Energy Analysis for Urban Transportation Systems: A Preliminary Assessment

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This paper discusses and evaluates the capability of conventional urban transportation planning system (UTPS) procedures in dealing with energy issues. Central energy-related issues for planning are identified as (a) re-evaluation of long-range plans, (b) modal alternatives, (c) investment needs, and (d) funding flow. The UTPS process is capable of dealing quite well with certain energy policies (e.g., speed reductions, increased vehicle efficiency) but generally is a weak tool for addressing other policies (e.g., rationing, Sunday driving bans, urban activity redistributions). Generally the sensitivity analysis capability of UTPS appears stronger than its ability to predict actual impacts. Specific information on gasoline price elasticity of travel by trip purpose, as well as trip priorities, would greatly increase the predictive power of the system.

One of the immediate effects of the energy crisis of the winter of 1974 was its impact on urban and intercity travel. As the energy crisis evolved through early 1974, certain travel patterns changed markedly while others changed only slightly. Most individuals and households appeared to have taken some steps to conserve energy and fuel in travel (1, 2, 3), but travel gradually returned to 1973 levels after the critical period was over.

In addition, shifts in travel behavior were not entirely as anticipated. Although transit ridership increased sharply in early 1974, some of this gain declined as the crisis subsided; thus urban transit appears not to have benefited substantially from the energy crisis. Rather, evidence suggests that people took more multiple-stop trips and perhaps patronized larger storage closer to home, particularly in nonwork travel. Car pooling was considerably less effective than had been anticipated. However, the sequence and ordering of these and other steps appear to be somewhat different for different income levels. Generally shifts in travel behavior appeared to have involved personal actions taken by individuals and their immediate households, rather than actions involving the social contact of individuals with other families.

The 1974 crisis also reoriented the process of transportation planning and investment decisions. For example, the distinct possibility (perhaps inevitability) of reduced fuel availability and significantly higher fuel prices in the future has raised basic questions concerning the relationship of future travel to energy constraints. This brings into question the appropriateness of large investments in new transportation facilities that may never be used to capacity and further highlights the importance of including energy considerations in a formal and quantitative manner in long-range transportation planning.

Short-range planning has also been affected, inasmuch as the immediate impact of a reduction in travel during a crisis would be a sharp reduction in revenues from fuel taxes and tolls. Because reductions in transportation program funds would become real if an energy crisis were to occur again and continue for more than a few years, the entire issue of appropriate funding sources for transportation investments is brought into question. Because many state transportation funding agencies, as well as the federal government, use fuel taxes as a revenue source, reduced availability of these funds would greatly increase the competition among possible improvements and would probably hamper the completion of needed transportation projects. If state funds were to fall, significant losses of federal funds might also ensue, with the result that difficult decisions concerning the priorities of transportation investment proposals would have to be made.

That the transportation planning profession was generally not well prepared to deal with these issues is well evidenced by the inability of the profession to address revelent issues during the 1973-1974 energy crisis and issues ensuing from it. While most professionals were generally able to surmise the impact of alternative policies on travel, they had very little hard information available on which to make accurate predictions of policy effects. In a particularly important area, the priority and sequencing placed on trips by households, projected energy-related actions did not occur according to conventional theory; unexpected travel shifts were observed.

This may have been anticipated to some extent, since transportation planning techniques evolved during the 1950s and 1960s, when the possibility of fuel shortages

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Table 1. Energy policy testing with UTPS.

Policy	Key UTPS Stages	Other Essentials Elements	Short-Term Forecasts: Sensitivity	Short-Term Forecasts: Estimate	Current Testing Capability
Speed reductions	Distribution (nonwork), modal split	–	H	L	Good
Increased vehicle efficiency	Assignment, evaluation	Gasoline use calculator	H	–	Good
Transit fare reductions	Distribution, modal split	–	H	M	Good
Car pooling	Automobile occupancy	–	H	L	Medium
Increased parking charges	Distribution, modal split	–	H	L	Medium
Tax on gasoline	Generation, distribution, modal split	Gas price elasticity	M	L	Medium
Staggered work hours, 4-day workweek	Generation, modal split	–	M	L	Medium
Transit use increase due to gas price increase	Modal split	Gas price forecast, elasticity	M	L	Medium
Automobile-free zones	Distribution, modal split	Redistribution activities	M	M	Fair
Gas price increase (general)	Generation, distribution, modal split	Gas elasticity by trip purpose, disposable income reallocation	M	–	Poor
Gas price in relation to consumption	Generation, distribution, modal split	Selective trip priorities and frequencies	M	L	Poor
Fixed ration ceiling	Location, generation, distribution, modal split	Trip priorities	M	L	Poor
Sunday driving ban	–	Weekend travel patterns and behavior	L	L	Poor
Urban activity redistribution	Land use activity	Long-term elasticity, redistribution of activities	L	L	Poor

