Guidelines To Reduce Energy Consumption Through Transportation Actions

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GUIDELINES TO REDUCE ENERGY CONSUMPTION THROUGH TRANSPORTATION ACTIONS

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EXECUTIVE SUMMARY

This document is intended to serve as an aid to local transportation planners, traffic engineers, and administrators in the incorporation of energy conservation considerations into the transportation planning process, especially in reference to short-range transportation planning. Various types of low cost, short-term transportation actions are summarized, and their potential for reducing energy consumption is estimated. Interrelationships between the energy consumption reduction potentials of groups of actions are discussed, and a process for formulation of coherent packages of such actions is presented. This process takes into account both interrelationships and criteria which may be important to local planners, engineers, and officials.

It should be noted that there are ongoing transportation-related programs in most urban areas. These include short-range transit development programs, traffic flow improvement programs, and transportation programs to improve air quality. Efforts to reduce energy consumption through low cost, short-term transportation actions should take into account actions already planned or being implemented. Development of a package of actions to reduce transportation energy consumption should be coordinated with existing plans and ongoing planning processes of agencies within the urban area.

Transportation actions may reduce energy consumption in one or more of the following ways by:

- Improving efficiency of vehicle operation, such as improving traffic flow on city streets.
- Causing a shift of trips from one or two passenger automobiles to higher occupancy buses, vans, or carpools.
- Reducing travel demand by, for example, instituting the four-day work week.

Individual transportation actions to reduce energy consumption are categorized into ten major groups:

1. Measures to improve flow of high occupancy vehicles

2. Measures to improve total vehicular traffic flow

3. Measures to increase car and van occupancy

4. Measures to increase transit patronage

5. Measures to encourage use of walk and bicycle modes

6. Measures to improve the efficiency of taxi service and goods movement

7. Measures to restrict traffic

8. Transportation pricing measures

9. Measures to reduce the need to travel

10. Energy restriction measures

The transportation actions and their potential reductions in energy consumption are described. In addition, summary tables are presented which array the actions in terms of relevant institutional and legal considerations and socioeconomic and environmental effects.

Guidelines are presented for evaluating and formulating packages of actions to reduce energy consumption. These guidelines set forth the criteria and process for formulating packages for large (1,000,000 and over population), medium (250,000 - 1,000,000 population) and small (50,000 - 250,000 population) urban areas.

Interrelationships between transportation actions are analyzed as a guide to packaging actions. The interrelationships point out actions which work together, are independent, overlap, or are counter-productive in reducing energy consumption. Some of the conclusions of this analysis are:

1. Measures to improve total vehicular traffic flow tend to be counter-productive to most other measures, especially measures to shift travel away from auto modes.

2. Carpooling measures and transit measures may overlap, thus reducing their effectiveness, depending upon the way they are applied.

3. Energy restriction measures and transportation pricing measures have similar effects and may tend to overlap or preempt each other's effectiveness.

4. Taxi service and goods movement-related measures are generally independent of other measures.

5. Traffic restriction measures, transportation pricing measures, and energy restriction measures are disincentive measures which assist the effectiveness of incentive measures such as transit improvements, walk and bike measures, and carpooling programs. At the same time, the incentive measures provide services which take up the travel demand released from low occupancy auto mode because of disincentive measures.

The example criteria used for evaluating the transportation actions for inclusion in an urban area package were:

- Short lead time
- Minimal institutional obstacles to implementation
- Favorable public reaction
- High energy reduction

Using the example criteria and guidelines, three sample action packages were formulated for each urban area size. Some general conclusions may be drawn from examination of the sample packages for all urban area sizes:

- Carpool-related actions are good candidates for implementation in most urban areas, regardless of urban area size or the percentage of energy consumption reduction required.

- Some level of restriction of quantity of sales of gasoline or other energy restriction measures would be likely to enhance the effectiveness of any size package.

- For a low level of energy consumption reduction it may not be necessary to implement both carpooling-related actions and transit-related actions which tend to overlap. Carpooling-related actions were selected for most urban areas because, in general, they may be quicker to implement. However, in many localities some transit improvements might be attainable quickly.

- Incentive-type actions which result in a sizable energy reduction tend to be more effective than disincentive-type actions because they may be expected to encounter fewer problems for implementation.

- Improvements of vehicular traffic flow should be carefully screened because they tend to be counter-productive to reducing energy consumption for several other groups of transportation actions.

- Taxi- and truck-related actions are suggested only in large urban areas, where they are more applicable.

- The energy consumption reduction that can be expected from implementation of a transportation action or a number of these actions depends on several local factors, such as extent of application, institutional and policy framework, existing degree of implementation of transportation control strategies to reduce air pollution, and local attitudes toward energy conservation.

