probably would be unacceptable. As a result, the factors of engine design and drive line modifications are arbitrarily assumed to demonstrate only one-third of the individual component savings potential.

It is quite different to suggest or demonstrate design changes in prototypes as opposed to conversion of production facilities.

TABLE 8

CONSERVATION POTENTIAL OF AUTO DESIGN CHANGES
(Thousand Barrels Per Day)

Measure	Savings 1978
Vehicle Weight Reductions *	–
Reduced Rolling Resistance	159
Reduced Aerodynamic Drag	17
Modified Engine Design	†
Drive Line Modifications	
• Transmission	†
• Axle Ratios	†
	35 (Actual Combined Total)
Improved Vehicle Accessories ‡	25
Total	**236**

*In light of safety and other regulations, significant vehicle weight reductions (within a given vehicle class) were deemed improbable over the 1974-1978 timeframe. Weight reductions will be accomplished through a shift to smaller cars (see "Vehicle Changes" in this chapter).

†See discussion under Auto Design in this chapter. Individual saving potentials not additive. Savings potential for these measures combine as follows:

Modified Engine Design	–	37
Drive Line Modifications		
• Transmission	–	24
• Axle Ratios	–	45
		106 X 1/3 = 35 (Actual Combined Total)

‡Air conditioning, power steering, etc.

Whatever design changes evolve in the future, increased costs may be involved and must eventually be passed on to the consumer. Beneficially, the design technology that serves to improve fuel economy may also prove effective in reducing vehicle emissions. In the following paragraphs the individual design parameters are discussed in light of these qualifications.

Vehicle Weight

Vehicle weight is a major factor affecting fuel economy, as more weight requires increased engine power to move the car. In recent years, an important element of increasing car weight has been the additional equipment required to meet government standards for emissions, crash impact damage, and/or occupant protection. These include stronger bumpers, door beams to diminish side impact intrusion, greater roof strength to prevent roll-over crush, and occupant protective devices such as seat belts/shoulder harness equipment and interior padding. Unfortunately, these weight increases have a compounding effect in that they require greater supportive strength or added weight in other areas of the vehicle.

Although the general effect of a weight increase reduces fuel economy, it has a more pronounced influence on vehicle acceleration.

To please the consumer and compensate for this loss in performance, engine displacement has been increased (sometimes requiring heavier supportive members) and axle ratios have been modified; all resulting in further losses in fuel economy. Significantly, the lighter, smaller cars are designed to achieve good fuel economy by utilizing smaller engines, but the addition of accessories and heavy equipment tax this system resulting in proportionately larger reductions on fuel economy than in the case of larger cars.

The fact that heavier cars generally imply other characteristics such as greater frontal area (air resistance), more accessories, and heavier engines, renders difficult any attempts to isolate the reduction in fuel economy due solely to changes in weight. Current studies indicate that a 3 percent gain in miles per gallon might be achieved through a 10 percent reduction in vehicle weight. Of course, there is no practical way to reduce the weight of the existing fleet of cars and it is doubtful that unit reductions of this magnitude can be made in new cars sold during the period to 1978, short of reducing actual vehicle size. Indirect gains in this area will be realized through the shift to smaller cars, but the only immediate alternative, of dubious effect, would be to discourage motorists from using the trunk or rear seat of their vehicle as a storage area for golf clubs, tools, or other heavy materials.

Rolling Resistance

Rolling resistance of a vehicle increases in nearly direct proportion to the speed of the vehicle and is primarily determined by the type of tire construction. It is also influenced, although to lesser degree, by the type of road surface, friction of bearings, and other moving components of the vehicle.

Being the most important variable of rolling resistance and fuel economy, tires are affected by the factors of inflation and construction. The proper inflation pressure varies depending on the type of construction, the number of plies, driving conditions, load being carried, and type of vehicle. Improper inflation pressures can affect fuel economy and tire life as underinflation causes tires to wear faster on the outer edges of the tread and reduces fuel economy. Overinflation can result in increased fuel economy, but wears more heavily on the center of the tire.

The method of construction employed in manufacturing a tire has the greatest effect on fuel economy. By way of comparison, the bias-belted tire of the early 1970's generally exhibited more rolling resistance and, consequently, less fuel economy than the non-belted tire previously employed. The latest development in construction is the steel belted radial-ply tire which has significantly lower rolling resistance and has been shown to improve fuel economy by 3 to 5 percent or up to 1 MPG.

During 1974, an estimated 25 percent of the new automobiles will be equipped with radial-ply tires and radials are also accounting for a sizable share of the replacement market. If it is assumed that the use of radials saves 4 percent (about 1/2 MPG) in terms of fuel consumption, and that 7 percent of the existing passenger car fleet is so equipped, 0.3 percent less fuel or 15 thousand barrels per day less than normal requirement would be used for operation in 1974. It appears likely that about 65 percent of the 1978 fleet of cars in use could be on radial tires which implies a fuel savings potential of 2.6 percent of passenger car consumption, or 159 thousand barrels per day in 1978.

Since the care and selection of tires is one area of auto design where the individual presently has a choice, educational materials could be made available to display the overall cost-effectiveness of using radial tires as an offset to the higher initial cost. However, promotion of radials in the replacement market may have a retarding effect on new car purchases, in order to realize the full benefit of the installation.

Aerodynamic Drag

Aerodynamic drag or the wind resistance presented by a vehicle consumes a substantial amount of fuel at highway speeds, and is influenced by the vehicle shape, in terms of frontal area and degree of streamlining over its length. The additional horsepower requirements to overcome this resistance also depends upon the density of the air and varies approximately with the cube of the speed of travel. As a result, rolling resistance, as previously discussed, is the major factor at low speeds, but this usually is exceeded by aerodynamic drag when speeds of 45-60 MPH are attained (see Appendix C, Exhibit IV, Figure 5), and it continues to grow at geometric rates.

The relationship between air resistance and fuel economy is one reason why smaller vehicles (less frontal area) are able to show greater miles per gallon than full-size cars. It is a major factor in realizing better fuel economy at the reduced speed limits. Moreover, the element of air drag also serves to explain why wind plays an important role in fuel economy, as even crosswinds disrupt the normal flow of air, causing greater resistance.

In attempting to reduce the influence of aerodynamic drag, the vehicle manufacturers are conducting wind tunnel tests to minimize these effects and it will become an important factor in future styling decisions. The installation of a fuel economy gauge could also play a part in this element as it would enable the motorist to more readily recognize the effect of driving into head winds.

Measuring the conservation potential available through improvements in air resistance design is possible only through hypothesis because the consumer undoubtedly will not accept the styling dictated by the optimum streamline configuration. Therefore, if it is conservatively estimated that 25 percent of the cars on the road in 1978 have been designed for a 2.5 percent efficiency improvement due to a lower drag coefficient, some 17 thousand barrels per day of fuel might be saved in rural (high speed) driving.

Engine Design

Engine design obviously plays an important role in vehicle efficiency as the engine converts the chemical energy in gasoline into mechanical energy which results in vehicle motion. Thus, the more efficiently this conversion process can be completed, the greater will be the level of realized fuel economy. However, it is important to note that improvements in this process are limited by a number of factors including friction, flow resistances and the basic laws of thermodynamics, and most of the available energy is lost in the form of waste heat.

Despite the fact that only 10 to 20 percent of the original fuel energy is available to propel the vehicle and operate accessories, variations in engine design parameters can have significant impact on vehicle efficiency and, disregarding any change in the number of cylinders, compression ratios and engine displacement are two of the more significant elements of design.

Preparatory to the introduction of catalytic exhaust systems for emissions control and the apparent need for lead-free fuel, the compression ratio of engines in passenger cars started to decline with the introduction of 1971 models. This reduction, according to Environmental Protection Agency (EPA) analysis, has resulted in a fuel economy loss of about 3.5 percent as compared to previous models and other estimates range up to an 8 percent economy loss. Techniques to restore compression ratios without increasing engine octane requirements are under investigation and could result in future economy improvements. As this aspect of design is so closely related to emissions control, the fuel conservation effects of any compression change is discussed in the emissions section in this report, where it is estimated that potential fuel savings of as much as 11 percent are possible by returning to high compression ratio engines.

The size of an engine, in terms of displacement, has a bearing on vehicle fuel economy, but the relationship is very complex and would require considerable documentation. Moreover, practical limits of engine size reduction are difficult to establish as vehicle performance usually deteriorates, and considerable time and costs would be involved for revising auto industry production capabilities. Recognizing that exceptions to many of the statements would be possible, the following brief discussion is presented as a general evaluation of the conservation effects of reduced engine displacement.

When two identical vehicles are operated under identical conditions, the vehicle with a smaller displacement engine will usually exhibit better fuel economy, but less acceleration capability. This condition results because the smaller engine will be required to operate nearer its optimum load limit (where it is more efficient) than the larger engine. However, when the smaller engine is taxed to its fullest capability, it becomes dramatically less efficient and the larger engine then shows greater efficiency because it is operating closer to its optimum level. This optimum load determination cannot be generalized because it depends on many other factors including carburetion, ignition configuration, axle ratio, etc. For example, increased displacement will allow the use of a numerically lower axle ratio which usually results in improved economy while maintaining an equivalent level of vehicle performance.

Practical considerations in reducing engine size for economy improvement, while generally reducing vehicle performance, include consumer acceptance, the time and cost required for changing industry production capability, effects on emission controls, and performance requirements dictated by aspects of safety, e.g., grade climbing and passing ability. Since it is too late for any effect in 1974 and as only subjective relationships have been found to substantiate these conclusions, it is reasonable to assume that a 10 percent reduction in displacement could be phased-in over the 1976-1978 period (across the entire production line) without inflicting a severe impact. Based on these assumptions (see Appendix C, Exhibit IV, Auto Design Computations) a fuel savings of 37 thousand barrels per day could be realized in 1978 through engine displacement reductions.

Drive Line

The drive line of an automobile consists of all vehicle components necessary to transform engine power to vehicle motion and includes the transmission, drive shaft assembly, rear axle assembly, wheels and tires. The drive line affects the fuel economy of a vehicle in terms of friction losses in each component (see "Rolling Resistance") and in the relationship between engine and vehicle speeds which is controlled primarily by the transmission and rear axle ratio. Although the transmission and rear axle are the major components of the drive line and the topics of the following discussion, it should be noted that they function with the engine as an integral unit and any significant change in one element generally dictates some modification of the others.

With this qualification, the use of automatic transmissions, as compared with manual types, results in significant economy losses when the engine and rear axle ratio are identical. Due to slippage in transmission torque converters, up to a 10 percent fuel usage penalty has been observed at steady highway speeds and as much as a 15 percent economy loss exists in urban traffic situations.

Probably 70 to 80 percent of the cars on the Nation's highways are equipped with automatic transmissions and many people have never driven with the manual type or have experienced trouble in mastering its operation. As a result, reversion to manual operation is questionable from a practical standpoint and could generate safety problems during any training process.

Alternate, more efficient, automatic transmission designs are under study and development, and the auto industry will undoubtedly introduce these changes as soon as capability permits. It seems reasonably certain that some improvement in automatic transmission performance will be realized by 1978, but the effect on fuel consumption is presently uncertain. If fuel efficiency gains of 2 percent could be realized through transmission improvements in the 1977 and 1978 model years, the total fuel savings could amount to about 24 thousand barrels per day in 1978.

The other drive line component having an influence on fuel economy is the rear axle ratio, i.e., the number of times the drive shaft turns for each revolution of the propelling wheels. On a numerical basis, this relationship ranges from about 2.25 to 3.75 for today's domestically produced automobiles, and options within this range are often available to the purchaser of a new car. (Some manufacturers give three or more choices labeled as economy, standard, or performance ratios.)

Generally, a numerically lower axle ratio will result in better fuel economy when all other factors are equal because the engine runs slower for a given vehicle speed. In simple terms, this tends to produce better fuel economy until the engine runs so slowly that it lugs or is taxed by insufficient momentum. Thus, fuel economy cannot be the only consideration in establishing a most desirable axle ratio as a balance must be maintained for high and low speed economies and acceleration response.

In the future it is conceivable that the "standard" axle ratio could become the "economy" ratio known today. A 10 percent reduction in ratio on new models would cause a 3-5 percent loss in acceleration and about a 2.5 percent gain in efficiency. Provided such a change is phased-in during the period to 1978, a potential fuel savings of 45 thousand barrels per day could result.

Vehicle Accessories

Vehicle accessories refers broadly to all components that require power for operation but may not be essential to vehicle motion. Almost all of these devices require mechanical or electrical power which is originally derived from the fuel, and consequently, they have an influence on the vehicle's operating efficiency. Significant amounts of fuel are consumed in the operation of the engine fan, alternator, power steering pump, emission control air pump, and air conditioning systems, plus the economy penalties that are associated with their addition to vehicle weight.

The power requirements for nearly all of these accessories generally increase in direct proportion to engine speed while the peak demand for the accessory usually occurs in urban type, low speed vehicle operation. A number of alternatives are under study to conserve the excess fuel required at higher speeds. One obvious solution is the temperature controlled engine fan which functions only when needed--and rarely at highway travel speeds.

Of all the accessories, vehicle air conditioning imposes the most severe penalty on fuel economy, as shown on Table 9.

TABLE 9

ESTIMATED FUEL CONSUMPTION
BY MAJOR VEHICLE ACCESSORIES
(Miles Per Gallon)

	Relative Operating Speeds	
	Low	High
Air Conditioning (Operating)	2.0	1.0
Alternator (Partial Load)	0.6	0.4
Engine Fan	0.1	0.5
Power Steering	0.1	0.4

It is interesting to note that these accessory fuel costs, when combined, amount to about 2.5 MPG or nearly 20 percent of the national average rate of miles per gallon. However, a number of these items (fan, alternator, etc.) are essential to vehicle operation and must rely on technological advancement for efficiency gains. Power steering and other electrical conveniences, such as power windows may become less important to the consumer if he continues to shift to smaller vehicles. New technology in air conditioning compressors (the major power use) and alternative cooling systems are being studied and improvements may be forthcoming.

Although highly subjective and difficult to quantify on an individual accessory basis, these devices have such a significant impact on automotive fuel consumption that considerably more attention will undoubtedly be focused upon them. If accessory operating efficiency improvements as small as 5, 7-1/2 and 10 percent can be achieved over the 1976-1978 model years, respectively, the potential fuel savings could amount to 25 thousand barrels per day in 1978 (see Appendix C, Exhibit IV, Auto Design Computations).

VEHICLE MAINTENANCE

The automobile manufacturing industry has an outstanding capability in technology, mass production methods, quality control and marketing. All of this expertise terminates, however, when the vehicle title is transferred from the dealer to private owner, who obviously views the vehicle from a much different vantage point. The individual, while basically concerned with the transportation he has purchased, must now weigh the trade-off between operating and maintenance costs as influenced by his rate of mileage accumulation and the practical economics or emotional whim (as the case may apply) of trading for another new car.

Despite the length of ownership or mileage, the automobile owner can improve the fuel economy of his vehicle through better maintenance, and by obtaining regular tune-ups as recommended by the manufacturer. Aside from the normal tune-up items of checking carburetion, spark plugs, distributor points, air cleaner elements, etc., it also serves the motorist, in the interest of best economy, to keep the tires properly inflated and front wheel alignment checked for proper attitude. As examples of the fuel economy influence of some variables, retarded engine spark timing of 5 degrees from specification can cause a 1 MPG loss; a spark plug misfiring only half the time at 60 MPH can reduce fuel economy by 7 percent (0.5 to 2.0 MPG); underinflation of tires increases rolling resistance and tire wear, and can lower fuel economy by as much as 1 MPG; and, improper front wheel alignment (toe-in) of only 1/4 inch can effect a loss of .2 to .4 MPG, besides causing excessive tire wear.

The typical manufacturers maintenance schedule varies but, on the average, seems to call for tune-up services at about 12,000 miles or at annual intervals. Unfortunately, there are no statistics to reveal the percentage of compliance with these recommendations and, as a result, no precise method for estimation of the fuel savings that could be achieved through greater owner participation. A reasonable and conservative basis for establishing a hypothetical scenario of savings potential through improved maintenance, assumes that half of the cars and (non-commercial) light trucks could exhibit a modest 5.0 percent increase in efficiency through an annual tune-up. Under these conditions savings potentials of 142 and 174 thousand barrels per day might be achieved in 1974 and 1978, respectively.

Generally, this proper maintenance is neglected by the auto owner due to factors such as inconvenience, high initial cost, dissatisfaction with previous service, ignorance, or simple disinterest. Absolute adherence to a prescribed maintenance schedule is likely to be accomplished only under some form of mandatory control; however, this implies a type of "proof of service" or inspection procedure which could become very costly if considered on fuel savings merit alone. Fortunately, past studies have given strong evidence that improved levels of maintenance enhance fuel economy while lowering the level of emissions. Therefore, an efficiency control strategy could easily be coupled with an emission inspection program, when and if the latter is determined as necessary on a national scale.

In terms of costs, a tune-up procedure for all vehicles presently on the road would approach $5 billion at a cost of $40 per unit. Greater than annual frequency for this maintenance has been suggested, but some studies conclude that this would be an extravagant venture. After a complete tune-up, very little economy or performance deterioration is found to occur during the first 5,000 miles of driving. Since the average vehicle travels about 10,500 miles per year, a more intensified maintenance program would not be cost effective unless fuel economy could be improved by 19 percent or until the price of fuel rose to $3.48 per gallon--very unrealistic conditions (see Appendix C, Exhibit V).

From a fuel economy and emissions standpoint, a proper maintenance strategy yields benefits but imposes cost burdens on motorists who have not maintained their cars, and on government for enforcement techniques. While adoption of such a program would add business for the vehicle service industry, the latter may not be prepared to cope with such an influx on short notice. Education of more servicemen and additional diagnostic equipment would be required to achieve maximum benefit.

Such a maintenance strategy has the disadvantage of discriminating against low income individuals, as those persons owning older vehicles of low value would be faced with disproportionate, and undoubtedly burdensome costs. Thus, as maintenance costs increase, the motorist would have to balance this cost with the true depreciated value of his vehicle. Overall, it is doubtful that any mandatory maintenance program could be justified solely on a conservation or cost-effectiveness approach, but the subjective values of lower emissions and better vehicle performance would serve as favorable modifiers.

VEHICLE CHANGES (SMALLER CARS)

Many factors of vehicle design, driver behavior, and vehicle use restrictions have been discussed in terms of achieving greater fuel efficiency and/or the conservation of fuel, but it is really the buyer of vehicles who is indirectly in control of the entire situation. The automobile industry, desiring to sell new cars, must produce approximately what the consumer wants to buy or face the uncertainties of lost sales. Unfortunately, the complex production techniques that must be employed to serve a vast number of consumers are handicapped by a lack of immediate flexibility which results in a time lag for the satisfaction of whatever preference is expressed in the marketplace. The delay in meeting the rapidly growing consumer demand for smaller cars was a prime example of this situation.

For a number of years the small imported cars have held between 12 and 16 percent of the market for new car sales. In recognition of this consumer attitude, the early 1970's saw the introduction of new domestic sub-compact models which have captured an increasing share of the market. Since 1970, when small cars (compact, subcompact, and imports) accounted for 29.6 percent of sales, consumer preference influenced by higher fuel prices and fuel shortages has pushed the small car share of market to more than 45 percent. Recent demand for small vehicles has risen so rapidly that sales are supply limited, and it is estimated that some 46 percent of the new car buyers will express a preference for these smaller cars during 1974 (see Appendix C, Exhibit VI, Figure 6).

The point of market saturation for these smaller cars depends on many factors such as vehicle prices, fuel availability and the future state of the general economy. Consumer acceptance of the smaller car seems well established so that the intensity of the shift becomes highly dependent on auto industry manufacturing capability. The trend over the past 4 years (1970-1974) indicates an absolute yearly gain of 4.1 percent in market share for these smaller cars, and based on industry efforts to expand production facilities, it is deemed reasonable that this growth could prevail through 1978. On this basis, 1978 small car sales would hold 62.4 percent of the market and would represent 40.3 percent of the passenger car fleet (see Appendix C, Exhibit VI for methodology).

The market forces in favor of the smaller car have served to hold average passenger car fuel economy at a relatively constant rate over the past few years. According to calculations (see Appendix C, Exhibit VI), the shift to smaller cars occurring between 1972 and 1974 is probably responsible for reducing 1974 fuel requirements by about 73 thousand barrels per day. If the small car growth trend continues as previously estimated (growing to 40.3 percent of the 1978 fleet), the apparent fuel savings could amount to 361 thousand barrels per day.

Provided the present considerations prompting the sale of small cars continue to prevail, consumers will undoubtedly persist in demanding as many of the efficient vehicles as the industry can produce. However, this gives rise to complications in the form of high capital costs for the production changeover, employment and production curtailment during the conversion process, and the potential loss of some of the profit margin which is greater on the large car. Moreover, the overall average price for new cars must be maintained at least at present levels if the industry is to generate sufficient funds for the conversion to small cars. As might have been anticipated, the consumer is showing greater tendencies to equip the smaller car with profitable options which should aid the industry. However, this detracts from the higher efficiency of the smaller car by adding weight and engine load. There is also an aspect of safety, based on the evidence that smaller cars offer less collision protection than the larger car.

From a more positive standpoint, the shift to smaller cars would lower resource requirements (steel, rubber, etc.) and could have a favorable impact on the balance of payments by virtue of greater export potential for the domestic small car, and/or by a reduction in the need for as many imported cars. The environmental impact is certainly favorable, but unclear as to degree because of lacking comparative data between the emissions of small *versus* large cars.

In total, the shift to smaller, more efficient vehicles is likely to be the largest single factor in terms of fuel conservation potential as the effect filters through all forms of vehicle use. The savings realized through this change would be compounded through implementation of other conservation measures such as car-pooling, speed limits, auto design and improved driver behavior. Policies for acceleration of the transition could include taxation of fuel and/or car inefficiency, and funding of auto efficiency research and consumer education to accelerate the current small car trend. Regardless, the transition can proceed only at a pace commensurate with the industry's capability to produce smaller cars which, in the final analysis, is dictated by the consumer's willingness to buy.

EMISSION STANDARDS AND LEAD PHASEDOWN

Automotive emission controls have reduced the average gasoline mileage of 1973-1974 model cars by about 15 percent compared to pre-control (1967) models. Predictions of mileage improvements for 1975 cars equipped with catalytic devices vary widely. Estimates of improvement range from 3 percent to about 15 percent, and average about 8 percent. Most estimates, however, are understood to include the combined effect of a variety of measures including the emission control system, radial tires, improved ignition and carburetion and lower average weight.

Fuel economy improvements in 1975 cars related to emission controls are the result of engine operating adjustments that are being made which improve fuel economy, but these adjustments result in higher emissions of pollutants from the engine which are converted by the catalytic emission control device. Future, progressively more restrictive emission standards and gasoline lead regulations are projected to have further adverse effects on energy consumption. These energy losses will occur in cars in the form of declining mileage economy and in petroleum refining as more energy is required to produce gasoline with lower lead content.

The key issue in the analysis of the emissions and lead regulations is the question of environmental protection on the one hand and energy penalties and higher costs to the consumer on the other. Many have argued that the emissions standards and lead regulations go beyond what is required to protect public health, resulting in unnecessary energy losses and higher costs.*

Moderation in the emissions standards and lead regulations would have a corresponding energy conservation result. Possible changes and their energy conservation effects could result in a total energy saving of approximately 311 thousand barrels per day crude oil equivalent by 1978, as shown in Table 10. After 1978, the potential energy economies from the above actions, particularly the above California standards scenario, increase rapidly. This will be discussed in the Phase II (1979-1985) report.

Background

In 1970 Congress passed the Clean Air Act Amendments which specified that:

- The hydrocarbon (HC) and carbon monoxide (CO) emission levels of 1975 model cars must be reduced 90 percent from the level of the 1970 cars.

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* At this writing, a study on the automotive emissions standards is currently in progress by the National Academy of Sciences (NAS) and is expected to be completed by October. On the lead phasedown, suits have been filed against the EPA challenging the legality of the regulations.

- The oxides of nitrogen (NO_x) emissions level of the 1976 car must be reduced 90 percent from the level of the 1971 car.

