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RESEARCH PRIORITIES IN TRANSPORTATION AND ENERGY

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A Circular of the
Committee on Energy Conservation
and Transportation Demand (A1F01)
December 1986

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David L. Greene

1. INTRODUCTION

High quality, timely research is the basis for the understanding needed to develop sensible policies and effective programs in any sector of the economy. This is particularly true now, in the transportation area, as we move into a period of increasing uncertainty in energy markets and increasing competition combined with technological change in the transportation market. The purpose of this circular is to bring to the attention of decision-makers and researchers what we believe are the high priority research areas where continuing or additional efforts are needed.

The United States has gone through two energy (oil) price and supply shocks and is in the middle of a third, characterized this time by a sharp drop in prices. While declining prices offer a welcome "breathing space", they also create the possibility of a false sense of security. Near-total oil dependence in the transportation sector continues (in fact, low oil prices discourage consideration of alternatives), and oil imports are rising. The resulting increase in U.S. dependence on uncertain energy supplies again threatens national security and the delivery of transportation services in the event of a future supply cutoff or price rise. The "breathing space" provided by current low prices should be used as an opportunity to review where we have been, to better understand how the current energy/transportation market is working and to look at the future in terms of how transportation can best respond to a period of uncertainty in energy markets followed by the likely depletion of this oil resource. The capability to be proactive, not reactive, depends on a solid understanding of the situation and robust transportation policies and programs, at all levels, built on that understanding.

The TRB Committee on Energy Conservation and Transportation Demand brought together experts from various areas to discuss the range and detail of the needed research. As a result of that discussion and review, the Committee identified five areas where continuing research is needed and the goals of that research appropriate to today's transportation/energy market:

- Market For Automotive Efficiency. A better understanding of the automotive efficiency market, the supply and demand for miles per gallon, is needed in order to determine the most appropriate and effective government policies.

- Energy Contingency Planning. A new focus on determining the ability of the transportation system to adjust to major future fuel price shocks is required.

- Transportation Energy Forecasting. The key role of transportation in the worldwide petroleum market makes it vital to develop better methods for predicting (i) the effıcency and fuel type of new equipment, (ii) the evolution of new equipment stocks, and (iii) the demand for transportation services.

- Conservation: What Works? During the 1970's a number of innovative approaches to conserving energy were tried with varying degrees of success. This period of relative calm offers an opportunity to improve the base of knowledge about how to promote operational efficiencies of transportation systems by evaluating and documenting past and ongoing efforts.

- <u>Alternative Fuels</u> As time passes, transition to alternative transportation fuels becomes ever more a question of when rather than if. Research is needed to (i) identify the most likely fuel(s), (ii) plan for and ease the fuel transition and (iii) define the appropriate role for government.

The Committee's findings and recommendations are detailed in the following pages of this circular. In each area a detailed statement of the problem is given, followed by a discussion of past and current research. A specific research agenda is then proposed.

The Committee believes that these areas of research are of the highest priority and deserve the attention of those involved in conducting and supporting transportation research. The special conjunction between changing transportation and energy markets makes now an excellent time to initiate and expand research in these areas.

2. MOTOR VEHICLE FUEL ECONOMY POLICY

2.1 THE ISSUE

What policy should the government adopt with regard to the market for motor vehicle fuel efficiency? Should the government make no attempt to modify the marketplace, even by providing consistent fuel economy information? Or should the government continue to set fuel economy standards for manufacturers, tax inefficient automobiles, and provide consistent fuel economy estimates to car buyers? To enable the government to make better policy decisions about fuel economy regulations, information, and taxation, we must increase our understanding of how the market demands and supplies automotive fuel economy.

2.2 BACKGROUND

The energy efficiency of new passenger cars in the U.S. nearly doubled between 1975 and 1986, increasing from 15.8 miles per gallon (mpg) to 28.0 mpg (Heavenrich, Murrell, and Cheng, 1986). Light truck fuel economy has also made impressive gains, from 13.7 mpg in 1975 to 21.5 mpg for the first six months of model year 86 (Figure 1). These test-cycle mpg estimates have translated into real fuel savings for consumers. Careful statistical analyses of in-use versus test fuel economy numbers have proven that despite shortfalls of 10-15%, proportional improvements have been achieved on the road (Crawford and Kaufman, 1983; Hellman and Murrell, 1982 and 1984; Lax and Duleep, 1983; Love, 1983; McAdams, 1980, 1981; McKenna and South, 1982; McNutt, Pirkey, Dulla, and Miller, 1978; McNutt and Dulla, 1979; McNutt, Dulla, Crawford, McAdams, and Morse, 1982; Murrell, 1980; Schneider, Freas, and McMahon, 1982). The National Highway Traffic Safety Administration (NHTSA) has estimated that cumulative passenger car and light truck energy savings due to efficiency improvements over 1976 levels will be 420 billion gallons of motor fuel by 1995 (NHTSA, 1986). The present value of cumulative savings from 1975 to 1984 has been put at $92 billion in 1984 dollars (Greene, Meddeb, and Liu, 1986).

