Urban Transportation Planning Under Energy Constraints

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Current knowledge concerning the impact of limited fuel availability on urban travel behavior is reviewed, and the application of this information to urban transportation planning is discussed. The 1973-1974 oil embargo is viewed as a short-term perturbation in the energy-transportation system that resulted in temporary changes in travel behavior. Short-range energy contingency planning can benefit most from the knowledge gained during this period. Energy contingency planning should emphasize non-capital-intensive policies that can be easily and quickly implemented to conserve fuel. The information gained during the embargo does not appear to be directly applicable to long-range urban transportation planning under energy constraints. Long-range urban transportation plans do not appear practical at this time because of the lack of information concerning the impacts of fuel availability on travel and living patterns. It may therefore be more beneficial to develop plans that have the flexibility to include this information as it becomes available. A standardized definition of fuel availability should be determined, and a mechanism for capturing fuel allocation and consumption statistics on a disaggregate level should be established. Trends in the attitudes of consumers toward the energy situation and transportation-related behavioral changes that result from these perceptions should also be monitored.

Since the 1973-1974 oil embargo, there has been considerable interest in national energy futures and in the analysis of the sensitivity of transportation-related energy consumption to alternative transportation and land-use policies. Much of the current literature is devoted to the review and analysis of strategies to reduce automobile fuel consumption in urban areas where approximately 34 percent of total transportation-related energy consumption occurs. These trips account for approximately 98 percent of the fuel consumption for urban passenger travel and approximately 92-95 percent of total vehicle person trips (1).

Traditionally, the urban transportation planning process has not dealt with the availability of fuel. Before the embargo, there appeared to be little need to develop urban transportation plans or strategies to cope with this possibility. Since the embargo, however, and after analysis of its impacts on urban travel behavior, planners have begun to reevaluate the urban transportation planning process in light of dwindling worldwide oil reserves.

IMPACT OF THE OIL EMBARGO ON TRAVEL DEMAND

The energy shortage of 1973 and 1974 did not last long enough for an evaluation of the long-term impacts of a reduction in fuel supply on travel behavior to be made. From the studies conducted, however, several general statements can be made about the short-term impact of the embargo on individual travel patterns.

The propensity for an individual or a household to change travel behavior under energy constraints appears to be most heavily influenced by income (2-5). In general, higher-income groups have more flexibility in their travel behavior and are more willing to absorb the increased cost of work-related travel without changing travel modes. They tend to conserve fuel by reducing the amount of discretionary travel. The emphasis on conservation is placed on shopping or social-recreational travel through the implementation of "trip chaining".

Lower-income groups generally have less travel flexibility, make fewer discretionary trips, and thus are more inclined to make adjustments related to work travel in an effort to conserve fuel. In the 1973-1974 embargo, this group was the most likely to shift to alternative modes of transportation and was also more likely to retain their changed travel patterns when the embargo was over.

Several other parameters, some of which are related to income level, also appear to have influenced travel decisions during the embargo. These include family size, automobile ownership, education and occupation of the head of the household, location (urban, suburban, or rural), city size, and the level of service of public transit.

Heads of households that have high gasoline price thresholds (i.e., the perceived price per liter of gasoline that would create a significant change in travel behavior) generally have an annual income of more than $15 000, are fairly well educated, and would rather pay higher prices for gasoline than have gasoline rationing. In contrast, houshold heads with low gasoline price thresholds earn less than $15 000/year, have lower education levels, and prefer rationing to substantial gasoline price increases (4).

Those families most likely to switch from the automobile to another travel mode are described as having three or more members and two or fewer automobiles, living in an urban area, and having an annual income of less than $15 000. The household head is over 30 years old and employed as a white- or blue-collar worker. Those most likely to drive their automobiles less frequently are described as families in cities of more than 25 000 population and whose heads of household are employed in managerial or professional positions. Those most likely to retain their new behavior patterns were families with three or more members, one automobile, and an annual income of less than $10 000 who lived in a city with a population of 2500 or more (2). Although the higher-income groups did not tend to change travel mode during the embargo, one study (3) showed that there is a high potential for a shift to transit for the work trip for this group provided an adequate level of service is supplied.

Analyses of changes in traffic volume during the embargo in various parts of the country (6-10) have led to the conclusion that most efforts to conserve fuel were made through the nonwork trip. The largest percentage change in traffic volumes occurred on weekends in both urban and rural areas. Lee (6) suggests that the larger relative reduction in leisure trips was caused in part by the greater uncertainty of obtaining fuel for these trips and may not reflect a simple priority ranking of trip purposes.

