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Energy for Transportation–How to Anticipate the Future

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ABSTRACT

Given the dependence of U.S. transportation on petroleum there are few serious students who do not see significant problems of supply in the relatively near future. The seriousness of this matter depends on a variety of variables, among them new transport technology developments, new sources of conventional energy, change in living patterns. Our immediate problem is, in fact, how to anticipate the future so as to provide for the lead time that is required for adjustments within the total transportation system, if such adjustments are to be accomplished in a non-destructive way.

This paper will pose a number of techniques for anticipating the future in this area. Included among them are: projection on current trends, projections from updated population trends, the Delphi technique, cross elasticity analysis and others. The purpose of all such techniques being to provide alternative scenarios of the transportation function under various energy constraints.

INTRODUCTION

THE POTENTIAL shortage of transportation fuels and the adverse environmental effects from their consumption are issues of high national concern. Some facts:

- Transportation accounts for some 24% of total U.S. energy consumption and approximately 55% of the total petroleum Consumption (1).[1]
- More than 95% of our transportation energy requirement is provided by domestic and foreign petroleum (2).[2]
- Current U.S. fuel consumption, in absolute terms, is very large—6.8 mill bbl./day of gasoline, for example (3).
- Transportation energy consumption is increasing rapidly, for the U.S., up 52% between 1960 and 1970 (1,3,4).

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1 Numbers in parentheses refer to the list of references.

2 There is currently almost no substitutability of the fuels used for transportation. The only alternative to petroleum in modern times has been coal, and its use for transportation declined to almost negligible amounts with the dieselization of the railroads.

- Domestic petroleum supplies are limited. Dependence on foreign sources poses grave economical and political problems (4,5).[3]
- Automotive emissions are estimated to account for 73.60% of carbon monoxide, 55.93% of hydrocarbon, and 47.06% of nitrous oxide emissions in 1969 (6).
- Meeting the 1970 Clean Air Act (7) may require the rationing of gasoline in certain population centers.

Out of the many significant transportation-related issues that obviously follow from even this abbreviated listing, it is proposed here to touch first on the credibility aspect of this subject. Then we will suggest why, at least for the short-term, energy conservation is a necessary course of action. Finally, four areas of potential fuel conservation where research is urgently needed will be described.

THE CREDIBILITY ISSUE

From the earliest days of this energy-intensive age there have been prophets predicting its early termination as a consequence of population explosion and/or resource depletion.[4] Many of today's adults heard such predictions as children and have lived to see them thus far proven false. Therefore, advocates of any conservation plan face a skeptical public which may voice a pre-conditioned negative response to their best proposals.

Public skepticism of long-range forecasts is not without justification. For example, U.S. population predictions, clearly a key element in estimating transportation demand, have varied widely over short time periods. In 1964 the Bureau of the Census predicted a 1985 U.S. population of approximately 276 million (see Figure 1). This was based on a fertility rate of 3.35 children per woman. In December 1972, the predicted 1985 population ranged from 231 to 249 million (fertility rates of between 1.8 and 2.775). Since then, our fertility rate has dropped to approximately the zero population growth level of 2.

Predictions of energy availability are numerous and extremely difficult to appraise. Figure 2 has been used to illustrate the transiency of our petroleum-based economy. It suggests that by the year 2000, 80% of the ultimate amount of U.S. petroleum will have been used. But the future is so heavily discounted by much of the public that even the most reliable of such information tends to fall on unreceptive ears.

A RATIONALE FOR CONSERVATION

Central elements of a rationale for national emphasis on conservation of energy in transportation are as follows:

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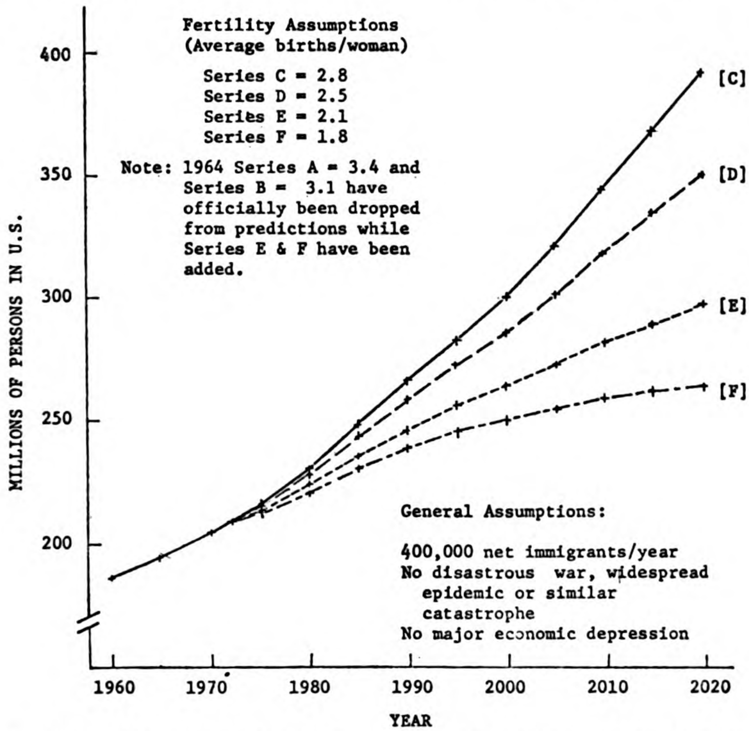
3 Among the issues attending our increasing reliance on foreign energy supplies, the trade deficit problem is central. Writing in Technology Review, Edward E. David, Jr., former Presidential Science Advisor states that the cost of our oil and gas imports could amount to almost $30 billion annually by 1980 (8, p. 26).