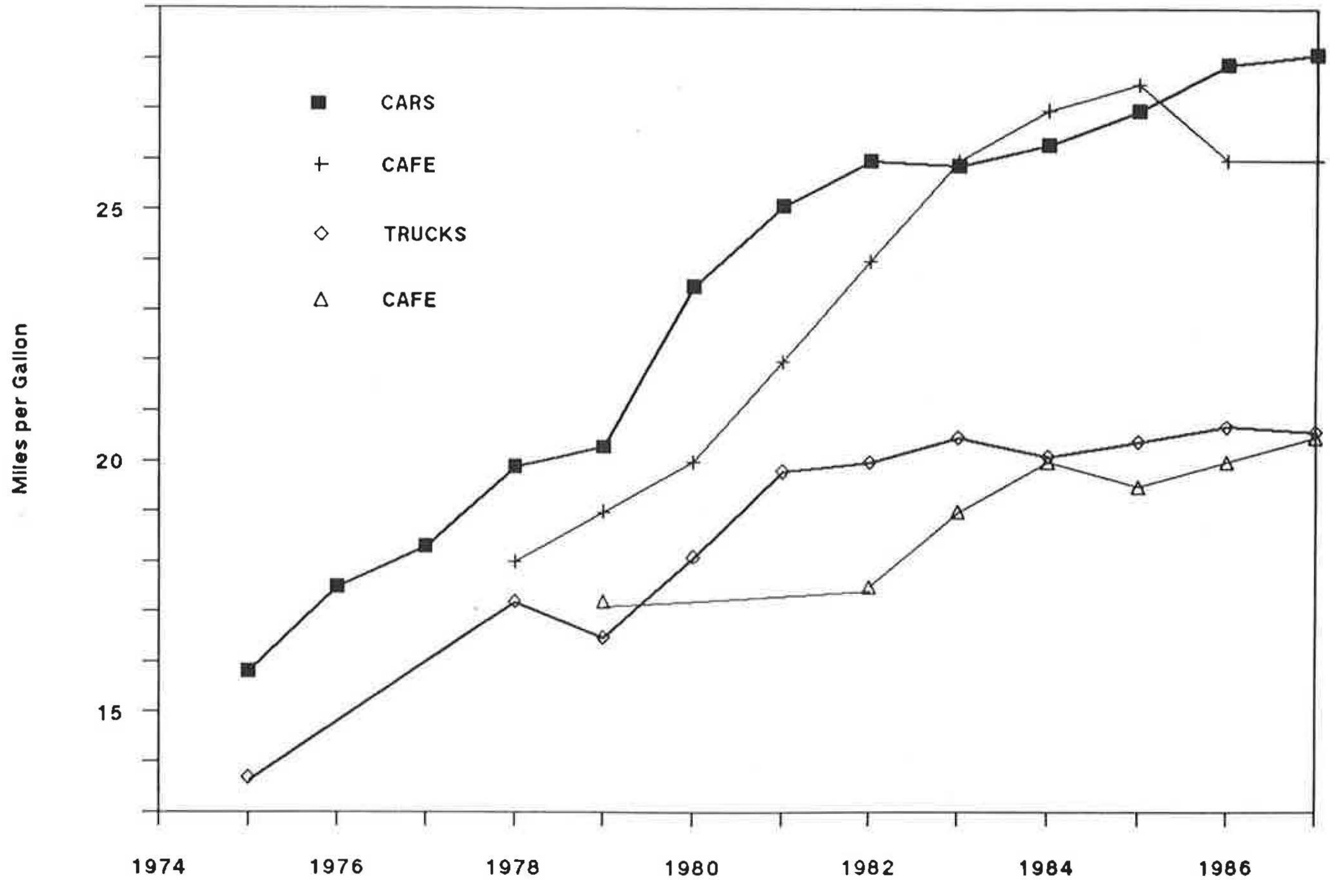

Figure 1, AUTOMOBILE AND LIGHT TRUCK MGP, 1975-86

Government regulation has been a prominent factor in light duty vehicle efficiency improvements, although there is no consensus about precisely what its effect has been. In December 1975 the U.S. Congress passed the Energy Policy and Conservation Act (EPCA), P.L. 94-163, which specified passenger car fuel economy standards of 18, 19, and 20 mpg for model years 1978, 1979, and 1980, respectively. Later rulemaking determined that fuel economy should increase to 27.5 mpg by 1985 (NHTSA, Federal Register, 1977). Standards were similarly established for light trucks. The correlation between the CAFE standards and realized mpg is prima facie evidence that the standards had some effect, but there are other plausible explanations. Aside from allowing market supply and demand conditions to determine energy prices, the light duty vehicle fuel economy standards could be the Nation's most important energy policy.

Improved fuel efficiency has costs as well as benefits. These costs may be directly reflected in higher retail prices for cars or in decreased satisfaction with altered vehicle designs. Estimates of price increases range in the hundreds of dollars per car by 1985 (EEA, 1986; U.S. Congress, 1980 and 1982; Greene and Liu, 1986). Estimates of the effect of new designs on consumer satisfaction range more widely from thousands of dollars lost (Cardell and Dunbar, 1980) to hundreds of dollars gained (Greene and Liu, 1986). In any case, the potential costs, like the benefits, are in the tens, and possibly hundreds, of billions of dollars.

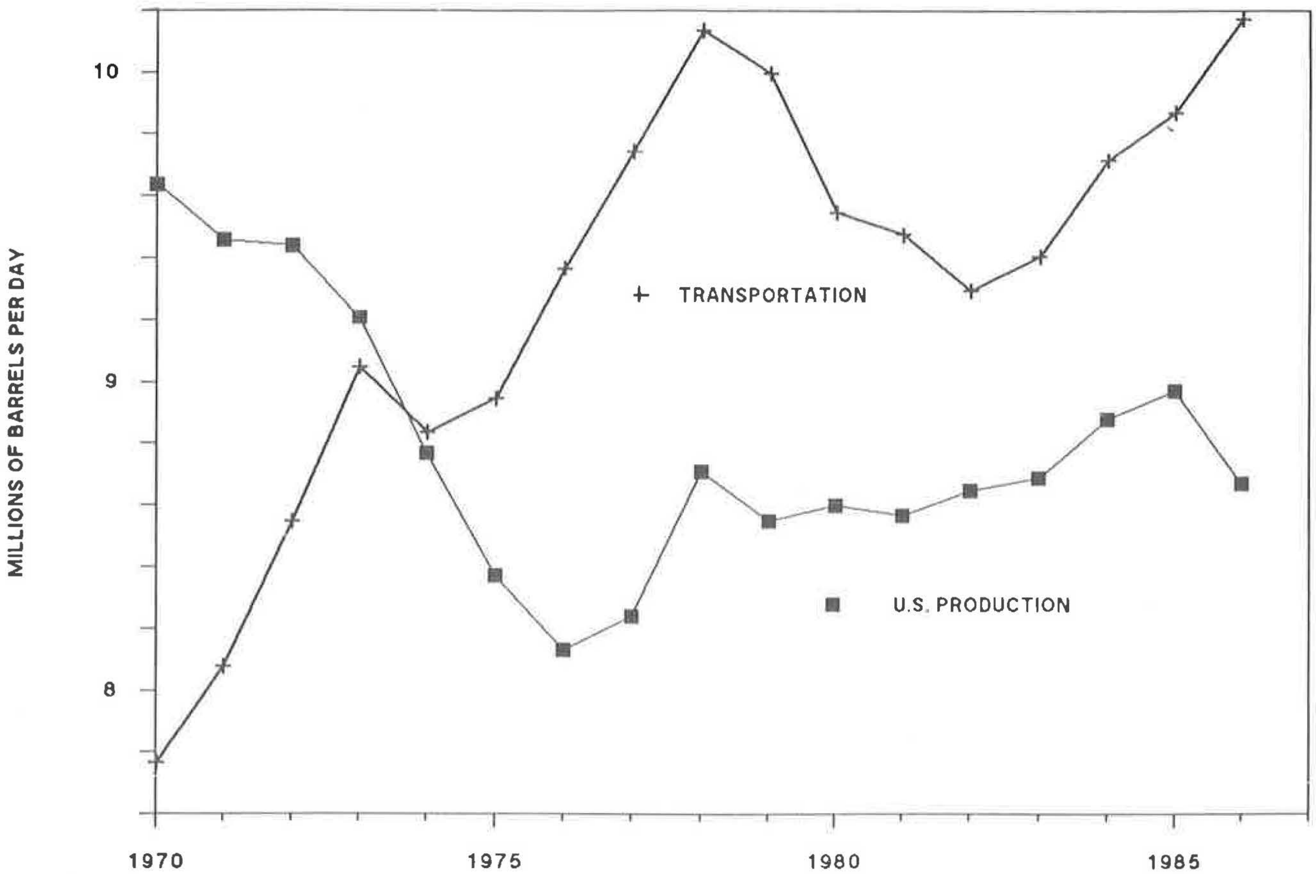

Figure 2, TRANSPORTATION OIL USE
AND DOMESTIC PRODUCTION: "THE GAP"

There are several reasons for considering a government role in the market for automotive fuel efficiency. Not the least of these is the major role it has already assumed. It is also reasonable to consider whether the petroleum market is providing the kind of price signals to which manufacturers can effectively respond. Automobile fuel economy first increased in 1975 (Figure 2), before fuel economy standards took effect in 1978 (they became law in December 1975). Because of the 2-3 year lead-time required for making significant vehicle design changes, the initial upturn in mpg can reasonably be attributed to the fuel shortages and price increases of 1973-74 (Figure 3). After 1975, however, gasoline prices declined until 1979, when they once again jumped upward. Indeed, fuel prices have resembled a roller coaster since 1973. Is it possible for producers and consumers to respond to such price signals in ways consistent with the long-run best interests of the United States?

There are other significant market issues, as well. Is it appropriate for the government to provide a consistent source of fuel efficiency information? If so, what is the best means of conveying this information? If fuel economy information is needed by the new vehicle market, is it not also necessary for the used vehicle market? How can one insure that the information is beneficial and not misleading? Studies of consumer choices of all types of energy using equipment suggest that consumers discount future savings heavily, using annual rates on the order of 20-30% (Train, 1985; Greene, 1983). Are such discount rates reasonable, or do they reflect inadequate information or other market imperfections?