Note: L = weak test is possible, M = some elements possible, and H = test can be done.

or price increases that would influence travel demand, and subsequently the need for transportation investments, was to most professionals remote at best. Only a handful of long-range transportation plans prepared in the 1960s gave more than lip service to the possibility of energy constraints in the future. And analysis of travel forecasting and evaluation techniques shows generally a paucity of procedures that are sensitive in any real sense to energy policies, particularly reduced fuel availability. The logical conclusion, then, is that, generally speaking, transportation planning and the projections made therefrom are not energy sensitive.

Fortunately, this situation is not irreversible. Transportation planning processes in most metropolitan areas are entering the continuing phase, in which, during the next 10 years, plans developed earlier will be reevaluated and perhaps rescaled, based on monitoring and surveillance of key travel parameters. This next round of plans should give considerably more emphasis to energy issues than did the previous round.

ENERGY ISSUES FOR TRANSPORTATION PLANNING

Energy issues that are likely to require consideration in the continuing transportation planning phase fall into three general areas:

1. Modal evaluations,
2. Systems plan reevaluation, and
3. Investment needs and funding.

The role of more energy-efficient modes, particularly urban bus transit, needs to be more carefully considered. Although urban transit is seldom justifiable from a benefit-cost viewpoint, the inclusion of energy considerations in an evaluation of modes may greatly change the picture.

Systems plans developed earlier must be reevaluated in light of energy constraints, and projections revised to account for probable energy-constraint futures.

If travel projections are rescaled downward, many questions about investment needs and funding must be answered: How will investment requirements be affected? What are the most reasonable investment needs under energy constraints in the future? What is the role of gasoline availability and price in influencing investment policies? Are project priority-setting methods capable of filtering out those projects that are most valuable under energy constraints.

POLICY OPTIONS

The ability of long-range transportation planning to address energy issues must be evaluated against the policies likely to be studied in the next few years. The following is a partial list:

1. Encouraging better and wiser use of existing vehicle fleets—These policies include actions such as car pooling that result from priority analysis by households of their travel requirements, gas taxes, rationing policies, and driving bans such as the Sunday driving ban. In all of these policies the objective is to encourage the driving public to use existing vehicles in a more efficient manner.
2. Improving the gas consumption efficiency of vehicles—Examples are speed reduction policies and improvements in vehicle engines.
3. Shifting travel demand in time so that peak loads are spread out, congestion is eased, and operating efficiency is improved—Increased parking charges by time of day, staggered work hours, 4-day workweeks, and differential transit fares could effect such shifts.
4. Inducing modal shifts—These policies include transit fare reductions and service improvements, increased parking charges, taxes on gasoline, gasoline price increases, and gas rationing.
5. Redistributing urban activities—Such policies include automobile bans, redistributions of urban activity locations, particularly work, and more efficient settlement patterns.

CAPABILITY OF PRESENT URBAN TRANSPORTATION PLANNING SYSTEM TECHNIQUES

Which policies can reasonably be evaluated with currently available long-range transportation planning procedures? Before this question can be answered, a distinction must be made between estimating the actual impact of a given policy and measuring the sensitivity of travel to assumed levels of a given policy. For instance, if a policy on car pooling were implemented, it would be difficult, if not impossible, to forecast exactly how much of the traveling market would form car pools (i.e., how much automobile occupancy would change for work trips). But it would be relatively easy to test the sensitivity of gasoline consumption to changes in automobile occupancy. For many of the policies listed, it is possible to determine the sensitivity of energy consumption to an assumed change in travel, but it is quite another matter to estimate the change in travel that would occur if such policies were actually implemented.