- The total reduction in energy consumption that can be expected from a package of actions is likely to be somewhat less than the sum of the energy reduction ranges given for individual actions in the package. This is because the energy reduction range for each individual action is stated exclusive of other actions. The greater the number of actions implemented, the more the energy reduction potential of an incremental action may be diminished.

The energy reduction packages developed in this document resulting from transportation actions are presented for illustrative purposes only. For a specific urban area, using this process, a different package from any of the samples may be developed. The extent of application as well as level of impact of each action will also vary, depending on local conditions, energy reduction goals, and attitudes toward energy conservation.

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CHAPTER I
INTRODUCTION

The purpose of this report is to examine the possibilities of using low cost, short-term transportation actions to reduce energy consumption and to suggest a process for assembling a package of such actions for an urban area. This document is intended as an aid to local transportation planners, traffic engineers, and administrators in the evaluation of a wide range of possible transportation actions aimed at reducing energy consumption while minimizing implementation problems and adverse social, economic, and environmental impacts. It is also intended to serve as a guide to the formulation of logical packages of such actions and as a reference tool for incorporating energy conservation considerations into the transportation planning process. The need for considering reduction in energy consumption in transportation planning was stated by the Secretary of Transportation on January 3, 1974, with reference to the Emergency Highway Energy Conservation Act of 1973. It should be emphasized, however, that there may be similar transportation programs at the local level (transit development programs, TOPICS, transportation air pollution control plans, etc.) which are presently being planned or implemented. Actions recommended by these programs should be tested for their energy reduction impact and, where their impact is significant, should be incorporated into the local energy reduction plan.

A general problem pervading any discussion of transportation actions is the institutional difficulty associated with implementation of an action. There is seldom an agency which combines the necessary scope of interest, technical capability, authority to act, and capacity for enforcement that are required to make transportation controls effective. As has been learned through experience with planning for air quality, special legislation is often required to permit action. Where this is the case, an action which is short-term in the technical sense may become long-term through institutional constraints.

On the other hand, the recent energy crisis, with shortages, extensive waiting for fuel, and widespread public awareness, has established an environment in which there is a special receptivity to transportation actions to reduce energy consumption. Carpooling, for example, long a relatively little used and generally unpopular idea for commuter travel, is now receiving national attention from both government and the private sector. Many of the transportation actions considered here might be more easily implemented in this current environment than would normally be the case.

FRAMEWORK FOR ANALYSIS

The framework for this exploration of the ways in which transportation actions may be used to reduce energy consumption is based upon a characterization of three major aspects of the problem:

- How does the transportation action effectively reduce energy consumption?
- What are the total effects of the action?
- In what size metropolitan area is the action practical for implementation?

Transportation actions may be characterized as potentially reducing energy consumption in three ways. First, there is a potential for direct reduction through improved efficiency of vehicle operation. Improvements to street traffic flow, for example, may reduce stopping and starting and, in turn, will thereby reduce fuel consumption for a constant amount of travel and vehicle usage. Second, improvements in systems efficiency and vehicle occupancy may reduce vehicle miles of travel. Energy consumption is then reduced while there is still a constant amount of person travel. For example, pricing actions that will increase transit ridership will give this result. Finally, there is the possibility of actually reducing travel demand, thereby cutting person travel, thus vehicle miles of travel, and thus energy consumption. The four-day work week and communications substitutes exemplify this third effect.

All of the effects of any transportation action must be examined to give a balanced view of the relative desirability of any one action. Energy consumption savings should be seen in context with socio-economic and environmental impacts, such as economic dislocation, changes in lifestyle, decreased travel time and congestion, less air and noise pollution, better safety, etc.

The applicability of these actions will vary among different metropolitan areas, both in their effectiveness as energy-saving devices and in the difficulties which might be anticipated in their implementation. Hence, consideration must be given to the relative value of proposed actions in small (less than 250,000 population), medium (250,000 to 1,000,000 population), and large (1,000,000 or more) urban areas.

Exhibit 1 illustrates the process of this analysis. The first step is to characterize actions, as described above, by the way in which they might contribute to the reduction of energy consumption. The actions thus characterized are then screened to determine if they are implementable in the short term and without major capital investment, and if they are consistent with the principles of air quality implementation plans. Actions which do not pass these criteria are given no further consideration because the purpose of this analysis is to present guidelines which are immediately useful to metropolitan areas in formulating energy conservation programs.