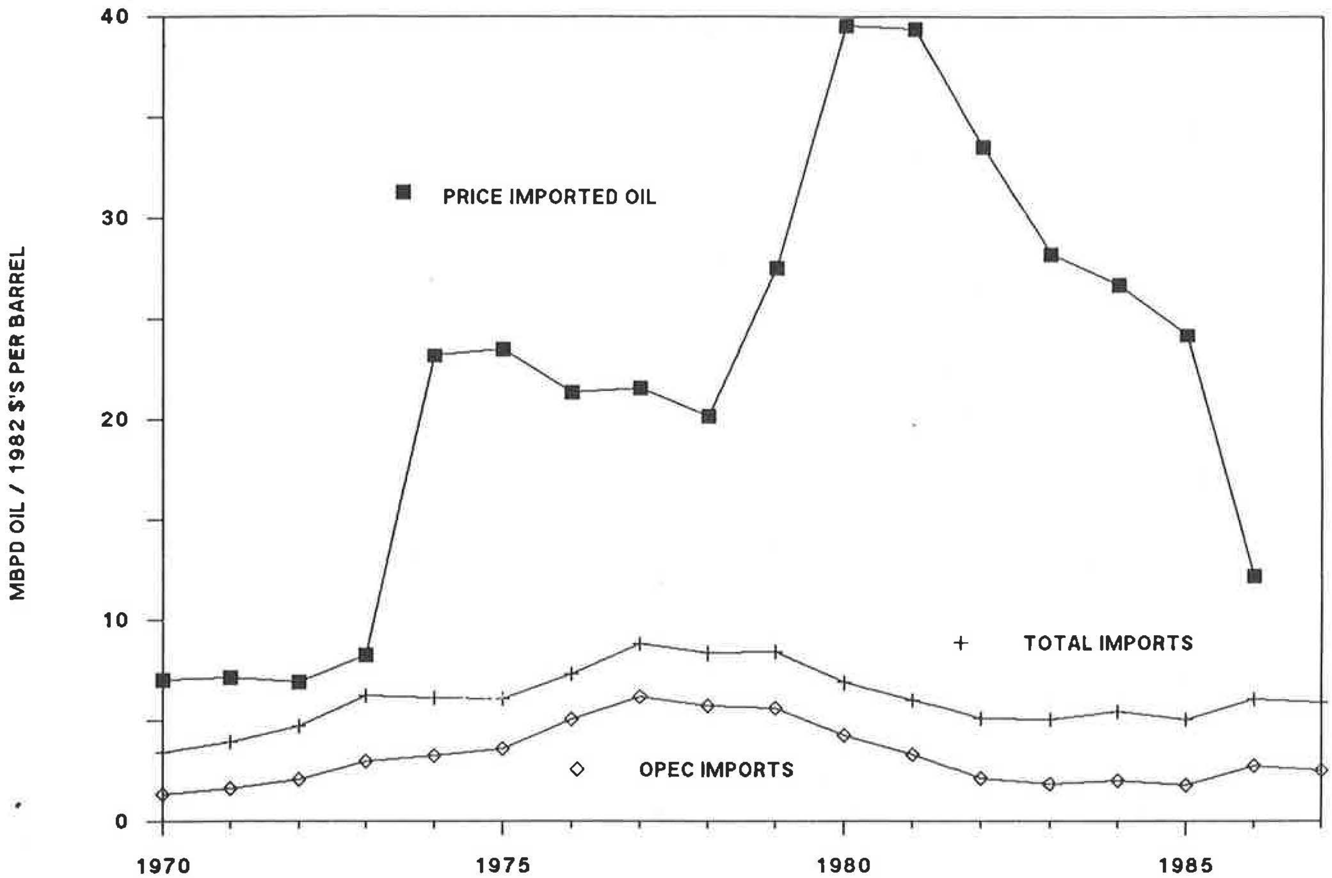

FIGURE 3, OIL IMPORTS AND OIL PRICES

Given the importance of petroleum use by highway vehicles in our national energy picture, and the fact that both costs and benefits or higher levels of vehicle fuel economy may be in the tens or hundreds of billions of dollars, it is crucial that we improve our understanding of the need for, and the effect of government policies in the market for motor vehicle efficiency. Our present situation, with pertroleum prices at their lowest levels in more than a decade and the CAFE standards reaching their 1985 target, requires us to reassess our current policies and determine a course for the future.

2.3 A RESEARCH AGENDA

From what is known about the economics of fuel economy improvements it is clear that the costs and benefits are on the order of $ 10^{10}. The difference between good, bad, or no fuel economy policy could easily mean billions of dollars annually. We need to know more than we know now to intelligently evaluate and formulate motor vehicle efficiency policy. Research is needed to improve our understanding in the following five priority areas.

1. <u>The supply of fuel economy</u>. How do market signals and regulations affect innovation and marketing strategies (Heywood, Jacoby and Linden, 1977; Siegel, Burrows, and LaCivita, 1978; Kearney, Inc., 1979; Kwoka, 1983)?

2. Consumer demand for fuel efficiency. What causes apparent discount rates of 30% or higher for automotive fuel savings (Greene 1983, 1986)? How do consumers use and what is their need for fuel efficiency information? How are price expectations formed (EEA, 1983; Cambridge Systematics, 1979) and how do they affect demand (Daly and Mayor, 1983)?

3. Evaluating the costs and benefits of fuel economy regulation. How should the costs and benefits of existing or new regulations be estimated?

4. The consumer acceptance of available technology for improved fuel economy. There is a continuing need to reassess the potential of existing technology to improve fuel economy and to determine whether that technology is both cost-effective and acceptable to consumers. Determining existence and cost-effectiveness of technology formed an important part of analyses for the CAFE standards, but more attention needs to be paid to consumer acceptance (Coon, et al., 1974; DOT and EPA, 1975; Hittman Assoc., 1976; Hurn, et al. 1976; NHTSA, 1977; EEA, Inc., 1979; U.S. Congress, 1980 and 1982; 96th Congress, 1980; Strombotne and Luchter, 1981; EEA, 1981; Ford and Sutherland, 1982; Whitford, 1984; Price and Stamets, 1984; EEA, 1985 and 1986).

5. Monitoring of in-use fuel economy is essential to insure that improvements in test fuel economy are realized by motorists and to insure that fuel economy information provided to car buyers reasonably reflects what they will achieve on the road. If either of these types of policies are pursued, there will be a need to develop more cost-effective methods of gathering and analyzing these data.

In area 5 considerable work has already been done and needs to be continued or extended. In areas 1 to 4, basic advances in both methodology and factual information are needed

2.4 WHAT WE ALREADY KNOW

Although a substantial amount of research related to fuel economy policy has been conducted, almost none of it directly addresses the key questions of whether regulation can stimulate innovation or is merely an impediment to the market, whether gas guzzler taxes are effective and efficient, or whether fuel economy information is effectively used by consumers.

