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THE EFFECT OF THE ENERGY CRISIS ON THE PRIVATE CAR IN THE U.S.

REUEL SHINNAR
Department of Chemical Engineering, City College, NY 10031, U.S.A.

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Abstract—It is often claimed that the future energy crisis will make the private car obsolete and demand a carless society. Some perspectives on this view are given here and it is shown that these claims are based more on emotion than on facts. The possible savings in gasoline by better design are such that we could allow a growth of 50–80 per cent in total mileage without any increase in total gasoline consumption, while maintaining safe convenient cars. The different options of achieving this are summarized and the possible compromises between high efficiency and low pollution are discussed. It is shown that higher compression ratios would have a significant advantage in reducing total energy consumption. So would lower weight, better maintenance and emphasis on designs which allow easy maintenance. The possible savings, due to better design, more reasonable size, and other options are as large or larger than the possible savings by public transportation.

INTRODUCTION

The original title of my paper did not include the limitation "in the United States" and the best way to outline the scope of the paper might be by explaining why I added this suffix in an international symposium.

First of all, I have studied the problem only in the United States. The United States has no foreseeable over population and no exploding birth rate. It also has enough fossil energy sources to sustain our present standard of living including the private car for the next few hundred years. If we add to this the known technology for alternative energy sources, such as nuclear, geothermal and solar energy, it becomes clear that the problem for the United States is far less serious than for the rest of the world. By some quirk of fate even some of the newer technology is more promising for us than for the poor countries. The United States is maybe the only place which could grow most of its energy needs.

My remarks seem to be somewhat in contradiction with the fact that just a few months ago we were trying to ration gasoline, a situation which is going to reappear in the next few years, as we build the needed refinery capacity. But, as I pointed out in a previous paper, our present crisis is really not an energy crisis in the sense it is normally understood. it was rather a crisis in our ability to manage a complex economy.

Ten years ago we had several options open to us. We could have limited the increase in gasoline consumption by going to smaller, more efficient cars and we would have driven the same mileage using 40 per cent less gasoline at a total saving of 2·5 million barrels a day, 1·0 million barrels more than our total import from the Middle East. Or alternatively, we could have developed our energy sources providing the added gasoline. In Table 1 I am giving estimated costs for alternative ways of providing added gasoline from various sources, including methanol from coal, all by conventional methods. The best way to put the problem of the car and the energy crisis in perspective is to note that gasoline from coal by World War II technology would cost about 40 cents a gallon at the factory before taxes, marketing cost, etc. a price which could probably be reduced by further development of some of the methods under present research. The investment needed to produce from coal all the gasoline presently needed for passenger cars is about 120 billion dollars. A ten cent markup on gasoline would produce this needed capital within 12 yr.

Three years ago however those options were much more limited, as the time needed to change most of the cars on the road is about 10 yr, and at least 3 yr are needed to make a significant impact. And it takes at least 3 yr to make any significant changes in design. It takes three to four years to plan and build major refineries and more to develop alternative fuel sources even by available technologies.

Three years ago however there was a price war on gasoline and it would have been hard for politicians to justify any measures to reduce car size.

The real problem is that we deal with a very sluggish system, that the risks and expenses involved in new solutions are large. We therefore need advance planning and cooperation between government and industry on an unprecedented scale, and judging from what happened in recent years with regard to control of exhaust emissions and many other problems we lack as yet the experience and tools to handle such cooperative programs.

As the basic problems are not technical we as engineers cannot solve them but we can at least try to illuminate what the choices are. Let me first try to define the scope of the problem.

The problem is not simply how to save energy, as some of the literature on transportation balance seems to assume. The problem, for the U.S. at least, is to save energy without substantially reducing our standard of living and without upsetting a complex economy. We don't even understand very well the operation and the delicateness of this economy. If we just would want to save energy, let us remind ourselves that advanced

Table 1. Cost of automotive fuels

Fuel	Costs in cents (gallon gasoline or gasoline equivalent)
Gasoline 1972 at $4 a barrel	22–27
Gasoline from foreign crude	
at $12	42–50
at $16	52–60
Gasoline from shale oil	35–45
Methanol	
2·2 gallons methanol equals 1 gallon gasoline	40–60
Ethanol (from cellulosic) wastes or trees) by fermentation	60–70
1·7 gallons ethanol equals 1 gallon gasoline	

Costs are ex taxes, average distribution costs included, but no dealer profit. Costs are given for the thermal equivalent of one gallon gasoline.