4 Clearly Thomas Robert Malthus was the founder of this line of thought with his theory that population would increase faster than food supply.

PROJECTIONS OF POPULATION OF THE UNITED STATES



Source: *Population Estimates and Projections*, U.S. Department of Commerce, Bureau of the Census, Series P-25, No. 493, Dec. 1972

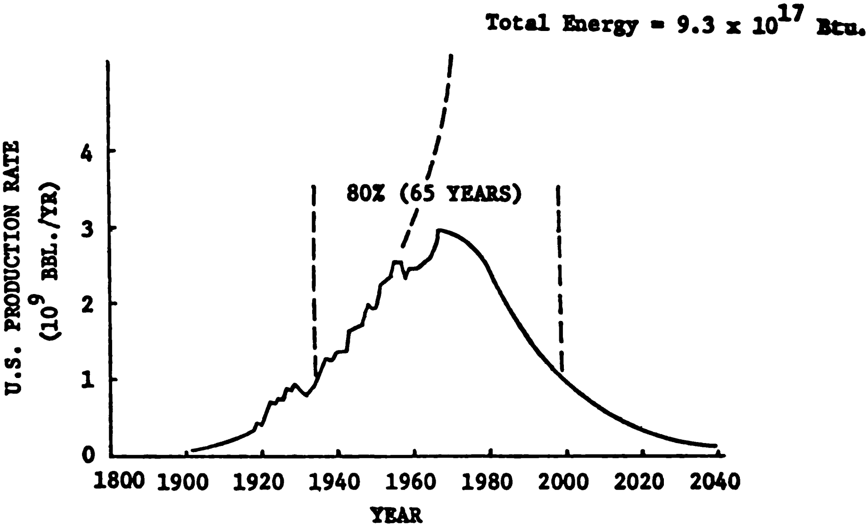
FIGURE 1

1. Our present transportation systems are almost wholly dependent on petroleum.
2. Readily available, low-cost petroleum supplies are being consumed rapidly. Significant increases in actual and relative costs of petroleum energy seem inevitable.
3. The resulting change in technology and in the institutional framework of our transportation systems will require a significant lead time if it is to be accomplished in a non-disruptive fashion.

In sum, conservation programs have the promise of stretching the period of economic utilization of our present energy sources until solution options not now available can be developed (9).[5]

5 The case for conservation can obviously be founded on a broader base than indicated here. For example, all current energy production involves environmental degradation—air and water pollution, strip mining, nuclear waste disposal—and a doubling of energy use each 16 years makes such problems increasingly difficult to handle (see Business Week, April 21, 1973).

COMPLETE CYCLE OF CRUDE-OIL PRODUCTION IN THE UNITED STATES AND ADJACENT CONTINENTAL SHELVES



Source: (5), p. 183

FIGURE 2

It is a central proposition here that fuel conservation will be a key factor in anticipating and providing for the near future transportation demand. From this follows the basic purpose of this paper—to examine several promising areas for fuel conservation with an emphasis on research needs in each.

CONSERVATION PLANS

The following four areas for potential transportation fuel conservation were selected as deserving special examination:

1. *Fuel Price Adjustment.*—What is the price elasticity of demand for transportation fuel? Representative Saylor (R-Pa.) suggests that within five years, the price of gasoline will be $3 per gallon.[6] It has already climbed above $1 per gallon in several European countries. What can be learned from their experience?

2. *Gasoline Rationing.*—Rationing has been suggested as a technique for insuring equitable treatment for all customers. It is also posed as a device to implement the Clean Air Act standards for air quality in urban areas. What is our past experience with fuel rationing? What should be known before embarking on this course of action?

3. *Mode Shifts.*—Some modes are inherently more energy efficient than

6 The Centre Daily Times, Feb. 18, 1973.

others, for example, bus vs. air travel. What must we know before major mode shifts are encouraged?

4. *Within-Mode Improvements.*—Within-mode improvements include a multitude of approaches. The basic intent in every case would be to improve the efficiency of fuel use within a given mode. Examples are reduction of speed limits on freeways; traffic flow improvements; reduction of taxi times at congested air terminals; reduction in automobile wind resistance, weight; or improved engine characteristics.