Very few researchers have attempted to analyze how the market would provide fuel efficiency improvements in response to fuel price changes without regulation (exceptions are Crandall, Gruenspecht, Keeler, and Lave, 1986; Greene and Roberts, 1984; Ford, 1984). A key question not yet addressed is whether regulation can stimulate technological change. Numerous studies have shown that engineering and design changes rather than sales shifts have been responsible for most of the mpg improvement to date. Technological contributions have been analyzed by NHTSA (1982), and by EPA researchers (Heavenrich, Murrell, and Cheng, 1986; Heavenrich, Murrell, Cheng, and Loos, 1985; Heavenrich, Murrell, Cheng, and Loos, 1984; Murrell, Loos, Heavenrich, Cheng, and LeBaron, 1983). NHTSA attributed over half of the mpg gain from 1978-81 to weight reduction alone. The EPA studies, on the other hand, attribute the majority of 1975-1985 improvements to "powertrain optimization", a catch-all category, and less than one fourth to weight reduction. The importance of sales shifts vs. engineering and design changes have been thoroughly analyzed for the 1978-85 period (Greene, Hu, and Till, 1985; Patterson, Westbrook, Greene, and Roberts, 1984; Patterson and Westbrook, 1983). What none of these studies has done is to identify advances in technology versus redesign with the same technology, nor have they been able to identify the role of regulation versus market forces in any of these changes.

From 1973 to 1984 highway travel increased 31%, from 1.3 to 1.7 trillion vehicle miles (Hanchey and Holcomb, 1985; FHWA, 1984), while gasoline use increased only 0.3%, from 6.674 to 6.693 million barrels per day (EIA, 1986) clearly showing that the efficiency of highway travel has improved significantly. The details of these improvements have been quantified in modeling analyses (Difiglio and McNutt, 1982; Hirst, Marlay, Greene, and Barnes, 1983). There is solid evidence that test-cycle efficiency improvements for new cars and light trucks have been translated into fleet mpg gains and, in turn, into fuel cost savings. Unfortunately, there is now no direct measurement of the on-road efficiencies of light duty vehicles so that we will have to continue to rely on models and indirect evidence to estimate efficiency improvements and compute fuel savings. We will also have no means of verifying that test-cycle mpg estimates consistently represent what drivers will achieve on the road.

Although direct energy savings can be estimated reasonably well, methods need to be developed for evaluating the total economic impacts of light duty vehicle efficiency improvements. Early studies which did not allow for the possibilities of technological change or changes in consumer tastes concluded that consumers' surplus losses due to unwanted vehicle design changes might run into billions and tens of billions of dollars (Boyd, 1979; Atkinson, 1981; Cardell and Dunbar, 1980). Consumer surveys have failed to find such massive dissatisfaction (Cambridge Systematics, 1979; Green and Rogers, 1980; J. D. Power & Assoc., 1984). One retrospective study which included actual vehicle changes but not taste changes suggests that consumers' surplus effects may be positive (Greene, 1986) and roughly equal in size to the cost of fuel economy improvements to the consumer (costs estimates can be found in NHTSA, 1977; U.S. Congress, 1980 and 1982; Shackson and Leach, 1980; Energy and Environmental Analysis, Inc., 1981 and 1985; Hittman, 1976; Tyner, Binkley, Matthews, and Whitford, 1981). The consumers' surplus effect of reduced costs per mile of travel have not been considered, nor has a single study attempted to integrate all the various components of economic and social costs and benefits.

Finally, remarkably little attention has been paid to the causes for success or failure of fuel economy policies. Some observations based on an international comparative study can be found in an OECD/IEA (1984) study, but there is little else.

2.5 CONCLUSION

The costs and benefits of government policies regarding motor vehicle fuel efficiency are on the order of tens of billions of dollars per year. The complexity of the motor vehicle market and the volatility of petroleum prices make it difficult to determine what government actions, if any, are needed, and how they will affect producers, consumers, and the national interest. Given the magnitude of the problem and its complexity, there continues to be a need to better understand how fuel economy policies have and will affect the motor vehicle market.

3. PETROLEUM SUPPLY EMERGENCIES

3.1 THE ISSUES

With several recent years of stable oil prices followed by a decline from $31 in November 1985 to $14 by the summer of 1986, there is understandably little concern or effort devoted to the analysis of future petroleum supply interruptions. Nevertheless, both the potential and the probability for an oil supply disruption during the 1990's remains high. (Nye, 1981; Plummer, 1982; Weyant, 1984; Ebinger, 1986) The Center for Strategic and International Studies at Georgetown University surveyed a panel of 50 energy experts in December of 1983 and found that most assigned a probability between 50 and 60% that there would be a major petroleum supply interruption by the 1990s. (Stein, 1983)

Even as late as 1984 energy was included in the TRB's list of ten critical transportation issues. Energy was cited because potential oil interruptions pose "a constant threat to mobility and the economy." (TR News, 1984) The issues, given the U.S. dependence on oil imports, are: 1) determination of where there are additional cost-effective ways of reducing our petroleum vulnerability, 2) resolution of the difficult equity issues in any emergency response effort, and 3) reevaluation of the capabilities of critical transportation sectors to respond to shortage conditions, given the changes in infrastructure and policies since the last energy crisis.

3.2 BACKGROUND

The federal role in energy contingency planning has evolved from the limited response in the 1973-74 oil embargo. That response included the implementation of the 55 mph speed limit, extension of daylight savings time, and some building temperature restrictions. By 1975, the Energy Policy and Conservation Act provided a substantial federal role for contingency planning. Later, the Emergency Energy Conservation Act of 1979 added a state and local focus by requiring the development of contingency plans -- with the threat of an imposed federal plan if states could not show that conservation targets could be met.

During the early 1980s, the emphasis on demand-restraint in response to oil price shocks was replaced with a "free market" approach, letting the petroleum product prices rise without price controls or direct allocation schemes. This approach transforms the problem of energy shortage into one of severe energy price dislocation. As a result of the change in orientation, much of the prior energy contingency analysis is no longer relevant.

Nevertheless, the severe economic impacts associated with even a relatively mild petroleum supply interruption are well documented. (e.g., U.S. DOE/EIA, 1979 and 1980; Johnson, et al., 1982; Sweeney, 1982) Individual sectors of the economy are affected differently during energy shortages; highly energy-intensive industries face severe economic difficulties. The transportation sector, both vehicle manufacturing and transport services, is in this group of highly vulnerable sectors.

As a result of the energy shortage experiences, there have been several notable changes that will affect the economics of energy and the effectiveness of any potential responses to future oil shortfalls. Crude oil and petroleum product prices have been decontrolled. High fuel prices during the early 1980s resulted in increased worldwide petroleum exploration. The recent sharp decline in world oil prices has, of course, produced the opposite effect, with the U.S. drilling rig count declining dramatically. Standby crude oil and product price and allocation authorities have been eliminated. And, the Strategic Petroleum Reserve (SPR) now contains over half a billion barrels of oil, equivalent to about three months of total crude oil and petroleum product imports at current consumption rates. (U.S. DOE/FE, 1986) (Indeed, the SPR represents the cornerstone of U.S. energy contingency response policy. (U.S. DOE/S, 1984)

The probability of a future oil shortage remains high due to a combination of several factors. First, the Mid-East remains the lowest cost oil-producing area of the world and has by far the largest proved oil reserves. Second, the Mid-East also remains a politically unstable part of the world, in which petroleum supplied could be rapidly removed from the world market. Third, the U.S., Europe,and Japan will remain oil import dependent for as long as can be reasonably predicted and, finally, Third World countries' economic growth will also be linked to oil imports. During this period of low energy prices it is important to maintain this long-term perspective, since the current oil price slide is due largely to a strategic decision by Saudi Arabia to attempt to reestablish control over petroleum supply and price.

In all industrialized societies, transportation will continue to be the most vulnerable end-use sector. In the U.S. especially, transportation is: 1) virtually entirely dependent on petroleum products, 2) the largest oil consuming end-use sector (using over 60% of all U.S. petroleum), and 3) without any cost-competitive technologies to use alternative fuels.