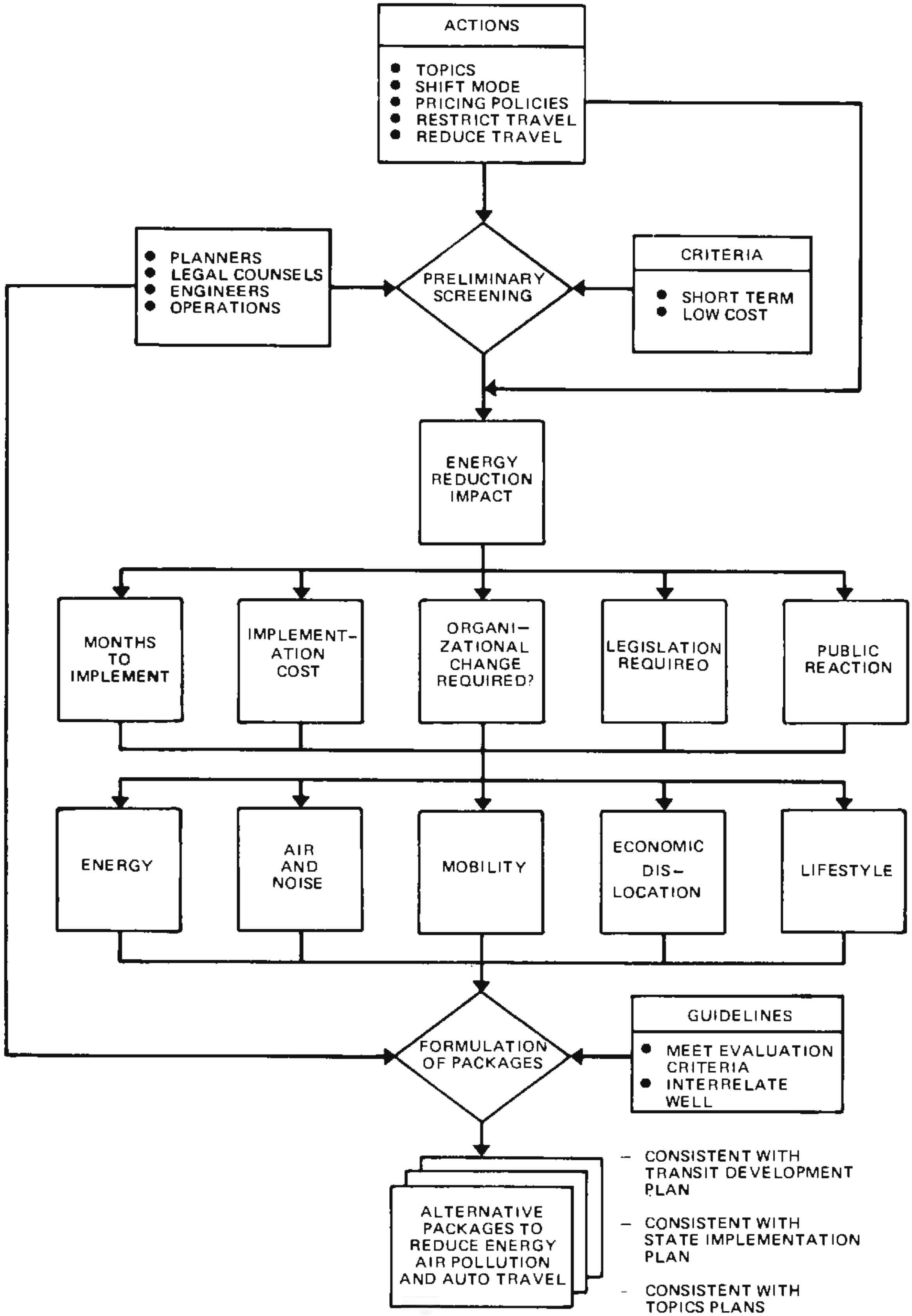
As a next step in the analysis process, the individual actions are organized into ten groups. The principal basis for these groupings is the "technology" of the action -- for example, a taxi or a carpooling incentive -- with the recognition that there may be considerable overlap among the individual groups. Another important consideration is that of difficulty of implementation. It is assumed that, in terms of public acceptance and political feasibility, the carpooling incentive type of action would be generally preferred to the tax type of action. Actions are therefore reviewed in terms of relevant implementation parameters and institutional and legal considerations.

Effects of actions -- energy consumption changes, air and noise impacts, mobility impacts and economic costs -- are also reviewed to determine how an action affects all goals. A process is then suggested as to how decision-makers in a particular urban area might wish to combine individual actions into a package for application. Typical packages are described for small, medium, and large urban areas.

REPORT ORGANIZATION

The first section of this report defines transportation actions and summarizes institutional and legal parameters, energy reduction impacts, and socioeconomic and environmental impacts. The next section

EXHIBIT 1
A FRAMEWORK FOR ANALYSIS



describes a process for formulating packages of transportation actions to reduce energy consumption. A brief list of references concludes the document. Three appendices present more detailed descriptions of individual actions, a discussion of the ways transportation actions reduce energy consumption and how these translate into regional energy reductions, and a bibliography.