Generally, the present conventional urban transportation planning system (UTPS) process more adequately addresses questions concerning sensitivity than questions concerning estimates. Data given in Table 1 show how short-term (1 to 5 years) travel forecasts for specific energy-related policies can be made through the UTPS process. An analysis of the table leads to the following general conclusions.

1. Certain policies can be tested adequately with the present process. These include policies on speed reductions and increased vehicle efficiency.

2. Policies concerning transit fares, car pooling, increased parking taxes, and taxes on gasoline can be tested with reasonable confidence. Information concerning gasoline price elasticity would greatly increase predictive skills in these areas. Although evidence is slowly accumulating that gasoline elasticity over the short term is very low (on the order of -0.1), we need to know considerably more about this phenomenon in order to make headway in the transportation analysis area.

3. Policies concerning general price increases or rationing schemes, as well as Sunday driving bans and urban activity distributions, appear to be beyond the capability of UTPS at this time. The primary reason for this is that there is a paucity of data on the probable impacts of such policies on household redistribution and its effect on trip sequencing and frequency. A parallel problem involves knowledge about the flexibility of disposable household incomes to pay more for available gasoline.

Table 2. Parameters affected by the energy crisis and their input to the simulation system.

Policy	Parameter and Direction of Effect	Input to Transportation Simulation Model
1. Speed change	Lowered speeds	Change speed limits on selected links
2. Car pooling	Increased automobile occupancy	Lower number of trip ends for selected purposes
3. Diversion to transit	Decreased automobile trips	Lower number of trip ends for selected purposes
4. Priority ranking of work and shopping trips	Decrease in either category relative to other	Lower number of trip ends for selected purposes
5. Trip length	Shorter trips	Adjust trip time values downward for shopping trips

Note: Item 1 is the expected effect of lowering the speed limit; items 2 through 5 are the expected effects if either the price of fuel rises dramatically (tax or free market price or both) or gasoline is rationed.

SENSITIVITY ANALYSIS

Table 2 gives a number of key parameters in the UTPS process and the way in which they might be input into a conventional UTPS model to determine energy impacts. Several tests have been made by the New York State Department of Transportation: (a) an 80-km/h (50-mph) speed limit, (b) a 15 percent reduction in work trips, and (c) a 30 percent reduction in work trips.

Results of these tests are given in Table 3. They demonstrate, as expected, that an 80-km/h speed limit (Rochester, New York, test area) would not decrease vehicle-kilometers of travel very much but would save approximately 2 percent in energy over a typical day.

Table 3. Sensitivity analysis of urban area energy policies.

Policy	Test Parameter	Comparison Base	Item	Percentage of Change
80-km/h speed limit	80-km/h maximum speed, redistribution of nonwork trips	1973 speed limit	Total cost/km of travel	+2.2
			Operation cost/km of travel	-3.1
			Accident cost/km of travel	+4.3
			Total	+3.8
			Vehicle-km of travel	-1.6
			Vehicle-h of travel	+2.0
			Speed	-3.7
			NO_x	-3.6
			HC	-0.2
			CO	+1.2
			PM	-1.6
			Fuel use	
			Liters	-2.1
			km/liter	+0.5
Car pooling, diversion to transit	15 percent reduction in work trips	80-km/h test	Total cost/km of travel	-2.5
			Vehicle-km of travel	-6.0
			Vehicle-h of travel	-9.0
			Speed	+3.5
			NO_x	-6
			HC	-7
			CO	-7
			PM	-6
			Fuel use	
			Liters	-6.3
			km/liter	+0.3
Car pooling, diversion to transit	30 percent reduction in work trips	80-km/h test	Total cost/km of travel	-4.5
			Vehicle-km of travel	-13.2
			Vehicle-h of travel	-18.2
			Speed	+6.2
			NO_x	-13
			HC	-14
			CO	-15
			PM	-13
			Fuel use	
			Liters	-13.3
			km/liter	-0.2

Note: 1 km/h = 0.62 mph; 1 liter = 0.26 gal; 1 km/liter = 2.35 miles/gal.