In some of these same studies (6, 9, 10), the availability of automotive fuel was found to be a much more important factor in determining travel demand than the actual retail price. The elasticity of demand in relation to price appears to vary with trip purpose, but it is small (-0.1 to -0.5) for all types of trips. This is true at least for the range of prices studied. The impact of the availability of fuel also appears to vary by trip purpose, but only one study has attempted to quantify this differential. Lee's analysis (6) indicated that weekday trips in California were more sensitive to increases in gasoline price than weekend trips (-0.263 versus -0.174). However, the percentage reduction in leisure travel was greater than that in work travel because the uncertainty of obtaining fuel on weekends made the "true" price of leisure travel more than twice that of work travel.

At this time, attempts to restructure the urban transportation planning process to accommodate the impacts of energy constraints can only be calibrated against information obtained during the oil embargo. This may ultimately prove to be unsatisfactory since the long-term response to energy constraints may not be the same as the short-term response.

PLANNING FOR ENERGY CONSTRAINTS

Hartgen (11) has evaluated the capability of urban transportation planning system (UTPS) procedures to deal with energy constraints. He concludes that the UTPS process can be used to determine the sensitivity of fuel consumption to certain energy policies (e.g., speed reductions, increased vehicle efficiency, and carpooling). However, the process is generally incapable of analyzing the impacts of policies such as rationing or bans on Sunday driving.

By using calibrated models from UTPS and other transportation planning packages, the impacts of certain energy policies on travel behavior can be estimated through sensitivity analysis techniques. There appear, however, to be some basic pitfalls in using the results of sensitivity testing to evaluate policy decisions. The individual and aggregate behavioral response over the long term may not be identical to the short-term response. In addition, the required policy actions may require limitations on fuel or the price of fuel to exceed the range of the values used in model calibration. For example, increasing automobile occupancy for the work trip to approximately 2.0 passengers/vehicle on the average would yield significant energy conservation results. It has been reported, however, that the estimated maximum national average automobile occupancy obtainable through carpool incentives is between 1.4 and 1.7 passengers/vehicle (12). Sensitivity tests may yield unrealistically high estimates of the fuel conservation advantages of carpooling.

In well-established urban areas, where the largest gains in fuel consumption can be made, implementing policies to redistribute urban activity may be extremely difficult because of the high potential for social, economic, and political pressure to maintain existing living, working, and shopping patterns. Controlling the location of new growth to conserve fuel may be possible, but the energy saved by such action in the nation's standard metropolitan statistical areas (SMSAs) would be insignificant compared with the energy consumed in existing living and travel patterns.

Another significant deficiency in sensitivity testing is the lack of available information on the combined effects of two or more policies. During a fuel reduction period, several energy conservation policies may be required simultaneously. A review of the energy conservation potential of urban mass transit conducted by the congressional Office of Technology Assessment (OTA) suggests that the most effective ways of accomplishing energy conservation "involve emphasis on disincentives to auto use coupled with transit use incentives" (1). Sensitivity analyses on existing models could only detect these combined effects if the cross elasticities were known or assumed.

There is little quantitative information available by which to test the results of sensitivity analysis. This is especially true for an environment of restricted fuel availability. Current capabilities for testing the sensitivity of fuel consumption in urban passenger transportation to specific conservation policies, either individually or in combination, are based on relations developed during periods of unlimited fuel availability. The question that arises is, Do these relations apply to environments of restricted fuel availability? A definitive answer is not available. It could be argued, however, that limited fuel availability is in itself an inducement to conserve and so travelers would be even more sensitive to conservation policies during a fuel shortage. Relations developed based on nonshortage system changes would therefore yield conservative estimates during a period of shortage.

To effectively use the UTPS or similar procedures for planning purposes, the planning process will have to be restructured to include better recognition of the impacts of national energy futures on urban mobility. Only in this way can the effectiveness of specific energy conservation policies be determined. Particular attention should be given to the effect of fuel availability on trip generation, distribution, and mode choice at the urban level. The long-range impacts of reduced fuel availability and conservation policies on land-use distribution should also be determined.

Several attempts have been made to evaluate such future impacts by indirect methods. These have generally taken the form of projections of various levels of transportation demand by mode with forecasts of energy consumption for alternative future transportation technologies. Several of these studies attempt to describe the cause-effect relation between supply and demand.