TABLE 10

POTENTIAL ENERGY CONSERVATION THROUGH
MODERATION OF EMISSIONS AND LEAD REGULATIONS
(Thousand Barrels Per Day Crude Oil Equivalent)

Proposed Regulation Amendments	Savings in 1978
Extend 1975 Emission Standards through 1977	140
Starting 1978, adopt 1975 California standards and use high octane (98 RON) leaded gasoline in high compression ratio engines	102
Rescind lead phasedown	69
Total	311

Emission standards are expressed in grams per mile of each pollutant emitted by the car. The standards for 1975 and 1976 established by the Clean Air Act Amendments are shown in Table 11.

TABLE 11

EMISSIONS STANDARDS ESTABLISHED BY THE
1970 CLEAN AIR ACT AMENDMENTS
(Grams Per Mile--1975 Test Procedures)

Car Model Year	HC	CO	NO_x
1974*	3.0	28.0	3.1
1975	0.41	3.4	3.1
1976	0.41	3.4	0.4

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* Established prior to the 1970 Amendments.

Since that time, the EPA granted, in April 1973, a 1 year suspension of the 1975 standards for HC and CO, and in August 1973, granted a 1 year suspension of the 1976 standard for NO_x. In each case an interim for the intervening year was established. In June 1974, Congress amended the Clean Air Act to continue the 1975 standards for the 1976 model year and established a NO_x standard for the 1977 model year of 2.0 grams per mile, deferring the stringent

0.4 grams per mile standard until 1978. The net effect of these decisions and of options granted to California because of its special status is shown in Table 12.

TABLE 12

EMISSIONS STANDARDS APPLICABLE AS OF SUMMER 1974
(Grams Per Mile--1975 Test Procedure)

	U.S. Excluding California			California		
Car Model Year	HC	CO	NO_x	HC	CO	NO_x
1974	3.0	28.0	3.1	2.8	28.0	2.0
1975	1.5	15.0	3.1	0.9	9.0	2.0
1976	1.5	15.0	3.1	0.9	9.0	2.0
1977	0.41	3.4	2.0	0.41	3.4	2.0
1978	0.41	3.4	0.4	0.41	3.4	0.4

The Energy Supply and Environmental Coordination Act of 1974 (HR 14368) also provides that an auto manufacturer may seek a 1 year suspension of the HC and CO standards applicable to the 1977 model year. If granted, the Administrator is required to establish interim 1977 standards. When Administrator Ruckelshaus announced the 1 year suspension for HC and CO in April 1973, he stated that:

> Applicants have established that an effective control technology is not available in time for compliance; and the National Academy of Sciences study and other information available to me have not demonstrated that the technology is available to meet the standards.

Interim standards were established which would, in EPA's judgment, lead to "phasing-in" of catalysts in 1975.

> It is my opinion that the public interest dictates that the catalysts be phased into use in 1975 by setting standards in California that will require their use on all domestic automobiles sold there in 1975 and further to set an interim standard for the rest of the Nation that will likely result in some catalysts used on some models nationwide by 1975. The standards for California in 1975 will be .9 grams per mile of HC emissions and 9 grams per mile of CO emissions. It is our technological assessment that these standards will require catalysts on substantially all cars sold in California in 1975. The standard nationwide in 1975 will be 1.5 grams HC and 15 grams per mile of CO. The technological assessment available to me

indicates that few catalysts will be required to meet this standard, although some manufacturers may elect to employ catalysts on selected lines sold outside California.

At that time, Mr. Ruckelshaus also stated: "our assessment of the health risk associated with NO_x no longer supports the statutory 90 percent reduction standard and this should be reviewed quickly, and if our analysis is correct, the standard should be changed." Although the NO_x standard was later suspended (in August 1973) for 1 year and again in June 1974 for 1 additional year, the stringent 0.4 grams per mile standard is still the ultimate target for 1978.

As the 1975 model year approaches, it appears that rather than the "phase in" which was expected, the auto industry has made a more substantial commitment to catalytic systems than the EPA anticipated. The EPA now estimates that 60 to 85 percent of the 1975 model cars will be equipped with oxidizing catalytic converters. The catalytic converters will keep HC and CO emissions within the limits and also permit engine operating adjustments which will improve fuel economy.

Regarding lead in gasoline, because it is believed that lead would deactivate the catalysts in emission control devices, the EPA promulgated regulations in January 1973 requiring the general availability of unleaded gasoline by July 1, 1974. In addition to the unleaded grade requirement, lead phasedown regulations were promulgated in the *Federal Register* on December 6, 1973, which provide that the average lead content of gasoline produced at any refinery not exceed the following grams per gallon in any 3 month period shown on Table 13.

TABLE 13

AVERAGE LIMITS OF LEAD IN GASOLINE
(Grams Per Gallon)

Effective Date	Limit
January 1, 1975	1.7
January 1, 1976	1.4
January 1, 1977	1.0
January 1, 1978	0.8
January 1, 1979	0.5

Conservation Options

Since the passage of the Clean Air Act Amendments of 1970, there has been considerable controversy over the basis of and need for standards that represent such severe reductions in emissions.

Numerous studies have been done to show the economic impact on the public in terms of higher cost cars and higher fuel consumption needed to achieve the established standards. The EPA has recently concluded that the ultimate NO_x standard of 0.4 grams per mile is not necessary and has recommended an extension of the 2.0 grams per mile standard through 1982. Others suggested an extension of 1974 standards to avoid the broad commitment to catalysts and unleaded gasoline. Still others, including the Administration suggested extending the 1975 standards. A 1 year extension has just been enacted (June 1974) by Congress.

The regulation requiring the phasedown of lead content in gasoline is based on the thesis that lead might be a health hazard. As there is some question about this contention, lawsuits have been filed against the EPA challenging the legality of the regulations. It has been suggested that, even if it is proven that automotive lead particulate emissions represent a health hazard, installation of lead traps on cars would be preferable to removing lead from gasoline. Marked progress has been reported in the development of these devices and they now represent a viable solution to the problem. Except for a slight weight addition they would cause no fuel penalty. If the lead phasedown is maintained, energy consumption will increase because more severe refining operations will be required to obtain the octane needed.

One of the greatest long-term potentials for economy in the manufacture and consumption of gasoline is in the use of high octane, leaded gasoline in high compression ratio engines. However, catalytic emissions control devices on cars are an effective block to such a strategy. Present regulations governing emissions from future automobiles will result in a rising population of cars equipped with catalytic devices. These cars will use less efficient low compression ratio engines to permit operation on low octane (91 research octane) unleaded gasoline. This use of catalysts will start with the 1975 emissions standards. Unleaded gasoline is necessary since lead in gasoline would deactivate the catalysts. As the emissions standards become more restrictive in the future, automotive fuel economy (MPG) will deteriorate. Looking ahead to 1978, there are presently no prospects for practical (non-catalytic) emission control systems which will permit the use of leaded high octane gasoline while meeting Clean Air Act emissions standards.

Pending the outcome of the NAS study on emissions and the suits on lead in gasoline, several potential energy conservation options are open in the area of emissions standards and lead in gasoline. For purposes of estimating the energy conservation volumes, the options analyzed are as follows:

- In 1975, it is generally agreed that automotive fuel economy (MPG) will improve when compared to 1974 cars, although industry estimates of the magnitude of the improvement vary. After 1976 automotive fuel economy will worsen as emissions standards become progressively more restrictive. Therefore, there is a potential for conserving energy by extending the 1975 standards. While doing so would save gasoline, total automotive emissions would still continue to decline. Congress has just enacted this extension for 1 year (1976) and given the EPA authority to grant automotive manufacturers, upon request, some relief from the 1977 standards. For purposes of quantifying potential energy savings, this extension is assumed for 2 years through 1977.

- If, starting in 1978, standards at the level of the 1975 California standards (0.9/9.0/2.0 HC/CO/NO$_x$, respectively), which are more stringent but not as restrictive as the 1978 statutory standards (0.41/3.4/0.4), were concluded to be protective of public health, improvement in fuel economy of cars could be possible by abandoning catalytic devices and using high compression ratio engines and high octane leaded gasoline. At these emission levels there is a reasonable chance by 1978, based on promising developments to date, such as the Honda CVCC engine and the Dresserator inductor carburetor, that these 1975 California standards could be met without catalysts and the automotive industry could produce lead tolerant, more efficient high compression ratio engines.

The potential fuel economies that can be realized from these options are compared with a base case which assumes continuation along the path of current emissions and lead regulations. The energy that will be conserved by the recent Congressional extension of the 1975 standards is also calculated. The emissions standards for the two cases are shown in Table 14.

TABLE 14

EMISSIONS STANDARDS
(Grams Per Mile)

	Base Case (Statutory Standards)				Conservation Case			
Car Model Year	Catalytic Converters	HC	CO	NO_x	Catalytic Converters	HC	CO	NO_x
1974	No	3.0	28.0	3.1	No	3.0	28.0	3.1
1975	Yes	1.5	15.0	3.1	Yes	1.5	15.0	3.1
1976	Yes	1.5	15.0	3.1	Yes	1.5*	15.0*	3.1
1977	Yes	0.41	3.4	2.0	Yes	1.5*	15.0*	2.0
1978 and forward	Yes	0.41	3.4	0.4	No	0.9†	9.0†	2.0†

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* 1975 standards extended two years.

† California 1975 standards nationwide; high compression ratio engines using high octane leaded gasoline.

The potential energy economy that can be realized in the conservation case, totaling 311 thousand barrels per day crude oil equivalent, results from several options each of which is discussed below.

Extending the 1975 Automotive Emissions Standards

Extending the 1975 automotive emissions standards will result in fuel savings. In order to calculate this savings, the 1975 HC and CO emissions standards are assumed extended for 2 years through 1977. Although there is not complete agreement on projections of automotive fuel economy over the next few years, an effort is made in this analysis to strike a reasonable balance among various industry predictions. Regarding 1975 model cars, there appears to be general agreement that the fuel economy of these cars, when equipped with catalysts in order to meet the 1975 interim standards, will show an improvement over 1974 cars. However, in 1977 this situation will reverse if the more severe standards are imposed since engine operating adjustments will be required that adversely affect fuel consumption.

For purposes of analyzing the effects of emissions standards on automotive fuel economy, using an index of 100 for 1975 cars' fuel economy, Table 15 shows the estimated fuel economy of future model years' cars.

TABLE 15

RELATIVE FUEL ECONOMY

Car Model Year	Index
1975	100 (base)
1976	100
1977	92 (8% worse fuel economy)
1978 and later	87 (13% worse fuel economy)

The 1978 model car fuel economy is difficult to predict because of the very stringent 0.4 grams per mile NO_x standard. The 13 percent worse fuel economy assumed above is based on a dual catalyst approach, although developmental work is in progress on a 3-way catalyst which could afford better auto fuel economy. To date, however, neither approach has demonstrated sufficient durability to meet the 50,000 mile requirement. The dual catalyst approach was assumed in this analysis as it appears to be under the most extensive industry development.

The recent (June 1974) Congressional action to extend 1975 standards 1 year means that 1976 cars will have an estimated 8 percent better fuel economy than would have been the case had the previous standards for 1976 (0.41/3.4/2.0) applied. This action will conserve 59 thousand barrels per day in 1976. If the 1975 standards are extended 1 further year to 1977, the fuel savings attributable to both of these extensions for each of the years through 1978 are estimated in Table 16.

TABLE 16

SAVINGS IN FUEL ECONOMY BY EXTENDING
1975 EMISSIONS STANDARDS TWO YEARS
(Thousand Barrels Per Day Crude Oil Equivalent)

Effective Date	Savings
1976	59
1977	132
1978	140

High Compression Ratio Engines and High Octane Leaded Gasoline

High compression ratio engines and the use of high octane leaded gasoline would result in improved fuel economy. For example, as compared with the use of 91 octane (research) unleaded gasoline in a low compression ratio engine, the addition of 2.5 grams per gallon of lead would increase the octane number to 98. This premium grade fuel, when used in an engine designed with higher compression ratio to utilize this quality, would result in better automotive fuel economy. If all of the efficiency gain were utilized to improve fuel economy, these changes would improve fuel economy 11 percent.

The presently applicable 1978 statutory emissions standards will not permit such a strategy. These stringent standards will, based on present knowledge, necessitate the continuing use of catalysts and, therefore, unleaded gasoline and low compression ratio, less efficient engines. As an alternative, following a 2 year extension of the 1975 standards, were the 1978 standards set nationwide at the level of the 1975 California standards (0.9/9.0/2.0), there is a reasonable chance that lead tolerant, high compression ratio engines which would meet these standards without catalytic devices could be produced on a commercial scale. It is estimated that such cars would have a fuel economy at least comparable to 1975 cars, or a fuel economy index of 100 rather than 87 as presently foreseen for 1978 cars. This conservation strategy, if implemented starting in 1978, would achieve savings of 102 thousand barrels per day in that year, and these savings would rise rapidly thereafter.

Phasedown of Lead in Gasoline

The phasedown of lead in gasoline must be weighed in terms of the aspects of health and energy conservation. The average lead content of gasoline in 1973 was about 2.5 grams per gallon. Under the EPA phasedown, this would be reduced to 1.7 grams in 1975 and progressively each year to 0.5 grams in 1979. This phasedown is based on the thesis that lead might be a health hazard. However, this has been a subject of controversy both between government agencies and between industry and government.

The reduction of lead in motor gasoline requires more severe refining operations which increase energy consumption. It is estimated that the loss in terms of crude oil equivalents will average about 0.5 percent of total crude refined for the period 1975 through 1980, resulting in the losses presented in Table 17.

TABLE 17

ENERGY IMPACT IN REFINING OF THE LEAD PHASEDOWN REGULATIONS
(Thousand Barrels Per Day Crude Oil Equivalent)

Year	Losses
1975	40
1976	64
1977	66
1978	69

Regarding the use of leaded gasoline as assumed in the sections above, even if it is determined that lead particulate emissions in automobile exhausts represent a health hazard, installation of lead traps to remove lead from vehicles' exhaust can be used. Several companies have reported marked progress in the development of these devices, and it is believed that they are feasible for 80 percent removal of lead particulates from exhaust. The lead trap causes no direct fuel penalty, although it adds slightly to the weight of the car.

Continued use of leaded gasoline would not prevent further reductions in auto emission standards at a later date. As indicated earlier, new technology on Honda CVCC type engines and new carburetors promise reductions in emissions by cars operating on leaded gasoline in the future. Meanwhile, with standards frozen at 1975 levels, the total emissions from automobiles would continue to decline until at least 1978.

Desulfurization of Gasoline

Desulfurization of gasoline could be a future possibility if studies, currently in progress, determine that sulfates emissions from catalytic devices will be a health hazard. If it is concluded that they are, one alternative is to moderate emissions standards to preclude the need for catalysts. Alternatively, the possibility has been suggested that refineries might have to install facilities to desulfurize gasoline. Since this is only a possibility, and the facilities could not be installed by 1978, analysis of this aspect has not been included. Such a step, however, would result in further energy requirements in refineries, a large additional burden on the construction industry for facilities and added costs to the customer.

Conclusions

The preceding discussion discloses that several energy conservation options are available in the area of automotive emissions standards and lead in gasoline, which in total would produce savings by 1978 of 311 thousand barrels per day crude oil equivalent. These options are summarized as follows:

- Extension of 1975 emissions standards through 1977 can avoid fuel economy losses in cars after 1975 that will accompany the progressively more stringent standards currently available.

- Establishing emissions standards starting in 1978 at levels which would permit the use of high octane leaded gasoline in high compression ratio engines operating without catalysts would result in improved automotive fuel economy. Pending the outcome of the NAS study, adopting the 1975 California standards starting in 1978 rather than the current Clean Air Act Standards is assumed in this analysis.

- Regarding lead in gasoline, rescinding the lead phasedown regulation would save energy in refineries.

Table 18 is a summary of the energy conservation options discussed above and the estimated potential impact of each option by 1978.

It should also be noted that increasing fuel requirements associated with current regulations represent an increment of petroleum, all of which must be imported since domestic crude production is not expected to meet requirements. The balance of payments aspect is substantial. The imports required to meet the increment of gasoline demand which could otherwise be conserved by the above actions could occur either as crude oil or as gasoline. If construction of additional refining capacity by 1978 is sufficient to fully meet product demands, crude oil could be imported. If not, finished gasoline would need to be imported. Depending on price levels prevailing in 1978, these imports could amount to several billion dollars.

TABLE 18

POTENTIAL ENERGY CONSERVATION THROUGH MODERATION
OF EMISSIONS AND LEAD REGULATIONS--1975-1978
(Thousand Barrels Per Day Crude Oil Equivalent)

Proposed Regulation Amendments	Savings 1975	1976	1977	1978
Extend 1975 Emissions Standards through 1977	0	59	132	140
Starting 1978, use high octane (98 RON) leaded gasoline in high compression ratio engines	0	0	0	102
Rescind lead phasedown	40	64	66	69
Total	40	123	198	311
Approximate Savings in Gasoline Equivalent	36	110	178	280

MODE SHIFTS (FROM AUTOMOBILES)

Public demands for speed and convenience in transportation have historically outweighed the cost of increased energy consumption. Despite some gains in the overall efficiency of motive systems, the general trend of transportation energy efficiency continues to decline. Government policies, social and environmental concerns, relatively low cost energy, the suburban life-style, and the penchant for increased mobility have all contributed to this situation.

Significant variation exists in the energy intensiveness or efficiency among the various modes of transportation and the major shifts that have occurred over the recent past have tended to move away from energy optimization. For example, buses and railroads have lost inter-city passenger traffic to automobiles and airplanes, while intra-city or urban travel has shifted from mass transit (buses and trains) to the automobile. These faster, more popular, means of conveyance have reached a level of saturation where congestion has become an important function of inefficiency. Moreover, this congestion has, in part, given rise to environmental constraints, some of which imply further decreases in energy efficiency for these modes of travel.

In the realm of highway travel, automobile energy efficiency has declined primarily due to increases in power, speed of travel, vehicle weight and emissions control equipment. The automobile's long-standing popularity, achieved through the individual flexibility and convenience it offers, continues to increase, and prominent consideration for continued use must weigh heavily in any plans for conservation. Examination of present policy assumes that curtailment of passenger movement is untenable. In the absence of feasible alternatives of necessary timing and scope, the burden of conservation must therefore be predicated on efforts to achieve efficiencies through improvements within the present systems. Initial action will require resolution of conflicting government policy (pollution abatement and conservation of fuel) and the provision of incentives, as described in this report, to optimize energy utilization. Thus, it is assumed that the emphasis on individual transit will remain; that conservation will be achieved by increasing the efficiency within the individual mode, and by improving the balance among modes.

A prime candidate for achieving this better balance, lies in the area of diverting some of the intra- and inter-city travel away from the automobile in an evolutionary manner. An appraisal of these categories of travel, along with the energy efficiency and present mix of modal utilization suggests that some shifting is feasible and in the interest of conservation.

Well over half of the energy consumed by automobiles occurs within urban areas where congestion and the fuel economy penalties (MPG) of stop and go driving play a significant role. Of the estimated 570 billion urban miles traveled by passenger (motor) vehicles in 1972, 99.6 percent was covered by automobile and only 0.4 percent was by bus, including school buses. More importantly, the efficiency of the urban motor bus, in terms of passenger miles per gallon can be 2 to 5 times greater than the automobile and any diversion from the latter obviously offers considerable savings potential.*

Recent studies indicate that approximately 20 percent of urban automobile travel could be diverted to buses through extension and improvement of bus service and by making auto travel less convenient and more costly. In terms of 1970 travel data, a shift of this magnitude would imply an 8-fold increase in bus travel and is therefore limited by the availability of buses. Of course, an immediate shift of this magnitude is unreasonable due to a lack of buses and should not even be anticipated during the timeframe covered under this Phase I report (1974-1978). However, as depicted in Table 19, it is calculated that buses would most likely be able to achieve a gain of 14.9 billion passenger miles by 1978, or more than 70 percent over the 1970 levels, with the resultant fuel conservation amounting to 498 million gallons or 33 thousand barrels per day (see Appendix C, Exhibit VII, Urban Bus Passenger Miles).

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* *Note:* It should be noted that the measurement of efficiencies for various transportation modes are extremely sensitive to the assumed factors of load (number of passengers) and fuel economy (miles per gallon). For example, the efficiency for high capacity passenger vehicles varies dramatically with the change in load between rush hours and off-peak times.

TABLE 19

CALCULATIONS OF URBAN BUS PASSENGER MILES

Year	Buses in Service	Average Passengers	Average Miles	Passenger Miles x 10^6
1960	49,600	18.8	30,380	28,330
1970	49,700	13.3	31,560	20,860
1978	65,000	16.6	33,140	35,760

Without expansion of the bus fleet, there is only modest potential to absorb urban auto travel. For example, if one assumes the same number of buses and mileage that existed in 1970 but increases the load factor (average passengers) back to the average 1960 level of 18.8 passengers, the potential fuel savings is only 303 million gallons or 20 thousand barrels per day. If the 1960 load factor could somehow be achieved along with expansion of the bus fleet and service, the savings potential jumps to 690 million gallons or 45 thousand barrels per day. These numbers, however, make no allowance for the quantity of smaller intra-city buses that may be manufactured by the recreational vehicle industry, or the capacity of school buses to absorb transit service peaks; nor do they attempt to determine any balance or trade-off between gasoline and diesel fuel in this net savings value.

Although a considerable range in the quantity of fuel conserved can be developed through variation of assumptions, it is most sensitive to the availability of buses. The general impact of such a shift can be stated for this set of assumptions because the degree of impact should change in proportion to the shift that actually occurs. Expanded production of buses would give an economic lift to the workers in vehicle manufacturing and related industry through added job opportunities. Of course, a larger bus fleet requires replacement in time; which implies increased plant and equipment investment for an industry already burdened with these problems to attain more small car output. There is also a question as to how the capital will be raised for the purchase of this equipment by cities or transit companies. Higher parking costs and/or reduced parking availability necessary to encourage buses will most certainly meet public resistance and the business community will undoubtedly fear further loss of sales to the suburban shopping centers.

Despite these apparent handicaps and a probable increase in average urban travel times, a move to expanded busing would offer the benefits of reduced auto air pollution, less traffic congestion and obviously, more convenience in public transportation. Another attribute is likely to be an increased margin of travel safety as the passenger fatality rate for urban transit is roughly 20 times lower than for automobiles.

Overall, a shift to buses for urban transit appears to be of significant value in terms of energy conservation and the success of implementation will largely depend on how much the deterrent to commuting by auto, as measured by cost differentials and loss of convenience, will be expanded. Utilization of buses can be encouraged through adoption of auto restrictive and parking policies as discussed under travel characteristics. Initial improvements in bus service will undoubtedly require federal assistance for equipment purchase and operating subsidy, but the major constraint for implementation lies chiefly in the availability of more buses.

Since the automobile increasingly dominates as the primary mode of travel for trips of less than 500 miles, another area of conservation opportunity lies in a shift away from the use of cars for inter-city travel. The present system alternatives for such a transition are bus, train and aircraft; however, while the latter is generally more energy intensive than the car, there is some potential for increasing the air load factor without attendant change in fuel consumption.

To define the parameters of conservation potential available through a shift to buses, trains and aircraft for inter-city travel, it must be observed that this is the area of the automobile's greatest efficiency. Of course, the inter-city bus is more efficient than the car; while the train can be more efficient than even the bus, present use experience does not substantiate this theory. Passenger train efficiencies are elusive not only through the vagaries of data, but because the addition of passenger car units to a train does not create a proportionate increase in fuel consumption.

In terms of inter-city travel, it is estimated that nearly 45 percent of total passenger car travel in 1972 (986 billion total vehicle miles) resulted from trips outside urban areas. Through application of an average load factor of 2.5 persons, some 107.13 billion inter-city passenger miles were traveled in 1972 by car; while, comparatively, 25.6 billion were by bus, 8.6 billion by train, and 117.7 billion were accounted for by air (excluding 10 billion by private planes). Analysis of the passenger car travel, however, reveals that much of the inter-city movement is for vacation, holiday and visitation purposes which occurs seasonally, has peaks of short duration, and is characterized by high rates of occupancy (load factor). It is therefore reasonable to suppose that diversion of this traffic would be difficult in terms of public acceptance and could not be economically justified in alternate mode capability. It is estimated that 38.2 percent of total inter-city passenger miles could be diverted (see Appendix C, Exhibit VII, Inter-City Automobile Travel).