Fuel Price Adjustment

Theoretically, the price of transportation fuel may be adjusted rapidly through well-established tax structures; in practice, however, public resistance has limited this flexibility. But even assuming that prices could be readily adjusted, is there a potential for conservation through fuel price increases? Thus far, experience shows what appears to be an inelastic price-quantity relationship. However, historic price increases have not been in the same range as those currently proposed; and consumer reaction may not be transferable between countries or predictable over time. The following data bear on the fuel price-transportation demand relationship:

1. *Italy.*—Figure 3 shows the steadily growing numbers of vehicles in circulation despite various fuel price increases. The per-capita disposable income level shows that fuel prices trail this index and that it closely matches the increasing passenger vehicle numbers.
2. *Germany.*—Figure 4 shows an apparent lack of sensitivity between vehicle use and gasoline price increases. While some slight change in the number-of-vehicles-in-use trend was observed during a period of relatively sharp gasoline price increase (1968), auto usage resumed its steady increase despite fuel price increases in the following years. Once again, the increasing per-capita disposable income appears to offset increased gasoline prices.
3. *United States.*—Passenger car motor fuel consumption has not been curtailed by fuel price increases—to date. It should be stressed, however, that the increases to this point in time have not been near the levels currently proposed and indeed have paralleled the increase in disposable income (Figure 5).

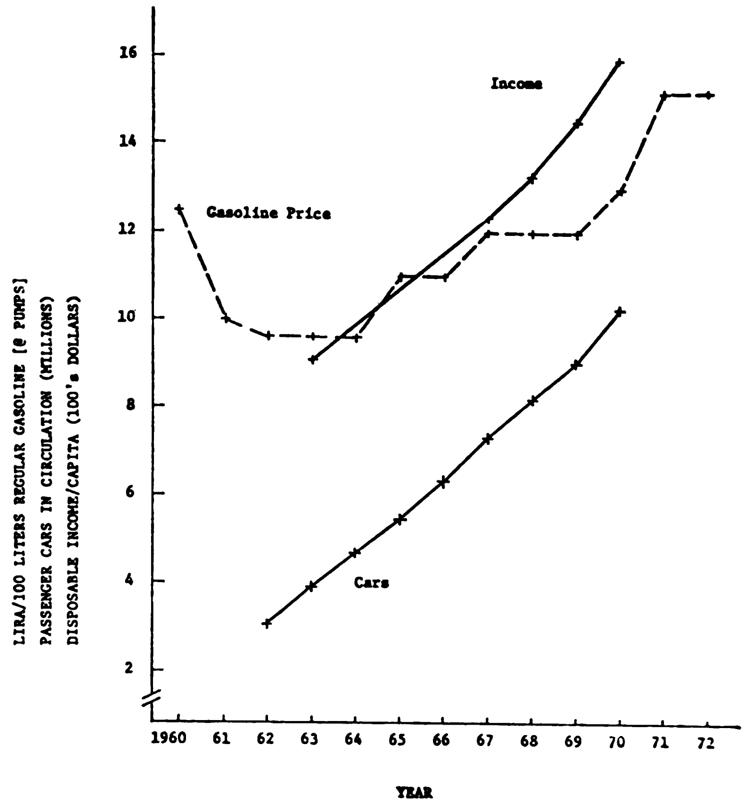
A specific research need in this area then is the detailed study of current data sources in an attempt to estimate the price elasticity of the demand for fuel. The 1968 experience in Germany and other specific situations might be highly illuminating under close examination.

For the longer term, it should be possible to develop trip generation predictive equations similar to those now used in urban studies[7] but with fuel

7 For example, in work by Fleet and Robertson (10, p. 17) a trip generation equation takes the form $TT = -0.69 + 1.39NP + 1.94CO$

where TT = total home based trips
NP = number of persons 5 years of age or older
CO = total cars owned

GASOLINE PRICES VS. PASSENGER CARS IN CIRCULATION AND DISPOSABLE INCOME PER CAPITA, ITALY



Sources: *Energy Statistics—1972 Yearbook,* Office of Statistics of the European Community; and *1971 United Nations Statistical Yearbook,* 23rd Issue, Statistical Office of the United Nations

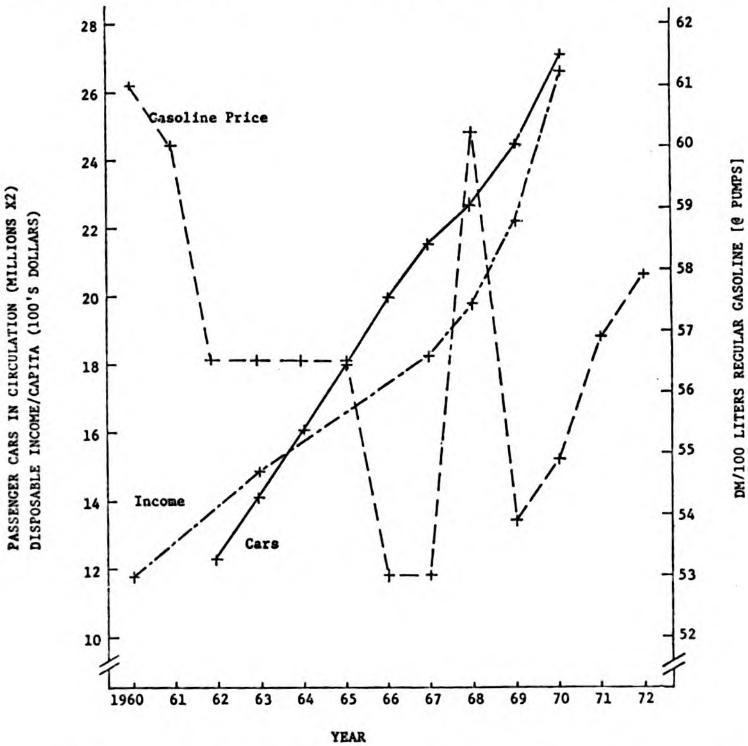
FIGURE 3

price included among the independent variables. However, as noted earlier, increases in disposable income have paralleled the rise in fuel prices, thus obscuring the significance of this variable.