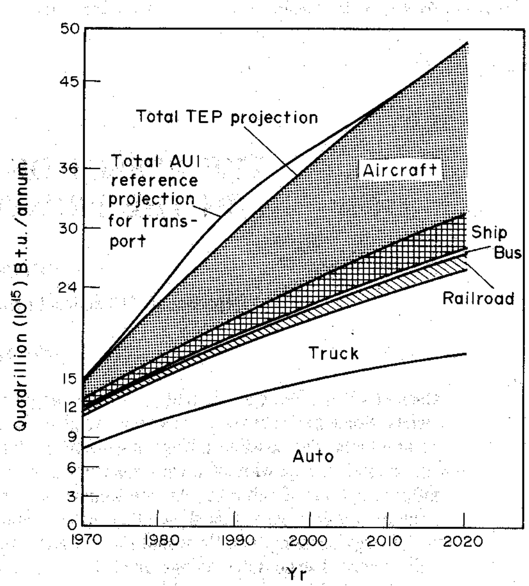

Fig. 1. Projected transportation energy consumption.

nations like Sweden or Germany who also drive cars use only half the total energy per person that we do.

The problem gets even more complex as a large part of the projected energy shortage is mainly due to the framework of projections used.

I'll give you just one example. In a recent DOT study (DOT 1972) the projection was made (see Fig. 1) that in 1990 fuel consumption for airplanes will equal that for cars and the reason given is very interesting. Real income is projected to double to 1990, and the money spent for traveling is also assumed to double. And the panel making the study realized that the number of cars and the distance traveled cannot increase that much so they had to look for other travel modes to take up the money and the only mode that could provide the needed increase is the airplane. Once we accept this way of forecasting there is really no sense in trying to save energy as we are just going to spend it somewhere else anyway.

Now I am not pretentious enough to even try to give you here a total picture of our energy needs, or even our transportation needs. What I try to do is to put the problem of the private car in some perspective.

PRESENT AND FUTURE ENERGY NEEDS FOR THE PRIVATE CARS

The present and projected energy consumption for private cars is reproduced in Fig. 2. We note that in 1985 the projected energy consumption increases by 50 per cent over the present. Now, nobody knows if this increase would happen if no controls are applied but the first thing we can ask ourselves is, "Is that increase really necessary?"

In Fig. 2 the projected increase in the number of cars and the number of people is also given. We note that all the curves are "S" shaped with a rapid increase till the 1990's and then leveling off to the population growth.

Once we recognize that the future growth is going to level off we may lose our ingrained opposition to anything which limits growth. As the level of the "S" shaped curves is limited by some factors, could we not control that asymptotic level at a desirable level. In DOT projections (1972) it is mentioned that final growth of the car is limited by congestion. This seems doubtful to me. At present we have one car for every 2·2 people, which means one car for every 1·3 eligible drivers. DOT

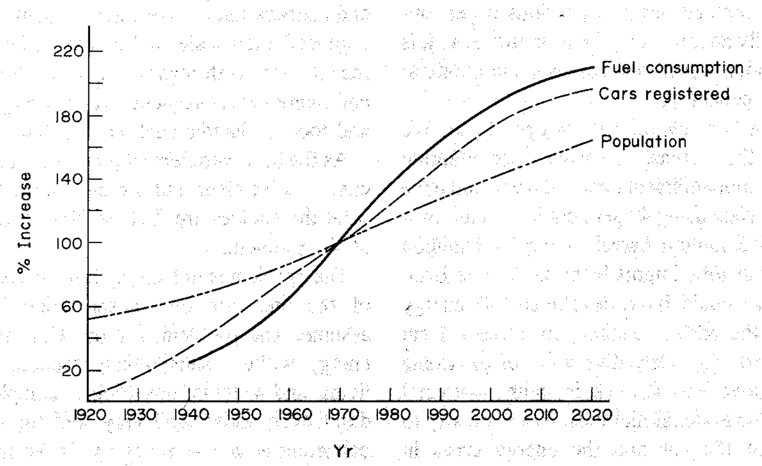

Fig. 2. Projected growth of population, number of cars and fuel consumption.

projections assume one car for every 1·1 drivers in 1990, and despite the fact that some experts (Inter Technology Co., 1971) predict more than one car per eligible driver it is hard to imagine that even without congestion we could drive more than one car at a time. Furthermore, each of us at present drives about 10–12,000 miles a year in a passenger car not counting public transportation. Would we really enjoy driving much more? The average number of passengers is now two and the main way to increase mileage is by driving always alone, a doubtful pleasure.

The projected population increase till 1995 is between 30–35 per cent and it might be much smaller. The number of eligible drivers will increase somewhat more. I can see little hardship if we would limit the growth in total car mileage to the projected increase in population. We would still have the same dependence on the private car that we have now. If we would increase the miles a car drives on a gallon of gasoline by 35 per cent we would need no increase in gasoline consumption by 1995. But we could do better than that.

At present the average gasoline consumption of American cars is about 12–15 miles per gallon. Doubling that mileage is perfectly feasible and the options available for it will be discussed later. This could take care of any present social inequities, as the population growth and we would still need less gasoline in 1990 than we need today.