Although a petroleum supply interruption probably is not imminent, the U.S. is particularly vulnerable to an oil shortfall for another reason. In recent years the transportation sector alone has consumed more oil than has been domestically produced. Consequently, if the industrial, residential, and commercial sectors all eventually use no oil (which is highly unlikely), there will still be a petroleum import problem for transportation.

3.3 RESEARCH AGENDA

Many studies were conducted during the late 1970s and early 1980s that examined different facets of petroleum shortages. Obviously, future research should not duplicate these efforts. Further, by many criteria the U.S. is better prepared to meet an oil shortfall than it was in the last decade, e.g., significantly increased oil supplies in the SPR, diversity in the suppliers of our oil imports, and the elimination of oil price controls and allocation procedures, which should dramatically improve market efficiency. Moreover, it is recognized that, by definition, an oil shortage will mean real costs and unpleasantness that no government program totally eliminate. (Winkler, 1983) Yet, in spite of the extensive federal studies on energy contingency response options and state and local analyses of energy emergency alternatives, there remain several unresolved energy response issues.

1. Preventive vs. reactive policies. Federal energy contingency planning has focused on reactive policies. The price and allocation controls were a reaction to the immediate circumstances of a fuel shortage. Even the current policy of a market solution is essentially a reactive one. Consideration should now be given to policies that would reduce the probability that a petroleum supply interruption could occur. For example, steps that enable transportation vehicles to utilize alternative fuels offer not only the benefits of a smooth economic transition away from oil but would also reduce the impact of any future energy shortages. Existing conservation research programs should be examined to see whether they can be contribute proactively to mitigating potential oil shortages.

2. Equity issues in a free market approach. There has been, and continues to be, concern about equity issues associated with a free market approach to an energy shortfall. (Alm, et al., 1981; Dorfman, 1981) Many schemes have been examined that would still allow the anticipated efficiency aspects of an uncontrolled market. (Difiglio, 1980; Lee, 1980; Stuart and Hocking, 1980; U.S. DOE/EP, 1983; Horwich and Weimer, 1984) Most would use existing mechanisms (e.g., unemployment compensation, welfare programs, payroll withholding taxes, etc.) to direct funds to some specified group of low income people that would bear a disproportionately heavy burden of the energy shortage. Further, different criteria (vehicles per household, drivers per household, etc.) would have vastly different distributional effects if some program were to be implemented. While much of the work has been done to identify several possible actions, no decision apparently has been made to implement any alternative, so that there is widespread perception that either no effort will be made to address equity issues or that the response will come too late. Some research is needed to determine the most cost-effective approach and to take action that will allow the selected approach to be implemented before a crisis occurs.

3. Current response capabilities in critical sectors. Since the oil crises of the 1970s, there has been continued suburbanization of employment, changes in highway and transit funding mechanisms, and new tax and regulatory policies affecting transportation, so that the capability of the various transportation sectors to respond to a future oil shortage may be quite different than what the analysis showed during the late 1970s and early 1980s. (Pikarsky and Johnson, 1983) For example, urban transit has historically experienced a surge in demand during a fuel shortage, yet has lacked the capacity (both a budget and equipment) to adequately respond to the need. These probelms were at least partially addressed in the past under priority allocation systems. (U.S. DOT, 1982) Creative financing will be required in the future, if this public service (and indeed there

essential services, such as fire, police, ambulance, etc.) is to be maintained. (Bloch, 1983) Further examination is also needed in the transit equipment area. Earlier studies recommended that transit properties maintain high spare vehicle ratios so that older stockpiled buses and trains could be quickly pressed into service in the event of an emergency. (U.S. DOT, 1980) However, this practice runs counter to good fiscal practices that encourage low spare ratios. Research is needed to determine which of the key transportation contingency recommendations are still prudent, given the new policy emphasis.

3.4 CONCLUSIONS

To put these contingency planning recommendations into context, it should be noted that the extensive studies of the early 1980s produced some excellent findings and recommendations of their own. With the threat of an immediate oil shortage so low, it is impractical to consider that major efforts should be directed at keeping all of the federal, state, and local contingency plans in a constant state of readiness. However, even the best of plans have to be reassessed periodically to incorporate changing events, policies, and circumstances. In addition, innovative ways should be sought to integrate energy conservation and alternative fuel R & D programs, as preventive elements, in the nation's overall contingency planning. The high risk and costs associated with any potential petroleum supply disruption justifies a reasonable effort to periodically review the preparedness status of the U.S. transportation system, which is using an ever-larger share of the nation's petroleum supplies.

4. TRANSPORTATION ENERGY FORECASTING

4.1 THE ISSUE

Because of the central role of transportation energy consumption in the worldwide petroleum market, modeling and forecasting transportation energy use is key to understanding the future energy picture. Projecting transportation activity levels is crucial to forecasting energy demand, but the desire for improved methods and data in this area is shared with the entire transportation research community. Energy forecasting has its own distinctive methodological and data requirements:

1. predicting the efficiency of new transportation equipment,

2. predicting the introduction and market shares of alternative powerplants and fuels,

3. preucting the retention and retirement of equipment stocks and,

4. preducting the long-run response of transportation activity (vehicle use, choice of mode, and all of the above) to changes in energy prices.

4.2 BACKGROUND

Transportation energy forecasts are used by federal agencies, oil companies, and others to identify fuel demands by type of fuel, to help set priorities for R&D efforts, to analyze the impact on the economy, to estimate emissions, etc. Models have been built for numerous purposes and have been applied in various ways (Richardson, 1986a and 1986b).

In the late 1970's, two comprehensive transportation studies which included energy forecasts were conducted by the Federal government. The Department of Transportation study (DOT, 1977) assumed that government regulation would be the major reason for automobile efficiency improvements, and that fuel prices would affect the level of energy use primarily through modal shifts. The National Transportation Policy Study Commission report (NTPSC, 1979) also stressed the importance of fuel economy regulations in promoting automobile fuel economy improvements but never explicitly modeled the determination of vehicle fuel efficiency, vehicle purchase, use, and scrappage.

Later studies by the Mellon Institute (Shackson and Leach, 1980 and 1982) and the Office of Technology Assessment (OTA, 1982) looked at fuel efficient automobile technology in some detail and attempted to link its introduction into the market to the price of motor fuel. These studies dealt with the eventual competition between further fuel economy improvements and a switch to alternative fuels (see also Whitford, 1981). These studies and others (EEA 1985) have assumed that whatever energy-saving technology was cost-effective would be made available in the market. Together with higher fuel prices, this assumption resulted in fuel economy predictions in the range of 40-60 miles-per-gallon by 2000. The market for fuel efficiency is far more complex, and simple cost-effectiveness calculations do not provide a sufficient basis for policy decisions.

The Department of Energy regularly produces two energy forecasts that have transportation energy demand components. The Energy Information Administration (EIA) in DOE annually produces a document (EIA, 1986) that uses a transportation energy demand model (Werbos, 1986) to project national transportation energy use by fuel type.

Currently, EIA does not project beyond the year 1995. The DOE policy office also makes projections to the year 2010 in support of the national energy plan that is required by Congress to be produced biannually (DOE, 1986). These projections use a vehicle stock model (EEA, 1985) to project highway fuel demands and a set of equations to project the remaining transportation fuel use.

The Office of Conservation in DOE regularly produces a projection of detailed transportation energy use (Millar and Vyas, 1985). Since 1977, the forecasted baseline transportation energy demand changed significantly according to the date the projection was made (Figure 4) due to changes in models and fuel price assumptions.