For urban transportation studies as mandated under the Federal-Aid Highway Act of 1962, the inclusion of a consumer survey aimed at developing trip priority in response to price increase would be useful. One might expect, for example, essential inelasticity for work trips when there is no alternative mode but perhaps a significant reduction in recreation travel.

Perhaps the most effective laboratory for studying demand elasticity is today's changing market place. Local shortages are affecting prices, and an

GASOLINE PRICES VS. PASSENGER CARS IN CIRCULATION AND DISPOSABLE INCOME PER CAPITA, GERMANY



Sources: *Energy Statistics—1972 Yearbook*, Office of Statistics of the European Community; and *1971 United Nations Statistical Yearbook*, 23rd Issue, Statistical Office of the United Nations

FIGURE 4

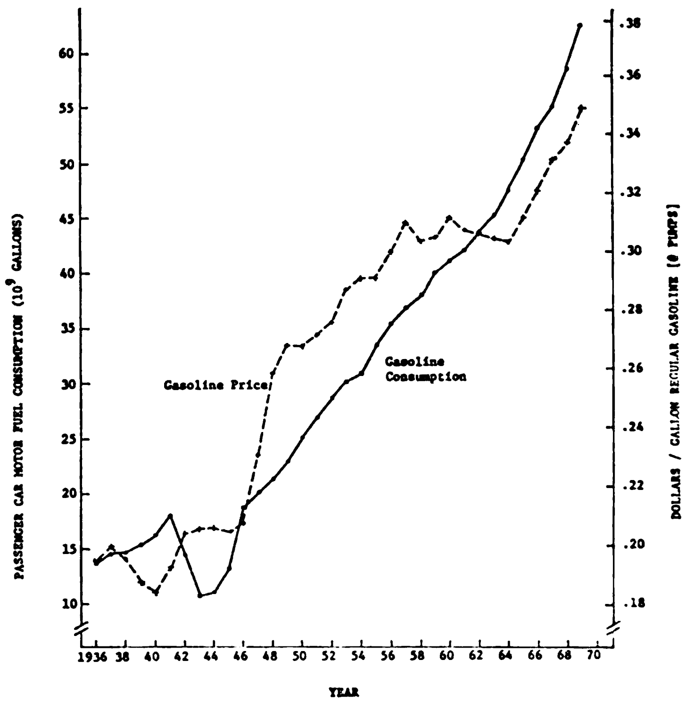
aggregation of this experience has the potential for providing the essential data.

As a final note, the social consequences of fuel price increases deserve careful attention. The gasoline tax which has paid for highway construction, maintenance, and operation since 1919 is reasonably equitable as a user charge. If, however, it is used as a device for energy conservation, it becomes unacceptably regressive.

Gasoline Rationing

During World War II, a nationwide fuel rationing scheme was used to conserve resources in the face of an enormous military demand. It was first used nationally on December 1, 1942, primarily to conserve rubber rather

GASOLINE PRICES VS. CONSUMPTION BY PASSENGER CARS, THE U.S.



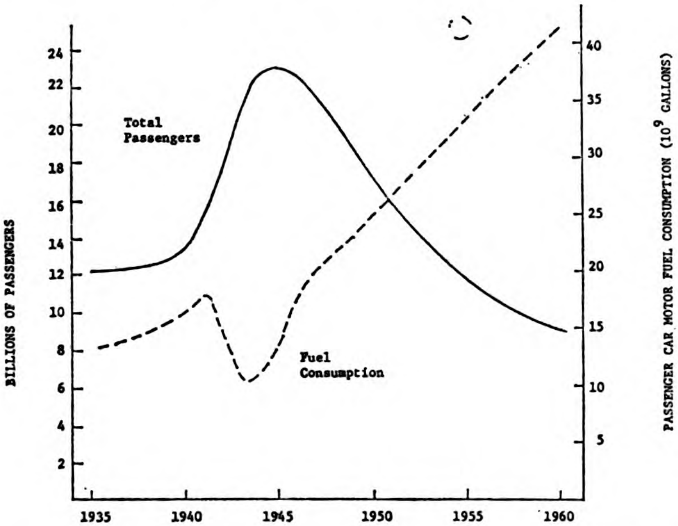
Source: *Petroleum Facts and Figures*, 1971 Edition, American Petroleum Institute

FIGURE 5

than gasoline. Domestic gasoline consumption decreased drastically, and public transit enjoyed a brief period of boom as shown in Figure 6.