As we will see it is feasible to develop policies that freeze the gasoline consumption for private cars at the present level or decrease it, without affecting our ability to drive as much as we want. This would be desirable for several reasons. We realize now that our present fossil energy sources are finite and should be preserved as much as possible, at least till we develop new ones. Limiting the growth rate of gasoline consumption will make the task of developing alternative fuel sources much easier and will reduce the drain on the environment.

However, I will immediately admit that at present I know of no technical development that will achieve this without a sacrifice in convenience. All presently available solutions to double mileage will involve either a smaller car or a car with a lower performance. Thermodynamically it is perfectly feasible to almost double the mileage at no penalty, but it would be hard to base policy decisions on research dreams as feasible as they might be.

In that sense I am somewhat contradicting my initial statement that any energy policy should maintain our present standard of living. However, there is a big difference between driving no car and driving a small car. A small car provides a comfort and mobility, and a sense of independence that cannot be matched by any public transportation system. The difference between driving a compact and full-size car is not that large, and it is not even clear that a large Chevrolet always provides a higher standard of living than a small Jaguar, or a small Mercedes Benz. So let us discuss what we can do about the fuel need of the private car.

THE EFFECT OF DESIGN PARAMETERS ON CAR EFFICIENCY

A considerable number of papers (Huebner and Gasser 1973, Brogan 1973, La Pointe 1973, Roeusch 1971), have been written about the effect of weight and car design on fuel efficiency and I don't intend to give here a full review but rather discuss some of the basic problems involved. To put the discussion in a proper framework I will give here first a few pertinent data.

In Fig. 3 (reproduced from Clewell and Koehl, 1973) the increase in gasoline consumption of cars is compared with the increase in the number of cars and increase in mileage,

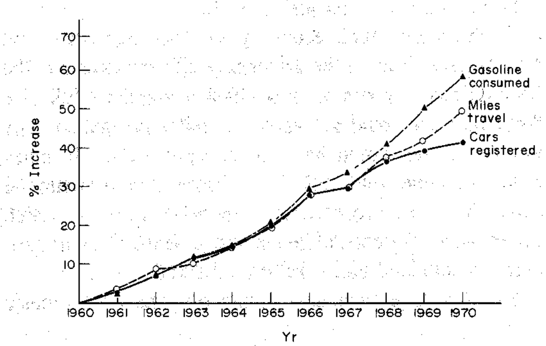

Fig. 3. Passenger car trends, 1960–1970 (from Clewell and Koehl 1973).

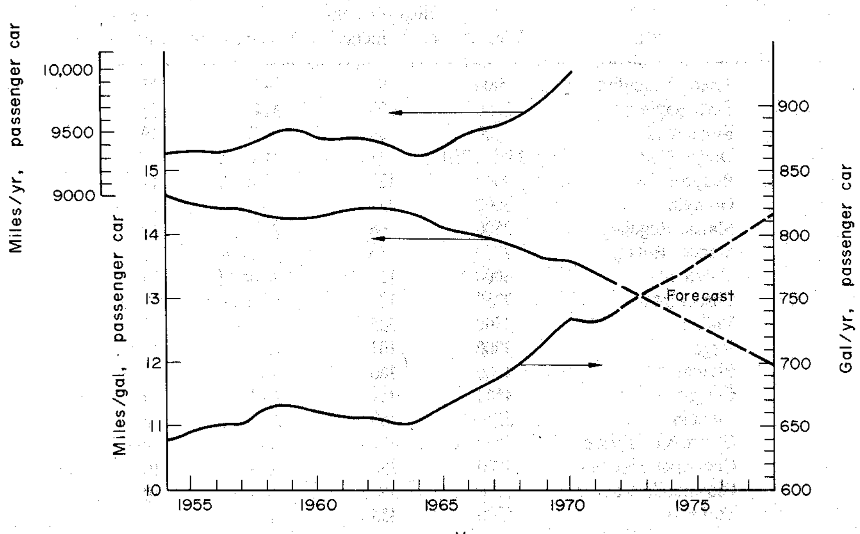

Fig. 4. Bureau of public roads fuel economy data and forecast.

and we note that only in recent years has the growth rate of consumption been larger than that of cars due to decrease in overall fuel efficiency. This increase is not explained by an increase in total mileage per car. I admit however that this evidence in itself is not conclusive. The first two parameters can be accurately measured, whereas the third is estimated based on sampling. However, there is other independent evidence available. In Fig. 4 some data from the Bureau of Public Roads are given showing the same trends, which have also been observed in direct tests. The average fuel efficiency of American cars has decreased despite the fact that the fraction of compact cars has increased. A full size 1974 American car uses 25–30 per cent more gasoline per mile than a 1965 standard sedan. Half of this increase is due to increased size and weight, increased accessories, etc. but the other half is due to antipollution measures discussed later.