A shift of this maximum potential is deemed unreasonable as it would mandate massive expansion in bus, train and/or air industries (3-fold for air, 16-fold for buses or 48-fold for trains based on 1972 passenger miles). Based on available factors for 1972, it is calculated that inter-city buses would be able to gain 23.7 billion passenger miles or 93 percent by 1978 over the 1972 level. The resultant fuel savings from such a shift would amount to 478 million gallons or 31 thousand barrels per day (see Appendix C, Exhibit VII, Inter-City Bus Travel).

The ability of the passenger train to absorb inter-city travel from automobiles is difficult to substantiate on a numerical basis due to lack of appropriate data. However, the consequences may be of little significance in the short term due to a number of factors such as the existing shortage of trains and skilled operating personnel. Despite these problems, a quantitative evaluation of conservation can be made in terms of eliminating a portion of automobile passenger mileage. For example, if trains were somehow able to double their passenger carrying capacity by 1978, and the equivalent amount or 8.6 billion passenger miles were diverted from inter-city autos, the potential fuel conserved amounts to 229 million gallons or 15 thousand barrels per day, less whatever additional fuel would be required for locomotives in this service.

The airline industry has the capacity to absorb a sizable increase in passengers if they are shifted from inter-city auto travel. Measured as the difference between available seat miles and revenue passenger miles, the actual load factor for domestic and local flights during 1972 was 52.1 percent. According to industry representatives, the theoretical load factor limit approaches 65 percent before access to the system is inhibited and/or additional planes are required, which leaves fuel consumption virtually unchanged.

Based on these factors, if one reasonably assumes that the various disincentives to inter-city auto travel could encourage utilization of 75 percent of this existing passenger mile capacity by 1978, some 21.9 billion passenger miles could be shifted to air. This transferal would result in an average airline load factor of 61.8 percent and a fuel savings of about 38 thousand barrels per day.

The impact of shifting to buses, aircraft and trains for inter-city service, as in the case of many other alternatives, would reduce pollution, congestion and increase traffic safety; and by so doing, make the option of driving the car more attractive. Provided shifts are made, there will invariably be a loss of convenience and time for the traveler (excepting shifts to air) plus the lack of flexibility upon arrival. For example, vacation plans to an isolated location might be abandoned due to lack of personal vehicle at the destination. On the other hand, government policies directed toward this shift would encourage expansion of the bus and train industries creating further employment.

The expansion of train facilities would take considerable time; and in view of financial conditions, would undoubtedly require federal assistance to ensure sufficiently rapid expansion and adequate service. Implementation of these shifts could be encouraged by raising the cost of driving via tolls and taxes and by lowering these alternate costs through subsidies. As evidenced by the calculations on capacity to absorb travel and on fuel saving, however, no amount of incentive will eliminate the car from inter-city travel during the next decade.

PART TWO: COMMERCIAL TRUCKING

The Nation's commercial trucking industry in 1972 accounted for virtually all local cargo transportation and for 23 percent of all inter-city freight ton-miles. The essential nature of these services is evidenced by the fact that no other known method of freight movement has the inherent overall flexibility nor the capability to efficiently move goods at a local level. Estimated fuel requirements and vehicle mileages attained in performing these services are set forth for 1972 in Appendix C, Exhibit VIII, Table 30.

The total consumption of fuels by all commercial trucks was 1,289 thousand barrels daily in 1972, or only 14.3 percent of all fuel used in transportation. However, the majority of service performed through trucking is indispensable relative to the quantity of fuel consumed and any reductions in fuel use must be measured carefully in terms of the potential impact of inadequate freight transportation within the economy of the Nation. Despite the significance of trucking's economic contribution, there are some areas open to the practice of fuel conservation, but these measures must be applied with caution. The areas of fuel conservation potential for commercial trucking are summarized in Table 20.

TABLE 20

HIGHWAY FUEL CONSERVATION POTENTIAL–COMMERCIAL TRUCKING
(Thousand Barrels Per Day)

	Savings	
Measure	1974	1978
Speed Limits (55 MPH)	18	22
Design Changes	6	7
Weight Changes	–	24
Maintenance and Operating Procedures	20	37
Mode Shifts (From Trucks)	25	30

SPEED LIMITS

On January 2, 1974, Public Law 93-239 was approved, establishing a national highway speed limit of 55 MPH. Although this law was directed primarily toward the automobile, which is the largest factor in highway consumption, the impact of the change carries through all users of the highway system. The implications of fuel conservation for commercial trucking, as affected by this change in speed limits, varies from efficiency gains of 5 percent to modest losses in overall fuel economy.

From the standpoint of mechanical efficiency, when a truck is geared for 70 MPH, it must have sufficient engine power to maintain that speed, which can allow for efficiency gains when cruising at lower speeds. For the trucking firm, this means purchasing an engine/gearing combination that gives the driver sufficient power to hold a given cruise speed in top gear. If neither full speed range nor ample power reserve is provided, top gear would not be usable as a cruise gear. Thus, operating a larger engine at reduced revolutions per minute (RPM) can give a 5 percent reduction in fuel consumption at the same average road speed, as compared to potential losses from a lower powered engine cruising at full RPM.

Most vehicles and particularly trucks achieve their maximum MPG at the lowest speed at which they operate smoothly in high gear. This is usually between 50 and 60 MPH for the large 10-speed over-the-road truck combinations. Below 55 MPH many inter-city trucks must shift into a lower gear which can reduce MPG; therefore, driving slower is helpful only as long as the driver can make effective use of top gear.

Although these complexities render changes in truck efficiency an elusive factor, the Task Group consensus estimates conservatively) that a 3 percent gain in fuel economy (MPG) could be achieved through lower speeds. However, it is considered realistic to assume that any savings will be realized only in the case of intercity travel since traffic congestion generally precludes speeds in excess of this new limit in urban areas.

As a consequence of these assumptions, the fuel conservation achieved through lower speed limits amounts to 8 thousand barrels per day of gasoline and 8 thousand barrels per day of diesel fuel (calculations in Appendix C, Exhibit IX).

The impact of these lower speed limits is obvious to those who have driven at 50 or 55 MPH for an extended period on the open road, where such a low speed is inefficient in terms of time for long trips. Slower speeds obviously cut the productivity of a truck, and trip times can be extended beyond safe driver limits.

It has been estimated by the Federal Highway Administration (FHWA) that this reduction in truck speeds has resulted in an overall productivity loss of 8 percent. However, the experience with these new speed limits has not been sufficent to formulate the full economic effect. It is possible that the impact may appear as slowed assembly lines, inventory build-up (in parts warehousing) or inadequate merchandise at retail levels. From a social viewpoint, it is likely to increase the time the truck driver must spend away from home; but, it may also enhance the safety of driving through lower fatality rates.

It has been suggested in some circles that an increase in nighttime speed limits be allowed for either trucks or autos but it is the opinion of the Task Group that such a move would destroy the credibility of the necessity for lower limits in the first place, while impairing the intended effectiveness of the action.

TRUCK DESIGN

In the area of truck design, the latitude of change is severely restricted by the need for sufficient cargo capacity to maintain economic operation. A major factor reducing the fuel economy of trucks is air resistance. The amount of this resistance depends on wind conditions, the frontal area and shape of the truck, road speed and the density of the air. One of the major causes of air resistance on volume van-tractor trailer combinations is the abrubt change in shape between the cab and trailer. Another cause, present on all combinations except flat beds, is the gap between the trailer and the cab.

No one has found a practical way to completely streamline this area, but there are commercially available devices that stabilize the air moving past the cab-trailer. These are the cab mounted "wind deflector" and the trailer mounted "vortex stabilizers." The effectiveness of streamlining devices is highly dependent on the particular vehicle and the installation of the equipment. Both are add-on devices requiring no basic change in the truck, although the wind deflector may require cab roof reinforcing. Here, an important caveat is necessary. The maximum gross vehicle weight allowed on the highways is determined by law. The additional weight added to a vehicle as a result of installing wind deflectors and vortex stabilizers or other fuel saving equipment reduces the amount of freight that can be loaded into the trailer by an equal amount. This becomes a problem when dense freight, which loads a trailer long before it is physically filled, is being hauled. Careful consideration must be given to the amount of fuel saved as a result of installing these devices *versus* the reduced payload and loss of productivity because of the additional weight that such equipment adds to the unladen vehicle.

The cooling fan on a diesel powered truck in line haul service is generally not required all of the time. The typical cooling fan uses about 5 percent of rated engine power at governed RPM. Temperature modulated fans have been used to save fuel by reducing the amount of time that the cooling fan is required. However, because of the unique installation problems a temperature controlled fan can cause, the truck manufacturer should be contacted for further information.

Since there are a number of truck transmission and engine technologies in the various stages of development at present, it would be fruitless to try to judge which would be likely to be adopted, much less project the effects in the future.

Replacement of existing trucks with new equipment which has been manufactured to specifications containing all of the known fuel saving devices will not have an immediate reductive effect on fuel consumption. Demand for new trucks is at an all time high. Between 1971 and 1973, 1 million heavy trucks of all kinds were sold. No company has been able to build facilities fast enough to keep up with the demand. Manufacturers have tremendous backlogs, some as long as a year to 18 months. In other words, the old equipment will be on the road for a considerable time.

Despite these problems, the potential fuel saving that could be derived from the various elements of design is undoubtedly important. Lacking extensive research, it is impossible to estimate values on an individual design change basis; but, it would seem reasonable that efforts toward improvement might reflect efficiencies of 1 percent or 7 thousand barrels per day of fuel savings by 1978.

WEIGHT (HEAVY TRUCKS)

In terms of energy conservation, the need for modern efficient motor truck operations is now greater than it has ever been. However, the trucking industry is handicapped in its ability to provide the most efficient type of service due to the existing limits on truck weights which have been in effect since 1956. We are close to completion of the most modern highway network in the world, but the continued presence of federal weight limits have the trucking industry operating under standards that are now 28 years old. Modification of these standards could generate fuel savings through more efficient movement of freight.

Prior to 1956, the control of motor vehicle size and weights had been left completely to the individual states with no federal intervention or controls of any kind. But when Congress passed the Federal Aid Highway Act in 1956, it decided that since the Federal Government was paying 90 percent of the cost of the system, from the Highway Trust Fund, it should set some size and weight limits for that system in order to protect the federal investment.

In looking for some standards to place in the federal law in 1956, the only ones for guidance were those adopted in 1946 (10 years prior to the passage of the Act) by the American Association of State Highway Officials (AASHO). These 1946 standards were slated for change by the highway officials' group but this revision was not initiated.

Nevertheless, the 1946 American Association of State Highway Officials recommendations of 18,000 pounds for a single axle load; 32,000 pounds, for a tandem axle load; 73,280 pounds gross weight limit, regardless of type of truck or truck combination; and a width of 96 inches were placed in the federal law, but as a temporary measure to be revised upward at the earliest practicable date.

However, in 1956 all states were at, or above the federal single and tandem load of 18,000 pounds and 32,000 pounds respectively. This means that since 1956 there has been a complete axle weight "freeze" as far as operations on the Interstate Highway System are concerned and the "freeze" is based on 1946 standards.

Some states were below the federal maximum gross weight limit of 73,280 pounds, but by 1961 all states were virtually at this ceiling, or higher if such higher limits were in effect in 1956. Thus, as far as operations on the Interstate Highway System are concerned, there has been a gross weight "freeze" since 1961--a "freeze" based on 1946 standards.

Section 108(k) of the Federal Aid Highway Act of 1956 directed the Secretary of Commerce (Bureau of Public Roads) to research and investigate the size and weight question and to report back to the Congress by July 1959, with recommendations for new size and weight limitations.

In 1964, the Bureau finally submitted its size and weight recommendations to the Congress (House Document No. 354, 88th Congress 2d Session). The Bureau recommended that as far as vehicle weight limitations in the federal law were concerned, the following changes should become effective in July 1967:

> Increase the 18,000 pound single axle limit to 20,000 pounds. Increase the 32,000 pound tandem axle limit to 34,000 pounds. Change the flat maximum gross weight of 73,280 pounds to a scientific formula that would permit higher gross weights as the length of the vehicles and number of axles are increased. (Highway Bridge Formula B.)

These recommendations were determined by federal and state highway engineers and officials after exhaustive studies and investigations. The report containing them is a comprehensive analysis of all facets of highway capabilities and motor truck operations. Every element of highway safety was researched and evaluated, as well as every element of highway engineering as it pertained to highway pavement and structure capabilities. The recommendations were not those of the trucking industry--but of the highway regulatory agencies, federal and state.

The Bureau's 1964 recommendations for modernizing the federal size and weight limits were endorsed in Congressional hearings in 1967 and 1969, and again in 1974 by the Department of Transportation and its Federal Highway Administration, the successors, respectively, of the Department of Commerce and the Bureau of Public Roads.

These changes also have been endorsed--in the intervening years and again in 1974--by the American Association of State Highway Officials, now the American Association of State Highway and Transportation Officials.

The studies that Congress ordered in 1956 which recommended revision are now 10 years old and the effective date for new limitations is now 7 years past. The 1946 weight standards governing highway use in 1974 affected trucking efficiency before the energy crisis, but the current need to obtain the most efficient use of available fuel supplies emphasizes the situation.

Industry studies show that if the vehicle operating under the present restrictive weight ceilings were permitted to operate under proposed revised limitations; 20,000 pounds single axle limit; 34,000 pounds tandem axle limit; and Highway Bridge Formula B (a scientific formula that would permit higher gross weights as the length of vehicles and number of axles are increased), the tonnage moved by trucks could be carried with a substantial savings in diesel fuel.

There is a problem in strict application of the gross weight formula, however, in states where the length limit is 55 feet and the standard vehicle is the ordinary 5-axle tractor, semi-trailer combination. This vehicle would get very little, if any, payload gain from the gross weight formula as presently devised.

Under the formula, two consecutive sets of tandem axles must be at least 39 feet apart in order to carry a gross weight of 68,000 pounds. The 50 to 55 feet combination usually operates with a semi-trailer 40 feet in length and such a vehicle does not have 39 feet between the first axle of the first set of tandems and the last axle of the second set. This distance is usually 36 feet and under the formula, as presently devised, could carry only 66,000 pounds.

Therefore, the gross weight formula, if placed in the federal law, could contain a special proviso allowing 68,000 pounds to be carried on two consecutive sets of tandem axles providing the distance between the first and last axles of such consecutive sets of tandem axles is 36 feet or more.

While this is a minor difference from the standpoint of bridge protection, it has great economic significance from the standpoint of the many thousands of vehicle combinations of the configuration mentioned. It is important for all such vehicles, regardless of the commodity being carried, but it is critically important to note that at this time, the prevalence of this size vehicle is in tank truck operations--the vehicles moving the commodity which is at the heart of the energy problem.

The higher axle and gross weights proposed for vehicles operating on the Interstate Highway System would result in substantial fuel savings in terms of gallons of diesel fuel required to carry a given volume of highway freight. This is best illustrated using a combination truck which is in common use today--a typical tractor, semi-trailer combination:

- Tractor semi-trailer (5 axles)--55 feet overall length with a 40 or 45 feet semi-trailer and a total empty weight of 26,270 pounds.
- Present maximum weight of 73,280 pounds permits a payload of 47,010 pounds with a fuel consumption rate of 0.238 gallons per mile.
- Proposed maximum weight of 78,000 pounds permits a payload of 51,730 pounds with a fuel consumption rate of 0.246 gallons per mile.
- Fuel/payload ratios--10.0 percent more payload with 3.4 percent more fuel consumed or a benefit ratio of 2.9:1.
- Put another way, higher weight would eliminate approximately one trip in ten.

These comparisons are based on the operations of "typical vehicles" now in use on the highways. Using the above fuel consumption factors and the ton-miles of freight conveyed by inter-city truck during 1972, the potential conservation of fuel would have achieved 19 thousand barrels per day (see Appendix C, Exhibit X). The majority of this diesel fuel savings could be attained as soon as weight limitations are modified. If it is assumed that no other efficiencies of design, operation or speed limitations are implemented and that truck freight movement grows through 1978 at the average rate of the past 5 years (3.9 percent), the savings, by virtue of the above example, could reach 24 thousand barrels per day in 1978 (based on 591 x 10^9 ton-miles).

TRUCK MAINTENANCE AND OPERATING PROCEDURE

Proper maintenance and good driving habits can increase fuel efficiency by as much as 20 percent. These include maintaining maximum specified tire pressure, maintaining proper engine adjustment, skillful driving to hold constant speed, avoidance of "jack rabbit" starts and shifts to higher gear at minimum speeds, and minimum use of air conditioning.

It is obvious that truck engines will run most efficiently when they are in good operating condition. Over-fueling due to changes in fuel pump adjustment and over-speeding as a result of changes in governor cut-off speed are inefficient ways to improve performance and may be illegal due to environmental regulations. One of the engine manufacturers estimated that a 10 percent increase in power gained this way can result in 15 percent more fuel consumption.

Due to the vast number of motor carriers operating in this country today, their different types of operations and commodities carried, and the different geographical regions within which they operate, it is virtually impossible to array a list of fuel saving strategies and to determine the approximate amount of fuel that can be saved as a result of each strategy or by all strategies combined.

However, based on a continuing American Trucking Association fuel consumption and cost survey, it was determined that during the interval between November of 1972 and November of 1973, motor carriers only consumed an additional 6.9 percent of fuel while miles operated increased by 14 percent. As a result of the voluntary fuel conservation strategies initiated by these 300 plus carriers, they were able to realize a 3.0 percent greater efficiency with gasoline powered equipment. Fuel consumption rates for this equipment decreased from 3.54 MPG in 1972 to 3.65 MPG in 1973. At the same time the efficiency for diesel powered equipment increased by 4.4 percent, consumption rates decreasing from 4.54 MPG in 1972 to 4.74 MPG in 1973.

During the summer of 1973 the American Trucking Association surveyed both regulated and private motor carriers, asking them to comment on fuel saving strategies being practiced at that time as well as those planned for the future. Replies from 319 respondents indicated that the following fuel strategies were in operation or would be placed into operation in the immediate future: reducing idling time and/or improved driving techniques, reduced or controlled speeds, consolidated and/or increased loadings, less deadhead (empty) miles operated, increased and/or improved maintenance, reduced service levels, more direct routings, limiting and/or derating engines, using "air shields," more use of twin trailers, not over-filling fuel tanks, conversion to diesel power, using better tires, reduced use of accessories, and no "pre-cooling" of refrigerated trailers.

The Interstate Commerce Commission has recently adopted a regulation governing gateway operations of irregular-route motor carriers which will permit some carriers to bypass existing gateways under appropriate expedited filing procedures. Under the rules, carriers will no longer have to observe gateways--that is, route their trucks through point C instead of going directly between points A and B--if they can save up to 20 percent in mileage by using a more direct route. The Interstate Commerce Commission expects the new regulation to conserve an estimated 300 million gallons (20 thousand barrels per day) of fuel a year.

There are numerous regulations applying to all forms of transportation including commercial trucking. While there are many instances where regulation is a necessity, the vast majority were promulgated when the effect on energy consumption was of minor consideration. Recognizing the current energy situation, regulations for all forms of transport should be reviewed to modify or eliminate those leading to extravagant energy use.

By virtue of this brief discussion, it is deemed both reasonable and conservative that all factors of maintenance and operating procedure, in combination, could yield a total fuel savings of 2.5 percent. Thus, through careful planning, improved techniques and driver education, the quantity of fuel conserved by heavy trucks could amount to 18 thousand barrels per day by 1978. When added to the estimate of fuel saved through the bypass of gateways, the total conservation potential reaches nearly 37 thousand barrels per day.

MODE SHIFTS (FROM TRUCKS)

Almost as soon as one begins a discussion of the possible fuel conservation measures available to the trucking industry, the topic of modal shifts--for example, the transfer of freight from truck to rail--emerges. The idea that shifting freight from trucks to rail could conserve appreciable amounts of energy is based upon misunderstandings about truck operations and of the basically non-substitutable role that trucks play in America's transportation system today.

Since diesel fuel (a middle distillate) is the principal source of energy used by heavy inter-city trucks, this discussion will be confined to diesel fuel consumption and to inter-city freight movements.

Approximately 3.3 percent of total petroleum fuels are consumed by heavy, inter-city trucks from which freight could possibly be diverted to rails. The idea that large amounts of inter-city freight traffic could, in practice, be shifted from trucks to rails overlooks several basic facts about inter-city truck and rail service. The first, and most important, fact is that for the most part, the two kinds of service are distinctly different and in many instances are not readily substitutable one for the other. However, the inherent economics of rail *versus* truck operations relative to long distance and bulk handling cannot be denied. The advantages of each mode are not always translatable into a proportionate rate structure, i.e., the fastest or lowest cost mode is not always the most economic mode for the shipper. Greater concentration by regulatory agencies on a rate structure based on the total economics of shipment by type of goods could also result in greater efficiencies of energy utilization.

A study of the freight commodity statistics for the railroads shows that they are generally long haul carriers of bulk commodities. Motor carriers, on the other hand, usually handle smaller shipments and manufactured commodities. In 1971, rails originated 110 million tons of metallic ores, 360 million tons of coal and 157 million tons of non-metallic minerals (stone, sand and gravel, fertilizers, etc.). The three commodities accounted for $2 billion in rail revenues for 1971.

Motor carriers, in the small shipments area which they dominate handled 83 million tons of "less truckload" (less than full load) traffic in 1971, receiving more than $4.9 billion for this service. The negligible competition between modes in these areas is clear from the contrasting figures for these commodities, as rails handled only 51 thousand tons of small shipments to go with a revenue of $3.3 million, compared to the $4.9 billion by motor carriers. For the three bulk commodities cited, motor carriers handled only 6.9 million tons with revenues of less than $37 million compared to the $2 billion for railroads.

The freight commodity statistics reveal that both modes carry substantial amounts of manufactured commodities. In regard to these commodities, a recent study by Alexander Lyle Morton, *Competition in the Intercity Freight Market*, U.S. Department of Transportation, Office of Systems Analysis and Information, provides a great deal of information on competition between the modes.

Mr. Morton analyzed a 1967 freight study of way bills compiled by the Middle Atlantic Conference from participating motor carriers. He compared the traffic of these motor carriers with the manufacturers and miscellaneous traffic of the railroads as determined from the 1965 Way Bill Sample of the Interstate Commerce Commission. Based on the characteristics of this traffic by commodity classification, Mr. Morton then analyzed the total manufactures and miscellaneous shipments in the 1967 Census of Transportation. The major finding of this study is that only 40 percent of this traffic might be competitive as between railroads and motor carriers. And this level is attainable only if it is assumed that shipment size can be readily altered without additional cost to the shipper and consignee for some portion of the less-than-truck-load traffic. The percentage of competitive traffic falls to only 25 percent if shipment size is not readily alterable. Mr. Morton summarized this finding in the following language:

> The Census of Transportation divides all shipments of manufactures among 85 shipper classes. All shipments within each class are classified into one of thirteen mileage blocks and into one of thirty weight-mileage blocks. Using the criterion that any block of traffic in which both rails and motor carriers show significant participation is 'competitive', it is found that roughly forty percent of the 1.4 billion tons of manufactures produced in 1967 can be considered competitive between motor carrier and rail. This fraction is raised to sixty percent if shipment sizes are thought to be readily alterable or are determined by the mode that shipper and consignee agree upon. On the other hand, the fraction of competitive tonnage is on the order of only twenty-five percent if shipment sizes are thought to be determined quite independently of the mode chosen and are not readily alterable without additional costs to the shipper and consignee.
>
> Using the more stringent criterion of competitiveness that shipment weights are relatively fixed and independent of the choice of mode, about 340 million tons of manufactures are judged to be competitive. Only seven shipper classes among the 85 account for nearly half of this total. They are: grain mill products and sugar, miscellaneous food preparations, pulp and paper, concrete, gypsum and plaster, steel works and rolling mill products, motor vehicles and parts, and hydraulic cement, cut stone, and stone products.*

Shipment weights in these areas are dictated primarily by market practices and needs.

The basis for Mr. Morton's conclusions can be readily seen in Appendix C, Exhibit XI, Tables 31 and 32, which show the distribution of manufactured commodities in the Census of Transportation, in terms of length of haul and size of shipment. For example, it is indicated that private and for-hire motor carriers handle more than 85 percent of all tons transported in shipments under 30,000 pounds in weight. From these data and his own study, Mr. Morton concluded that rails were not competitive for traffic weighing less than 10,000 pounds.