Gasoline rationing was achieved by issuance of coupon books of two general types: highway (e.g., automobiles) and non-highway (e.g., farm machinery). Various classes of coupons (worth 2-5 gallons each depending upon how the Director of Petroleum assessed the general domestic supply in each quarter-year period) were issued to users according to their need. Books were designated, A, B, C, D, T-1, T-2, and X. The "A" book (28 coupons) was the basic rationing book for passenger cars and as such was the most limited travel category; "B" (16 coupons) was for motorcycles; "C" (64 coupons) was for those whose driving needs were considered essential to the war effort; "D" (32 coupons) was supplemental to the "A" book; "T-1," and "T-2" (96 and 384 coupons, respectively) were for commercial operations considered essential to the domestic operation and economy (trucks, buses, ambulances, etc.); and "X" was for those with unlimited needs (e.g., governmental officials, farmers, etc.). In order to obtain additional rations, one had to demonstrate

MASS TRANSIT PASSENGER VOLUMES AND PASSENGER CAR FUEL CONSUMPTION OVER THE PERIOD OF WAR-TIME GASOLINE RATIONING



Source: *'69-'70 Transit Fact Book*, American Transit Association and *Petroleum Facts and Figures 1971*, American Petroleum Institute

FIGURE 6

need, usually done on an honor system. A window sticker was placed on each car to indicate which type of ration book was available to the owner and, thus, which coupons would be honored at service stations. The Office of Price Administration and local boards (volunteers) administered the program by keeping records of the numbers of each coupon issued. Coupons were collected by gasoline retailers and then passed on to the licensed distributors. The distributors were not required to exchange such coupons to get supplies replenished.

The program was successful in that a 32.6% reduction of total automobile mileage was achieved during 1943 over the 1941 figures (11). However, many shortcomings existed. The honor system for acquiring additional fuel was considered a major weakness. Also, the allocation of fuel to suppliers without exchange coupons allowed dealers to engage in black market operations. Not unexpectedly, counterfeit coupons emerged. The rationing program was terminated September 2, 1945, when the war with Japan ended.

Recently, the Environmental Protection Agency (EPA) has suggested that automotive transportation be controlled to reduce air pollution in 17 urban areas (12). Los Angeles is undoubtedly the best known of these area and here EPA has proposed an 80% reduction of emmissions. Researchers f the Los Angeles region suggest, "In view of the massive pollutant reductio required to achieve the air quality standards, it appears that rationing gasoline is the only alternative which would accomplish the task" (13).

Probably the most difficult problem with implementing fuel rationing today is the lack of a "common cause" such as was available during World War II. In fact, there are those who question if a crisis really exists (14) and so the credibility issue is very much before us.[8]

Before rationing can be considered seriously, research must be conducted to determine the possibility of its success in the present situation. World War II experience should be examined in detail, and a new plan devised. To determine the circumstances for public acceptability, the Delphi approach might be used.[9]

A first round should be devoted to identifying issues or conditions central to public acceptance; for example, conditions of price, availability, national need, etc. Attention should then be given to estimating the timeframe in which these conditions will be met. This entire exercise could provide a substantive context in which a complex, politically sensitive but potentially effective conservative strategy could be developed.

Mode Shifts

Transportation, defined in very basic terms, is simply overcoming resistance. This resistance is offered by the ground, air, water or whatever combination of media the vehicle travels through. The principles of physics, moreover, dictate that some transport modes will have inherent advantages over others; e.g., lower resistance per unit output. Rice (15, 16) presents efficiency data which show these differences.[10] As can be seen from Figure 7, some of the least efficient modes are currently being used most heartily. Figure 8 depicts transportation energy consumption by mode. If modal shifts (e.g., automobile to bus) could be accomplished, a net energy savings would be possible. For example, Rice (16) estimates:

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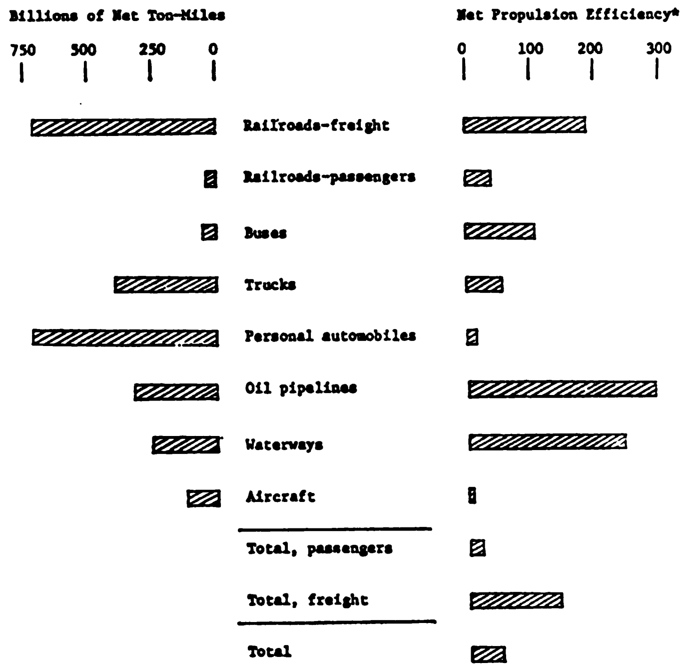
8 An increasing number of authorities, however, agree that there is an energy problem. Dr. Edward E. David, former Science Advisor to the President, states that "energy is a bona fide and credible challenge to the nation. It provides a focus for effort on a national scale. The challenge is to our national well-being" (8, p. 26).