CHAPTER II
TRANSPORTATION ACTIONS AND THEIR IMPACTS

In this chapter, brief definitions of appropriate low-cost, short-term transportation actions are presented. Actions are then characterized according to parameters relevent to specific concerns decision-makers may have such as:

- Who implements the action?
- Will new legislation be required?
- What is the energy reduction impact?
- What effect will there be on air pollution?

These parameters are defined and the results are summarized in three tables, Exhibits 2, 3, and 4, presented at the end of the chapter.

More complete descriptions, including implementation methods, institutional and legal considerations, and indirect effects of the transportation actions and expected energy reduction ranges are presented in Appendix A. For more detailed information the reader is referred to the list of references.

For ease of exposition, low cost and short-term transportation actions to reduce energy consumption are arranged into ten "Action Groups:"

1. Measures to Improve Flow of High Occupancy Vehicles
2. Measures to Improve Total Vehicular Traffic Flow
3. Measures to Increase Car and Van Occupancy
4. Measures to Increase Transit Patronage
5. Measures to Encourage Walk and Bicycle Modes
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement
7. Measures to Restrict Traffic

8. Transportation Pricing Measures

9. Measures to Reduce the Need to Travel

10. Energy Restriction Measures

DEFINITIONS OF TRANSPORTATION ACTIONS

The following paragraphs present brief summary definitions of likely actions within the ten major action groups aimed at reducing energy consumption.

1. Measures to Improve the Flow of High-Occupancy Vehicles

Bus-Actuated Signals -- Traffic signals whose operation is modified by the detection by sensors of a bus.

Reserved Lanes or Dedicated Streets for Buses -- A single lane (usually the curb lane) or an entire street reserved exclusively for the use of buses.

Exclusive Bus or Bus/Carpool Lanes and Ramps -- Freeway and expressway lanes or ramps reserved for the exclusive use of buses and/or other high-occupancy vehicles.

Bus Priority Regulations at Intersections -- Regulatory measures, such as "Yield" ordinances favoring buses, signal cycle modifications favoring buses, or exemptions from turning restrictions.

2. Measures to Improve Total Vehicular Flow

Improved Signal Systems -- Computerization and/or improved timing of signal systems and the upgrading of traffic control equipment.

One-way Streets, Reversible Lanes, No On-Street Parking -- Traffic engineering measures which improve capacity within the existing right-of-way and without major capital expenditure.

Eliminate Unnecessary Traffic Control Devices -- The removal of unwarranted traffic signals and "Stop" signs.

Widening Intersections -- Addition of lanes at intersections, e.g., provision of turning lanes.

Ramp Metering, Freeway Surveillance and Driver Advisory Displays --Measures to control total volume entering limited access facilities, and to maintain operation at a level of service most efficient with respect to total energy consumption.

Staggered Work Hours -- The spreading of starting and quitting times by employers, either within a single company or among companies, which can be implemented in a systematic fashion or by the introduction of flexible work hours.

3. Measures to Increase Car and Van Occupancy

Carpool Matching Program -- A program, computerized or manual, to identify potential carpool groupings and to further encourage the formation of carpools by assisting with scheduling and routing.

Carpool Public Information -- Radio, television, newspaper and/or other media campaigns to promote the use of carpools.

Carpool Incentives -- Cost-, convenience-, or travel time-related measures intended to enhance the attractiveness of carpooling.

Neighborhood Ride Sharing -- Ridesharing in the community centered around the common (home-based) origin of the participants for various trip purposes.

4. Measures to Increase Transit Patronage

Bus, Subway and Commuter Rail Service Improvements -- Scheduling, routing, expansion and/or marketing improvements, and the initiation of special services.

Fare Reductions and the Elimination of Transfer Fares -- Reduction or complete elimination of fares and transfer charges.

Traffic-Related Incentives to Ridership -- Bus priority measures such as reserved lanes, reserved streets and signal system priority.

Park-Ride Facilities with Express Bus Service -- Provision of convenient parking in fringe areas, with express bus service to and from the CBD or other major attractions.

Demand-Responsive Systems -- Services provided in response to individual demand, with schedules and routes determined at least partially by individual trip origins and destinations.

5. Measures to Encourage Walk and Bicycle Modes

Pedestrian Malls in High Activity Centers -- Zones or streets from which almost all private vehicular traffic is prohibited.

Bicycle Priority Regulations at Intersections -- Regulatory measures such as "Yield" ordinance favoring bicycles, or signal cycle modifications favoring bicycles.