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* Morton, Alexander Lyle, *Competition in the Intercity Freight Market*, Department of Transportation, Office of Systems Analyses and Information, Washington, D.C., February 1971, p. 7-8.

Mr. Morton also concluded that shipments of more than 60,000 pounds, or 30 tons, were relatively immune from motor carrier competition because of the size of shipment. Thus, the area of competition between railroads and motor carriers is practically limited to shipments weighing between 10,000 and 60,000 pounds. According to the 1967 Census of Transportation, there were approximately 407 million tons of traffic in these weight categories, of which 72 million tons moved by rail and 335 million tons by private and for-hire motor carriers. This represents approximately 25 percent of the total manufactures and miscellaneous commodities studied in the Census of Transportation.

It may be argued that some larger portion of inter-city truck traffic may be shifted to rail piggyback service which will result in energy savings. There is no factual basis for any such conclusion. To the contrary, there is sound reason to conclude that such a shift, should it occur, could worsen the energy situation.

The primary reason for shifting traffic to rail piggyback would be to reduce the consumption of diesel fuel in the inter-city movement of truck traffic. The question of fuel saving through transfer of traffic to rail piggyback revolves around the 3.3 percent of transportation fuel used by the heavy-duty inter-city truck operations. The actual amount that might be involved, however, is somewhat smaller than this percentage for the following reasons:

- A significant portion of the consumption is by trucks that in no way operate competitively with any other form of transportation. These are private business non-freight, heavy-duty construction vehicles, dump trucks, heavy hauling operations, etc.

- An equally significant portion of the consumption is by trucks that are engaged in freight transportation of special commodities or in short-haul operations that are not transferable to rail under any imaginable circumstances.

- Of the remaining portion of truck consumption, which might contain transferable traffic, a large percentage actually presents a fuel saving through the highway mode, as this traffic goes directly from origin to destination with no significant movement through heavily congested urban areas. It is, therefore, a truck movement of the most efficient type from a fuel use standpoint.

If this traffic moved by piggyback it would, of necessity, involve origin and destination movements in the congested urban areas (to and from rail assembly and breakup points). This is the most inefficient type of truck movement from a fuel standpoint.

Since most shipments travel relatively short distances, it may be unwise to suggest that a shipment of general merchandise bound for a destination of less than 200 miles distant should be hauled perhaps 50 miles out of its way (by truck) to a piggyback terminal to travel by train some distance to another terminal, there to be picked up by a truck for another 50 mile haul to its consignee. Yet piggyback terminals are generally sited at switching yards, and since the average distance between yards is 160 miles, that is exactly the situation that would prevail if an attempt were made to divert the majority of truck freight to piggyback. Further switching to piggyback places additional trucks in urban traffic situations where they are highly energy intensive.

Research by the Department of Transportation indicates that an expansion of piggyback loadings, from the current rate of 2.5 million per year to 7.5 million in 1980, is regarded by the railroad industry as feasible and likely to occur. If half of this expansion represented tonnage diverted from the trucking industry--9 percent of inter-city truck ton-miles--fuel savings could amount to 369 million gallons per year in 1972 (24 thousand barrels per day) or 0.2 percent of all transportation fuel (see Appendix C, Exhibit XI). This assumes that the average shipment diverted from trucking weighs 15 tons and travels 1,000 miles.

It is estimated that the capital investment in rolling stock and terminals required for such growth by 1980 approaches $15 billion. However, an examination of intermodal transfer of freight between motor carriers and rails indicates that rails suffer from a host of intangible institutional problems which adversely affect service and thus drive shippers to trucking. Resolution of these difficulties will be a more important determination of their success in winning traffic back from trucking than the availability of capital.

In summary, the present use of fuel in heavy duty truck operations is small in terms of total petroleum transportation fuel consumption. However, the transportation service performed through utilization of this relatively small percentage of total fuel needs is vital. Dependency on this service is of such significance that any reduction could have serious effects on the Nation's economy, as evidenced by the recent driver strike. The portion of trucking fuel requirements that could be affected by any transfer of intercity traffic from highway to piggyback by 1978, would be relatively insignificant except when considered as a part of the total conservation effort.

PART THREE: INTER-CITY BUSES

Travel on inter-city buses totaled an estimated 25.6 billion passenger miles during 1972 and reflected a continuing increase for charter and special service while regular-route operations continued to decline. These trends have characterized much of the period since World War II, yet inter-city bus companies carried about 387 million passenger trips and logged roughly 1.18 billion bus miles in 1972.

In providing this service inter-city buses of all types consumed an estimated 14 thousand barrels per day of fuel; more than 85 percent of which was diesel fuel. In terms of conservation of fuel, this level of consumption is a very small base from which to extract saving; but, it is estimated that some 100 barrels per day of fuel or 0.7 percent of consumption could be conserved through increased operating efficiencies. However, one of the major objectives of conservation should be the encouragement of greater bus utilization and this implies a higher level of fuel consumption in this sector of the highway mode of travel.

EXPANDED UTILIZATION

Data on the inter-city bus industry indicates that the interstate segment could provide about 32.6 billion passenger miles of transportation annually over regular routes. Such potential volume represents an increase of approximately 110 percent over current regular-route volume of some 15.5 billion passenger miles. In terms of number of passengers, the currently estimated annual total of about 175 million for regular-route service of this segment of the industry could be increased to some 368 million.

Much of this increase can be handled almost immediately with the present bus fleet and some diversions to regular routes of buses currently in charter and special operations. All of the projected increase could be handled within 1 year as more buses become available. More intensive utilization of the fleet would depend, to some extent, on public acceptance of somewhat less comfort and convenience than at present. On the other hand, lack of motor fuel, other supplies, or manpower could cut sharply into industry potential.

Estimates of the potential noted here are predicated primarily on experience during World War II and subsequent periods of high travel demand, particularly August 1966, when operations on several airlines were halted by strikes.

During World War II, miles per bus reported by the Class I carriers showed relatively little change. On the other hand, their average load factors in regular-route inter-city service increased by at least 50 percent. Averages of more than 86 percent of available seat-miles were experienced in 1943 and 1944 as compared with roughly 57 percent in 1939 and 1940. Total passenger miles rose substantially more during the same years as a result of increasing numbers of carriers in the Class I group, a greater number of buses in their fleets, and a gradual increase in the average seating capacity of their buses.

Results for operations of one company in the United States for the month of August 1966, when assumed to be continued for 12 months at the same level and compared with a recent annual period (October 1, 1972-September 30, 1973), indicate that this company could increase its passenger-mile volume on inter-city routes by about 93 percent without substantial fleet augmentation or diversion of buses from charter or special operations. This increase would involve operation of 63 percent more bus miles than at present and an increase of 18.5 percent in the average passenger load. This company has increased average seating capacity of its buses 6.4 percent between 1966 and September 1973, a development which it believes is more than offset by the loss of productivity which results from the imposition of a national uniform maximum speed limit of 55 MPH.

Another company believes that, judging from its operating experience, it could handle an increase of 75 percent in passenger miles on its regular inter-city routes, requiring an increase of 50 percent in its bus miles and, in effect, an increase of about 17 percent in passenger miles per bus mile (average load). However, the company also believes that the imposition of a 55 MPH speed limit will require about 15 percent more buses just to operate its current level of service, reflecting an approximately proportionate reduction in effective bus miles per bus and diversion of an equivalent number of buses or bus miles from charter and special service.

Vehicle utilization for inter-city bus fleets currently in regular-route service probably can be increased 25 percent in terms of bus miles per bus, and average bus loads for such fleets can be increased some 25 percent. Such increases would result in an average load, per bus, of 22.6 passengers as compared with 18.1 in 1972. These increases are believed to represent conservative estimates which may well be surpassed in practice and probably can be achieved under the 55 MPH speed limit.

If some 150 million bus miles are diverted from charter and special service to regular-route operations, an additional 3.4 billion passenger miles of regular-route travel can be handled with a concurrent and somewhat greater decrease in passenger miles in charter and special service. Expected annual production of 2,650 inter-city buses, if put into service of the interstate carriers without off-setting retirement of buses now in the fleet, can be expected to provide another 4.1 billion passenger miles in potential regular-route volume.

Together, the increases in potential volume resulting from more bus miles, greater average loads, diversions from charter and special service, and expected fleet augmentation would make possible the total annual volume of approximately 368 million passengers or about 32.6 billion passenger miles noted above. Such an increase probably could be handled within a year and without significant reduction in travel comfort or convenience. Further increases are clearly feasible but would require additional buses to be manufactured and probably greater crowding of buses and less convenient schedules.

These preceding estimates relate to the interstate segment of the inter-city bus industry and specifically to the regular-route service operated by such carriers. It is currently estimated that the entire industry, including intrastate carriers, provides a total of about 25.6 billion passenger miles of travel annually for some 387 million passengers in both regular-route and charter service.

The average passenger load on buses in scheduled inter-city service for Class I carriers was 19.4 persons in 1972, but the overall passenger load for all carriers in all service including charters was somewhat greater--probably about 21.7--as a result of greater average loads carried in charter and special service.

Upon completion of new inter-city bus assembly facilities presently under construction, the inter-city bus industry will have the capacity to expand its bus fleets by roughly 5 percent in addition to retiring aging equipment.

During World War II, miles per bus showed little change; however, average load factors in regular-route inter-city service increased by 50 percent. Load factors in regular-route service could realistically be increased by 25 percent to 27.1 passengers per bus without crowding which the traveling public would find abhorrent. In addition, it is estimated that vehicle utilization in regular-route service can be increased 25 percent in terms of average miles per bus. However, average loads and average bus mileage probably cannot be increased significantly for charter and special services, and this will have a moderate influence on the outlook unless these buses are diverted to regular-route service.

Based on these assumptions and estimates, it is concluded that the total industry may be expected to handle about 49.3 billion passenger miles by 1978, an increase of 93 percent. Through diversion of an equal amount of passenger car travel, this level of bus utilization would save about 31 thousand barrels per day of fuel (see Appendix C, Exhibit VII, Inter-City Bus Travel).

The current industry total for passenger miles of travel (25.6 billion as noted above) represents 15.8 percent of total travel on public carriers by air, rail, water and bus (161.6 billion) or 2.0 percent of all inter-city travel (1,300 billion including that by automobile and general aviation). With attainment of industry potential estimated herein, total annual bus travel of nearly 50 billion passenger miles could account for more than 20 percent of the public carrier total in 1978.

OPERATING EFFICIENCIES

The greatest single factor determining actual operating efficiency of an inter-city bus is the driver. It is nearly axiomatic that a driver thinks he can operate a bus better than any of his contemporaries. Unlike airliners which have flight engineers and trains which have firemen, the bus driver has no one beyond the terminal to monitor his performance. The introduction, recently, of automatic transmissions in inter-city buses has resulted in a 3-5 percent increase in operating efficiency by eliminating some of the driver variables. A majority of new equipment built between now and 1978 will be so equipped,but the total saving potential from this change will be very modest at best. If, for example, 5,000 new buses of 4 percent greater efficiency are added to the fleet by 1978, the net gain in overall bus fleet efficiency, as weighted by old and new buses, would be only .7 percent or about 100 barrels per day based on 1972 consumption levels.

The inter-city bus manufacturers in cooperation with the Department of Transportation are conducting aerodynamic tests on inter-city buses. It is conservatively estimated that incorporation of aerodynamic improvements can save 10 percent in fuel usage. However, in order to retrofit these devices on existing bus fleets, legislation increasing maximum vehicle width from 96 to 102 inches will be needed. These devices can be incorporated in new bus designs with no protrusion beyond the bus sides.

If this legislation to increase width could be achieved by 1978 and all buses were so designed, a 10 percent savings could amount to 1 thousand barrels per day. Provided only the new buses added to the fleet are aerodynamically improved, the fuel savings would approximate only 250 barrels per day.

The adoption of 55 MPH speed limits has proven counter-productive in terms of bus efficiency. Typical inter-city buses have been designed to operate most efficiently in the 60-65 MPH speed range. Slower speeds result in engine overload in high gear or engine overspeed in lower gear posing higher levels of fuel consumption and the possibility of damage to the engine and/or transmission. Additionally, it is suspected that slower speed limits (and increased trip time) may have resulted in the diversion of some passenger traffic from buses to less fuel-efficient modes such as airplanes and private cars.

As the inter-city bus industry consumes only .16 percent of the total transportation energy requirement, any savings achieved will have very small impact. However, the high efficiency level of buses would indicate the need for greater utilization and any improvements in this efficiency would have a compounding effect on future fuel savings.

PART FOUR: ROADWAY IMPROVEMENTS

Within the United States during 1972 more than 122 million motor vehicles accumulated nearly 1.3 trillion vehicle miles, over 3.8 million miles of paved roadway, while consuming over 105 billion gallons (6,835 thousand barrels per day) of fuel in the process. Although not the most apparent, one of the areas to consider in the conservation of fuel is literally the highway itself. Highway projects such as new construction or resurfacing are undertaken for many reasons--to provide access to new dwellings, shorten travel time, reduce or eliminate safety hazards, improve vehicle flow (less stop and go), reduction of gradients and better, smoother surfaces on which to travel.

In the selection of specific highway projects the priorities of need, cost, benefit and environmental impact are carefully weighed. More recently, the aspect of fuel shortages adds a new dimension of energy impact to the evaluation process. For example, if fuel shortages were to become more severe than has been experienced, it would seem inappropriate to consume fuel for construction of roads unless all other priority demands have been fulfilled. Of consequence, the development of methodology for determining the energy impact of highway projects is of considerable importance.

The Federal Highway Administration has developed an example of hypothetical analysis of this energy impact (see Appendix C, Exhibit XII). Through use of this methodology and some of their highway construction data, the supposition has been imposed that the average road improvement would increase vehicle efficiency by 5 percent. On this basis the appended example relates that the improved quality of the average highway project, with 2-lane asphalt paving of one mile in length, will save 7,075 gallons per year at a traffic volume of 5,000 vehicles per day. Thus, a comparable highway segment of 100 miles in length might save 46 barrels per day. Moreover, when measured against all petroleum requirements for the cited project, it is noteworthy that only 3.6 years of road use are required before a net benefit in fuel conservation begins to accrue.

This payout time is obviously a fraction of the useful life of the project and savings appear to occur in sufficient time to be of real value in the conservation of highway energy. Of course, alternates to asphalt surfacing materials could be considered in an even greater savings effort, but the manufacture of cement requires substantial amounts of energy for dehydration. Increased use of coal tars in asphalt would relieve the demand on petroleum, and emulsified asphalts have some potential for reducing the need for asphalt volatiles (the drying agents) which can account for as high as 50 percent of some grades. Another alternative of no-paving improvement is undesirable from the standpoint that fuel requirements for vehicles traveling over gravel surfaces often exceed smooth surface needs by 50 percent or more.

At this time, when many states are considering reduction of maintenance and repaving programs in an effort to conserve fuel, this exercise indicates that such cutbacks may be shortsighted--in terms of conservation and the attendant unemployment such reductions would undoubtedly create. It should also be noted that the cited project example holds 96 percent of the jobs' petroleum requirements as asphalt. In other cases, where extensive excavation or structural work are required, asphalt might only account for one-fourth of the petroleum requirements. In such instances, every additional barrel of oil required to complete the project adds 2 days to the payout time before net savings accrue to the particular job.

Chapter Two

AIRWAYS

INTRODUCTION

There are various fuel conservation measures possible in aircraft operations, and, for the present, there are also opportunities for fuel savings through curtailment. However, the available conservation measures have all been in practice to a varying extent for several years, and while future fuel demands will benefit from these conservation measures, the potential for additional future savings through conservation is limited. Moreover, increasing demand for air transportation by passengers and shippers could soon require the restoration of flights recently curtailed and the addition of even more air service. Therefore, during the period covered by this Phase I (1974-1978) report, the requirements for aviation fuels will increase although at a level reduced by the conservation measures discussed hereafter.

The consumption of aviation fuels in the United States during the base period year of 1972 is shown in Table 21 which depicts consumption both by type of fuel and by type of user.

TABLE 21

U.S. CONSUMPTION OF AVIATION FUELS--1972
(Thousand Barrels Per Day)

Fuel	Consumption
Aviation Gasoline	46
Jet Fuel Naphtha Type	242
Jet Fuel Kerosine Type	803
Total	1,091
User	
Jet	
Military	288
Scheduled Airlines	670
Supplemental Airlines	6
General Aviation	37
Other Aviation	20
Non-Aviation Uses	24
Subtotal--Jet	1,045
Aviation Gasoline All Users	46
Total	1,091

The consumption of aviation fuels in 1972 represented 11.8 percent of the total fuel consumed in the transportation sector. The normal first quarter 1974 demand for aviation fuels was projected to be 1,138 thousand barrels per day but estimated actual consumption in this period was at a rate of about 950 thousand barrels per day with an apparent 17 percent savings.

Since the preponderance of aviation fuel consumed is jet fuel, this analysis will not involve conservation measures relating to the operation of airplanes which use aviation gasoline. Neither will it deal with military aircraft operations except to note that operational techniques for conserving fuel that apply to civil jet airplanes also apply to military jet airplanes to the extent that the military mission will allow the use of such techniques.

Fundamentally, there are two approaches to or methods of conserving jet fuel. The first is to improve the operating efficiency or the air transportation system--getting from point A to point B using the least amount of fuel. Improved operating efficiencies include reduced cruise speeds, reduced air traffic control delays, and reduced in-flight pilot training and proficiency checking through simulating. The second is to fly the airplane less or fly fewer airplanes or some combination with an end result of a reduction of flights. This analysis will look at each of these two methods in terms of how they can be accomplished; the savings that could be achieved by them (as shown on Table 22); what the difficulties are in accomplishing them; and what the effects are of accomplishing them. Reduction in non-aviation use of jet fuels, chiefly by electric utilities, would require the substitution of alternate fuels for power generation.

TABLE 22

AIRWAY FUEL CONSERVATION POTENTIAL
(Thousand Barrels Per Day)

	Savings	
Measure	**1974**	**1978**
Operating Efficiencies		
• Cruise Speed Reductions	33	41
• Improved Traffic Control	5	10
• Training Simulation	3	4
Flight Reductions	104	Unclear

IMPROVED FLIGHT OPERATION EFFICIENCY

Efforts to optimize the operating efficiency of jet airplanes have been under way literally since the first jet airplanes were introduced. In recent years, for a combination of economic, environmental and conservation reasons, those efforts have been intensified. The result is that much of what can be gained through improved operational efficiency has already been attained. However, there remain some savings to be realized through improved air traffic control procedures and improved aircraft operating procedures.

The following are conservation measures all of which to varying degrees are already being practiced, which apply to jet aircraft operations:

- *Reduced Cruise Speeds*: A slight reduction in cruise speeds from the previously used normal cruise speeds will bring about a savings of from 3 to 5 percent of total fuel consumed. A reduction of .02 to .04 mach number (15 to 30 MPH) is the optimum speed reduction that can be made to maximize fuel savings. A speed reduction greater than that will result in more fuel being burned rather than less. Cruise speed reductions are in effect in most airline operations today. Annual savings from these measures are estimated at 500 million gallons or 33 thousand barrels per day.

- *Improved Air Traffic Control*: A number of factors exert an influence in the area of air traffic control: optimized cruise altitudes, optimized climb and descent profiles, expedited airborne handling in airport terminal areas, and increased use of point-to-point routings. It is estimated that air traffic control delays consume 130 to 150 million gallons of jet fuel annually or 9 to 10 thousand barrels per day.

- *Training Simulation*: Reduce in-flight pilot training and proficiency checking through the use of simulation techniques. The continuing advancement of aircraft cockpit training devices and simulators has provided ongoing opportunities for fuel savings through the substitution of training devices and simulators for aircraft in the training and checking of pilots. A December 1973 change to Federal Aviation Regulations will allow considerably more pilot training and checking to be accomplished in simulators resulting in annual fuel savings of 60 million gallons or 4 thousand barrels per day.

Before leaving the area of improved flight operations, this report should make mention of several other widely claimed measures that would improve aircraft efficiency in order to put those measures in their proper perspective.

Such things as improved jet engine design and improved airframe/wing design are certainly measures that would increase the fuel efficiency of aircraft operations. However, it is unrealistic to expect that such improvements can be accomplished during the period covered by this report. The types of airplanes flying today are the types that will be flying throughout the next 5 years and beyond. Long-range research and development in the areas of engine and airframe design provides hope for the future but no fuel savings for the present.

FLIGHT REDUCTIONS

After flight operation efficiency has been improved to the maximum extent for fuel conservation purposes, any remaining need to conserve still more fuel can be met only through a reduction of flights. Flight reductions have various impacts on the several different types of users of jet fuel:

- For the military, reduced flying means reduced training and potential reduced readiness.
- For the supplemental airlines, reduced flying results in a directly proportionate reduction in public service since supplemental airline load factors are virtually 100 percent. Employment reductions and reduced aircraft utilization also result.
- For general aviation, reduced flying has numerous adverse effects ranging from reduced numbers of beginning pilots; to reduced numbers of aircraft being manufactured, maintained and serviced; to reduced flexibility and efficiency of corporate executives using business aircraft.
- For other aviation categories such as aircraft manufacturers, reduced flying means fewer reserach, development and test flights--a slowing of essential work toward improved designs.

The major user of U.S. produced or imported jet fuel, however, is the scheduled airline industry, and this report deals primarily with that industry.

Under previous conditions of plentiful and inexpensive jet fuel, the highly competitive and aggressive scheduled airline industry built up a capacity level which, under the prevalent passenger traffic levels, resulted in an industry average load factor of approximately 50 percent. This means that the hypothetical average airliner was half full/half empty. This does not mean, however, that the scheduled airline industry could cut half its flights and operate at a full load factor all the time, nor does it mean that twice as many people could fly without any increase in flights. In order to provide convenient access to a scheduled air transportation system, an average load factor of any given airline, based on advance reservations, should not exceed approximately 65 percent. The actual (flown) load factor could of course be higher if seats still available at departure time were to be filled by charter or space available passengers. Experiments are presently being conducted with such combinations of regularly scheduled and charter-type passengers on the same airplane in order to increase the actual (flown) load factor without unduly inhibiting free access to regular, advance reservation type, scheduled air transportation.

The load factor equation has two parts--the passengers [figured as revenue passenger miles (RPM)] divided by the capacity [figured as available seat miles (ASM)]. If the RPM remain constant while the ASM are reduced, the load factor increases. Holding the ASM constant while the RPM increases also results in an increased load factor. Likewise, a combined reduction of ASM and increase in RPM--the factual situation that existed in first quarter 1974--results in an even more steeply increased load factor. From the foregoing examples, it can be seen that increasing load factors, as an end in itself, is not necessarily a conservation measure, because increased load factors can result with no reduction in flights. Furthermore, the number of passengers carried at a given load factor can be increased by increasing the seating density--the number of seats per plane. Seating density can be increased either by placing rows of seats closer together or by increasing the ratio of coach to first class seating--even completely replacing first class seating with coach seating. In addition to fuel considerations, factors of the marketplace, including the newly revamped fare structure announced in March 1974 by the Civil Aeronautics Board that will increase the cost differential of first class over coach service, will come to play in determining future seating density. So the analysis comes back then to the real fuel saver--flight reductions.

In addition to saving fuel, however, flight reductions in the scheduled airline industry might have other effects which include: reduced public service, reduced employment, and reduced aircraft utilization with no consequential reduction in fixed costs. Furthermore, reduction of flights automatically means no growth, which precludes an ability for the industry to at least partially absorb increasing costs rather than having to pass them on totally to the consumer. Nevertheless, the need exists for some conservation through flight reductions, keeping in mind the practical load factor limitation of approximately 65 percent.

The U.S. scheduled airline industry during the first part of 1974 reduced its daily flights from approximately 14,000 to approximately 11,800 (a 16 percent reduction) and in doing so saved approximately 104 thousand barrels per day of jet fuel. During this period, as a result of the reduced flights and a marked increase in passenger traffic, the airline industry's average load factor approached 60 percent with several individual airline average load factors exceeding 60 percent. If passenger traffic growth continues at its current rate, there soon will be a need to add flights rather than reduce them.

Increasing demand for air transportation by both passengers and shippers will quickly (within a year or two) require the restoration of all flights that have been cancelled and an addition of even more flights. Therefore, the requirements for aviation fuels will increase, though moderated by conservation measures.