9 The Delphi procedure, developed at the RAND Corporation, is an effective way for utilizing expert opinion in forecasting. The three principal characteristics of this technique are: anonymity, controlled feedback, and statistical response. That is, the committee members do not know the identities of other members; the ideas and comments of the individual members are filtered by a director before they are presented to the committee; and the committee estimate is stated in terms of average position and the degree of dispersion about that average.

In a Delphi forecast, a list of major events that might occur during the time period of interest must be obtained. Where such a list is not available, the director will ask the committee to forecast such events in the first questionnaire. He then summarizes the important events in his second questionnaire. For each event, the committee will estimate the date by which there is a 50-50 chance it will have taken place. The director then calculates the median and the quartiles for each event. This completes the second round. On the third round, the members are to reconsider their earlier estimates in the light of the estimates made by the other members. If a member's estimate falls below the first quartile or above the third quartile from the first round, he shall offer his reasons. The director again prepares a new questionnaire, and asks the committee to make the fourth-round estimates and comments. This procedure continues until there no longer is any significant change of opinion between rounds. The median date in the final round thus is the committee forecast for a specific event to occur.

10 Energy efficiency may be defined as passenger-miles or cargo ton-miles per gallon of fuel. To generalize the units for different fuels, Rice suggests use of the term "net propulsive efficiency" (NPE) which is defined as passenger-miles or ton-miles per Btu. equivalent of a gallon of fuel.

UTILIZATION AND EFFICIENCY OF TRANSPORTATION MODES



* Net propulsion efficiency is defined as cargo ton-mile or passenger miles per gallon of fuel or its Btu. equivalent.

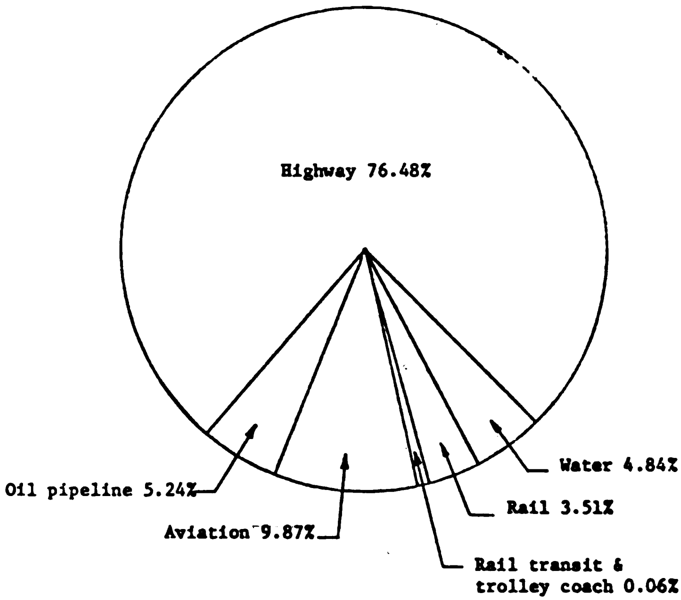
Source: (16, p. 36)

FIGURE 7

> If bicycle and pedestrian journeys were substituted for two-thirds of the 2,050 trips of two miles or less that most urban autos make per year, the savings per household (@ 1.3 autos) would be 1,800 trips involving 270 gal. of fuel (about 35 million Btu. per household). For this there would presumably be substituted the requisite 1,800 personal one-way trips, each of which by cycle or walking would consume only about 500 Btu. of human energy from 130 calories (16, p. 32).

Clearly, certain mode shifts could conserve energy. The magnitude of such savings is discussed by Hirst (1), who uses a two-scenario approach to predict energy consumption based on the extension of present modal split trends versus an improved modal mix projection. This improved mix for freight, intercity passenger, and urban passenger traffic which he calls "Future II" would result in an annual savings of about 6×10^{15} Btu. by the year 2000 over that of "Future I," the extension of present trends toward less energy efficient travel. However, the modal mix improvements of "Future II"

ENERGY CONSUMPTION, 1970 BTU'S



Source: *Summary of National Transportation Statistics*, U.S. Department of Transportation, Nov. 1972

FIGURE 8

(i.e., motor carrier to rail, auto to bicycle, etc.) may not be implementable.

The bulk of the research in this area should be directed toward the sociological, political, economic, environmental, and practical aspects of implementability. Specifically, research must be done on all types of mode-shift possibilities, be they voluntary or mandatory.