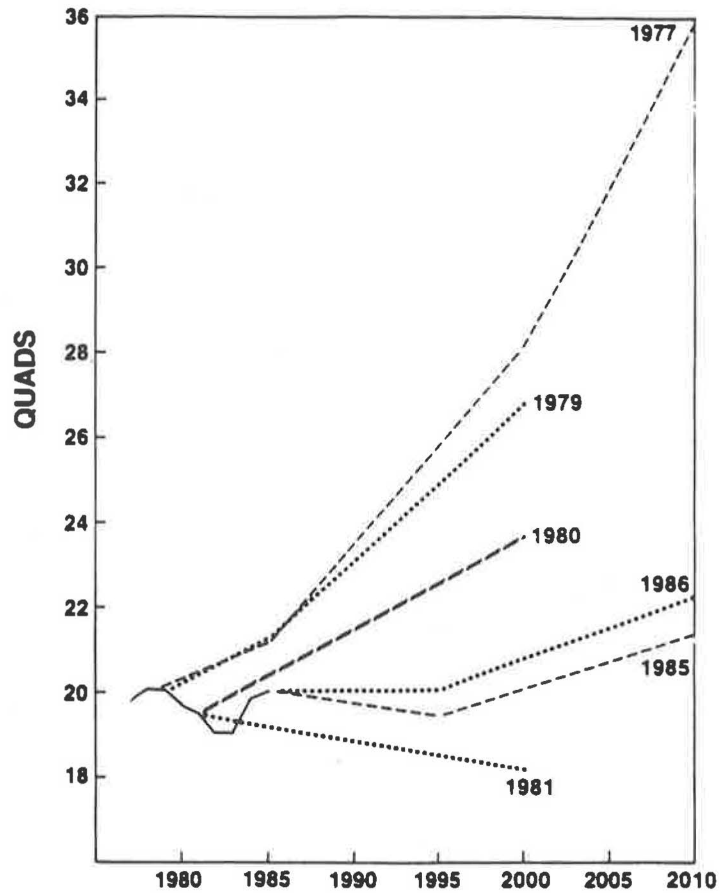

Figure 4, BASELINE TRANSPORTATION ENERGY PROJECTIONS
USED BY THE OFFICE OF TRANSPORTATION SYSTEM (DOE)

The chief weak points in the current state of the art of transportation energy demand forecasting are:

1. modeling the determination of fuel efficiency and fuel type for new equipment,

2. modeling the dynamics of the vehicle stock, particularly decisions to add or scrap equipment, and

3. long-range projection of the demand for transportation services and, in particular, the fuel price sensitivity of the demand for passenger and freight transportation.

It is clear now that high future automobile fuel economies cannot be just assumed (University of Michigan, 1984). Manufacturers must be willing and able to produce such vehicles and consumers must be willing to buy and use them. The vehicles purchased by individuals and businesses in the future will have fuel efficiencies determined by the interaction of the buyer's demands and manufacturer's offerings. Both parties will be affected by current and anticipated fuel prices. Manufacturers will be further affected by government regulations and competition in various vehicle classes. Buyers will be affected by advertising and other information sources. The assumption that all fuel efficient technology which is cost-effective will be made available appears to be questionable (EEA, 1985). Methods of modeling the fuel efficiency of vehicles offered for sale which reflect the complexity of manufacturer and consumer decsion-making in an uncertain market are needed (Difiglio, 1985).

The selection of vehicle type by new car buyers has received a great deal of attention. The original Lave-Train auto choice model (Lave and Train, 1976) and others (Lave, 1980) have seen substantial development (CSI, 1980; Golomb, 1979; Richardson, 1982). The various model types (e.g., disaggregate, compensatory, etc.) have been described nicely by Train (1985) and recent advances in auto demand modeling have been summarized (Mannering and Train, 1985). From the energy perspective, what remains to be dealt with is the effect of uncertain future fuel prices, the role of fuel economy information in the consumer's evaluation of automotive energy efficiency, and methods for Forecasting market acceptance of alternative engine technologies and fuels (Tenure, 1980; Beggs, 1981).

A second major forecasting problem of special importance for energy use, is that of projecting the dynamics of the mix of vehicles owned (by type, age, etc.). In particular, how the scrappage and use of vehicles is affected by fuel prices, efficiencies and other economic factors needs to be better understood (Greene and Hu, 1983; Manski and Goldin, 1983). The importance of the technical composition of the vehicle stock is key to energy demand forecasting since it is the chief determinant of the efficiency of travel and the fuel type composition of transportation energy use. If usage or scrappage rates by age, efficiency, or fuel type change, forecasts must adjust accordingly.

The problem of projecting demand for transportation services is a concern shared by at least four other TRB committees (A1B07 - Urban Goods Movement, A1C02 - Passenger Travel Demand Forecasting, A1D05 - Transportation and Land Development, and A1J02 - Aviation Economics and Forecasting). The Energy Conservation and Transportation Demand Committee's interest is focused on how energy prices, availability, and vehicle efficiencies affect vehicle and fuel use. This includes the selection of the most fuel efficient mode (Vyas, 1986) or the most efficient vehicle in multi-vehicle households (Mannering, 1983; Greene and Hu, 1984). Also of concern is how the price and availability of fuel affects the amount of travel (Brunso and Hartgen, 1985), trip chaining (Hummon and Burns, 1981), and vehicle maintenance for fuel economy and how urban form (Kim and Schneider, 1985) affects energy use.

4.3 A RESEARCH AGENDA

Over the years, the Transportation Research Board has served an important role by publishing some of the most significant contributions to transportation energy forecast research. Reports have dealt with topics such as forecasting and models (TRB, 1980), forecasting and conservation (TRB, 1981), energy issues (TRB, 1982), energy planning and modeling (TRB, 1983), and urban energy issues (TRB, 1984a and 1984b). It is important that the TRB continue to foster and publish advances in the science and art of transportation energy forecasting.

The following research topics and procedures are suggested as presently the most important to undertake in the area of transportation energy forecasting:

1. predicting the efficiency of new transportation equipment, from manufacturer decision-making under uncertainty to consumers' evaluation of efficiency improvements,

2. predicting the introduction and market shares of alternative powerplants and fuels, from methanol to electric vehicles,

3. predicting the retention and retirement of equipment stocks for both households and firms and the effect of fuel prices on those decisions, and

4. predicting the long-run response of transportation activity (vehicle use, choice of mode, location, and spatial structure) to changes in energy prices.

4.4 CONCLUSION

Energy prices have not followed a smooth pattern. Rather, short periods of sharp price rises have been followed by longer periods of price stability or decline. Past fuel price fluctuations have, no doubt, been responsible for the big changes in the yearly forecasts of transportation energy use and for much of the dissatisfaction with transportation energy forecasting. There is little that transportation researchers can be expected to do to solve this basic problem of uncertainty about future energy costs.

What researchers must do is to develop methods capable of predicting the response of the transportation system to wide fluctuations in energy costs. When vehicle manufacturers, vehicle buyers, and vehicle users receive cyclical fuel price stimuli, their decisions may differ significantly from what would have happened if a smooth price increase had occurred. Developing useful models of the transportation energy system, from manufacturer behavior to vehicle use, presents a significant research challenge.

5. CONSERVATION, WHAT WORKS?

5.1 THE ISSUE

In response to the energy shocks of 1973-74 and 1979-80, a great deal of effort and creativity was focused on improving the operating efficiency of the transportation system. In the short-run, when the equipment stock cannot be changed substantially, improving operating efficieny is the only way to reduce energy use without reducing mobility. Some of these innovations have proven robust and continue to be practiced despite plentiful fuel supplies and low prices. Others have fallen by the wayside. While there are adequate catalogs of energy-saving strategies (e.g., Parviainen and Assoc., 1983; Stowers and Boyar, 1985), there is a shortage of carefully documented case studies that document what has worked, how much energy has been saved, and what factors determine success or failure.