MODE SHIFTS

There is little potential for fuel conservation in this sector through the shifting of airline passengers and freight to alternate methods of travel. This situation is the result of the unique services provided by the airlines.

In the passenger movement sector there remains an apparent excess capacity to absorb 21.9 billion passenger miles from alternate modes in spite of recent flight reductions (see a more detailed discussion in the "Mode Shifts (From Automobiles)" section in Chapter One). The airplane also offers convenience and speed with resultant greater periods of time at one's destination. For a given trip interval, this feature is not available through other methods, which makes it unreasonable to assume that there could be a significant shift of passengers to other means of transportation. The only area where there is a potential for shifts away from air travel, is that of the short haul flights, but the savings would be insignificant because many of the passengers on these flights are interconnecting with other flights.

In the freight movement area of the airline industry there is no significant potential for shifts to trucks and railroads due to the nature of the cargo and the method of movement. The small quantity of cargo, 5.4 million ton-miles in 1972, that is transported by air must be moved in such a manner due to the need for its timely delivery.

Chapter Three

RAILWAYS

INTRODUCTION

It is generally recognized that the railroad is one of the most efficient modes of transportation in terms of fuel efficiency. During 1972 the railroad industry consumed slightly more than 250 thousand barrels per day of petroleum products. Except for the small amount of electrified operation (about 500 million KWH) or 800 barrels per day diesel equivalent, this energy was essentially all in the form of diesel fuel and represented about 2.8 percent of total transportation fuel.

As railroads consume this relatively small percentage of transportation fuel, it should be noted that they still account for roughly 39 percent of all inter-city ton-miles within this Nation's freight transportation system. These facts suggest that maximum utilization of the rail mode for the haulage of freight should be encouraged whenever time considerations are not paramount.

Conservation of fuel is important to the railroads and while their efforts may not possess a large impact because of the relatively small fuel base from which they operate, efforts in that direction could still be a significant contribution. Studies are being conducted by some railroads in an effort to track the results of conservation measures which have been instituted and to identify further opportunities.

As discussed in this section on railways, the most likely conservation potential to be achieved by 1978 will approximate 20 thousand barrels per day. At this writing, the fuel conservation value for 1974 appears to be in the area of 15 thousand barrels per day as achieved through various operating efficiencies.

OPERATING EFFICIENCIES

Because the cost of fuel has always been a significant element in the expense of railroad operations, reasonable conservation steps have been standard procedure. However, with the increasing shortage of middle distillates beginning in the fall of 1972 and the rapidly escalating costs, the industry redoubled its efforts and put into practice some new measures. Considering the inter-city freight transportation only, in 1973 railroads hauled about 850 billion ton-miles, which represented an increase of 9 percent over the traffic hauled in 1972. At the same time, in this service Class I railroads consumed 264 thousand barrels per day of diesel fuel--a 5.6 percent increase over the fuel consumed in 1972.

In 1972, the average consumption of diesel fuel per 1,000 revenue ton-miles was 5.047 gallons. In 1973, the average consumption of fuel per 1,000 revenue ton-miles was 4.764 gallons-- a reduction of 5.61 percent. Conservation measures which have been applied by the railroads, or are under consideration, and their estimated potential are as follows:

- *High Level Energy Conservation Committee:* Most railroads during recent years established such a committee of high ranking officers with broad authority to require energy conservation not only of fuel, but in all regards. Immediate results are obtainable but very difficult to quantify because this depends on the base from which they start and the trade-offs that must be considered.

- *Reduction of Spillage of Fuel*: While most railroads had previously installed automatic shut-off devices on the fueling nozzles, reexamination of their operation points toward the need for improvements, better maintenance, and standardization and it was found that further savings were available.

- *Use of Train Performance Calculator (TPC)*: Many railroads have made use of a computerized operating analysis technique (TPC) to develop for each line segment of the railroad the most effective balance between horsepower, tonnage and speed in the interest of overall fuel conservation. There are a number of trade-offs involved which have to be considered in implementing this possibility. The railroad managers must consider the impact of increased transit time on the overall economics of the railway, the impact on shippers of increased transit time and the impact on the industry car supply at a time when demand for cars is at an all-time high and the supply does not meet the demand.

  Another factor that can weigh heavily on a decision whether or not to maximize loading at a cost in speed and transit time involves the possible modal shift. The overall energy savings to the Nation may not be served by saving a small fraction of railroad fuel if it discourages or makes uneconomic a shift of traffic to the rails from a more energy intensive mode. A rather dramatic demonstration of the need for capacity on the railroads to accept additional traffic occurred when the fuel shortage was so intense for a short period that a large reduction in truck traffic took place.

- *Verification of TPC Results*: Railroads who have used this technique verify the predictions from the TPC by actual test runs, and before making policy decisions with respect to changes in operating strategies.

- *Diesel Engine Maintenance*: Fuel consumption can be reduced by maintaining a high level of diesel engine performance. This is a measure which can be put into effect promptly, may reduce the availability of locomotives a small amount but improves their output as well as conserving fuel.

- *Adjustment of Service on Low Density Lines*: Some branch line operations which have very low demand were found to be consuming a disproportionate amount of fuel for the service performed. By providing service on a less frequent basis, more cars could be moved on each trip and fuel conservation achieved. This same situation prevails with respect to industry switching.

- *Other Measures*: Extension of run-through trains or blocks of cars is another strategy being implemented increasingly by the railroads. This, of course, is beneficial to service and overall efficiency and saves fuel by eliminating intermediate switching operations. Where climatic conditions permit, locomotives are shut down during temporary periods when they are not in service. This is a limited opportunity and has to be very carefully controlled to avoid damage to locomotives and consequent loss of their service.

The quantity of fuel saving potential resulting from implementation of these actions and policies is impossible to estimate on an individual basis. There seems to be a consensus in the industry that possibly 5 to 10 million barrels of fuel (20 thousand barrels per day) might be conserved through all conservation efforts in concert by 1978.

MODE SHIFTS

Due to the inherent efficiencies of the railroad system, as previously discussed, it would be energy extravagant to attempt to shift the movement of freight or passengers to another mode. In fact, intensified utilization of the railroad system should be a primary goal in the conservation effort, whenever feasibility allows. Possible shifts from cars, trucks, and airways to railways are related in those sections of the report.

Chapter Four

WATERWAYS

INTRODUCTION

An estimated 348 thousand barrels per day of gasoline, distillate and residual fuel oil or 3.9 percent of total energy used in the transportation sector was consumed on waterways in 1972. Most of this fuel was used by vessel and barge operations where energy costs per ton-mile are less than for any other form of transportation. Two general types of potential energy savings have been identified based on existing use patterns and technology--modified operating practices aimed at reducing energy consumption and more intensive use of energy-efficient waterborne transportation. Estimates of possible energy conservation potentials are developed based on literature data, Maritime Administration and St. Lawrence Seaway Development Corporation information, and judgments of marine engineers and operators.

As identified in this section, quantified energy conservation potentials are noted in Table 23; however, these savings potentials may be maximum values.

TABLE 23

WATERWAY FUEL CONSERVATION POTENTIAL
(Thousand Barrels Per Day)

Measure	Savings 1974	Savings 1978
Operating Efficiencies		
• Speed Reductions	1	1
• Improved Turnarounds	4	4
• Operating Practices	18	20
Increased Utilization	–	3

OPERATING EFFICIENCIES

For purposes of establishing a base line from which quantitative estimates of energy conservation proposals can be measured, projections were made for total marine fuel requirements prior to application of conservation measures discussed below (see Appendix D, Tables 33, 34 and 35).

Residual Fuel

For U.S. and foreign vessel operations using residual fuel in U.S. waterways, data on ton-mile movements were projected in accordance with historical trends with adjustments for anticipated North

Alaskan oil movements in 1977 and 1978. Improvement in unit fuel consumption was assumed as trends to larger size vessels continue. Total fuel requirements for such vessel operations were then developed from projected total ton-miles and unit fuel requirements, and then split into underway and port utilization in a 70:30 ratio. The difference between estimated 1973 total marine residual fuel consumption and that portion accounted for by U.S. and foreign vessel operations in U.S. waterways was assumed to be vessel operations in international waters. This portion of residual fuel consumption was related to tons of imports and exports. Projections of growth in international trade and improvement in unit fuel consumption then led to estimated residual fuel consumption for vessel operations in international waters.

- *Improved Efficiency:* As usually found in most fleets, various fuel economies are possible through more efficient operation of vessel equipment and changes in operating practices. Examples are reduction in excess combustion air; elimination of excessive ventilation, air conditioning, and pumping; minimization of cargo heating; and maintenance of cleaner hulls and boilers. Based on large fleet experience, the potential maximum fuel savings for reasonable improvements in these and other practices will result in fuel savings of about 8 percent for average size ships. Application of this estimate to the underway portion of the vessel fuel consumption base line projection yields fuel savings of about 6.2 million barrels per year (17 thousand barrels per day).

- *Reduction in Port Turnaround Time:* Minimizing port turnaround time can produce significant fuel savings since approximately 30 percent of vessel fuel consumption occurs when the vessel is in port. Faster loading and discharging, fewer port calls, and reduced port time are estimated to result in a maximum 10 percent savings of the portion of fuel consumed when docked or not underway. Volumetric savings are estimated at about 1.5 million barrels per year (4 thousand barrels per day) maximum.

- *Speed Reduction:* Vessel fuel consumption varies roughly as the cube of shaft speed. Therefore, although the overall economic optimum speed for tankers usually is in the range of 15-16 knots, the most efficient speed from a fuels standpoint for a given vessel may be 12 knots--at which fuel consumption when underway would be decreased by perhaps 50 percent. However, since tankers and other bulk carriers normally are fully laden, more ships would be required to haul a constant tonnage. Also considering declining engine efficiency, no fuel savings are estimated for speed reductions for tankers and other bulk carriers. Non-bulk and liner-type carriers, however, are generally underutilized. Hence, speed reductions on these vessels would result in net fuel savings. A rough approximation of possible savings for these types of vessels at a 3-5 knot speed reduction leads to net fuel savings of about 500 thousand barrels per year (1 thousand barrels per day).

Distillate Fuel

As in the case of vessel operations using residual fuel, a base line was established for towing vessels and barge operations using distillate fuel from which quantitative estimates of energy conservation proposals can be measured. Data on towing vessel and barge operations ton-miles were projected based on historic growth trends. Total horsepower in use was also projected according to past trends. Average annual utilization and specific fuel consumption were estimated to obtain total distillate fuel consumption.

- *Improved Efficiency:* More efficient utilization of equipment and changes in operating practices were judged to enable a 2.5 percent savings in fuel consumption. Included are improved engine operations, elimination of unnecessary use of auxiliary equipment, more efficient make-up of tows, etc. Volumetric savings are estimated to range from 700 thousand barrels per year (2 thousand barrels per day) in 1974 to 1 million barrels per year (3 thousand barrels per day) in 1978.

- *Speed Reduction:* No fuel savings through reduced speeds are deemed practical because of the low-speed of typical operations and nearly full utilization of existing equipment.

MODE SHIFTS (TO WATERWAYS)

Overseas

Possibilities for diverting substantial quantities of air cargo to waterborne transportation appear limited because of typical requirements for speed and flexibility inherent in air cargo movements. Some potential may exist for diversion of air passengers to ships, especially for recreational travel. However, extensive retirement of passenger liners limits this possibility for increased use of waterborne transportation, at least for the Phase I period.

Inland

With some exceptions inland waterways are almost fully utilized from the standpoint of equipment availability. Construction facilities for new propulsive equipment are booked through 1977; new barge equipment requires 17 to 24 months for delivery. An exception, however, is the St. Lawrence Seaway which currently is operating much below capacity. Underutilization of this facility has been attributed to freight rate structures that encourage truck or rail shipments of Great Lakes area freight to Gulf or Atlantic tidewater ports for export.

The St. Lawrence Seaway Development Corporation has made approximate determinations of fuel savings premised on reallocation of the domestic leg of foreign trade flows between Great Lakes and tidewater ports, based on the relative efficiencies of the domestic modes--truck, rail, and water. The analysis was confined to grain and non-bulk or liner-type cargo which represent most of the potential. Mileage was determined from selected interior points for tidewater and Great Lakes routings; ton-miles and weighted average length of haul calculated using tons now moving through tidewater ports; modal fuel efficiencies applied for each route; and the Great Lakes consumption differential multiplied by potential tons to arrive at fuel savings. The result of this determination was an indicated annual fuel savings of about 1 million barrels per year (3 thousand barrels per day) when shifting cargo from tidewater ports to Great Lakes ports.

Attainment of the indicated energy savings would be impeded by opposition to transfer of revenues from carriers and ports now enjoying this business to other carriers and ports. Revision of existing freight rate schedules would be required, thereby, indicating a rather long and difficult process would be necessary to attain the indicated energy savings.

Chapter Five

URBAN PUBLIC TRANSIT

INTRODUCTION

Urban public transit refers to those modes of transportation which any person has the right to use upon payment of the proper fare. With the exception of taxicabs, there has been a steady and rapid decline in public transportation since World War II. Not only have many companies gone out of existence completely, but the remaining systems appear to be underutilized, particularly during off-peak hours. The dramatic decline in ridership probably has its cause in the rapid increase of population outside the central cities and the resulting suburban living, typified by low housing and population densities and the large number of origins and destinations which make conventional public transportation a poor alternative to the private automobile.

Of the 784 billion urban passenger miles traveled in the United States during 1970, only 7 percent were by the various modes of urban public transit. A brief review of the absolute size and composition of the major modes of urban public transit is given in Table 24.

TABLE 24

SELECTED URBAN TRANSIT STATISTICS--1970

Mode of Transportation	Revenue Passengers (Millions)	Revenue Miles Traveled (Millions)	Number of Vehicles (Thousands)
Bus	4,058	1,409	50
Rail*	1,746	441	11
Trolley Coach	128	33	1
Commuter Rail†	247	NA	NA
Taxicab	2,378	3,417	170

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* Includes elevated and subway rail rapid transit, grade-separated surface rail, and streetcar operations.

† Urban passenger rail service provided by railroad companies.

Table 25 reveals the maximum energy conservation potential which can be realized by 1978, but it must be recognized that there is an overlap or interaction among several of these measures and the full potential of savings is less than the sum of the measures listed.

The estimated energy consumption of the urban public transit systems in 1972 was equivalent to 100 thousand barrels per day of

TABLE 25

URBAN PUBLIC TRANSIT CONSERVATION POTENTIAL—ALL FORMS
(Thousand Barrels Per Day)

Measure	Savings 1974	Savings 1978
10-percent increase in peak-hour ridership of rail and bus systems	14	14
Staggering of work hours	—	69
Improvement in bus load factor and bus service	—	19
Additional urban buses (15,000)	—	33
100,000 vans for work trips	—	8

motor fuels or 1.11 percent of the total transportation fuels consumed (urban buses, 22 thousand barrels per day or 0.25 percent; non-highway systems, 4 thousand barrels per day or 0.04 percent; and taxis, 74 thousand barrels per day or 0.82 percent). Because of this small base, the net transportation fuel savings that can be expected in the short run from the fuller utilization and expansion of urban public transit cannot be large relative to the total fuel consumed by the U.S. transportation sector.

INCREASED UTILIZATION OF PRESENT SYSTEMS

The shift from private automobiles to existing public transit not only conserves energy but has other, on balance, favorable impacts. These, including problems of implementation, will be discussed later in this section. Several methods for better utilization of existing systems are discussed below.

Increased Peak Hour Ridership

Urban public transit systems typically have little excess capacity during peak load hours; they are generally grossly underutilized during off-peak hours. Peak hour ridership on urban public transit could probably be increased by 10 percent but only at the expense of further crowding, standing, and general discomfort. Motor fuel savings from diverting these additional riders from private cars would amount to 14 thousand barrels per day (see Appendix E).

Spreading Peak Hour Ridership

The heavy concentration of morning and evening peaks suggests that a spreading of the work load by staggering work hours could theoretically almost double the carrying capacity of the existing systems. However, such drastic reductions of the travel peaks would involve working hours wholly incompatible with the desires of the affected employees and business firms. For more practical purposes it is assumed that the carrying capacity could, at a maximum, be increased by 50 percent through the staggering of work hours, resulting in fuel savings of approximately 69 thousand barrels per day (see Appendix E).

Improved Bus Load Factor

Bus-only-lanes increase the average speed of the bus system and, thereby, expand its carrying capacity. Although bus-only-lanes have been successfully introduced on selected routes in some communities, it is believed that large-scale introduction of this concept, without significant expansion of the bus fleet, will reduce the speed of the largely unchanged auto traffic and result in no fuel savings and may even increase overall fuel consumption.

Off-peak utilization of buses for purposes other than journey-to-work could, at least in theory, be increased dramatically. The majority of the potential users are living in the suburbs; because of the low population and housing density and the large number of origins and destinations, conventional public transit is extremely costly to provide the transportation services necessary for suburban living. Increasing the number of routes traveled and the frequency of service to accommodate more of the non-journey-to-work transportation needs of the suburbanite could be accomplished through additional government subsidies, but transportation fuel savings are not easily quantified. If we assume that the 1970 bus load factor will increase by 25 percent and that improvements of bus service will increase the miles traveled by the average urban bus by 5 percent, then fuel savings from a reduction in car use could be 19 thousand barrels per day (see Appendix E).

Improved Utilization of Taxicabs and Jitneys

Taxicabs represent an important, often unrecognized, component of urban public transit. Since every privately owned automobile can potentially be used as a taxicab, changes in the regulations controlling entry into the industry, shared ridership, level and structure of fares, etc., would not only help to improve the utilization of the existing taxicab fleet but, also, encourage its expansion. In principle, there is no reason why the use of taxis could not be increased significantly for journey-to-work trips; this, however, would require a change in the rigid fare structure and permission of shared ridership. Likewise, privately owned vehicles can be used as jitneys that operate within more or less rigidly defined routes and are hailed by passengers. Drivers can tailor the route, schedule and stops of each trip to satisfy the specific needs of passengers. Unfortunately, jitneys generally operate without legal status, are opposed by bus and taxis operators, and not infrequently are the object of police actions. Transportation fuel savings attributable to better utilization and expansion of taxicabs and the use of jitneys cannot be quantified.

EXPANSION OF URBAN PUBLIC TRANSIT SYSTEMS

In the short run (to 1978), no significant expansion is possible of rail-oriented systems except completion of projects under construction in Washington-Maryland-Virginia, Baltimore and Atlanta. The net fuel savings that can be achieved by switching from cars to these new systems cannot be quantified due to lack of data and operating experience. However, several other methods of expanding public transit systems are examined below.

Additional Urban Buses

Expansion possibilities exist for conventional urban buses, the production of which in the United States is currently at a rate of about 6,000 units per year on a single shift basis. Most of these units are intended as replacement equipment. Output of buses can be increased by operating existing production facilities on a two or three shift basis, but constraints such as availability of parts (engines, axles, etc.), availability and timing of finance for new bus equipment, and the ability of transit companies to put additional equipment into service (maintenance facilities, drivers, planning, etc.) will limit the net additions to the bus fleet that can be achieved by mid-1978 to about 15,000 units.

With a modest increase in bus mileage and utilzation rate, these additional buses will allow 14.9 billion passenger miles to be diverted from automobiles to public transit, and result in net fuel savings of 33 thousand barrels per day (see Appendix C, Exhibit VII, Urban Bus Passenger Miles).

Demand Responsive Systems

Since there is considerable agreement that the major reason why most public transit systems have difficulties in attracting ridership is that it cannot come anywhere near to the service characteristics of the private automobile, it may be necessary to place much more emphasis on the development of systems that are fully or partially demand-responsive. Taxicabs and jitneys have already been mentioned in the previous section; other demand-responsive systems that have recently come into being are discussed below.

Dial-a-Ride vehicles are small buses that carry several passengers who call them by phone. For example, one system's primary mission is to serve travelers between suburban residences and a commuter rail station. During off-peak periods, the system serves the needs for local travel among diverse origins and destinations. Such systems appear to be beyond the pilot program stage and suitable for broader applications. Net fuel savings cannot be quantified at this point in time due to lack of data.

The 3M Company has recently instituted a mini-bus commuting system for some of its employees. The company, located in the suburb of St. Paul, Minnesota, employs 9,000 persons who, before the introduction of this service, were almost completely dependent on the automobile to get to work. Basically, the system works as follows: 3M buys the vans and allocates them to geographic areas in which there is sufficient concentration of employees; each van is assigned to a regular employee (back-up drivers are available among the riders) who rides free of charge and is reimbursed by 3M for the maintenance and operating expenses of the van; the passengers are picked up at the door and pay monthly fees for this service ranging from $16 to $40, depending on how far they live from the place of work. The company started this service with six vans in March/April 1973. The pilot program was successful, an additional 25 vans were added in September 1973, and currently (March 1974) 48 vans are in operation. The vans are made by Ford, Dodge, Plymouth, cost about $6,000 each, get 9 to 10 miles per gallon, are air conditioned, and hold 12 people (1 driver and 11 riders). The system operates at an average occupancy rate of 11 people (including driver). Passenger miles per gallon of fuel consumed is 100 to 110 as compared with 21 for private automobiles used for commuting and 52 for urban buses at current utilization.

Large-scale introduction of such a system should be feasible in the short run. The only real bottlenecks appear to be in getting such projects organized by companies and enterprising private individuals and removing laws and regulations which interfere with such operations. Every 1,000 vans that are put into this type of operation (average occupancy rate of 8) can save 81 barrels per day of transportation fuel (see Appendix E).

FACTORS OF IMPLEMENTATION AND IMPACT

The increased use of urban public transit not only results in energy savings, but has other impacts, particularly in the longer term which, on balance, are favorable and have been the justification for new systems. Among the positive factors that can be cited are reduced urban auto congestion, particularly during the rush hours, reduced urban auto air pollution, and reduced traffic accidents and deaths. The main negative factors are the increased average urban travel time and restrictions on the use of the automobile that may have to be imposed to assure full utilization of the systems.

The problem of public acceptance, the major obstacle of increased ridership, is of fundamental importance. The dramatic decline in ridership of the Nation's buses, subways and commuter rail lines over the past 20 years is principally due to the competition of the private automobile. Given the dispersion of residences, shopping centers, job locations, schools, etc., there is no feasible alternative for many auto trips. But, even where public transport is an alternative, the car is preferred because it offers unique service characteristics which include speed, comfort, privacy and complete independence from any schedule. Stimulation of a shift to urban public transit requires that it must come closer to the service characteristics of the automobile (e.g., a more extensive coverage, shorter door-to-door travel times, more frequent service, increased comfort, etc.). Obviously, these are difficult goals for any public transit system. Their realization, being a far more difficult task than most people are willing to admit, could result from a variety of circumstances and actions.

- *Higher Fuel Prices:* This will encourage some shift to urban public transit. However, it should be realized that the average commuter round trip is 18 miles and requires only 1.5 gallons of gasoline. A $0.30 increase in the price of gasoline raises monthly commuting costs by only $10--a very small fraction of typical monthly household expenses. Also, in the longer run, consumers can buy smaller cars which achieve greater miles per gallon and, thus, retain most of the convenience of auto travel while keeping cost more or less constant.

- *Shortages of Gasoline or Rationing:* Gasoline shortages or the imposition of rationing will result in a noticeable rise in the use of public transit as experience in recent months confirms. How many riders will abandon public transit after gasoline is again conveniently available remains to be seen.

- *Travel Time Reduction:* Travel time can be reduced by techniques such as bus-only-lanes, priority access of buses to highways and tunnels, and bus-activated traffic signals that allow buses to increase their speed in city traffic.

- *Increased Government Subsidies:* Subsidies mainly from the Federal Government, will be required to prevent the further demise of existing systems, to expand and modernize equipment and to keep fares at reasonable levels. Reduced fares will stimulate some shifts from car to urban public transit, but many studies of transit fare and service changes indicate that service improvements have a much greater impact on ridership than lowering of fares.

- *New Systems:* Development of new systems should be concentrated to those of low capital and operating cost and high flexibility even if they are not as prestigious as fixed rail systems.

- *Regulatory Constraints:* The present regulatory constraints on urban public transportation including obsolete franchise limitations and market-entry barriers for taxicabs and jitneys, restricts the efficient operation of the urban transportation system. The removal of such regulatory constraints should lead to more efficient use of the transportation system and increase the options available to its users.