The following questions are posed, and suggested research avenues are given:

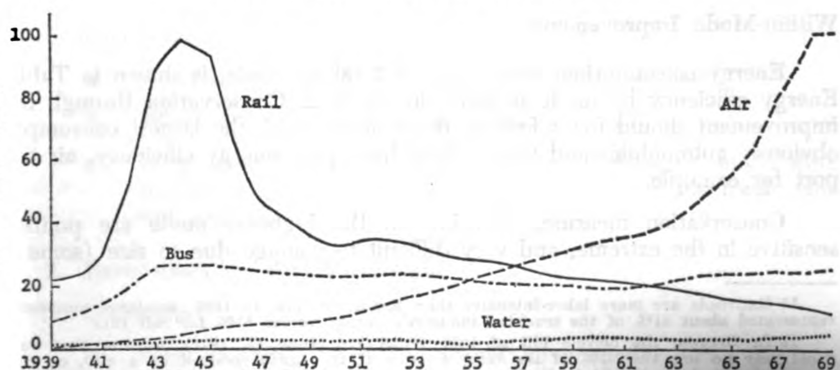
1. What is the array of energy savings possible under alternate mode-shift plans? Scenarios from the current literature present only black-white analyses, i.e., optimistic-pessimistic projections. Research using mathematical models may provide realistic "middle ground" projections which could be used to bring about incremental change. An acceptable model should be able to deal with variable energy use input and should yield optimal modal split output (under certain constraints). The model should be applicable at the federal, state, or local level. Once energy policy is formulated at the federal level, planners could determine how best to "spend" their energy.
2. How should we view the rapid growth of air travel in view of its

poor energy efficiency? Currently, no public mode offers the same level of service as air travel as evidenced by the consumer's mode choice (Figure 9). However, the Tokaido line in Japan has shown that high speed rail service in corridors can effect significant shifts to more efficient travel modes. This line should be examined in detail to determine its energy consumption. Corridor research should be continued to determine if rapid rail transit should be pursued as a desirable alternate from an energy conservation point of view.

3. What savings could be achieved by causing mode shifts from the automobile to public transit? This question is more difficult than it first appears. While substantial energy differences exist between moving 50 passengers in 26.3 cars (allowing the average auto ridership in 1972, or 1.9 occupants per car (17, p. 35)) versus moving 50 passengers in one bus, transit ridership in the past has not approached capacity. Where is the ridership break-even point from an energy standpoint? Further, to achieve a mode shift from car to bus, transit must offer a similar level of service. Buses will have to run at much shorter headways than they do at present, with counterbalancing energy consequences. What is the headway-ridership break-even point? To estimate countrywide energy conservation from car-to-transit shifts, the successes of individual lines on exclusive rights-of-way such as the Shirley busway in Washington should be analyzed and the results extended to corridor travel in general.

4. What savings can be achieved by causing mode shifts from motor carrier to railroad? For a given commodity, one could calculate the energy savings for transfer of certain cargos, especially the bulk commodities, to the more energy-efficient modes. But the question is again one of cost and level of service. Railroads, because of heavy

INTERCITY TRAVEL BY MODES



Source: *Transportation Association of America, Transportation Trends*, July 1972, p. 16

FIGURE 9

regulation and labor costs,[11] may not be able to offer generally lower shipping charges than motor carriers. Further, the quality of service is often not satisfactory to the shipper. However, research on energy savings from specific shifts for commodities which could travel by rail along certain routes should be encouraged with attention given to the potential economic dislocation from such shifts.

5. What energy savings can be achieved by causing mode shifts from automobile to bicycle or walking? The aforementioned savings possible through car-to-bicycle (or walking) are generally not possible unless exclusive bicycle-walking rights-of-way are provided.[12] Trial programs including experimental hike-bike trails should be initiated in urban areas to investigate the promise of this mode shift. To provide further impetus to this mode shift, the health benefits of regular walking or bicycling should be advertised. Additional research on pedestrian shelters, signalization and design, and maintenance of ways should be encouraged.

The key to altering transportation energy demand through mode shifts is funding. In the past, the railroad eras, canal eras, and highway eras have each followed federal and state spending in those areas. Today the goal is for a balanced national transportation system. This is not possible unless spending, perhaps beginning with research and development is balanced.

It is interesting to note that each of the suggestions outlined above has been made by others for reasons other than to relieve the energy crisis. These reasons include releasing urban highway congestion, enhancing urban air quality, improved health through increased exercise, revitalization of the railroads, and relieving air terminal and air traffic congestion. It is also interesting to note that four of the changes in the transportation sector would tend to correct four of the six symptomatic problems in transportation today as outlined by former Transportation Secretary Volpe.[13]

Within-Mode Improvements

Energy consumption, percentage of total by mode, is shown in Table 1. Energy efficiency by mode is given in Table 2. Conservation through mode improvement should focus first on those modes with the largest consumption, obviously automobiles and those which have poor energy efficiency, air transport for example.

Conservation measures focusing on the highway mode are politically sensitive in the extreme, and very difficult to manage due to size (some 113

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11 Railroads are more labor-intensive than motor carriers. In 1965, employee compensation represented about 41% of the trucking industry's output versus 51% for rail (6).

12 In Oregon, the bicycle bill of 1971 (ORS 376, June 11, 1971) requires that in any fiscal year no less than 1% of the total amount of the funds received by a city, or county, or commission from the State Highway Fund be expended for the establishment of footpaths and bicycle trails and that a uniform system of signing footpaths and bicycle trails be established.