Fuel efficiency data for typical present cars are given in Table 2 taken from EPA test results. (EPA, 1974). However, we should immediately point out that such data are not directly translatable to real fuel consumption for a typical driver. Fuel economy is a strong function of the way a car is driven. It is much better for long distance driving than for short drives. The EPA test is supposed to be typical of an urban drive cycle. But one should be careful. In Government statistics the term urban driving refers to any trip below 20 miles and is therefore typical of suburban daily driving just as well.

Furthermore, fuel economy is also dependent on maintainance and on the driver himself. For example, the Mobil Economy run in 1966–1968 a standard full size 8-cylinder car could get above 20 miles per gallon. The average driver would have been happy to get 14 miles under the same conditions. In the Mobil Economy run the car is driven by professional, experienced drivers which can make a difference of 20 per cent at least. Cars are also better maintained and carefully adjusted.

But this difference also points out one of the basic problems that anyone trying to deal with the policy research faces. It is hard to measure the average energy consumption under realistic conditions, and one should be careful to compare efficiencies obtained by different measurement methods. However, we can rely on the data for some relative effects. The main design parameters are:

(1) *Weight*

Weight has a strong influence on efficiency and the effect is especially noted in urban driving due to the many stops and starts involved. The effect is not directly proportional but other conditions being equal it almost is. Let us give two examples: A Pinto weighs half as much as a Lincoln Continental and uses about 60 per cent less fuel. A Diesel bus weighs 7 times as much as a Diesel taxi (Mercedes or Peugeot) and needs five times as much fuel per mile. However, the relation is not unique as can be seen from Fig. 5 where mileage is plotted vs weight for different models. The reason for the differences are due to design. We also note that small and big cars seem to be on

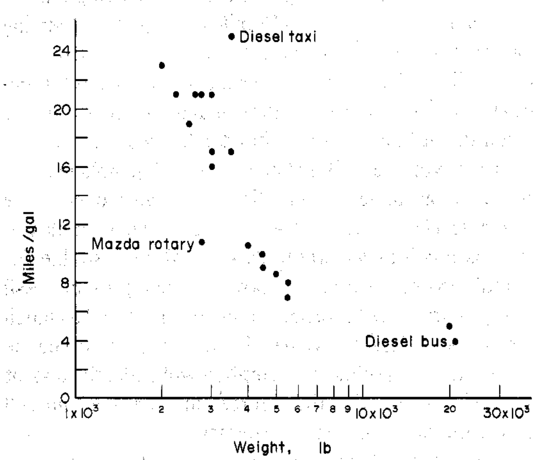

Fig. 5. Fuel economy vs car weight.

Table 2. Typical fuel efficiencies of various cars from the EPA test*

Car	Weight	Engine size (displacement cubic inches)	Transmission	Miles/ gallon
Triumph Spitfire	2000	91	M4	23
Saab Sonnett	2250	103	M4	21
Renault 12	2500	100	A–3	19
Dodge Colt	2500–2750	97	M or A	21
Peugeot 504	3000	120	M or A	17
Gremlin	3000	232	A–3	16
Mazda Regular	2500	96	A	19
Mazda, Rotary	2750	70	M or A	10·7
Volvo 144	3000	121	A or M	17
Ford Pinto	2750	122	M–4 or A	19–23
Valiant	3500	225	M	17
Vega	3000	101	A	17–23
Plymouth	4000	360	A–3	10–11
Cougar	4500	351	A–3	9
Lincoln	5500	460	A–3	8
Chevrolet Caprice	5000	454	A–3	8·5
Chevrolet Malibu	4500	350	A–3	10
Oldsmobile Cutlass	4500	350	A–3	10
Tornado	5500	455	A–3	7

*EPA (1974).

two different lines. That is mainly due to the fact that large cars are in most cases built for higher performance.

(2) *Performance*

The second most important parameter affecting the mileage of the car is its performance. On a weight basis a Toronado or Lincoln uses 2·3 as much gasoline as a bus, but they are much better performing cars. A Mercedes Diesel taxi on a weight basis uses only 10 per cent more fuel than a bus but it has a rather poor performance. Its slow acceleration poses some safety problems on a high speed highway. A bus has the same problem, but it is protected by its size. It does not need to accelerate fast. Burke (1957) gives an excellent comparison of the relation between performance and fuel consumption and written in 1957 it concludes that the increased fuel consumption is worth the cost. On standard highway driving the penalty for performance is rather small but in urban driving the penalty is very high and might double fuel consumption. (Urban driving is very short distance drive with stops and goes and therefore also refers to typical suburban driving.) Present cars are designed mainly for highway driving and are therefore inefficient in the city.