One attempt to quantify this relation was developed by OTA (1). A log-linear regression analysis that used national data for 1971 to 1974 generated a relation between the annual growth rate in transit patronage and the annual growth rate in vehicle kilometers of highway travel. Alternative future national levels of fuel consumption were then translated into annual growth rates in vehicle kilometers of highway travel by using assumptions as to the future proportion of available petroleum that would be used as fuel for highway travel and the average fuel economy of highway vehicles. Growth rates for vehicle kilometers of highway travel were then used to forecast future transit patronage under each energy alternative. Although this represents one attempt to formulate a relation between supply and demand, it assumes that the historical relation between transit and highway travel will prevail under all conditions of fuel availability.

Beltrami and others (13) propose an analysis technique that is not constrained by this assumption. Most significant in their approach is their incorporation into the automobile trip interchange forecasting technique of the delay experienced by motorists as they search and wait for gasoline. In incorporating the availability of fuel into the automobile time parameter, however, assumptions are made that this delay is equally distributed across all types of trips and that it has the same significance for all automobile trips as a reduction in travel speed. These assumptions are not substantiated.

The controlling variable may in fact be the degree of the limitation of fuel availability. Fuel availability has been identified as the variable that was most influential in causing changes in travel behavior during the oil embargo. But fuel availability has not yet been quantitatively defined. Quantification of this parameter and its relation to travel behavior appears to be an essential ingredient in the restructuring of the urban transportation planning process to forecast future travel behavior under energy constraints.

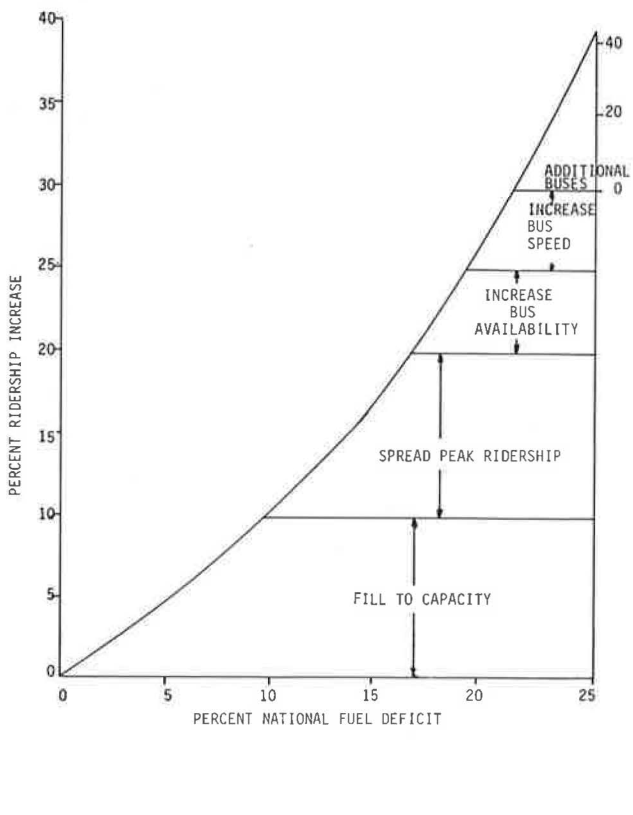
The limited available information on the impact of fuel availability on urban travel all resulted from the short-term 1973-1974 perturbation in the energy-transportation system. The applicability of this information to long-term planning is doubtful. Since the oil embargo was perceived by the general public as a temporary situation, the actions taken to reduce travel may also have been viewed as temporary. For example, while total purchases of automobiles fell sharply, no shift to smaller automobiles was observed (14). Smaller, more efficient automobiles might be an attractive alternative in a long-term environment of restricted fuel. It takes time for many automobile purchasers to reach this conclusion and act on it. The oil embargo was too short to allow for such long-term adjustments in consumer behavior, so analysis of the changes that occurred in that period would not necessarily apply to long-range planning.

Another difficulty with applying information gathered from the oil embargo to long-range planning is that most long-term policies that would reduce energy consumption were not implemented. Thus, no empirical evidence exists to evaluate their impacts. The effects of improved technology, changes in transportation systems, and shifts in land-use activity can only be speculated on. It may therefore be necessary to develop two different approaches to planning under energy constraints—one for short-term planning and one for long-term planning.