5.2 BACKGROUND

Efforts to improve operating efficiencies in transportation have spanned all modes from mass transit to inland water transport. Since the highway mode accounts for nearly three quarters of transportation energy use, it is understandable that it has received the most attention. Conservation strategies for the highway mode can be broadly grouped into three areas:

1. Commutation strategies: carpooling, vanpooling, and high occupancy vehicle lanes (HOV's), alternative work schedules,

2. Transportation systems management strategies: traffic signal management, speed limits, and

3. Driver information and education strategies: driver training and improved maintenance.

While a great deal has been written about carpooling and vanpooling (see, e.g. Southworth, 1985 for a bibliography), much of it deals with modeling or predicting commuter response (e.g., Kocur and Hendrickson, 1983; Kostyniuk, 1982; Daganzo, 1981), or identifying attitudinal or institutional barriers to ridesharing (e.g., Ayele and Byun, 1984; Dobson and Tischer, 1976; Kearney, 1979). Substantial work has also been done on the evaluation of ridesharing programs and strategies (e.g., Hartgen, 1977; Maxwell, Petersen, and Peterson, 1984) but there are relatively few carefully documented measurements of the actual energy savings of particular ridesharing programs (some exceptions are Kulp, Tsao, and Webber, 1982; Shu and Glazer, 1979; Maxwell and Williamson, 1980). Additional rigorous evaluations in other locatons under different conditions would be welcome.

Southworth (1985) surveyed HOV projects nationwide and found 17 "mainline" projects in operation. Although Southworth estimated that these HOV projects were saving between 40 and 340 thousand gallons of gasoline per HOV mile, he noted that very little effort has gone into actual energy savings calculations.Only three projects reported estimated impacts on energy consumption:

1. I-45N Houston, 1.2 million gallons/year,
2. I-5 Seattle, 0.2 million gallons/year, and
3. Banfield Freeway, Portland, 0.2 million gallons/year.

Although energy savings are not the most important of the economic benefits of HOV lanes, further documentation of their fuel saving impacts would be useful, especially in the future when fuel costs may be significantly higher.

Modifying work schedules is another strategy whose costs and benefits, are for the most part, not energy conservation. The TRB and NCHRP have reviewed the subject extensively (1980) and concluded that such strategies could be useful during a severe energy supply shortage.

Numerous studies have indicated that how drivers control their vehicles can influence their energy efficiency by 10%, or more (Hooker, 1986). Similar levels of savings are possible through improved maintenance practices, such as keeping tires properly inflated, using "fuel saver" lubricants, and keeping experiments (e.g., see Greene 1986, for a literature review). There is a reasonable amount of anecdotal evidence to indicate that drivers trained by a course such as the DOE DECAT course, do reduce there fuel consumption by about 10% (Orkand, 1982). However, there is a notable absence of rigorous evaluations of actual experience (an exception is Greene, Kowalski, Araya, and Hu, 1987). The most acute need is for careful measurement of the retention of fuel efficient drving knowledge and practice over time. To the best of our knowledge there have been no studies of this type. Ten percent of all highway energy use is such a vast amount of energy (about 12 billion gallons of motor fuel) that it provides more than adequate justification for such research.

Traffic signal management is another conservation strategy with significant, non-energy, synergistic benefits. By far the most thorough implementation and evaluation of traffic signal timing costs and benefits is the state of California's Fuel-Efficient Traffic Signal Management (FETSIM) Program (Institute of Transportation Studies, Berkely, 1986). Over 3,000 signals across California were retimed, reducing vehicular delays by 15%, stops by 16%, and reducing overall travel times by 7.2%. Although it is not possible to directly measure fuel savings, rigorous analytical techniques were used to calculate them based on observed changes in speeds, stops, and waiting times. Direct fuel cost savings were put at $73 million, about one-third of the program's total estimated savings. The estimated benefit-cost ratio for FETSIM is greater than 50:1. Corroborating evidence from other implementations could lead to nationwide adoption of improved signal timing techniques.

Energy conservation practices from driver training to maintenance to aerodynamic devices have received widespread acceptance in the trucking industry. Driver training courses like DOE's DECAT program have been widely judged effective by trucking companies (e.g. see Bertram, 1984; Society of Automotive Engineers, 1981). The acceptance and energy-saving effects of energy-conserving equipment such as radial tires, aerodynamic add-ons, fan clutches and fuel economy diesel engines has been documented (e.g., Roberts and Greene, 1983; Dept. of Transportation, 1982; Bertram, Saricks, Gregory, and Moore, 1983). Once again, what is lacking is a number of carefully documented case studies of such applications, measuring the costs and benefits of driver training, improved maintenance, and conservation devices.

Energy conservation measures in rail, marine, and air transport have also been proposed (FAA, 1978, 1979, 1982; Argonne Matrices Work), implemented, and proven successful. Of these aviation is the largest energy consumer. Operational strategies such as optimal cruise speeds and flight planning have been implemented by the airline industry (Schooley, 1981). A great deal has changed, however, since airline deregulation and it is probably time to reevaluate the potential of improved air traffic control, improved maintenance and other operational procedures under today's operating conditions.

5.3 A RESEARCH AGENDA

The above review points up the need for carefully documented case studies of energy conservation measures which measure their energy savings, other costs and benefits, and identify the factors influencing their success or failure.

Such case studies would serve two important purposes. First, they would help avoid wasteful attempts to save energy by ineffective methods and allow individuals to direct their attention to techniques of proven effectiveness. Second, well documented case studies would help in the marketing of ridesharing, driver training, and other programs by public agencies. Rigorous evaluations are most needed in the area of driver training for improved fuel economy, especially the retention of knowledge and continuation of practice over time. More documentation of the factors influencing success and failure and measurement of energy savings and other costs and benefits are needed in all areas to permit intelligent decision-making by public agencies and private individuals alike.

6. ALTERNATIVE TRANSPORTATION FUELS

6.1 THE ISSUE

Diminishing domestic petroleum production combined with the transportation sector's continuing dependence on petroleum inevitably results in a growing dependence on oil imports. To escape this result, the nation must substitute alternative fuels for petroleum. The key questions are when, to which alternative should we turn, and what role should government play?

Because of imperfections in the world petroleum market, the subject of when and how to introduce alternative transportation fuels needs to be addressed. The concentration of petroleum resources in a few, often politically unstable, countries leads to politicized and erratic petroleum prices; the resulting uncertainty discourages investments in research, development, and commercialization of new energy production processes and in end user technologies. The uncertainty also discourages consumers from purchasing non-petroleum vehicles even when they are economically superior choices. Without government intervention, the transition may be further slowed by the interdependent, but uncoordinated nature of energy production, fuel distribution, and vehicle manufacturing activities -- that is, by the "chicken-and-egg" syndrome of reluctance of fuel producers and marketers on the one hand, and motor vehicle manufacturers on the other, to risk the initial investment in a substantial innovation (Sperling, 1984). In summary, waiting for market forces to direct the transition could be disruptive and highly inefficient.

The transition to non-petroleum fuels is not an exotic or unique situation. Already, several countries with insufficient petroleum resources have initiated such transitions. Over 11% of New Zealand's light duty vehicles now run on natural gas and an additional 33% are running on synthetic gasoline (made from natural gas via methanol). In Brazil over 90% of cars sold since 1983 operate exclusively on ethanol.