- *Cooperation:* Increased cooperation of communities in a given urban area will be necessary to build efficient area-wide public transportation systems in which the various modes of transportation are planned and meshed carefully to provide the varied transportation services required by the potential users. There must be greater effort to disseminate information on schedules and changes in service.

- *Regulation of Automobile Use:* Increased regulation of automobile use, particularly in downtown areas, will be necessary not only to achieve a greater shift to and improvements in public transit but, also, to achieve the air quality standards promulgated in the Clean Air Act. Likely devices are strict licensing of off-street parking, imposing severely high taxes on both on- and off-street parking, requiring special licenses to enter the central business district by automobile, establishing car-free zones, etc. Such actions may not significantly add to the inconvenience of motorists or harm retail sales in the central city if convenient alternatives to the car can be made available.

Chapter Six

PIPELINES

INTRODUCTION

The pipeline mode of transport is employed, for the most part, in the movement of natural gas and petroleum liquids (crude oil and product). Quantification of the 1972 energy consumption level in the pipeline mode was based on these uses. The estimate of fuel consumption in gas pipelines (791 trillion BTU's) is based on U.S. Bureau of Mines data, which is in turn based on industry surveys. The estimate of fuel consumption in liquids pipelines (358 trillion BTU's) is based on Interstate Commerce Commission data, and an estimated unit energy consumption level in all existing pipelines of 800 BTU's per ton-mile. The 1,149 trillion BTU's consumed in pipeline operations in 1972 equates to nearly 540 thousand barrels per day distillate equivalent and accounts for 6.0 percent of the energy consumed in the transportation sector.

The basic data used in the case of gas pipelines is probably superior to that for liquids because it is a survey of, among other things, fuel consumption itself. The liquids data is given in barrel-miles, so it was necessary to expand upon this number to estimate energy usage levels. Also, 1971 is the latest published data available to date, so it was necessary to estimate the 1972 level of pipeline liquids transport.

It is estimated that the use of exhaust heat economizers to improve the efficiency of gas turbines in pipeline service could produce a savings of 10 trillion BTU's per year (5 thousand barrels per day). Other measures, such as the use of in-place internal pipeline coating, friction reducing polymers, larger diameter line in new construction and coal slurry pipelines in place of trains are discussed but not quantified due to the limited savings to be realized or the unlikelihood of their implementation.

EXISTING PIPELINES

The potential for energy conservation is very limited in this transportation mode. Most of the flexibility, insofar as energy requirements are concerned, is removed when the pipeline is installed. The only remaining areas of flexibility are in the efficiency level of the pipeline driver (pumps, compressors) and whatever friction reduction techniques can be employed.

One specific conservation method that has been considered is the use of exhaust heat economizers to improve the efficiency of gas turbines in pipeline service. Estimated savings, assuming two-thirds percent conversion of existing machines over 5,000 horsepower from "simple cycle" to "regenerative cycle," is about 10 trillion BTU's per year or 5 thousand barrels per day (1972 base).

Implementation of this energy conservation technique would almost certainly be on an economic basis. This would require that the cost of the fuel burned in these turbines escalate sufficiently to warrant the relatively high capital expenditure required to make the conversion. The timing of such conversion would probably not substantially lag the increase in unit fuel cost (cost per BTU) required for economic justification. Conversion would have little impact of a social, political or environmental nature, and the only economic impact would be that concerning equipment purchase. The impact on the equipment supplier would probably be relatively small.

Other conservation methods considered are the use of in-place internal pipeline coating and use of friction reducing polymers (injected into a liquid pipeline stream). Both of these techniques are in the category of emerging technology and, therefore, not currently quantifiable. Implementation, when technologically feasible, would be on an economic basis, but potential savings in these areas are very limited.

NEW PIPELINES

In the construction of new pipelines, considerable flexibility exists in determination of the energy efficiency of the new system. Pipelines offer, potentially, the most energy-efficient mode of transportation for liquid and gaseous materials. For example, it is estimated that the Trans-Alaska pipeline will consume less than 250 BTU's per ton-mile.

The energy efficiency of a new pipeline is determined by the size (diameter) of the pipe. For instance, the energy requirement for a 16-inch diameter pipeline would be over 150 percent of the requirement for an 18-inch diameter line at the same rate of material flow. However, the capital cost required to attain energy savings through increased pipeline size is substantial. Typically, the energy expense required in the operation of a pipeline is a relatively small portion of the total operating expense plus annualized capital charges. Therefore, to make economic sense, the value of energy would have to increase substantially to offset the larger investment that is required to install larger pipelines. Whatever the economics, however, energy savings potential is available in the case of new pipeline installations.

The method by which the installation of relatively larger pipelines would likely be accomplished is, again, economic inducement. It is difficult to conceive of a rational situation in which a project that does not make long-term economic sense would be implemented, either voluntarily or through some legally dictated procedure. In the consideration of pipelines, the energy-capital trade-off must be made on a realistic cost basis.

The overall impact of building larger pipelines than would otherwise have been built would be small, limited to the marginally higher capital investment requirement. The increased investment would not be substantial, relative to the cost of the smaller line, but would require a large change in energy cost to implement because of the relatively low importance of energy cost in pipeline economics.

COAL-SLURRY PIPELINES

There are currently in operation in the United States at least 273 miles of coal-slurry pipeline transporting over 4 million tons per year of coal. This method of transport might be considered as feasible on a large scale but it is technologically immature. However, slurry pipelines are receiving serious consideration as a means of transporting the huge quantities of coal that could be extracted from the western coal fields as their development accelerates. It is considered as an alternate to: (1) transport by railroad unit trains, and (2) construction of SNG (synthetic natural gas) plants at the mine sites and transport of the resulting gas by pipeline to existing load centers.

It is estimated that the energy requirement for a slurry pipeline capable of transporting 30 million tons per year would be about 775 BTU's per ton-mile. This figure appears to offer little advantage, energywise, over rail transport (assuming rail transport at 670 BTU's per ton-mile). It is close enough, in any case, that use of one of these modes or the other will not have a significant impact on energy consumed in transporting the coal. The determination of which mode to use will, in all likelihood, be made as the result of factors other than energy consumption.

Chapter Seven

MISCELLANEOUS

INTRODUCTION

This area includes the special non-transportation subcategories--farm equipment, construction equipment, utility engines, snowmobiles and race cars. As a group, in 1972 they consumed 631.5 thousand barrels per day or the equivalent of 7.0 percent of the energy consumed in the transportation sector. There is very little substantive data available on fuel consumption in this sector; thus, some of the consumption levels depicted in Table 26 are estimates.

TABLE 26

MISCELLANEOUS ENERGY USAGE--1972

	Consumption (MB/D)	Consumption (BTU's x 10^{12} /Yr.)
Farm Equipment		
Gasoline	134	255
Diesel	144	305
Total	278	560
Construction Equipment		
Gasoline	45	86
Diesel	281	598
Total	326	684
Utility Engines		
Gasoline	22	43
Snowmobiles		
Gasoline	5	10*
Race Cars		
Gasoline	0.5	1*
Total	631.5	1,298

---

* Includes only the energy used by snowmobiles and race cars. Does not include spectator travel by automobile, etc.

In this category, the greatest savings potential is in the farm equipment and snowmobile sectors. Energy conservation can be accomplished in the farm equipment area through the implementation of improved energy management techniques and reduced tillage practices for a potential savings of 20 thousand barrels per day or 39 trillion BTU's per year. In the snowmobile sector, fuel can be conserved by means of improved management techniques and reduced trailering of snowmobiles, resulting in a potential saving of 1 thousand barrels per day or 1.9 trillion BTU's per year. The savings that can be realized in the areas of construction equipment, utility engines, and race cars are either insignificant or unquantifiable. Each category of fuel consumption is discussed individually, and Table 27 summarizes the fuel conservation potential thought to be available in those areas.

FARM EQUIPMENT (MOTORIZED)

Data concerning the level of fuel consumption by farm equipment is available only as estimates because of insufficient data on fuel sales to farmers for use in farm equipment, per se. Quantification of the 1972 energy consumption level was, therefore, made on the basis of the available estimates.

Two separate sources of basic information, Department of Agriculture estimates of fuel usage and a Southwest Research Institute Study containing power usage estimates, yield substantially the same estimates of the consumption level for both diesel fuel and gasoline. These are:

- Diesel Fuel--144 thousand barrels per day (305 trillion BTU's per year)
- Gasoline--134 thousand barrels per day (255 trillion BTU's per year).

The trend in the past several years has been for gasoline consumption to remain almost constant while diesel consumption has increased as farmers converted their equipment from gasoline to diesel. This trend is expected to continue.

The U.S. Department of Agriculture is in the process of issuing an "Energy Management Package" which will contain a wealth of energy conservation measures that can be used by farmers. The Department has also issued a checklist of energy conservation measures, the essence of which is shown in Appendix F. In general, these measures can be divided into two categories: improved energy management techniques and reduced tillage practices.

Improved energy management techniques will probably be implemented by a combination of voluntary acceptance, encouraged by Department of Agriculture publications and other educational information directed at the farmer to increase the level of awareness of potentials for fuel savings, and the anticipated increase in price

TABLE 27

ESTIMATED CONSERVATION POTENTIALS

	Savings (MB/D)	Savings (BTU's x 10^{12})
Farm Equipment		
Energy Management		
Gasoline	7	13
Diesel	3	6
Total	10	19
Reduced Tillage		
Gasoline	5	9
Diesel	5	11
Total	10	20
Total Farm Equipment	20	39
Construction Equipment	--	--
Utility Engines	--	--
Snowmobiles		
Energy Management		
Gasoline	0.25	0.5
Reduced Trailering		
Gasoline	0.75	1.4
Total Snowmobiles	1.00	1.9
Race Cars	--	--
Total Conservation Potential	21	40.9

and somewhat limited fuel availability, which will further encourage adoption of improved energy management policies. These techniques--increased frequency of tune-ups, increased sharpness level of farm implements, etc. (see Appendix F)--are generally inexpensive, requiring only an increase in the attention given by farmers to the operation of their equipment. Adoption of these techniques will probably be gradual, increasing with the pressures of fuel availability and price. No significant impact is anticipated.

Quantification of the savings potential is highly subjective in this instance, but fuel consumption reductions in the order of 5 percent for gasoline powered equipment and 2 percent for diesel equipment seems attainable. This would result in the following fuel savings at 1972 consumption levels:

- Diesel Fuel--3 thousand barrels per day (6 trillion BTU's per year)
- Gasoline--7 thousand barrels per day (13 trillion BTU's per year).

Another measure, reduced tillage practices, refers to the cultivation practices used by farmers. Apparently, the practice of farmers in the past has been to "over-till" their fields. It has been found that a substantial reduction in cultivation intensity can be made in the production of some crops with little or no reduction in crop yield. This is a generalization, however, and is not fully applicable to all climate and soil conditions. Appendix F, Table 36 shows a University of Nebraska estimate of fuel consumption for various tillage intensities in the production of corn. According to this tabulation, reductions in fuel consumption of over 80 percent can be attained.

In quantifying the fuel savings potential for reduced tillage practices, it has been assumed that a 25 percent reduction from 1972 tillage levels can be attained. It was further assumed that the method is limited to the corn, sorghum and soybean crops. These assumptions result in an estimated savings potential of:

- Diesel Fuel--5 thousand barrels per day (11 trillion BTU's per year)
- Gasoline--5 thousand barrels per day (9 trillion BTU's per year).

Implementation of reduced tillage conservation practices will likely be similar to the implementation of improved management techniques. However, it will probably require a relatively intense and continued educational commitment on the part of the Department of Agriculture to attain a high rate of compliance by the Nation's farmers. Little impact is anticipated excepting a probable small reduction in farm yields as more drastic reductions in tillage levels are made. The balance between the extent of yield reduction to be tolerated and the quantity of fuel saved will undoubtedly be established on an economic basis in the long run. This is a relatively new concept insofar as wide application of the practice is concerned, and an increasing level of technological sophistication in future years will almost certainly clarify the savings potentials available. Total potential savings in farm equipment are:

- Diesel Fuel--8 thousand barrels per day (17 trillion BTU's per year)
- Gasoline--12 thousand barrels per day (22 trillion BTU's per year).

CONSTRUCTION EQUIPMENT

There is very little data available on fuel consumption by construction equipment. The only attempt at quantification that has been located is an estimate by the Federal Highway Administration that the average amount of fuel required in all types of highway construction is 107 thousand gallons per $1 million of total expenditure, on federal-aid highway construction projects. Application of this number to the $10.2 billion of total highway construction in 1973 results in a fuel consumption estimate of 71 thousand barrels per day. This estimate covers highway construction only, and highway construction represents less than 10 percent of total construction.

Another indicator of fuel consumption levels by construction equipment is an estimate based on horsepower-hour usage. The basis for such an estimate is contained in a Southwest Research Institute Study and the derived estimates which cover fuel consumption for all construction equipment in the United States are:

- Diesel Fuel--281 thousand barrels per day (598 trillion BTU's per year)
- Gasoline--45 thousand barrels per day (86 trillion BTU's per year).

No energy conservation measures of any significance have been found in this area. There seems to be little government activity directed toward conservation in construction equipment, and industry contacts have been generally non-responsive.

The Federal Highway Administration estimate of 107 thousand gallons per $1 million of highway expenditures (7 barrels per day per $1 million per year) can be used as a guideline to the amount of fuel that may be saved as the result of reduced construction activity. Reduced construction activity is not suggested as an energy conservation measure because of the obviously undesirable impact it would have on employment and the economy.

UTILITY ENGINES

Quantification of fuel consumption by utility engines was based on information contained in a Southwest Research Institute Study concerning engine emissions. The resulting estimate of consumption was 22 thousand barrels per day, all gasoline. A partial listing of the types of engines included in the estimate follows:

- Walking Mowers
- Garden Tractors
- Lawn Tractors

- Motor Tillers
- Snow Throwers
- Small Electric Generators
- Compressors
- Pumps
- Mobile Refrigeration Units
- Minibikes.

Items not included are:

- Motorcycles
- Outboard Motors
- Snowmobiles
- All Terrain Vehicles (ATV's).

A population in excess of 50 million engines was employed for the fuel usage estimate of 22 thousand barrels per day, which is the equivalent of less than 7 gallons per machine per year. Considering the low level of per unit consumption, no significant conservation measures short of not using the machinery are available.

SNOWMOBILES

The International Snowmobile Industry Association (ISIA) has estimated the 1972 fuel consumption of snowmobiles to be about 5 thousand barrels per day, all gasoline. This is limited to gasoline actually used in snowmobiles and does not include that consumed by cars trailering snowmobiles. The estimate, based on a U.S snowmobile population of 1.5 million appears reasonable.

The International Snowmobile Industry Association has also recommended fuel conservation measures. These can be considered in two categories:

- Improved utilization techniques--potential savings, 500 barrels per day.
- Reduced trailering of snowmobiles--potential savings, 2 thousand barrels per day.

The first of these measures is detailed in Appendix F, and includes techniques that would largely be implemented on a voluntary basis. This would be the result of an educational campaign by the ISIA or other such group. Little impact is anticipated from the implementation of such measures. If a compliance rate of 50 percent in these measures, probably a liberal assumption, could be achieved, the level of energy savings would be:

- Energy savings by snowmobiles (gasoline)--250 barrels per day (0.5 trillion BTU's per year).

The second of these measures, reduced trailering of snowmobiles, is actually out of this miscellaneous area. While this aspect of travel is covered under highways, it still seems appropriate to treat it here as well. ISIA estimates that the typical snowmobile is trailered nearly 400 miles per year and assumes a 50 percent reduction is attainable. Adopting a more conservative estimate of a 25 percent reduction, anticipated savings could be:

- Energy savings by cars towing snowmobiles (gasoline)--750 barrels per day (1.4 trillion BTU's per year).

Implementation of reduced snowmobile trailering would be on a largely voluntary basis, encouraged by economic factors. The economic impact would be felt by businesses in formerly popular snowmobiling areas. Little social, political or environmental impact would result.

RACE CARS

The quantity of fuel consumed by race cars, as estimated by Motor Sports Marketing Corporation, is about 500 barrels per day. Any reduction in this amount would have to result from the shortening or cancellation of races. The former measure is obviously not a significant energy conservation technique, but a symbolic gesture. The latter could yield savings in consumption by race cars but, more importantly, would affect an estimated 15 thousand barrels per day of gasoline used by spectators in conjunction with racing events.

No significant savings are anticipated from shortening races. Cancellation of races is not considered a viable conservation measure in that such an action would destroy the automobile racing industry and inflict severe hardships on an already ailing tourist industry and other associated industries.

Appendices

Appendix A

March 3, 1849

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

In Reply Refer To:
AS-EM

July 23, 1973

Dear Mr. True:

In his energy statement of June 29, the President announced additional steps being taken to conserve America's fuel supplies and their use, and called upon private industry to respond to the energy conservation directives with all the imagination and resourcefulness that has made this Nation the richest on earth.

In December 1972, the National Petroleum Council submitted to me a comprehensive summary report on "U.S. Energy Outlook," the supporting detailed task force reports being now received for each fuel as completed. The results of this exhaustive work done by the energy industries has been of major value to the Department and other agencies of Government, shedding considerable light on the U.S. fuel supply situation in particular.

In order to further assist us in assessing the patterns of future U.S. energy use, the National Petroleum Council is requested to conduct a study which would analyze and report on the possibilities for energy conservation in the United States and the impact of such measures on the future energy posture of the Nation.

You are requested to submit a progress report by January 1, 1974.

Sincerely yours,

Rogers C B Morton

Secretary of the Interior

Mr. H. A. True, Jr.
Chairman
National Petroleum Council
1625 K Street, N. W.
Washington, D. C. 20006

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Exhibit I

CAR-POOLING COMPUTATIONS

1. Load Factor: 1 person per car x 50% + 3 persons per car x 50% = load factor of 2.0.

2. Savings (S): Due to circuity, a modifier should be assigned to the load factor to represent the carpool trip length as a function of the lone commuter trip length as: $y = .96 + .04\,x$: where y is the circuity factor and x is the load factor. The percentage of vehicle miles eliminated, or the savings (S) in vehicle miles can now be calculated through:

$$S = \frac{xT - (.96 + (.04x)\,T}{xT}$$

where T is the lone driver commuter trip length (which appears in each term and cancels out). Of course, there is existent saving value being derived from the present car-pooling load factor as it exceeds unity. Based on the premise that little change has occurred in this load factor (1.6) and that total vehicle miles for commuting have grown to 344×10^9 since the Department of Transportation survey of 1970, this current vehicle mileage saving value is calculated as:

$$S = \frac{1.6 - (.96 + .04 \times 1.6)}{1.6}$$

in which S equals 36 percent.

3. Change in Savings (CS): This saving value of 36 percent in vehicle mileage through the present level of car-pooling implies that 1972 mileage would be 538×10^9 with no car-pooling or 194×10^9 miles more than actually driven. Thus, to find the potential, or changed saving (CS) in vehicle miles through intensified car-pooling, the present level of saving (194×10^9) must be subtracted. This change in saving (CS) for vehicle miles may then be translated to fuel equivalent by dividing by the assumed level of fuel consumption per mile (MPG).

1974 -

$$CS = 538 \times 10^9 \text{ VM} \left(\frac{1.7 - (.96 + .04 \times 1.7)}{1.7} \right) - 194 \times 10^9 \text{ VM}$$

$(18.67 \times 10^9 \text{ VM}) \div 13.2 \text{ MPG} = 1.41 \times 10^9$ gallons $\div$ 42 gallons/barrel = 33.6 MMB $\div$ 365 days = 92 MB/D

1978 -

$$CS = 538 \times 10^9 \text{ VM} \left(\frac{2.0 - (.96 + .04 \times 2.0)}{2.0} \right) - 194 \times 10^9 \text{ VM}$$

$(64.24 \times 10^9 \text{ VM}) \div 12.9 \text{ MPG} = 4.98 \times 10^9$ gallons $\div$ 42 gallons/barrel = 118.6 MMB $\div$ 365 days = 325 MB/D

Appendix C, Exhibit I

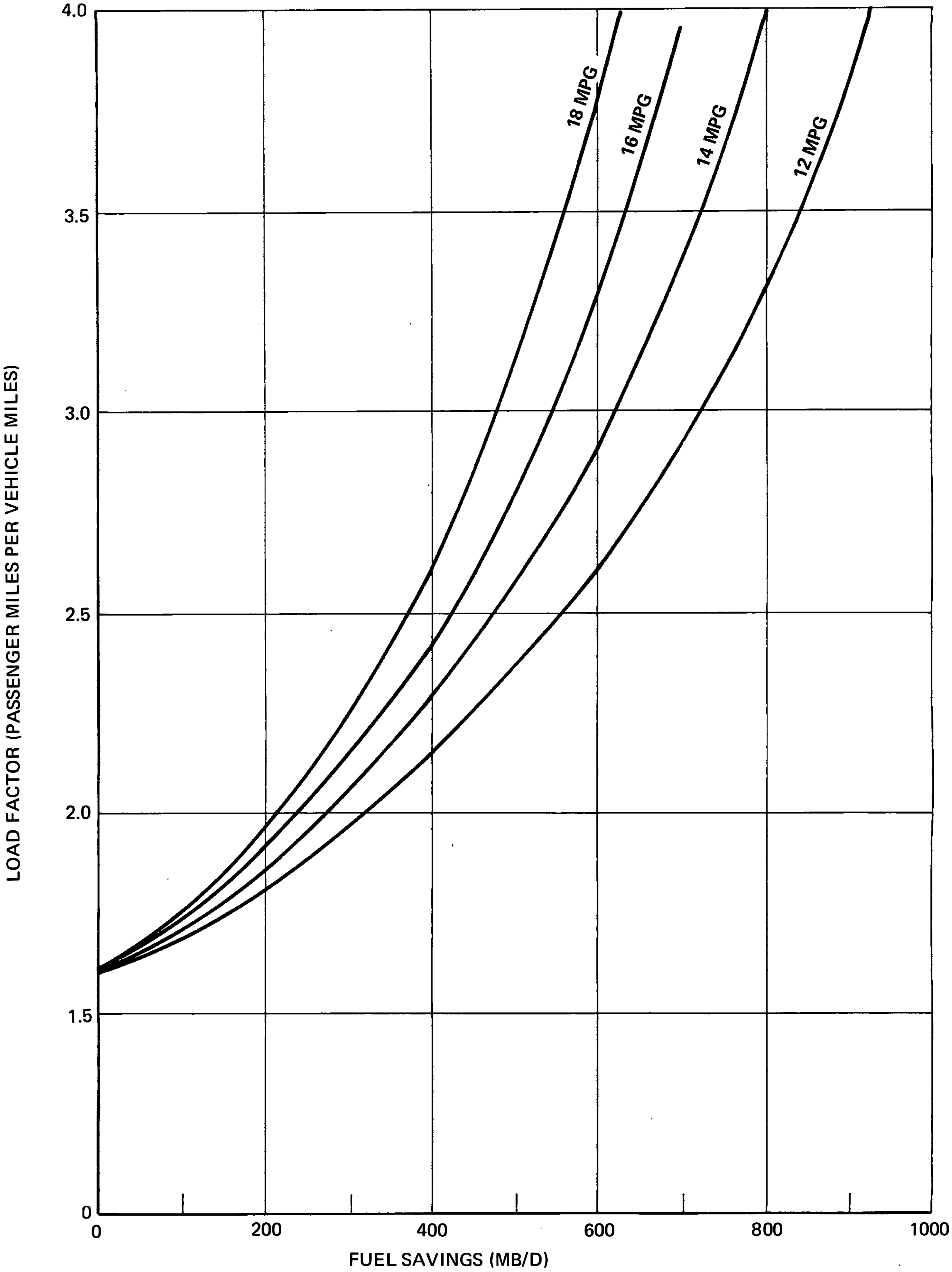


Figure 3. Gasoline Savings Through Increased Load Factors at Various Miles Per Gallon and Constant Total Vehicle Miles.

Exhibit II

TRAVEL CHARACTERISTICS COMPUTATIONS

1. Assumptions for 4-Day Work Week:

   a. Six-sevenths or 85.7 percent of to-and-from work and related business motor fuel is consumed driving the 5-day work week.

      2,267,110 B/D x .857 = 1,942,910 B/D

   b. One-fifth or 20 percent of this fuel is consumed each of the 5 days.