(3) *Aerodynamic form, tires, etc.*

Other factors such as proper aerodynamic form, tire design and properly inflated tires are also important and could account for 10 per cent fuels savings.

(4) *Accessories (see Table 3)*

The data in Table 2 refer to a basic car and the only accessory included is the automatic transmission where indicated. The power consumption of different accessories is given in Table 3 and we note that it is considerable. Smaller cars will need less power accessories, which increases the difference reported in Table 3. One accessory which American drivers will find hard to do without is the automatic transmission which in urban driving can cause a 15 per cent fuel loss. This however is really a cost problem as it is perfectly feasible to design automatic transmission with a small fuel loss.

Table 3. Power consumption of main accessories

	Urban driving	Inter-city driving
Automatic transmission	10–15%	3–5%
Power steering	1	3
Air conditioning	10–15	7

Another fuel consuming accessory which is becoming standard equipment is air conditioning. But this is really not a transportation problem as increased use of air conditioning is creating a major energy utilization problem that has to be faced.

(5) *Engine design*

The two main factors listed above, weight and performance, are really only constraints. Even for equal weight and performance there can be large differences in fuel consumption from one car to the next as we are quite far from thermodynamic constraints. Fuel consumption is primarily a function of engine design and present cars are not optimized for low fuel consumption. Fuel price in the U.S. was always so low and still is, that for most people it is really not a major factor compared to the other expenses involved in running a car.

Fuel distribution, fuel air ratio and other design factors which also affect performance are important.

There are, however, two design factors effecting fuel economy that have received recent attention due to their effect on emissions.

The first is compression ratio, the effect of which is given in Fig. 6 (from Roensch, 1971). A higher compression ratio gives higher efficiency but needs higher octane. The present Wankel is an inefficient engine partly due to its low compression ratio necessitated at least at present by mechanical seal problems. The major factor in the poor performance of post 1971 cars is the fact that they are designed for a 91 octane in anticipation of lead free gasoline. The second is exhaust gas recirculation and spark retardation which is used to reduce NO_x emissions. (see Figs. 6 and 7). In 1974 these effects are still small, about 6 per cent but if 1977 regulations which mandate extremely low NO_x emissions are not changed then we could see a 30 per cent increase in fuel consumption which could have catastrophic effects.

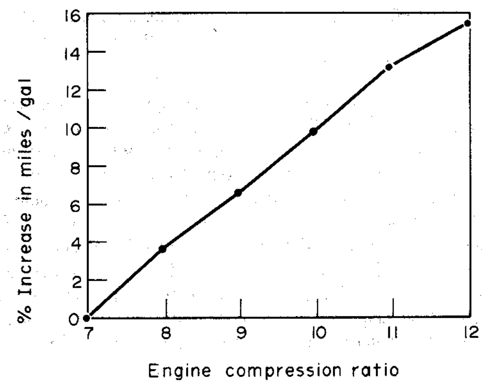

Fig. 6. General effect of engine compression ratio on fuel economy. Example: If a vehicle obtained 15 miles per gallon with a 10:1 compression ratio engine, the same vehicle with an 8:1 compression ratio engine would get 14·1 miles per gallon.

Actually the effect of the design changes is larger than the 15 per cent reported as the car suffered a simultaneous deterioration in performance. At constant performance the present deterioration in fuel economy is probably larger than 25 per cent.

Here we have one of the most severe problems facing us. Compliance with the standards of the Muskie commission (1970 clean air act) might undo anything we can do to reduce energy requirements of cars.

Now I am all for clean air and this tremendous waste of energy is really not necessary to obtain it. Let me just briefly explain why.

1. There was no real need to reduce compression ratio especially not in 1971. Given a proper timetable refineries could have reduced lead continuously reaching zero level with 10 yr. Making 96 octane gasoline is more expensive but the energy penalty is less than we lose in the engine.

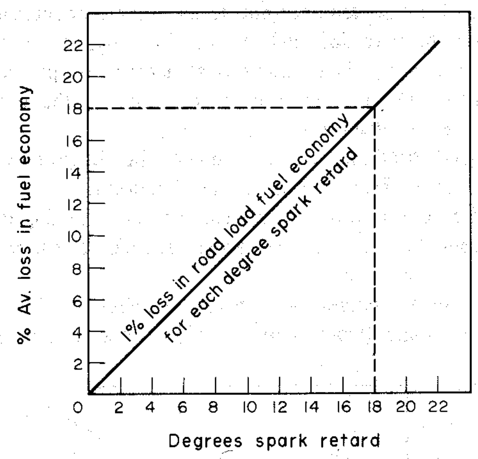

Fig. 7. Effect of spark retard on fuel economy at road load (cruise). From 1969 to 1973 avg. max. vac. spark advance has been reduced from 20° to 12°, and avg. max. mechanical (centrifugal) spark advance has been reduced from 27·1° to 16·8° for a total of 18·3° spark retard, which at road load (cruise) could account for an 18·3% reduction in fuel economy. Roensch, M. M., The Automotive Engine—Today and Tomorrow", Paper 710845 presented at SAE meeting, St. Louis, Missouri, October 1971. Boldt, K., Clark, D. T., Union Oil Research Department memo, *Effect on Fuel Economy of Vacuum Spark Disconnect at* 40, 50 *and* 65 *Miles per Hour—Road Load,* 21 *May,* 1973.