Short-Term Energy Contingency Planning

A short-term embargo-type shortage will be characterized by a duration of from several months to possibly one or two years. The availability of gasoline will be

Figure 1. Effect of increases in ridership on bus use in the Dallas transit system.



sharply curtailed, but public and private decisions will be based on the assumption that fuel supplies will return to normal at some future date. There will probably be another rapid increase in the price of gasoline and, as before, there will be temporary changes in travel behavior. In general, the picture will be very similar to the embargo of 1973 and 1974.

Planning for the short-term fuel shortage should stress policy alternatives that can be applied easily and quickly and yield significant results. Short of rationing, such policies could include

1. Stronger enforcement of lower speed limits;
2. Carpooling and vanpooling with or without priority lanes;
3. Automobile disincentives such as driving bans and increased parking charges;
4. Transit incentives such as reduced or free fares and service improvements within the limits of system capabilities;
5. Rerouting or rescheduling of bus fleets to increase system efficiency; and
6. Efforts to reduce congestion, such as staggered work hours, a four-day workweek, and time-differential transit or parking fees.

Sensitivity analysis is useful in evaluating the potential energy conservation effects of these policies, but it should be limited to the feasible range of values of the independent variables. A priority plan that rank orders the potential impact of each of these measures, individually and in combination, should be developed and tested for each urban area through the use of UTPS or some similar package. Figure 1, which represents such a priority system for Dallas, Texas, shows the percentage of national fuel deficit at which speculative increases in transit ridership would occur and describes the order of policy implementation and the projected limits of increased capacity in Dallas (15). If the fuel deficit exceeds 10 percent (the level during 1973 and 1974), action other than using the space on existing transit runs will be necessary. Policies for spreading peak ridership that could be tested by UTPS include staggered work hours, shorter workweeks with variable days off, and flexible work hours. If the next set of actions is required, the options that could be tested include maximizing availability of the current bus fleet by increasing the maintenance budget, reducing the number of out-of-service buses, and shifting buses to lines that experience the greatest increases in ridership. Finally, methods for increasing bus speed that can be tested include designation of bus-priority lanes, signal preemption, or the increased use of express service. Increasing the fleet size through the purchase of new vehicles is not generally feasible in the short term because of the capital investment required and the time needed for purchase and delivery (one to two years).

In short-term energy contingency planning, emphasis should be placed on

1. Analysis of the relations between fuel supply and travel demand detected during the oil embargo,
2. Analysis of disaggregate travel behavior characteristics and attitudes during the embargo, and
3. Non-capital-intensive policies to conserve fuel.

With or without rationing, the public will be required to adjust their travel behavior based on reduced availability of fuel. It is important to analyze the knowledge gained during the 1973-1974 embargo with respect to the impact of fuel availability on travel behavior so that it can be applied in short-term contingency planning. This may not be a simple task because much of the information that would be useful does not appear to be available. As part of a research effort at Michigan State University, agencies in the 36 states that contain the 79 largest SMSAs and the District of Columbia were surveyed in an effort to collect county-level data on gasoline consumption or availability for the period 1972 through 1975. Only nine respondents indicated that the information was available either directly or indirectly through tax reports. The remainder (four states did not respond) indicated that the information was available only on an aggregate statewide basis and that there was no method of obtaining this information at the county level.

Another important aspect of contingency planning is understanding the impact of policy decisions on travel behavior and hence on energy consumption. Care must be taken not to be misled by sensitivity analyses that indicate that particular policy measures will yield significant results based on unrealistic assumptions about induced changes in travel behavior. Potential gains that were to result from a shift from the private automobile to public transit during the fuel shortage were generally overestimated.

Long-Term Planning

A long-term decline in the availability of fuel is characterized in much of the literature as a gradual annual decline in fuel availability over the next 20 years and beyond (1, 16, 17). Because the actual rate of decline is difficult to predict, speculation often centers on two or more possibilities and the ramifications of each. This slower rate of decline in the availability of fuel will be accompanied by changes in transportation technology, probable shifts of financial resources to nonhighway modes, longer-lasting adjustments in societal attitudes and behavior, and shifts in land-use pattern (17).

Modification to the long-term planning process should stress the more basic changes in the structure of cities and transportation systems. The effect of the transportation system on long-term changes in land use and travel behavior must be better understood. Sensitivity analysis may be helpful in this respect but only as a guide on which direction will yield the greatest return for the investment. Conclusions reached by sensitivity analysis will be suspect because the reaction of travelers to an extended fuel shortage will most likely be different than it was during the 1973-1974 period. Therefore, the empirical data collected during that shortage will not necessarily be valid for long-term planning, and the relations developed from those data should not be extrapolated. On the other hand, the use of purely theoretical relations is suspect because of a lack of knowledge about long-term patterns of human behavior, especially in environments we have never encountered.