      1,942,910 B/D x .20 = 388,580 B/D

   c. One-fourth or 25 percent of the work force can be placed on a 4-day work schedule thereby saving a fourth of one day's auto commuting fuel requirement.

      388,580 B/D x .25 = 97,145 B/D

2. Assumptions for Fuel Saving Potential Through Diversion of Trips to Bicycling and Walking:

Since there are no absolute deterrents to these activities (other than the available supply of bicycles) arbitrary values deemed reasonable have been selected for the following calculation of saving potential. For example, it is proposed that greater trip length would, of its nature, achieve a lesser diversion and that shorter trips in automobiles result in a proportionately lower MPG factor. These assumptions are applied to total vehicle miles (for 1972) as shown on Table 28 and savings are derived by trip length for 1974 and 1978 as: total vehicle miles ($1{,}110.7 \times 10^9$) x annual growth (2.5%) x percent of vehicle miles x percent of miles diverted = vehicle miles diverted ÷ miles per gallon = fuel conserved.

Appendix C, Exhibit II

TABLE 28

ESTIMATED PARAMETERS OF VEHICLE TRIPS AND MILES OF TRAVEL BY PURPOSE--1972

Purpose of Trip	Occupants Per Trip	Occupancy (Passenger Miles Per Vehicle Miles)	Percent of Trips	Percent of Vehicle Miles*	Average Round Trip Length (Miles)	Miles of Travel (Miles x 10^6) Passenger Cars	Light† Trucks	Total
Earning a Living								
To and From Work	1.4	1.6	31.8	34.6	18.8	343,900	39,900	383,800
Related Business	1.6	1.7	4.3	8.1	32.0	75,500	14,300	89,800
Total	1.4	1.6	36.1	42.7	20.4	419,400	54,200	473,600
Family Business								
Medical and Dental	2.1	2.6	1.7	1.5	16.6	16,200	800	17,000
Shopping	2.0	2.2	15.2	6.5	8.8	68,400	3,400	71,800
Other	1.9	2.2	14.0	9.0	13.2	95,400	4,800	100,200
Total	2.0	2.3	30.9	17.0	11.2	180,000	9,000	100,000
Social and Recreational								
Vacations	3.3	3.3	0.1	4.1	330.2	37,500	8,400	45,900
Visits (Relatives, etc.)	2.3	2.7	8.9	11.6	24.0	122,000	6,700	128,700
Pleasure Rides	2.7	3.0	1.3	3.3	39.2	31,500	5,100	36,600
Other	2.6	3.0	11.8	16.5	22.8	147,700	35,900	183 600
Total	2.5	2.9	22.5	35.5	26.2	338,700	56,100	394,800
Education, Civic, Religious	2.5	2.5	9.2	4.8	9.4	48,300	5,000	53,300
Total--All Purposes	1.9	2.2	100.0	100.0	17.8	986,400	124,300	1,110,700

Note: Based on data from *National Personal Transportation Study* and Federal Highway Administration. Data functions may not agree due to sampling error and rounding.

* Passenger cars only in columns 1-3, 5; Column 4 includes light trucks for personal (non-commercial) use only.

† Light trucks for personal (non-commercial) use only.

Appendix C, Exhibit II

TABLE 29

ESTIMATED HIGHWAY CONSUMPTION OF GASOLINE BY PURPOSE OF TRIP--1972*

	Consumption (MM Gallons)				
Purpose of Trip	Passenger Cars	Light Trucks†	Total	Total Consumption (MB/D)	Percent by Purpose
Earning a Living					
To and From Work	25,035	3,130	28,165	1,832	33.8
Related Business	5,495	1,190	6,685	435	8.0
Total	30,530	4,320	34,850	2,267	41.8
Family Business					
Medical and Dental	1,195	75	1,270	83	1.5
Shopping	5,955	360	6,315	410	7.6
Other	7,630	480	8,110	528	9.7
Total	14,780	915	15,695	1,021	18.8
Social and Recreational					
Vacations	2,440	645	3,085	201	3.7
Visits (Relatives, etc.)	8,880	610	9,490	617	11.4
Pleasure Rides	2,195	390	2,585	168	3.1
Other	10,670	2,990	13,660	889	16.3
Total	24,185	4,635	28,820	1,875	34.5
Education, Civic, Religious	3,625	415	4,040	262	4.8
Total--All Purposes	73,120	10,285	83,405	5,425	100.0

---

* Based on factors in Table 28.

† Light trucks for personal (non-commercial) use only.

Exhibit III

CONSERVATION EFFECT OF LOWER SPEED LIMITS COMPUTATIONS

The proportion of air conditioned cars in the EPA study sample (42.9 percent) is assumed as representative of the car fleet. However, it is also assumed that these air conditioners are operated only 25 percent of the vehicle operating time on a nationwide basis. Thus, a weighted average change in consumption by change in speed is shown in the following:

	Percent Change in Consumption with Changes in Speeds		
	40-50 MPH	50-60 MPH	60-70 MPH
12 Cars (Air conditioning off)	+8.11%	+11.31%	+17.28%
9 Cars (Air conditioning on)	+6.64%	+ 9.47%	+13.90%
Weighted Average	+7.88%	+11.02%	+16.75%

The change in consumption by virtue of increased speed is a curvilinear function and the change in consumption is expressed on an index basis on Figure 4; assuming 40 MPH is equal to 100.

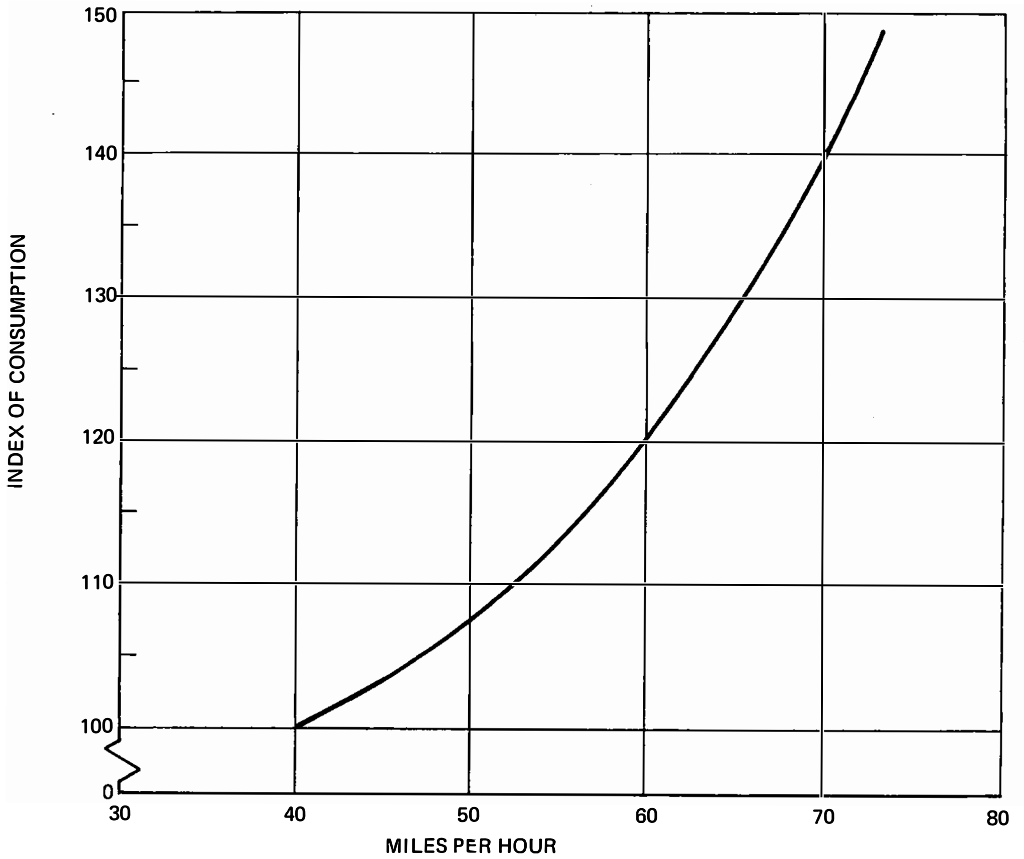


Figure 4. Fuel Consumption *Versus* Speed.

Appendix C, Exhibit III

As suggested by the relationship on Figure 4, a reduction in national average speeds from an estimated level of 62.5 MPH in 1972, to the new limit of 55 MPH, would result in a fuel savings of 8.9 percent. When related to actual driving, this savings must be modified as:

a. Speed limits would apply only to rural operation of cars and light trucks or 50.5 percent of the total miles driven. It is assumed that this mileage would expand at an annual rate of 2.5 percent.

b. An estimated 15 percent of the vehicles are already traveling at or below the 55 MPH limit (at the 62.5 MPH average) and reduced speed limits will have no effect on fuel consumption for that part of vehicle travel.

c. As rural type driving results in greater efficiency (MPG), the normal projections of MPG are increased by 15 percent.

d. A factor of speed limit compliance must be incorporated and 90 percent is deemed appropriate (although presently unrealistic) because the limit is law.

Therefore, savings is calculated as:

	1974	1978
Miles Driven x 10^6	1,138,470 x	1,256,655 x
Rural Percent	50.5 = 574,927 x	50.5 = 634,611 x
Percent over 55 MPH	85% = 488,688 x	85% = 539,419 x
Compliance Factor	90% = 439,819 ÷	90% = 485,577 ÷
Miles per Gallon	15.18 =	14.84 =
Gallons Consumed x 10^6	28,973.6 x	32,714.1 x
Percent Saved	8.9%	8.9%
Savings (Gallons x 10^6)	2,578.7	2,911.6
(Thousand Barrels Per Day)	168	190

Exhibit IV

AUTO DESIGN COMPUTATIONS

1. Assumptions for Fuel Savings Through Engine Displacement Reduction:

To calculate the effect of phasing-in an engine displacement reduction over the 1976-1978 model years (across the entire production line), the following conditions are assumed:

a. Displacement reductions will equal 6 percent in 1976; 8 percent in 1977; and 10 percent in 1978.

b. Each year's production will amount to 10 percent of the cars on the road in 1978.

c. Reductions in displacement result in fuel economy improvements in a percentage relationship of about 4 to 1 respectively, as determined by averaging the findings of several studies.

Therefore:

	Displacement Change	Economy Change	Percent of Fleet
Pre-1976 models	0%	0.0%	70%
1976 "	6%	1.5%	10%
1977 "	8%	2.0%	10%
1978 "	10%	2.5%	10%

1978 - Weighted economy change equals 0.6 percent of normal passenger car fuel requirements or about 36.6 thousand barrels per day.

2. Assumptions for Fuel Savings Through Accessory Operating Efficiencies:

To calculate the effect of phasing-in accessory operating efficiencies over the 1976-1978 model years (across the entire production line), the following conditions are assumed:

a. Accessory efficiency improvements will equal 5 percent in 1976; 7.5 percent in 1977; and 10 percent in 1978.

b. Each of the above year's production will amount to 10 percent of the cars on the road in 1978.

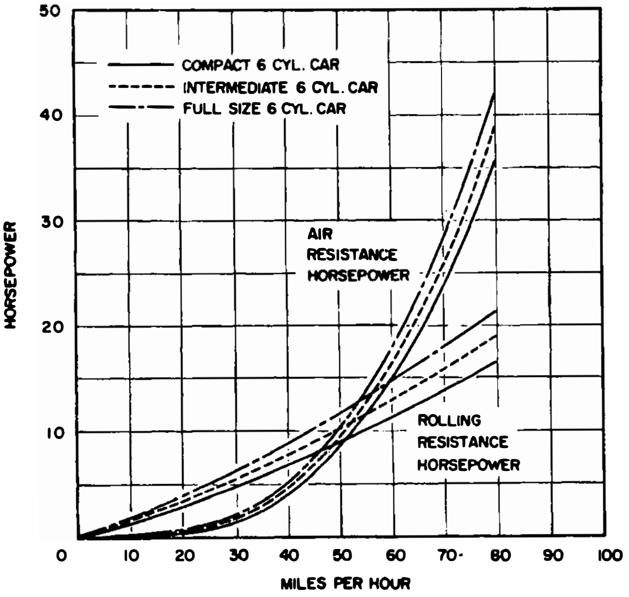
c. Total accessory fuel consumption amounts to 18.65 percent of total passenger car fuel consumption.

Appendix C, Exhibit IV

Therefore:

	Efficiency Change	Percent of Fleet
Pre-1976 models	0.0%	70%
1976 "	5.0%	10%
1977 "	7.5%	10%
1978 "	10.0%	10%

1978 - The weighted efficiency change equals 2.25 percent of 18.65 percent of normal passenger car fuel requirements or 25 thousand barrels per day.



Source: Cornell, Jack C., *Passenger Car Fuel Economy Characteristics on Modern Superhighways,* SAE Rept. No. 650862; report to the National Fuels and Lubricants Meeting, Society of Automotive Engineers, Tulsa, Okla., November 2-4, 1965 (New York: Society of Automotive Engineers, 1965).

Figure 5. Air and Rolling Resistance Horsepower *Versus* Vehicle Speed.

Exhibit V

VEHICLE MAINTENANCE COMPUTATIONS

Cost Effectiveness of Semi-Annual Tune-Ups*
- 1972 Base Data -

DATA

Passenger Cars and Light Trucks	117,110,000
Cost of minor (semi-annual) tune-up	\$25†
Price of fuel (cents/gallon)	36.13
Fuel economy improvement	2%‡
Fuel consumed (gallons x 10^6)	83,405

ASSUMPTIONS & CONCLUSIONS

a. The cost of minor tune-up is: \$2.9 billion

b. The cost of fuel saved is:
$(83{,}405 \times 10^6) \times (50\%) \times (2\%) \times (36.13) =$ \$301.3 million

c. To equal the cost of mid-year tune-up, fuel price must rise to:

$$\frac{\$2.9\text{ billion}}{(83{,}405 \times 10^6) \times (50\%) \times (2\%)} = \qquad \$3.48/\text{ gallon}$$

or

Fuel economy improvement must rise to:

$$\frac{\$2.9\text{ billion}}{(83{,}405 \times 10^6) \times (50\%) \times (36.13)} = \qquad 19.25\%$$

---

* Non-major, mid-year maintenance.

† Estimated cost for minor tune-up.

‡ Applies only to second half of year as improvement over no action.

Exhibit VI

VEHICLE CHANGES (SMALLER CARS) COMPUTATIONS

1. Assumptions for Breakdown of the Passenger Car Fleet:

In order to project the future mix of vehicles by size of car, it is essential to have a benchmark which reflects the composition of the existing fleet. The small car is estimated to represent 29.0 percent of the fleet in 1972 (by the Patterns of Consumption/Energy Demand Task Group), and, while not precisely defined by model, is assumed to include compact, subcompact and imported cars.

Using this data as a base, a simplified method of computation is used to determine changes in fleet composition assuming:

a. Cars can be meaningfully grouped into two efficiency categories.

b. New car sales represent 10 percent of the changed fleet for the ensuing year.

c. The existing fleet therefore represents 90 percent of the new fleet.

d. Assumptions b and c account for vehicle scrappage. The changing fleet mix for small cars is calculated based on the 1972 values, the actual sales mix for 1973 and the estimated sales mix for 1974 and ensuing years as follows:

	Base Percent	x	Weight in New Mix	+	New Sales Percent	x	Weight in New Mix	=	New Base
1972	29.0	x	90%	+	39.6('73)	x	10%	=	30.06
1973	30.06	x	90%	+	46.0('74)	x	10%	=	31.65
1974	31.65	x	90%	+	50.1	x	10%	=	33.50
1975	33.50	x	90%	+	54.2	x	10%	=	35.57
1976	35.57	x	90%	+	58.3	x	10%	=	37.84
1977	37.84	x	90%	+	62.4	x	10%	=	40.30
1978	40.30								

Thus, the percentage of small cars in the existing fleet rises from 29.0 percent in 1972 to 31.65 percent in 1974. Standard size cars would obviously represent the difference, or 68.35 percent of the 1974 fleet.

Appendix C, Exhibit VI

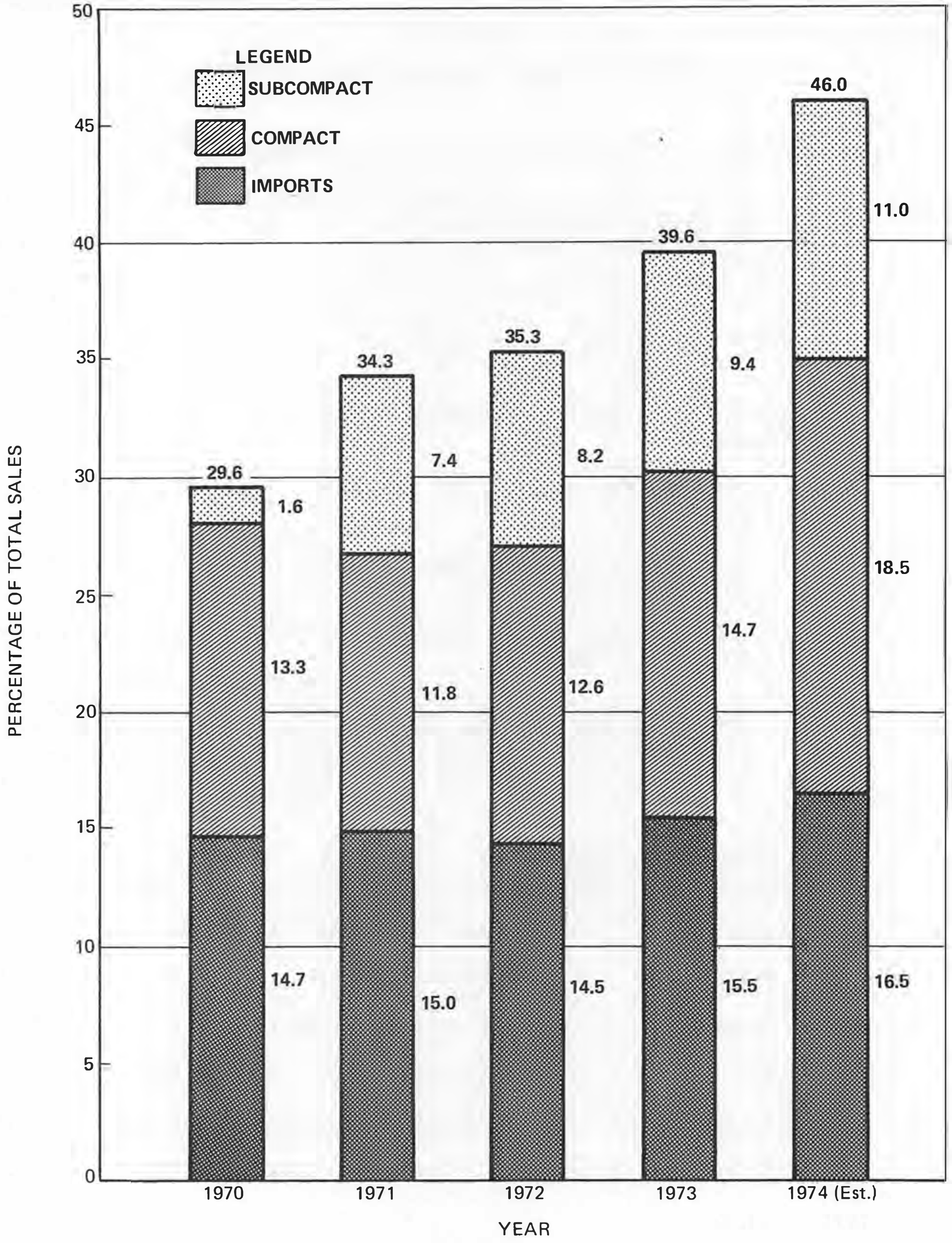


Figure 6. Small Car Share of Market Sales.

Over the period of 1970 through 1974 the market sales share of small cars has risen from 29.6 percent to 46.0 percent of an absolute increase of 4.1 percent per year. If it is assumed that this rate of change prevails through 1978, small car sales will hold a 62.4 percent share of the market. By using this growth trend for sales and the foregoing calculation method, the 1978 passenger car fleet would consist, as shown, of 40.30 percent small cars and 59.70 percent standard size models.

2. Assumptions for Fuel Conserved by Smaller Cars:

To determine the effect on fuel consumption solely from the calculated shift to smaller cars, it is necessary to hold a number of factors as constants, which also serves to reduce complexity. Thus, it is designed that:

a. All cars travel an equal number of miles regardless of size or age.

b. No other changes occur to effect the difference in miles per gallon between small and standard size cars.

c. Estimated average miles per gallon remain at constant 1972 levels--which attributes any future change in consumption to factors other than the shift to smaller cars.

Therefore, it is assumed:

a. Total cars (1972) = 96,860,000 (x 3.5% Annual Growth)

b. Average annual miles per car = 10,184

c. Small car miles per gallon = 22.00

d. Standard car miles per gallon = 11.65

1972 Consumption (actual FHWA)
Registrations = 96,860,000

	Small Cars (29.0%)		Standard Cars (71.0%)	
No. of Cars	28,089,400	x	68,770,600	x
Average Miles	10,184	=	10,184	=
Total Miles x 10^6	286,062	÷	700,360	÷
Miles Per Gallon	22.00	=	11.65	=
Gallons x 10^6	13,003		60,118	

Total Consumption = 73,121 x 10^6 gallons or 4,757 thousand barrels per day.

Appendix C, Exhibit VI

1974 Consumption (hypothetical)
Registrations = 103,760,000

	Small Cars (31.65%)		Standard Cars (68.35%)	
No. of Cars	32,840,040	x	70,919,960	x
Average Miles	10,184	=	10,184	=
Total Miles x 10^6	334,443	÷	722,249	÷
Miles Per Gallon	22.00	=	11.65	=
Gallons x 10^6	15,202		61,996	

Total Consumption = 77,198 x 10^6 gallons or 5,036 thousand barrels per day.

Thus, the apparent fuel savings from the present shift to smaller cars could amount to 73 thousand barrels per day, *versus* potential consumption at the 1972 percentage of small cars.

1978 Consumption (hypothetical)
Registrations = 119,060,000

	Small Cars (40.30%)		Standard Cars (59.70%)	
No. of Cars	47,981,180	x	71,078,820	x
Average Miles	10,184	=	10,184	=
Total Miles x 10^6	488,640	÷	723,867	÷
Miles Per Gallon	22.00	=	11.65	=
Gallons x 10^6	22,211		62,134	

Total Consumption = 84,345 x 10^6 gallons or 5,502 thousand barrels per day.

Thus, the apparent fuel savings from a potential shift to smaller cars could amount to 361 thousand barrels per day, *versus* potential consumption at the 1972 percentage of small cars.

Exhibit VII

MODE SHIFTS (FROM AUTOMOBILES) COMPUTATIONS

1. Urban Bus Passenger Miles:

To establish proper perspective and to estimate the fuel conservation potential for an urban shift to buses during this short-term period, the following assumptions are employed:

a. The present capacity to produce urban buses is about 6,000 units per year on a single shift basis and most of these are used as replacements. Time is not adequate for new production facilities in this timeframe so that increased output must stem from two- and three-shift work patterns at present plants. Assuming production parts are available, bus output for service extension could probably reach 500 units in 1974, 2,500 in 1975, 4,000 in 1976, and 8,000 in 1977 and 1978; thus, the total number of buses available for 1978 urban service might be 65,000 compared to 49,700 in use during 1970.

b. It seems reasonable to assume that modest incentives could generate a 25 percent increase in bus load factors so that an average of 16.6 persons would be riding in 1978 compared to 18.8 in 1960 and 13.3 in 1970.

c. It is deemed that the extension and improvement of bus service would add a factor of 5 percent to the mileage of the average urban bus.

Through these assumptions, buses would be able to achieve a gain of 14.9 billion passenger miles by 1978, or more than 70 percent over the 1970 levels. Accordingly, if it is assumed that 1970 urban automobile travel (737 billion passenger miles) increases at an annual rate of 2.5 percent to 1978, assuming no diversion, the 14.9 x 10^9 passenger miles diverted to bus becomes 1.7 percent of the automobile travel (898 x 10^9 passenger miles). Similarly, the fuel savings attained through this change can then be calculated as passenger miles diverted times the difference in efficiencies (miles per gallon x load factor) between the average passenger car and bus, or:

$$\begin{array}{ccccc}
\underline{\text{Passenger Miles Diverted}} & & \underline{\text{Car Efficiency}} & & \underline{\text{Bus Efficiency}} \\
(14.9 \times 10^{9}) & \times & \left(\dfrac{1}{(12.9 \text{ MPG} \times 1.6 \text{ LF}} \right. & - & \left. \dfrac{1}{4.0 \text{ MPG} \times 16 \text{ LF})} \right)
\end{array}$$

and the resultant fuel conservation amounts to 498 million gallons or 32.5 thousand barrels per day.