We get less gasoline from the crude but we receive other clean fuels instead. In the meantime we would not have lost tremendous amounts of gasoline in low compression engine driving on leaded gasoline.

2. There are other alternatives to EGR such as the stratified engines which do not have any fuel penalty. Their problem is that while their NO_x emissions are negligible compared to present cars they do not comply with the totally arbitrary standards of the 1970 clean air act. They also need time to be developed. But I am convinced, that if the clean air act would have decided on reasonable obtainable specifications, they would already be available today, as the development of the best alternatives was delayed, or stopped, due to the specifications chosen. There is probably no better example for our present incompetence to deal with complex technical problems than what happened between EPA and the car industry.

INDIRECT ENERGY CONSUMPTION OF THE PRIVATE CAR

Direct gasoline consumption of cars is only part of the energy picture. The car economy involves expenditures of considerable amounts of energy in an indirect way (see Hirst and Herendeen (1973)).

(1) Energy is consumed in the conversion of crude oil into gasoline (10 per cent) and in transporting the crude as well as the gasoline (about 2–5 per cent for local crude). This expenditure can be directly related to the fuel economy of cars driven.

(2) The manufacture of cars involves energy both in the production of the steel and other raw material as well as in the car itself. Smaller cars would reduce this amount, it is estimated about 10 per cent of a car's gasoline consumption (Hirst 1973).

(3) Another way of further reducing it would be to design cars which last longer, and in which the metals can be easily recycled. This would lead to important savings in both energy and mineral resources.

(4) Highway construction and maintenance. Energy is spent on highway construction in many ways in the manufacture and operation of construction equipment in the production of concrete, asphalt, etc. Regretfully, there are no reliable data and we lack a detailed input output matrix for our total energy economy. Hirst (1973) estimates this item at about 10 per cent of gasoline consumption or half a million barrels oil a day. Even if it is true it is a rather questionable number. Highways are used for trucks and buses which use 30 per cent of the fuel, but due to their weight contribute much more to the deterioration of roads than the private car does. It is therefore rather hard to divide the costs in a proper way.

FUTURE CARS

In summary we can state that in the present state of the art an increase of 50 per cent in gas mileage for new cars is possible within a time span of 3 yr. This could be achieved by smaller cars with less accessories, smaller more efficient engines with some penalty in performance and maybe higher compression ratios. Over a period 10 yr doubling the mileage is definitely within our technical reach without any technological breakthrough, and would be a worthwhile goal in terms of energy conservation.

This could be achieved by using smaller cars (a mix of intermediate compacts and subcompacts) and more efficient advanced engines such as the stratified engine, larger use of disels, etc. (provided their odor and smoke problems could be solved).

If we could keep total gasoline consumption at present levels or reduce it by 20 per cent for the next 20 yr, then there are many solutions to the fuel problem and it will be feasible to economically produce the amount of fuel needed from non-petroleum sources such as coal, oils, shale, agricultural wastes, cellulose, etc. for the next few hundred years.

Our real problem here is not technical, but how to sensibly achieve it within the framework of a free economy.

The worst problem that we face is that of the next years. While we have reasonable alternatives for the long range, the next few years could lead to a catastrophe if present trends are not reversed. What we need is careful planning and immediate action to avoid a large increase in gasoline consumption by the private cars over the next few years. As even minor design changes in size will take at least two years to implement and major engine changes much longer, we need a long range policy almost yesterday.

As a first step we can convince, by proper taxation, both Detroit and the customer to shift to smaller cars. But taxation for large cars must be such as to really have an impact and we are, therefore, probably talking about taxes of several thousand dollars for larger cars.

Second, we need an immediate change of the pollution laws for 1976. High EGR ratios are far too costly in terms of energy and we need to search for other methods even if we have to relax the NO_x specifications outside California and change our timetable.

We also need to look anew at octane levels and compression ratios. But the problems are solvable and in fact need to be solved in the near future. We definitely have no alternatives for the next ten years. Let us just remember that buses pollute too. But even for the long run there is no real good alternative in sight. Let us shortly examine the energy implications of the presently available alternatives.