Pedestrian Signals -- Traffic signals which can be actuated by pedestrians (push buttons, etc.)

Second Level Sidewalks -- Walkways and connecting passageways, grade-separated from street level, connecting stores and other pedestrian trip attractions.

Bikeway Systems -- Facilities designed and intended primarily for travel by bicyles.

Bicycle Storage Facilities -- Storage racks, weather protection facilities, and other amenities located at major trip attractions.

6. Improve the Efficiency of Taxi Service and Goods Movement

Improve Efficiency of Taxi Service -- Regulatory measures to permit higher taxi occupancy, less cruising; encourage jitney-type services; etc.

Improve Efficiency of Urban Goods Movement -- Alterations to delivery hours and routes, consolidation of terminals, provision of loading zones, or other features to improve goods handling.

7. Measures to Restrict Traffic

Vehicle Free or Traffic Limited Zones -- Prohibition of all or some traffic from certain areas, for example, from high-activity centers such as the CBD.

Limit Hours and Location of Travel -- Restrict vehicles to certain hours or locations of travel, depending on factors such as trip purpose, occupancy, etc.

Limit Freeway Usage -- Restrict the use of freeways according to time of day, vehicle type or trip purpose.

8. Transportation Pricing Measures

Bridge and Highway Tolls -- Increased tolls at these facilities based on levels of congestion, vehicle occupancy, or time of day.

Congestion Tolls -- Variable tolls with levels determined by the level of traffic congestion.

Vehicle Fee for Crossing Cordon Line -- Imposition of a toll for entry into an entire area.

Increased Parking Charges -- Changes in rates and rate structures at public and/or private parking facilities.

Impose Gasoline Tax at Pump -- Additional tax applied on a per-gallon basis.

Impose Mileage Tax -- A tax applied directly to vehicle miles of travel.

Differential Fee to Promote Energy-Efficient Vehicles -- Graduation of annual licensing fees on the basis of power, weight, engine displacement, special equipment, etc.

Tune-Up Requirements -- Mandated regular servicing of vehicles, and associated verification system.

Tax on Second or Third Car Ownership -- A progressively greater one-time or annual tax on multiple car ownership.

Tire Tax -- A tax on replacement of tires and/or retreaded tires.

9. Measures to Reduce the Need to Travel

Four-Day Work Week -- Change to a four-day work week for individuals, or business, usually staggered over a five-day business week with a different day off for different individuals. This may involve either compression of a 40-hour week into four days or reduction in working hours; reduction in work travel may be somewhat offset by increased recreational travel.

Zoning -- An emphasis on zoning against land use which is totally auto-dependent; relaxation of zoning requirements in order to permit diverse land uses together with a resultant decrease in the need to travel; moratoriums against development which is totally auto-oriented, etc.

Home Goods Delivery -- The substitution of home delivery of convenience goods for in-person shopping at a retail outlet.

Communications Substitutes -- The substitution of communications media such as teletype, video, etc., for face-to-face communication requiring personal travel.

10. Energy Restriction Measures

Retail Gasoline Rationing Without Transferable Coupons -- Rationing with all the allocations limited to a single person or household and not transferable to any other person or household.

Gasoline Rationing With Transferable Coupons -- Rationing system in which allocations can be transferred or sold to persons or households other than original owner.

Restriction of Quantity of Fuel Sales on a Geographical Basis -- Controlled allocations of gasoline and other fuels, based on fixed geographic subdivisions.

Ban on Saturday and/or Sunday Gasoline Sales -- Partial or total restriction of the sale of gasoline on these days.

Reduced Speed Limits -- Federal and/or state implementation of reduced maximum speeds on freeways, expressways, arterials, or rural highways.

DEFINITIONS OF IMPACTS EXAMINED

Energy reduction impact, institutional and legal considerations, and indirect effects for each transportation action are summarized in Exhibit 2, "Actions to Reduce Energy Consumption and Their Institutional/ Legal Considerations," Exhibit 3, "Actions to Reduce Energy Consumption and Their Indirect Socioeconomic Effects," and Exhibit 4, "Actions to Reduce Energy Consumption and Their Indirect Environmental Effects." These tables are used to determine how well each action meets selected evaluation criteria.

In Exhibit 2, estimates are made for the factors which are defined below:

- *Regional Energy Reduction* -- Percent reduction in regional energy consumption that can be expected from implementation of the transportation action. A range of values is given.

- *Time to Implement* -- Months required for implementation of the action; although all actions are "short-term," a finer breakdown of time within the short-term constraint is made to allow comparisons between actions. A range of values is given.