While it is clear that a transition to non-petroleum fuels is inevitable, it is not clear what the timing of that transition should be. For example, it is clear in hindsight that Brazil began its transition too soon, but it is also clear that it can be costly to start too late. The inefficiencies in the United States (and elsewhere) of inadequate responses to the 1973-74, 1979, and 1986 price shocks have undoubtedly cost the economy many hundreds of billions of dollars in foregone growth. The availability of a viable alternative fuel would dampen these shocks by increasing the elasticity of the economy's response.

The transition process will be complex. While one fuel now dominates the transportation fuels market, a number of alternatives may be practicable replacements: compressed (and perhaps liquefied) natural gas (CNG and LNG), methanol, ethanol, shale oil, petroleum-like coal liquids, batteries, electrified roadways, and eventually hydrogen. Indeed, natural gas fuels are already cheaper per BTU and environmentally superior to gasoline. Each feedstock-fuel combination may be attractive in particular locations and market niches. The challenge is to make the transportation system more receptive to new fuels and thereby more resilient.

6.2 BACKGROUND

Considerable research has been devoted to developing the knowledge and technologies for producing and using non-petroleum fuels, and much still remains to be done, but at this time at least equal importance must be given to research that addresses which of these options should receive priority and how, when, and where they should be pursued.

Industry is already developing the knowledge to adapt compression and spark ignition engines to alcohol and gaseous fuels and will continue to do so. Ford, General Motors, Toyota, and Volkswagon (and others as well) all have the expertise to market an alcohol or natural gas, light-duty, duty spark ignition vehicle almost immediately. Considerable effort is being expended by diesel engine manufacturers to adapt compression ignition engine technology to methanol and natural gas, motivated principally by the impending (1988) EPA diesel engine emission standards. The Electric Power Research Institute (EPRI), many electric utilities, and various battery manufacturers have invested large amounts of resources in the development and commercialization of electric vehicles.

In the public sector of this country, the U.S. Department of Energy, the California Energy Commission, and others support research into technology development and demonstration. Likewise, the Brazilian and Canadian governments invest considerable resources in engine development and adaptation.

Considerable knowledge has also been generated regarding the feedstocks and processes for producing transportation energy. The necessary scientific and engineering knowledge now exists to produce high quality transportation fuels from coal using indirect liquefaction processes (i.e. to produce methanol or substitute natural gas, or synthetic gasoline from methanol). Direct coal liquefaction processes, which in theory are more efficient than indirect processes, still require considerably more R&D. Improved energy conversion processes to produce liquid and gaseous fuels from biomass, and hydrogen from water are also the subject of various R&D programs, although funding has been severely curtailed in the mid-1980s.

Despite the accelerated research and development of coal and oil shale-based energy production processes in the late 1970s and early 1980s, the most attractive non-petroleum transportation fuel in the near to medium term future (and possibly much longer) will be natural gas from remote areas of the world and, in the U.S., from unconventional geologic formations. Natural gas is being found in much greater abundance than previously expected Moreover, some scientists theorize that natural gas is not of biologic origin and may be naturally occurring and available in practically unlimited quantities (Gold, 1985). Natural gas may be used directly, may be converted into methanol (at additional cost), or may be converted into synthetic gasoline (at still more cost and with worsened pollution characteristics). In general, natural gas and methanol fuels are economically and environmentally superior to petroleum-like fuels produced from oil shale, direct liquefaction of coal, and catalytic conversion of methanol. But natural gas and methanol, as well as ethanol and hydrogen, are not compatible with the existing systems for distributing and using petroleum fuels. Thus, the introduction of gaseous and alcohol fuels (and electric power) will require new and adapted vehicles and fuel distribution systems.

Little research has been devoted to when, where, and how this process of introducing new fuels could or should proceed (Sperling, 1988). Research into the implementation of non-petroleum transportation energy has been sparse and scattered, except for battery vehicles which have received considerable support from the Electric Power Research Institute (Berg et al., 1984; Mader and Bevilacqua, 1985). Little effort has been made to learn from past experience in the U.S. or elsewhere. For example, few studies have examined the introduction of unleaded gasoline (Sperling, 1987) and diesel cars in the U.S. (Comsis, 1986), ethanol in Brazil (Barzelay, 1986; Sperling, 1986), compressed natural gas in New Zealand (Harris et al., 1980; Phillips, 1981), and liquefied petroleum gas in Europe and elsewhere.

To plan a successful transition, it is important to identify market niches for fuels and engines, and to be able to forecast their market potential under different energy and economic conditions. There is a remarkable lack of knowledge, however, of how consumers value (both positively and negatively) the different attributes of new fuels and vehicles. The automobile choice literature is dominated by econometric modeling of a narrow range of attributes, most of which are irrelevant to the purchase of non-petroleum vehicles (Mannering and Train, 1985). The few studies of attributes in the range relevant for non-petroleum vehicles (e.g. driving range) are based on postulated choices (e.g. Calfee, 1985) or extrapolated from survey data of gasoline drivers that were collected for other purposes (Train, 1986). These econometric models do not use revealed preference data and are not clearly tied to behavioral theory.

An especially glaring gap is the lack of knowledge about vehicle fleets, a market niche often cited as the natural first market for new fuels. Existing surveys and studies are old (Wagner, 1979; Shonka 1980), incomplete (Berg et al., 1984), and do not address the decision-making process of fleet managers.

6.3 RESEARCH AGENDA

What is lacking is a knowledge base for determining which options are attractive and how to go about introducing them in a timely manner at minimal cost to government, to the nation, and to the world economy and society. A list of important and unresolved research questions follows:

I. <u>Which fuels are most economically, environmentally, and politically attractive to society and most acceptable to the consumer?</u>

* What are the national security effects of replacing petroleum imports with natural gas or methanol imports?

* If, as mounting scientific evidence indicates, the "greenhouse" effect is a serious and real threat, what are the energy implications for the transportation sector?

* What is the value of air quality benefits derived from of using methane, alcohols, hydrogen, battery, and electrified roadways, for applications in light duty spark ignition vehicles, urban transit buses, and diesel trucks?

* How do consumers value the different attributes associated with different fuels and engines? For instance, how much less must natural gas fuel cost to offset the lower power and shorter driving range of a natural gas vehicle? A better understanding of consumers' evaluation of alternatives will help answer a host of policy and planning questions.

II. <u>What is the appropriate role of government?</u>

* What roles have governments played previously in introducing new vehicles and fuels in the U.S. and in other countries?

* What regulations inhibit the introduction of new fuels and engines (e.g., emissions testing, fuel quality, safety, anti-trust rules against inter-industry collaboration)?

* What incentives could be provided to vehicle operators and fuel marketers, and what would their effect be?

III. <u>What planning is desirable for a transition to alternative fuels and when should it begin?</u>

* What government actions would be most effective, inexpensive, and acceptable for initiating a transition (see Gray and Alson, 1986; McNutt and Ecklund, 1986)?

* What are the economic costs to the nation of initiating a transition too late, or too soon (see Mellon, 1980; OTA, 1982; Binkley et al., 1983; Santini, 1986)? What effect would the development of a viable non-petroleum alternative have on world petroleum prices?

* How do vehicle fleet managers and owners value the different attributes associated with different fuels and engines? Under what conditions would a fleet owner purchase non-petroleum vehicles? Which types of fleets are more likely to purchase a non-petroleum vehicle?

* What problems are caused by a limited network of retail fuel outlets and what can be done to reduce this obstacle to transition (Sperling and Kitamura, 1986)?

* Are there effective policies and actions which can reduce consumer and industry uncertainty?

* How will international energy markets and alternative fuels policies affect the transition in the United States?

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