ALTERNATIVES TO THE PRIVATE CAR

Having summarized the possibilities that we have for saving energy while driving as much as we want, we can now ask the question that is really pertinent to this symposium. Does the so called Energy Crisis justify a shift towards public transportation?

Let us examine that problem in detail and let us first look at some alternatives for the far future where we have reached a new steady state. On a mileage basis we could by proper development use half the fuel we use now driving the same mileage. We could increase the number of cars and the mileage driven and still use an amount of fuel which provides no strain for the economy. But if we need to we could reduce the total mileage driven without changing our life style by just traveling less. In Table 4 the distribution of trips for private car is given by purpose and we note that at least 50 per cent is optional.

Now let us compare these savings with what we could obtain by shifting to public transportation and let us look at the three modes of public transportation.

(1) *Airplanes*

Long distance travel has already started to shift from the car to the plane and about 50 per cent of all travel above 500 miles is done by plane and the percentage is going to increase. This shift does however lead to an increased use in energy due to two reasons. Planes use more energy per passenger rate than a present car and definitely more than our envisioned car (see Table 5). But more important, planes are more convenient than cars for long distance travel and therefore promote more travel and more energy use. I have no accurate data but my own estimate is that 50–80 per cent of airplane travel would not

Table 4.

Purpose of travel	Percentage trips	Distribution travel	Average trip length one-way (Miles)	Average occupants per car
Earning a living:				
To and from work	32·3%	34·1%	9·4	1·4
Business related to work	4·4	8·0	16·0	1·6
Total	36·7	42·1	10·2	1·4
Family business:				
Medical and dental	1·8	1·6	8·3	2·1
Shopping	15·4	7·6	4·4	2·0
Other	14·2	10·4	6·5	1·9
Total	31·4	19·6	5·5	2·0
Educational, civic or religious	9·4	5·0	4·7	2·5
Social and recreational:				
Vacations	0·1	2·5	165·1	3·3
Visit friends or relatives	9·0	12·2	12·0	2·3
Pleasure rides	1·4	3·1	19·6	2·7
Other	12·0	15·5	11·4	2·6
Total	22·5	33·3	13·1	2·5
All purposes	100·0%	100·0%	8·9	1·9

Table 5. Energy efficiency of different transportation modes

	Miles/gallon		Passenger miles per gallon fully loaded		Passenger miles per gallon average occupancy	
	Urban	Local	Urban	Local	Urban	Local
Full size car	8	12	48	72	16	24
Subcompact car	20	30	80	120	40	60
Compact car (Valiant)	14	20	70	100	28	90
Desirable average car	20	30	100	150	40	60
Diesel bus	3–5	4–6	20–120	150–300	30–100 (57 av)	75–150
Minibus	6–12		50–150		25–70	
Railroad						100–150
Airplane						12–20

occur at all if the traveler would have to use alternative modes.

(2) *Rail travel*

Travel by train at present presents a small fraction of the total miles traveled. It is an efficient way to move both freight and people and it is somewhat regretful that this mode of travel is decreasing due to the incompetence of the railroads and the special situation created by subsidies and controls. However, while trains might provide an alternative to the bus, truck and the plane for many uses, their possible effect on cars is limited though no accurate numbers are available. The potential for shift is probably less than 10 per cent. But rails should be promoted for center cities and short and medium distance inter-city travel, as they are the fastest and most convenient alternative. But we should not kid ourselves that this is mainly a problem of shifting. In Manhattan 93 per cent of all commuters and 80 per cent of all other travelers use public transportation and railroads are still in deep trouble. (Manhattan Auto Study, 1972). The case of Manhattan illustrates another aspect of public transportation that is often neglected. Manhattan has excellent transportation by subway and buses and still people drive in especially those who do not come during rush hours, especially in the evening. One of the possible reasons for it is that public transportation in New York is unsafe and one would rather stay home than go to a theater by subway.

(3) *Buses*

If we look at the present use of the car then the nearest and most easily realizable alternative is the bus. It uses the same available roads and can get almost anywhere a car can. It is therefore not surprising that it has received the main emphasis. Still there is no reliable detailed study as to how much of our travel by car can be served by buses and what is really involved. Such a study would be highly desirable for many reasons but we can get a good estimate on its effect on energy consumption in another way.

Large buses weight about 400–500 lbs per passenger vs 500–600 for reasonably sized cars. Being larger it can take the advantage of a diesel and, if the fact that its size gives it safety, minimizing the need for high acceleration. If both are full the advantage of a bus compared to a well designed compact car is rather small, about 30 per cent in passenger mile efficiency. A GMC transit coach for 51 people used 3·8 gallons on the average Sayres (1974). At 50 per cent occupancy this gives 95 passenger miles per gallon. Two people in a small car should get between 45–50 passenger miles per gallon. The number given by DOT for average urban driving is 45 passenger miles per gallon for a compact car and 57 for a bus.