- *Implementation Cost* -- Although all actions are "low cost," a finer breakdown of cost within the low cost constraint is made to allow comparisons between actions; the costs considered are implementation or capital costs, not user costs or costs of indirect effects. These are "ball park" type estimates, where (L) stands for $0-$50,000, (M) for $50,000-$250,000, and (H) for $250,000-$1,000,000.

- *Implementing Agency* -- The responsibility for implementing an action will lie with one or more private (P), local (L), or state(S), agencies; examples of such agencies are employers, county governments, traffic departments, transit authorities, state departments of transportation or highway departments.

- *Organizational Change Required* -- This is an index of the amount of reorganization of present agencies or development of new agencies required to implement an action; requirements for organizational change tend to increase the difficulty of getting an action implemented.

- *Significant Legislative Action* -- In some case, authorization or legislation by city councils, county boards, state legislature, or the Federal government may be required before an action can be implemented.

- *Initial Public Reaction* -- Favorable public reaction is desirable to implement an action quickly; for each transportation action public reaction is rated as positive (+), negative (-), or positive for some groups and negative for others (+/-). However, an action which may receive unfavorable reaction at first may become more popular after being implemented when impacts become fully known.

- *Enforcement* -- Actions which are likely to require enforcement are denoted (yes); those which may or may not need enforcement are denoted (maybe); and those not likely to need enforcement are denoted (no).

In Exhibit 3, indirect socioeconomic effects are analyzed as defined below:

- *Travel Time* -- Whether the action (increases), (decreases), or has no effect (NE) on travel time for the group or geographic area involved.

- *Cost Distribution* -- Who pays for the action, i.e., the public (PU) in direct taxes or fares, the private sector (PR) in subsidy of carpools or shorter work hours, or the government (G) as part of general governmental responsibilities and expenditures.

- *Safety* -- Some actions will reduce circulation problems and accident potential, and thus (improve) the personal safety of those directly affected by the action. Others will have no effect (NE) on safety.

- *Lifestyle Change* -- Some actions will have no effect (NE) on mobility, driving habits, or work, shopping and recreation times and places; others may require (minor) or (major) changes.

- *Economic Dislocation* -- Some actions will have no effect (NE) on the location or number of jobs, the jurisdiction's tax base or the sales from commercial establishments; others may result in (minor) or (major) impacts on economic considerations in the action location.

- *Development Opportunities* -- Some actions may present (major) or (minor) opportunities to expand current or develop new programs or projects; others will have no effect (NE) on development opportunities.

In Exhibit 4, indirect environmental effects are analyzed as defined below:

- *Air Quality* -- An action may (increase), (decrease), or have no effect (NE) on ambient levels of air quality in the vicinity of the action.
- *Noise* -- An action may (increase), (decrease), or have no effect (NE) on ambient levels of noise where it is implemented.
- *Congestion* -- An action may (increase), (decrease), or have no effect (NE) on congestion resulting from automobiles in the location of implementation.
- *Land Use Patterns* -- The energy reduction measures may cause changes of (major) or (minor) magnitude in land use or land use interrelationships, or there may be no effect (NE) on land use.

SUMMARY TABLES

The tables presented in Exhibits 2, 3, and 4 summarize institutional/legal, socioeconomic, and environmental factors for the transportation actions as described above.

Some generalizations may be drawn from Exhibit 2: 1) the energy reduction ranges are quite small, except for energy restriction measures; 2) most of the measures will involve some intergovernmental cooperation; 3) "disincentive-type" measures tend to require more organizational change and/or new legislation than "incentive-type" measures; and 4) most measures will require some enforcement provisions.

From Exhibits 3 and 4, the following generalizations may be made: 1) most measures to reduce energy consumption also tend to reduce travel time, air pollution, noise pollution, and congestion, 2) impacts on safety are generally positive; and 3) measures to reduce the need for travel and energy restriction measures will have the most effect on lifestyle change, economic dislocation, and land use patterns.