Travel would (in theory) be shifted from expressways to the local street system. On the other hand, a 15 percent reduction in work trips would result in about a 6 percent reduction in vehicle-kilometers of travel and approximately the same reduction in total energy consumption. The results further suggest that decreases in gas consumption are approximately linearly related to decreases in work trips.

These three tests demonstrate the utility of sensitivity analysis for long-range planning. Many proposed policies can be translated into UTPS parameters for testing purposes.

NEEDED IMPROVEMENTS

This overview suggests that, while the conventional UTPS process is capable of addressing certain long-range energy questions with reasonable ease, it falls short in making reasonable predictions in a number of key areas, particularly rationing. Some elements that appear to be essential to increasing the ability to plan for long-range energy impacts are discussed below.

Travel Behavior

We need to know considerably more about the ways in which individuals and households will reorganize travel patterns and priorities under energy constraints. Without this information, predicting the sequence and magnitude of responses to a variety of energy constraints would be impossible.

Elasticity of Fuel Supply and Price

Although a considerable number of studies have been done on the question of gasoline price elasticity, data on the relationship of this information to the travel sequencing and priority are particularly scarce.

Location Decisions

We must know a great deal more about the ways in which households and firms make location decisions. In particular, we need to know the influence of energy constraints on such decisions.

Demand Forecasting Procedures

Models are needed that relate travel demand (generation and distribution as well as modal split) to both gasoline price and availability and socioeconomic factors. This may involve the careful structuring of longitudinal studies to obtain sequential information from a panel of households during periods of gasoline price increases.

PROPOSED RESEARCH

Some of these questions can be answered only after (a) appropriate procedures for analyzing energy price and availability in long-range transportation planning have been developed and (b) methods for including energy and fuel factors in transportation programming and budgeting have been developed. The product of the research ought to be a set of procedures fully integrated with existing methods to assist state and local transportation planning groups in preparing, updating, and revising realistic energy-oriented transportation plans. The research should include the following elements.

1. Land use and transportation effects—Procedures for studying the impacts of the fuel shortage on regional transportation demands and land uses should be researched. Based on estimates of travel behavior, demands on existing and planned transportation systems could then be defined. Procedures for studying existing capacities of transportation modes should also be developed to determine the availability of alternate transportation services.
2. Travel behavior—Research should concentrate on procedures for describing travel behavior under energy constraints, particularly with respect to (a) the sensitivity of travel to energy constraints, (b) the sequencing of household actions as a basis for determining the effects of further tightening or loosening of energy constraints, and (c) household priorities placed on travel needs.
3. Demand forecasting procedures—Virtually none of the current demand forecasting procedures available today can handle energy constraints realistically, let alone provide estimates quickly or base such estimates on sound theory. Research is badly needed to develop special procedures for fast-turn-around travel estimates in response to a variety of energy-related policies.
4. Alternatives—The range of alternatives typically considered in long-range planning should be expanded to include energy-reduced options. Methods to identify and describe such options should be developed.
5. Financial data—The effects of gasoline consumption on transportation finance and fund allocations should be determined. Based on current financial sources, an evaluation of funding levels likely for the states under conditions of a fuel shortage should be made. New sources of revenue should be explored that will be equitable to society and that will promote efficient uses of fuel. Advantages and disadvantages (administrative, political, and economic) should be defined for each taxation strategy.
6. Project evaluation and scheduling—Procedures need to be developed for setting priorities and scheduling project proposals. Such procedures should take into account the impact of proposed projects on energy consumption and impact of energy on availability and cost of construction materials.

CONCLUSION

The efficient use of resources for transportation purposes is critical. Until very recently transportation planning and investment operated under the basic assumption of plentiful, almost unlimited, and cheap fuel supplies; fuel conservation played an extremely minor role in planning. Now that the era of cheap energy is over, it is important that these assumptions be revised. This paper has highlighted the use of sensitivity analysis with conventional UTPS tools to address some of these shortcomings. But many basic questions cannot be easily addressed; research is suggested to improve the overall capability of the profession to deal with energy issues.

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