2. Inter-City Automobile Travel (Potential for Diversion):

Estimated Inter-City Automobile Travel - 1972

	Passenger Miles x 10^9
Total	1,071.3
Non-Divertible	
Earning a Living	
• Related Business x 75%	96.2
Family Business	
• Shopping x 95%	143.0
• Other x 80%	167.9
Social and Recreational	
• Vacations x 90%	111.3
• Visits x 25%	82.4
• Pleasure x 5%	4.7
• Other x 10%	44.3
Education, etc. x 10%	12.1
	661.9
Potential for Diversion	409.4 (38.2% of Total)

3. Inter-City Bus Travel:

To establish perspective, and based on estimates provided by the motor bus industry, the following calculations are exhibited to formulate the capacity of the inter-city bus fleet to absorb passenger miles and to determine the fuel savings that could be derived. Thus, as based on available factors for 1972, if:

a. The bus fleet were capable of a 5 percent annual expansion through less equipment retirement by 1978,

b. The average number of passengers were to increase by 20 percent through automobile disincentives (tolls, taxes, etc.) during this period,

c. Average miles per bus were increased by 20 percent, all buses would be able to gain 23.7 billion passenger miles or 93 percent over the 1972 level.

Calculation of Inter-City Bus Passenger Miles

	Buses in Service	Average Passengers	Average Miles	Passenger Miles x 10^9
1972	22,700	21.7	52,000	25.6
1978	30,400	26.0	62,400	49.3

Accordingly, if it is assumed that 1972 inter-city auto travel (1,071 x 10^9 passenger miles) increases at an annual rate of 2.5 percent to 1978 (assuming no diversion) and that the proportion subject to diversion remains constant (38.2%), then the 23.7 x 10^9 passenger miles diverted to inter-city bus becomes only 5.0 percent of the shiftable auto travel at that time (474 x 10^9 passenger miles). The resultant fuel saving can be calculated on the same basis as the intra-city shift to buses or:

$$\begin{array}{ccccc} \underline{\text{Passenger Miles Diverted}} & & \underline{\text{Car Efficiency}} & & \underline{\text{Bus Efficiency}} \\ (23.7 \times 10^9) & \times & \left(\frac{1}{15 \text{ MPG} \times 2.5 \text{ LF}}\right. & - & \left.\frac{1}{5.9 \text{ MPG} \times 26.0 \text{ LF}}\right) \end{array}$$

and the fuel conserved amounts to 477.5 million gallons or 31,150 barrels per day.

Exhibit VIII

COMMERCIAL TRUCKING

TABLE 30

ESTIMATED PARAMETERS OF COMMERCIAL TRUCK TRAVEL--1972*

Vehicle Type	Vehicle Miles x 10^6	Fuels Consumed† MM Gallons	Fuels Consumed† MB/D (Gasoline/Diesel)
Light Trucks‡			
Urban	54,625	7,165	447/19
Inter-city§	28,255	4,160	258/13
Total	82,880	11,325	705/32
			737
Heavy Trucks#			
Urban	17,855	3,295	27/187
Inter-city§	28,170	5,195	42/296
Total	46,025	8,490	69/483
			552
Total Commercial Trucks*			
Urban	72,480	10,460	474/206
Inter-city§	56,425	9,355	300/309
Total	128,905	19,815	774/515
			1,289

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* Trucks for personal and government use are excluded.

† Includes a small quantity of LPG.

‡ Single unit, 2- and 3-axle trucks.

§ Includes private business non-freight use.

Combination tractor-trailer trucks.

Exhibit IX

CONSERVATION EFFECT OF SPEED LIMITS ON INTER-CITY COMMERCIAL TRUCK TRAVEL

The Conservation Effect of 55 MPH Speed Limits on Inter-City Commercial Truck Travel

From Exhibit VIII, Table 30 it is estimated that 609 thousand barrels per day of fuel is consumed in inter-city truck travel. At this point, it is further estimated that this fuel consists of 300 thousand barrels per day of gasoline and 309 thousand barrels per day of diesel fuel.

Assuming a 3 percent savings potential as developed in the text, and 90 percent compliance with the lower speed limit (as it is law), the following savings are calculated:

- Gasoline--300 thousand barrels per day x (.03 savings x .90 compliance) or 8 thousand barrels per day potential savings.
- Diesel Fuel--309 thousand barrels per day x (.03 savings x .90 compliance) or 8 thousand barrels per day potential savings.

Thus, the total fuel conservation potential via truck speed limit reduction becomes 16 thousand barrels per day for 1972.

Exhibit X

INTER-CITY TRUCK FUEL SAVING THROUGH MODIFIED WEIGHT STANDARDS

Calculation of Inter-City Truck Fuel Saving Through Modified Weight Standards:*

- Present Standards allow--47,010 pound payload at a fuel consumption rate of .238 gallons per mile which equals 98.761 tons per MPG.
- Proposed Standards would allow--51,730 pound payload at a fuel consumption rate of .246 gallons per mile which equals 105.142 tons per MPG.

Based on Inter-City Truck Freight Movement of 470 Billion Ton-Miles During 1972 the Fuel Used Would Be:

- Present Standards = $470 \times 10^9 \div 98.761$ = 4,758,963,500 gallons
- Proposed Standards = $470 \times 10^9 \div 105.142$ = 4,470,145,100 gallons
- Savings = 288,818,400 gallons or 19 thousand barrels per day.

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* Intended to serve as an example as the change in payload is dependent on truck dimensions.

Exhibit XI

MODE SHIFTS (FROM TRUCKING) CALCULATIONS

Assumptions for Truck to Rail Freight Shift

Calculations of fuel saving potential resulting from the diversion of freight from inter-city trucks to rail.

a. Inter-city truck ton-miles will continue to increase at an annual rate of 3.9 percent from a base of 470 x 10^9 ton-miles in 1972.

b. Through expansion of railcar piggyback loadings it would be possible to divert 9 percent of the inter-city truck ton-miles.

c. The difference in efficiency between the modes (rail advantage) equals .008724 gallons per ton-mile.

Calculations

1972 -

470 x 10^9 ton-miles x 9% x .008724 gallons per ton-mile = 369,025,200 gallons or about 24.0 thousand barrels per day

1974 -

507 x 10^9 ton-miles x 9% x .008724 gallons per ton-mile = 398,076,120 gallons or about 25.9 thousand barrels per day

1978 -

591 x 10^9 ton-miles x 9% x .008724 gallons per ton-mile = 464,029,560 gallons or about 30.3 thousand barrels per day.

TABLE 31

Tons Transported By Length of Haul By All Modes of Transportation — 1967 (1)

(in 1000 tons)

Length of Haul (miles)	Rail	% of Total	For Hire Motor Carriers	% of Total	Private Motor Carriers	% of Total	Total Private & For Hire	% of Total	Other Modes (2)	% of Total	Total All Modes
Under 50	25,373	18.6	53,529	39.3	51,588	37.8	105,117	77.1	5,839	4.3	136,329
50-99	38,367	27.5	55,775	39.9	41,452	29.7	97,227	69.6	4,137	2.9	139,731
100-199	64,811	37.1	66,566	38.1	39,203	22.5	105,769	60.6	4,029	2.3	174,609
200-299	61,649	48.5	44,008	34.6	16,204	12.7	60,212	47.3	5,325	4.2	127,186
300-399	40,372	49.4	29,510	36.1	7,009	8.6	36,519	44.7	4.848	5.9	81,739
400-499	34,761	59.8	17,041	29.3	4,245	7.3	21,286	36.6	2,070	3.6	58,117
500-599	26,754	61.4	12,730	29.2	3,291	7.6	16,021	36.8	783	1.8	43,558
600-799	43,016	62.5	19,696	28.6	3,413	5.0	23,109	33.6	2,662	3.9	68,787
800-999	27.795	64.8	9,917	23.1	1,665	3.9	11,582	27.0	3,542	8.2	42,919
1,000-1,199	14,824	64.5	4,668	20.3	1,011	4.4	5,679	24.7	2,482	10.8	22,985
1,200-1,499	13,347	70.3	3,478	18.3	474	2.5	3,952	20.8	1,686	8.9	18,985
1,500-1,999	23,187	81.0	3,352	11.7	473	1.7	3,825	13.4	1,628	5.6	28,640
2,000 & over	16,970	72.3	2,465	10.5	284	1.2	2,749	11.7	3,743	16.0	23,462
TOTALS	431.226	44.6	322,735	33.4	170,312	17.6	493,047	51.0	42,774	4.4	967,047

(1) Census of Transportation; Commodity Transportation Survey — Shipper Group 9 (Petroleum and Coal Products) has been omitted because it is moved in bulk quantities predominantly.

(2) Other modes include: air, water, parcel post, railway express, freight forwarders, motor express carriers, etc. Movements by pipeline were not included in the survey.

SOURCE: Bureau of the Census; 1967 Census of Transportation; Commodity Transportation Survey — Shipper Groups.

Appendix C, Exhibit XI

TABLE 32

Tons Transported By Size of Shipment By All Modes of Transportation — 1967 (1)

(In 1,000 Tons)

Shipments (lbs.)	Rail	% of Total	For-Hire Motor Carriers	% of Total	Private Motor Carriers	% of Total	Total Private & For-Hire	% of Total	Other Modes (2)	% of Total	Total All Modes
Under 50	25	2.4	404	39.4	133	13.0	537	52.4	464	45.2	1,026
50-99	41	3.2	806	63.6	240	18.9	1,046	82.5	181	14.3	1,268
(Under 100)	(66)	(2.9)	(1,210)	(52.7)	(373)	(16.3)	(1,583)	(69.0)	(645)	(28.1)	(2,294)
100-199	84	2.9	2,051	71.4	570	19.8	2,621	91.2	169	5.9	2,874
200-499	211	2.7	5,770	74.7	1,487	19.2	7,257	93.9	260	3.4	7,723
500-999	263	2.9	6,713	74.0	1,856	20.5	8,569	94.5	232	2.6	9,064
(Under 1,000)	(626)	(2.9)	(15,744)	(71.7)	(4,281)	(19.4)	(20,025)	(91.1)	(1,309)	(6.0)	(21,960)
1,000-9,999	7,984	10.7	45,199	61.4	19,464	26.4	64,663	87.8	1,083	1.5	73,730
10,000-29,999	16,372	13.6	57,966	48.0	45,261	37.4	103,227	85.4	1,165	1.0	120,764
(Under 30,000)	(24,982)	(11.5)	(118,909)	(54.9)	(69,006)	(31.9)	(187,915)	(86.8)	(3,557)	(1.6)	(216,454)
30,000 & Over	377,946	55.2	184,240	26.9	85,924	12.5	270,164	39.4	36,736	5.4	684,846
Totals	402,928	44.7	303,149	33.6	154,930	17.2	458,079	50.8	40,293	4.5	901,300

(1) Census of Transportation; Commodity Transportation Survey — Shipper Group 9 (Petroleum and Coal Products) has been omitted becuase it is moved in bulk quantities predominantly.

(2) Other modes include: air, water, parcel post, railway express, freight forwarders, motor express carriers, etc. Movements by pipeline were not included in the survey.

Source: Bureau of The Census; 1967 Census of Transportation, Commodity Transportation Survey — Shipper Groups.

Appendix C, Exhibit XII

Exhibit XII

ROADWAY IMPROVEMENTS CALCULATIONS

Hypothetical Petroleum Conservation Analysis

Analysis for a 1-mile, 2-lane, 24-feet wide, paving project carrying 5,000 vehicles per day which will improve vehicular fuel efficiency by 5 percent.

Petroleum Requirements

At jobsite		
Tack coat 0.25 gal./sq. yard	3,520 gal.	
Bitumen in sheet asphalt	19,510	
Subtotal, asphalt		23,030
Heat and propel distributor	15	
Operate paver	10	
Haul plant mix to project 20-mile round trip	600	
Operate roller	20	
Crew transport to and from worksite	12	657
Offsite		
Produce aggregate	1,000	
Heat bitumen	120	
Dry aggregate	300	
Plant operation	100	
Transportation of bitumen from refinery	300	
Oil well through refinery	20	
Construction and manufacture of equipment	2	1,842
Total		25,529

Annual fuel saving - 10 percent

$$.05 \times \frac{5{,}000}{12.9 \text{ MPG}} \text{ VMT/day} \times 365 \text{ days/yr.} = 7{,}075 \text{ gal./yr.}$$

Days of improved operation required to break even:

$$\frac{25{,}529}{7{,}075} \times 365 = 1{,}317 \text{ days or } 3.6 \text{ years.}$$

TABLE 33

U.S. FOREIGN AND DOMESTIC WATERBORNE COMMERCE
POTENTIAL FUEL SAVINGS--VESSEL OPERATIONS

	Anticipated Normal Operations					
Parameters Affecting Consumption	1973	1974	1975	1976	1977	1978
U.S. Waterways						
Billion Ton Miles	439	452	470	488	591	690
Fuel Efficiency (1,000 Ton Miles Per Barrel)*	8.78	9.22	9.68	10.16	13.42	15.73
Residual Fuel Oil Consumption (Million Barrels)						
At Port (30%)	15.0	14.7	14.6	14.4	13.2	13.2
At Sea (70%)	35.0	34.4	34.0	33.6	30.8	30.7
Total Consumption	50.0	49.1	48.6	48.0	44.0	43.9
International Waters						
Imports and Exports (Million Short Tons)	741	767	857	970	1,123	1,170
Fuel Efficiency (Short Tons Per Barrel)†	19.7	20.7	21.7	22.7	23.9	25.1
Residual Fuel Oil Consumption (Million Barrels)						
Total Consumption (All At Sea)	37.6	37.1	39.5	42.7	47.0	46.6
Total Fuel Consumption in Both U.S. and International Waters (Million Barrels)						
At Port	15.0	14.7	14.6	14.4	13.2	13.2
At Sea	72.6	71.5	73.5	76.3	77.8	77.3
Total Consumption	87.6	86.2	88.1	90.7	91.0	90.5

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* Estimated to rise 5 percent per year, adjusted upward for North Slope volumes beginning in 1977.

† Estimated to rise 5 percent per year through entire period.

TABLE 34

U.S. FOREIGN AND DOMESTIC WATERBORNE COMMERCE
POTENTIAL FUEL SAVINGS--VESSEL OPERATIONS
(Million Barrels)

	Potential Fuel Oil Savings					
Parameters Affecting Consumption	1973	1974	1975	1976	1977	1978
Operating efficiency savings at 8 percent of fuel consumed at sea	NA	5.7	5.9	6.1	6.2	6.2
Faster loading and discharge, fewer port calls and reduced port time at 10 percent of fuel consumed at port	NA	1.5	1.5	1.4	1.3	1.3
Speed reduction savings for liner-type vessels and non-bulk carriers at 0.7 percent of fuel consumed at sea*	NA	.5	.5	.5	.5	.5
Total Savings (Million Barrels)	NA	7.7	7.	8.0	8.0	8.0
Total Savings (Percent of Normal Consumption)	NA	8.9	9.0	8.8	8.8	8.8

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* Calculated at an estimated 18 percent fuel savings on 4 percent of fuel bunkered for use at sea.

TABLE 35

U.S. FOREIGN AND DOMESTIC WATERBORNE COMMERCE
POTENTIAL FUEL SAVINGS--TUG AND BARGE OPERATIONS

Parameters Affecting Consumption	Anticipated Normal Operations					
	1973	1974	1975	1976	1977	1978
Billion Ton Miles	286	308	334	362	394	426
Propulsion Efficiency (1,000 Ton Miles Per Horsepower of Units in Service)*	63.37	65.59	67.88	70.26	72.72	75.26
Tow and Tug Capacity in Use (Million Horsepower)	4.508	4.699	4.913	5.149	5.411	5.655
Annual Round Trip (Hours Under Tow Per Unit)†	4,030	4,190	4,358	4,534	4,716	4,904
Billion Annual Horsepower Hours of Propulsion	18.17	19.69	21.41	23.35	25.52	27.73
Fuel Efficiency (Pounds of Diesel Fuel Per Horsepower Hour)‡	.421	.440	.436	.432	.427	.423
Annual Diesel Fuel Consumption (Million Barrels)	25.2	28.5	30.7	33.2	35.8	38.6
	Potential Fuel Oil Savings (MMB)					
	1973	1974	1975	1976	1977	1978
Total Operating Efficiency Savings at 2.5 percent of Total Fuel Consumption	NA	0.7	0.8	0.8	0.9	1.0

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* Estimated to rise at 3.5 percent per year throughout.

† Estimated to rise at 4 percent per year due to improved utilization and longer trips.

‡ Calculated to decline 1 percent annually from 1975 through 1978 due to increased proportion of larger horsepower tugs.

1. Peak Hour Ridership (A 10 percent increase in urban public transit and utilization; excludes taxis):

Assumptions:

Average car occupancy	1.6
Average car miles per gallon	12.9
Passenger miles handled by urban public transit (bus & rail) in 1972	45 billion
Passenger miles that can be shifted from cars	4.5 billion (a 10% increase in ridership)
Increase in fuel consumption by urban public transit systems	negligible

Since "Average car occupancy" is defined as $\frac{\text{Passenger miles}}{\text{Vehicle miles}}$ the passenger miles diverted from cars can be converted into vehicle miles by

$$\text{Vehicle miles} = \frac{\text{Passenger miles}}{\text{Average car occupancy}} = \frac{4.5 \times 10^9}{1.6}$$

$$= 2.8 \text{ billion miles per year.}$$

Fuel savings from not using cars are calculated as follows:

$$\text{Fuel savings} = \frac{\text{Vehicle miles}}{\text{Miles per gallon}} = \frac{2.8 \times 10^9}{12.9}$$

$$= 218 \text{ million gallons per year}$$

$$= 14 \text{ thousand barrels per day.}$$

2. Staggering of Work Hours (Allowing a 50 percent increase in urban public transit utilization; excludes taxis):

Assumptions are the same as above except that 22.5 billion passenger miles (a 50 percent increase) are diverted from cars to urban public transit by virtue of staggered work hours. It is also assumed that miles traveled by the bus and rail systems will increase by 10 percent thereby increasing the fuel consumption of these systems by 10 percent. Fuel consumption by the bus and rail systems was 26.25 thousand barrels per day in 1972.

Using the same approach as in (1) above the fuel saved from not using cars is:

$$\frac{22.5 \times 10^9}{12.9 \times 1.6} = 1{,}090 \text{ million gallons per year}$$

$$= 71 \text{ thousand barrels per day}$$

This saving must be reduced by the additional fuel consumed by the public transit systems which is 10 percent of 26,790 barrels or 2.6 thousand barrels per day. Net fuel savings are about 69 thousand barrels per day.

3. Increased Urban Bus Load Factor and Improved Bus Service:

Assume that the bus load factor will increase by 25 percent over 1970 level and that improved bus service requires a 5 percent increase in the annual miles traveled by the average urban bus. These data are summarized below:

	Assumed Changes		1970 Basis
Bus load factor	16.6		13.3
Number of buses	49,700		49,700
Average annual miles per bus	33,140		31,560
Passenger miles (million)*	27,341		20,860
Average car occupancy		1.6	
Average car miles per gallon		12.9	
Average bus miles per gallon		4.0	

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* Bus load factor x Average annual miles per bus x Number of buses.

Since 6,481 million passenger miles can be diverted from cars (i.e., 27,341 million less 20,860 million), the fuel saved can be calculated by using the approach as in (1) above; i.e.,

$$\frac{6{,}481 \times 10^6}{12.9 \times 1.6} = 314 \text{ million gallons per year}$$

$$= 21 \text{ thousand barrels per day.}$$

Since the average annual miles traveled per urban bus increase by 1,580 miles, the total increase in miles traveled by the bus fleet is 1,580 times 49,700, the number of buses. This results in 78.5 million vehicle miles. Since buses are assumed to get 4 miles to the gallon, the additional fuel consumption is:

$$\frac{\text{Vehicle miles}}{\text{Miles per gallon}} = \frac{78.5 \times 10^6}{4.0} = 19.6 \text{ million gallons per year}$$

$$= 1{,}280 \text{ barrels per day.}$$

Hence, net fuel savings are 19.2 thousand barrels per day (i.e., 20,480 less 1,280).

4. Demand Responsive Systems:

Assuming that there are 250 working days in the year, that the average round trip is 18 miles, and that the van has an average occupancy of 8 persons, each van will carry 36,000 passenger miles per year (18 miles x 8 persons x 250 days) and travel 4,500 miles (18 miles x 250 days).

Assuming further:

Average car occupancy	1.6
Average car miles per gallon	12.9
Average van miles per gallon	9.0

then net fuel savings from employing 1,000 vans can be calculated as follows:

Since 36 million passenger miles can be diverted from cars with the use of 1,000 vans, the reduction in car miles traveled is:

$$\frac{\text{Passenger miles}}{\text{Average car occupancy}} = \frac{36 \times 10^6}{1.6} = 22.5 \text{ million miles per year.}$$

Fuel savings from this reduction in car travel is thus:

$$\frac{\text{Vehicle miles}}{\text{Miles per gallon}} = \frac{22.5}{12.9} = 1{,}744 \text{ million gallons per year.}$$

Since the 1,000 vans will travel 4.5 million miles a year, the fuel consumption will be:

$$\frac{4.5 \times 10^6}{9} = 0.5 \text{ million gallons per year.}$$

Hence, net fuel savings are 1,244 million gallons per year or 81 barrels per day.

Appendix F

TEN WAYS TO SAVE ENERGY ON THE FARM

1. Keep engines tuned up.
2. Reduced tillage.
3. Connect implements to cut out trips and save fuel.
4. Shift up and throttle down.
5. Shut off engines, idling wastes fuel.
6. Use wheel weights for light jobs.
7. Match equipment to job.
8. Keep equipment sharp and in adjustment.
9. Keep proper air pressure in tires for maximum efficiency.
10. Refer to operating manual and consult dealer.

Source: Starnes, Bruce, Office of U.S.D.A., *Energy Activities*, U.S. Department of Agriculture.

TABLE 36

ENERGY REQUIREMENTS AT VARIOUS LEVELS OF TILLAGE INTENSITY-- NEBRASKA CORN CROP

(Horsepower Hours Per Acre)

Tillage Steps Start to Finish	Conventional Tillage	Reduced Tillage	Minimum Tillage	No Tillage
Chop Stalks	9.0	9.0	9.0	--
Disc	6.6	6.6	--	--
Plow	19.1	--	--	--
Disc	6.6	--	--	--
Harrow	5.5	--	--	--
Plant	4.0	7.3	3.7	2.0
Spray	1.0	1.0	1.0	1.0
Cultivate	6.6	6.6	8.8	--
Combine	8.2	8.2	8.2	8.2
Total	66.6	38.7	30.7	11.2
Estimated Fuel Requirement (Gallons of Diesel Fuel Per Acre)	5.33	3.10	2.46	0.90

Appendix F

EIGHT SIMPLE OPERATIONAL PROCEDURES TO REDUCE GASOLINE CONSUMPTION IN SNOWMOBILES BY 10 PERCENT

1. Measure and mix gas and oil accurately, using the manufacturer's recommended ratios. Excess oil in gas increases fuel consumption.

2. Use regular grade fuel. To avoid spillage, never turn or leave the vehicle on its side.

3. Drive at moderate speed. Constant moderate throttle operation with slower acceleration will utilize fuel more efficiently.

4. Do not idle the engine. Idling consumes fuel without any positive result and may cause inefficient operation due to spark plug fouling and high operation temperatures.

5. Follow packed or groomed trails instead of making new paths in deep loose snow.

6. Keep the engine in top operating condition at all times.

7. Check engine ignition timing. Use only new or very clean spark plugs of the proper heat range and with the proper gap. Do not change any of the carburetor settings.

8. Maintain all vehicle components in good order throughout the season. Proper track and drive chain tension, proper ski and clutch alignment and proper lubrication are important factors for fuel economy as well as lower maintenance costs.

Source: International Snowmobile Industry Association and the International Snowmobile Council.