SUMMARY TABLES

EXHIBIT 2

SUMMARY TABLE: ACTIONS TO REDUCE ENERGY CONSUMPTION AND THEIR INSTITUTIONAL/LEGAL CONSIDERATIONS

Action Group	Action	Regional Energy Reduction (%)	Months to Implement	Implementation Cost	Implementing Agency	Organizational Change Required	Possibly New Legislation	Initial Public Reaction	Enforcement
1. Measures to Improve Flow of High Occupancy Vehicles	Bus-actuated signals	0 - 0.5	6 - 12	L	L, S	None	No	+/-	No
	Bus-only lanes on city streets	0 - 2.0	2 - 6	L	L, S	None	No	+/-	Maybe
	Reserved freeway bus or bus/carpool lanes and ramps	1.0 - 3.0	2 - 24	L-H	L, S	None	No	+/-	Yes
	Bus priority regulations at intersections	0 - 0.5	3 - 9	L	L, S	None	Yes	+/-	Yes
2. Measures to Improve Total Vehicular Traffic Flow	Improved signal systems	1.0 - 4.0	6 - 18	M	L, S	None	No	+	No
	One-way streets, reversible lanes, no on-street parking	1.0 - 4.0	6 - 12	M	L, S	None	No	+/-	Yes
	Eliminate unnecessary traffic control devices	0 - 2.0	3 - 6	L	L, S	None	No	+	No
	Widening intersection	0 - 1.0	6 - 12	M	L, S	None	No	+	No
	Driver advisory system	0 - 0.5	6 - 12	L-H	L, S	None-Adapt	No	+	No
	Ramp metering, freeway surveillance, driver advisory display	0 - 1.0	6 - 18	M-H	L, S	None	No	+/-	Yes
	Staggered work hours	0	4 - 12	L	P, L, S	None-New	No	+/-	No
3. Measures to Increase Car and Van Occupancy	Carpool matching programs	3.0 - 6.0	2 - 6	L	P, L, S	Adapt	No	+/-	No
	Carpool public information	2.0 - 4.0	2 - 6	L	P, L, S	Adapt	No	+	No
	Carpool incentives	4.0 - 6.0	2 - 6	L-M	P, L, S	Adapt	No	+/-	Maybe
	Neighborhood ride sharing	0 - 1.0	3 - 24	L	P, L	None-New	No	+	No
4. Measures to Increase Transit Patronage	Service improvements	1.0 - 3.0	3 - 18	M	P, L, S	None	No	+	No
	Fare reductions	4.0 - 6.0	2 - 12	M-H	L, S	None	Yes	+	No
	Traffic-related incentives	1.0 - 5.0	2 - 24	L-M	L, S	None	No	+/-	Maybe
	Park/ride with express bus service	0.5 - 2.5	18 - 24	M-H	L, S	Adapt	No	+	No
	Demand-responsive service	0 - 1.0	6 - 12	H	L, S	Adapt-New	Yes	+	No
5. Measures to Encourage Walk and Bicycle Modes	Pedestrian malls	0.5 - 2.5	6 - 12	M-H	L	Adapt	Yes	+	Maybe
	Second level sidewalks	0 - 0.5	6 - 12	M	L	Adapt	No	+/-	No
	Bikeway system	0.5 - 2.0	6 - 12	L-M	L, S	Adapt	Yes	+	Maybe
	Bicycle storage facilities	0 - 1.0	2 - 4	L	L, S	Adapt	No	+	No
	Pedestrian actuated signals	0 - 0.5	6 - 12	L	L, S	None	No	+/-	No
	Bicycle priority regulations at intersections	0 - 0.5	3 - 9	L	L, S	None	Yes	+/-	Yes

EXHIBIT 2, Continued

6. Measures to Improve the Efficiency of Taxi Service and Goods Movement	Improve efficiency of taxi service	0 - 2.0	3 - 18	M	P, L	None-Adapt	Yes	+	Yes
	Improve efficiency of urban goods movement	0 - 1.5	6 - 18	H	P, L, S	Adapt-New	Yes	-	Yes
7. Measure to Restrict Traffic	Auto-free or traffic limited zones	0.5 - 2.5	12 - 18	M-H	L	Adapt	Yes	+/-	Yes
	Limiting hours or location of travel	0 - 3.0	4 - 12	M-H	L, S	Adapt-New	Yes	-	Yes
	Limiting freeway usage	0 - 1.0	3 - 6	L-M	L, S	None-Adapt	Yes	-	Yes
8. Transportation Pricing Measures	Bridges and highway tolls	1.0 - 5.0	12 - 24	L-M	L, S	None-New	Yes	-	No
	Congestion tolls and road cordon tolls	1.0 - 5.0	18 - 24	M-H	L, S	Adapt-New	Yes	-	Maybe
	Increased parking costs	0.5 - 3.0	3 - 12	M	L	Adapt-New	Yes	-	Maybe
	Fuel tax	2.0 - 8.0	2 - 6	L	L, S	Adapt	Yes	-	No
	Mileage tax	2.0 - 6.0	6 - 12	M	L, S	Adapt	Yes	-	Maybe
	Vehicle-related fees	2.0 - 10.0	6 12	M	S	Adapt	Yes	-	No
9. Measures to Reduce the Need to Travel	Four-day work week	1.0 - 6.0	4 - 12	L	P, L, S	None-New	No	+/-	No
	Zoning	1.0 - 10.0	6 - 12	L	L, S	None-New	Yes	+/-	Maybe
	Home goods delivery	0 - 1.0	12 - 24	L	P, L	New	No	+/-	No
	Communications substitutes	0 - 1.0	18 - 24	L-H	P, L, S	None-New	No	+/-	No
10. Energy Restriction Measures	Gas rationing without transferable coupons	10.0 - 25.0	2 - 6	L-H	S, F	New	Yes	-	Yes
	Gas rationing with transferable coupons	10.0 - 25.0	2 - 6	L-H	S, F	New	Yes	-	Yes
	Restriction of quantity of sales on a geographic basis	5.0 - 20.0	0 - 5	L-M	P, L, S	New	Yes	-	Maybe
	Ban on Sunday and/or Saturday gas sales	2.0 - 10.0	1 - 6	L	P, L, S	New	Yes	-	Yes
	Reduced speed limits	0 - 2.0	1 - 6	L	L, S	Adapt	Yes	-	Yes