13 The six symptomatic problems are: urban highway congestion, the severe deterioration of local public passenger services, airport and air traffic congestion, hazards to safety, environmental degradation, and the financial distress of important segments of the transport industry (6, p. 9).

PRESENT U.S. TRANSPORTATION ENERGY USE

Transportation Mode	Percent of Energy Usage
Intercity and rural automobile	26.4
Urban automobile	30.7
Aircraft (domestic, overseas, military)	11.4
Intercity railroads	3.5
Urban railroads	0.1
Waterways and pipelines	1.4
Intercity buses	0.2
Local (urban and rural) buses (including school buses)	0.6
Intercity trucks	7.0
Local (urban and rural) trucking	14.9
Other	3.8

Source: (18), p. 276

TABLE 1

million vehicles in 1972); but the potential payoff is very large. Some energy conserving strategies and typical attending questions are as follows:

1. Speed reduction on some highways, especially on interstate highways.

   Questions–

   a. What are the legal constraints on implementation?

   b. What is the potential payoff in fuel saving?

   c. What second-order effects may occur, for example, mode shift, change in accident experience, loss of respect for traffic control authority?

2. Restrictions on auto size-weight.

   Questions–

   a. What enabling legislation would be needed?

   b. At what rate would the automobile fleet be changed by such action?

   c. How would domestic-foreign auto compet[illegible]d?

MODE ENERGY EFFICIENCY

(a) Intercity Freight Transport

Mode	Ton-Miles Per Gallon
Pipeline	300
Waterway	250
Railroad	200
Truck	58
Airplane	3.7

(b) Intercity Passenger Transport

Mode	Passenger-Miles Per Gallon
Bus	125
Railroad	80
Automobile	32
Airplane	14

Source: (1), p. 113

TABLE 2

d. How would the auto industry profitability and the U.S. economy be affected?

3. Encouraging car pooling.

Questions—

a. What will be the effect on other modes, particularly public transit?

b. How will total miles per capita change? Will non-work trip usage increase?

All potential energy conservation strategies appear to have major second-order effects that deserve careful study. Some lend themselves to an incremental non-controversial implementation, and progress is already being made, car pooling, for example (19). A very high level of public need perception must attend others if there is to be any hope of implementation.

Recent improvement in air traffic control provide an excellent illustration of within-mode energy conservation with only positive side effects. The fuel savings from reductions in take-off and landing delays at major airports over the recent past should be highlighted and used as the basis for other improvements.

It is perhaps worth noting that the decision not to proceed with SST aircraft was eminently sound on the basis of fuel conservation. Rice (16) estimates that "a single Concorde S.S.T. aircraft, weighing 180 tons and flying 11 hrs./day, might consume 25 million gal. of fuel annually." He further stated that "if all present air carrier transport plans should materialize, some 88 billion additional gallons of fuel might be required per year for transportation by 1985."

SUMMARY

The U.S. transportation system is almost totally dependent on petroleum as its source of energy. While there is an historic credibility gap concerning energy availability that has made conservation largely unacceptable to the public, a combination of political, economic, and resource availability considerations now argues for research that could improve public acceptance and provide time for the transition to other energy sources. It is the thesis of this paper that transportation planning for the future must take into account energy availability and, moreover, that energy conservation will be central to the matter of availability.

Four areas for potentially achieving fuel conservation are suggested as appropriate for immediate research.

1. *Fuel Price Adjustment.*—We should determine the price elasticity of fuel demand and consider the economic and social consequences of price manipulation by means of fuel taxes.
2. *Gasoline Rationing.*—World War II experience shows that consumption was significantly reduced and mass transit usage vastly increased through fuel rationing. There were problems, however, even when national security provided the "common cause." We should study the public acceptance issue and the mechanics, as well as economic implication, in anticipation of this course of action.
3. *Mode Shifts.*—If energy conservation is taken as a primary consideration, the current modal splits are unacceptable. What kinds of mode shifts are possible and with what energy savings? There appears to be the potential for large savings in this area if an adequate understanding of extremely complex issues can be developed.
4. *Within-Mode Improvements.*—Automotive transportation accounts for the largest percentage of petroleum consumption. Energy efficiency could be improved by reduced speed limits, size and weight reductions, higher utilization rates. The payoffs and side effects should be considered carefully. Air transport is the least energy efficient, but recent experience points to areas for significant improvement.

Perhaps even more important than the research areas suggested here is the integration of research results. Transportation energy research should follow a preplanned scheme so that individual results may be coordinated and implemented. Only through such a coordinated approach will the necessary or desired overall energy savings be possible.

There is a growing consensus to the proposition that we are moving from an age of resource abundance to one of resource scarcity. There is no easy way to provide the vast quantities of energy our society consumes. Again quoting Edward E. David, "There are large stakes in the 'energy crisis' " (8, p. 26). "A coalition of forces and policies—not a monolithic technological attack—is the only appropriate response" (8, p. 27). At least for the short term the almost total reliance of transportation on an increasingly scarce resource lends urgency to research into techniques for ener[illegible]tion. On this depends our ability to predict, and provide for, f[illegible] demand.

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