Many of the policies discussed for energy contingency planning may also be applicable in the long term. It is more realistic, however, to assume that the gradual nature of the decline in the availability of fuel will be accompanied by policies that will seek parallel improvements in the transportation sector. Such policies include

1. Encouragement of improved technology, such as more efficient automobiles and use of alternative fuels in the transportation and industrial sector (this would include the advancement of the electric automobile);
2. Transportation system changes, including improved transit systems, and automobile-free zones and restricted traffic zones;
3. Redistribution of urban activities, including more efficient settlement patterns, higher density, and more efficient patterns of work location (this would result in shorter work trips and allow for transportation system changes to improve levels of transit service); and
4. Long-term rationing programs if the decline in fuel availability is too rapid for the other measures to keep pace.

At this point, almost nothing can be stated as fact concerning the impact on travel patterns of a long-term decline in the availability of fuel. The consumer will undoubtedly attempt to maintain maximum mobility within the limits of fuel availability. Traditional long-range planning has relied on past experience with growth and travel patterns to forecast future needs. Comparable data for planning under energy constraints are simply not available at this time. The results of contingency planning cannot merely be extended because the assumptions on elasticities may not be valid.

To meet the future need for long-range planning under energy constraints, the framework for such planning should be established now. A procedure to capture data on fuel allocation and consumption at a disaggregate level should be developed and a standardized measure of fuel availability determined. This information can be collected by each state, but federal coordination may be required to ensure consistency across all geographic areas.

A program to monitor trends in consumer behavior and in the public perception of the pending decline in the availability of fuel should also be initiated. Regional attitudinal surveys could help to determine public perception of the future availability of fuel. These perceptions should then be correlated with consumer behavior patterns as a guide to potential future modifications of behavior. For example, changes in automobile-buying behavior or in mode choice related to consumer attitudes on energy might reflect public perception of the energy future.

CONCLUSIONS

The urban transportation planning process will require some changes to adequately reflect the impact of fuel availability. The impact of the oil embargo of 1973 and 1974 has given rise to a new planning tool—the urban transportation energy contingency plan. The problems that were encountered during the shortage and the possibility of a reoccurrence suggest that such plans should be developed for every major metropolitan area. These contingency plans should describe policy options and realistically assess the energy conservation potential of each individual policy and policies in combination. These should be comprehensive, regional, multimodal action plans that can be easily implemented in an emergency.

The basis for long-term planning needs reevaluation. Current 20-year plans based on past trends in growth and travel may not be valid. The information obtained from the impacts of the oil embargo does not appear to be of much value in updating these plans. The planning process must be redefined to include the effects of long-term limitations on the availability of fuel as this information becomes available. The framework for capturing the necessary data should be established now. Future long-range plans will need to be reevaluated and updated periodically so that new information on behavioral patterns and policy impacts can be integrated. It may prove to be more beneficial to develop mid-range (5- to 10-year) plans that can be updated easily as more information becomes available.

A standardized definition of fuel availability and a method for capturing data on fuel allocation and consumption at a disaggregate level need to be established. This information should be coordinated with data on long-term public perceptions of, and reactions to, the future transportation-related energy environment.

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Redevelopment of a Comprehensive Approach to Urban Transportation Planning

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An attempt is described that is under way in southeastern Wisconsin to convert the conventional urban transportation planning process into a more problem-centered planning process, one that considers and integrates short-range and long-range considerations and comprehensively examines alternative facility and systems management solutions. The key to this improved planning process is the use of a new short-range transportation system plan in place of the conventional short-range transportation systems management plan. The new plan would be aimed at existing and short-range problems. Alternative solutions to be considered would include management and operational actions as well as facility improvements as staged and recommended in the long-range plan. The recommendations of the short-range plan should be appropriate for direct inclusion in the transportation improvement program. The short-range transportation planning process and its relation to long-range transportation planning, the steps that have been taken to apply the process, and some of the general principles used in developing the new short-range plan are discussed.

Urban transportation planning has undergone radical change in the past 10 years. Witness the list of acronyms of newly required or increasingly regulated urban transportation planning documents: TSM, TIP, LRP, AA, EIS, and TDP. Some believe these changes have led to necessarily fragmented urban transportation planning. The urban transportation planning process that has evolved is most commonly composed of a number of planning elements, each of which is largely considered separately from, and is not strongly related to,