However, such numbers might be misleading. At present, the number of passenger miles supplied by buses including school buses take up less than 5 per cent of the passenger miles driven by the car. We therefore have a selection procedure favoring bus trips only where they are economical. If we want to increase bus use providing convenient service, we would probably have to decrease size and accept a lower occupancy rate. Buses are excellent for city transportation and for moving large numbers of people all going to the same place as in the center city. These increased number of buses using special lanes could reduce congestion and thereby (at least temporarily) reduce energy consumption of the remaining cars. Here the bus or the train can provide much more convenient service as compared to a private car. However, while 50 per cent of all passenger miles traveled are so-called urban traveling, this does not mean that even a major fraction is a candidate for shift. Urban travel is defined as any travel below 20 miles and it therefore is just as typical of the modern suburb as even small town community. Only 32 per cent are commuting trips to work. The rest have a significant random feature both in time and direction and are therefore not well suited at all for public transportation. To provide service we would have to use smaller buses and smaller occupancy rates thereby losing almost all the advantages of buses. In addition in a random situation there is no way that we can provide service without an increase in miles traveled. Passenger miles per gallon is therefore a misleading number. If I want to go to my place of work, which is in the city but not the center city by public transportation, the mileage is about 60 per cent higher. If I visit my sister, the trip is between double to three times as long depending on the route chosen. Even if we provide excellent public transportation the trip will be on the average at least 20–30 per cent longer which eliminates all advantages a bus has. In Table 6 we give some corrected fuel efficiencies which are based on effective passenger mile.

Table 6. Energy efficiency per effective passenger mile.

	Effective energy mile per gallon (average occupancy, urban travel)
Full size car	13
Subcompact car	33
Compact car	23
Average energy efficient car 1980	33
Bus (Diesel)	33–66
Minibus	15–45

But the last example illuminates another problem of shifting to buses in a random transportation problem. It takes me 20 min to go to my sister by car. At present by public transportation (bus, train or subway) the round trip takes three to four hours. But even if we would have an excellent network the round trip would take more than two hours due to the interfaces involved. It would be good to have such a transportation network but it would never fulfill the role the car does. And here I come back to my basic point. Shifting makes sense only if it leads to convenient transportation. Pure saving in energy at a tremendous expense in convenience makes no sense in the present context. If we would be ready to do that we would have no energy problem in the first case. And while I have no data, the evidence seems to be that the amount that could be shifted conveniently is a rather insignificant percentage. These are however areas where a shift would increase convenience.

I admit that the data I presented are probably inaccurate. We lack accurate data for almost any point I made, especially for travel patterns. But the evidence we have indicates that the amount of energy that can be saved by shifting to buses is less than we can get by shifting to smaller cars.

This does not say that shifting transportation to the bus by putting heavy taxes on the car would not save energy. It would but in a rather indirect way. For most of the present uses of a car, buses are highly inconvenient and a trip would take much longer. People would therefore travel less and adjust their lifestyle to it. Which brings me back to the same point I made before. We cannot compare the effects of shifts by efficiency alone. Convenient, cheap travel means generate travel, whereas inconvenient or expensive means reduce it. If we would build an efficient, cheap, fast train from New York to Suffolk, lots of people would move to Suffolk and commute and we would not save energy but increase its use. Just as cheap, convenient planes to the Carribbean have increased vacation travel.

The tendency of planners and politicians to consider only first order effects and neglect feedback effects has already caused havoc with many of the ambitious plans of the last decade.

SUMMARY

In the United States the energy crisis and the projected energy shortage do not seem to suggest any need for a shift in the transportation balance. If we maintain our present way of life, public transportation cannot offer any substantial energy savings as compared to a well designed energy efficient car. And before we spend too much effort on loose talks about changing our lifestyle, we better check as to what is really involved in this, and what the options are.

If we want however to save energy without substantially reducing our standard of living, we should put all of our emphasis on developing reasonably sized energy efficient cars. It is feasible within 5–10 yr to double the miles per gallon obtained by an average car. Policies could be developed that could keep total gasoline consumption at present level or reduce it to 80 per cent of its present value. Such a consumption would be sustained for a very long time using liquid fuels or even gasoline.

Public transportation should be developed for short distance travel as it is convenient for specific uses such as travel to and from a center city, and better and faster public transportation is desperately needed in some areas. It also serves the sick, the young and poor. But promoting public transportation should be done on its own merits and not by any false claims that it will relieve the energy shortage.

The real problem with the private car is how do we get Detroit to develop an energy efficient, reasonably sized car, since neither Detroit or the public is interested in it. It could be done by developing a proper tax structure both on gasoline as well as on large cars. The large inertia of the total system and the long time lags involved require that we plan for the future in a more efficient way.

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