SYMBOLS:

Implementation Cost: L = Low, M = Medium, H = High, within the low cost constraint on type of actions considered
Implementing Agency: P = Private, L = Local, S = State
Initial Public Reaction: + = Positive, - = Negative, +/- = Positive or negative, depending on group affected

EXHIBIT 3

SUMMARY TABLE: ACTIONS TO REDUCE ENERGY CONSUMPTION AND THEIR INDIRECT SOCIOECONOMIC EFFECTS

			Socio-Economic					
Action Group	Action	Regional Energy Reduction (%)	Travel Time	Cost Distribution	Safety	Lifestyle Change	Economic Dislocation	Development Opportunities
1. Measures to Improve Flow of High Occupancy Vehicles	Bus-actuated signals	0 0.5	Decrease	G	Improve	NE	NE	NE
	Bus-only lanes on city streets	0 - 2.0	Decrease	G	Improve	Minor	NE-Minor	NE
	Reserved freeway bus or bus/carpool lanes and ramps	1.0 - 3.0	Decrease	G	Improve	Minor	NE	NE
	Bus priority regulations at intersections	0 0.5	Decrease	G	Improve	Minor	NE	NE
2. Measures to Improve Total Vehicular Traffic Flow	Improved signal systems	1.0 - 4.0	Decrease	G	Improve	NE	NE	NE
	One-way streets, reversible lanes, no on-street parking	1.0 - 4.0	Decrease	G	Improve	NE-Minor	NE-Minor	NE
	Eliminate unnecessary traffic control devices	0 - 2.0	Decrease	G	Improve	NE	NE	NE
	Widening intersection	0 - 1.0	Decrease	G	Improve	NE	NE	NE
	Driver advisory system	0 - 0.5	Decrease	G	Improve	NE	NE	NE
	Ramp metering, freeway surveillance, driver advisory display	0 - 1.0	Decrease	G	Improve	NE	NE	NE
	Staggered work hours	0	Decrease	PR	NE	Minor/major	Minor	Minor/major
3. Measures to Increase Car and Van Occupancy	Carpool matching programs	3.0 - 6.0	NE	PU/PR/G	NE	NE	NE	Major
	Carpool public information	2.0 - 4.0	NE	PU/PR/G	NE	NE	NE	Major
	Carpool incentives	4.0 - 6.0	NE	PU/PR/G	NE	NE	NE	Minor
	Neighborhood ride sharing	0 - 1.0	NE	G/PU/PR	NE	Minor	NE	NE
4. Measures to Increase Transit Patronage	Service improvements	1.0 - 3.0	Decrease	G	Improve	NE	NE	Major
	Fare reductions	4.0 - 6.0	NE	G	NE	NE	NE	NE
	Traffic-related incentives	1.0 - 5.0	NE	G	NE	NE	NE	NE-Minor
	Park/ride with express bus service	0.5 - 2.5	Decrease	PU/G	Improve	NE	NE	Major
	Demand-responsiveness service	0 - 1.0	Decrease	PU/G	Improve	NE	NE	Major

EXHIBIT 3, Continued

5. Measures to Encourage Walk and Bicycle Modes	Pedestrian malls	0.5 - 2.5	Decrease	PR/G	Improve	Minor	NE-Minor	Major
	Second level sidewalks	0 - 0.5	Decrease	PR/G	Improve	NE	NE	Major
	Bikeway system	0.5 - 2.0	Decrease	G	Improve	Minor	NE	Major
	Bicycle storage facilities	0 - 1.0	NE	PU/PR/G	Improve	NE	NE	Minor
	Pedestrian-actuated signals	0 - 0.5	Decrease	G	Improve	NE	NE	NE
	Bicycle priority regulations at intersections	0 - 0.5	Decrease	G	Improve	NE	NE	NE
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement	Improve efficiency of taxi service	0 - 2.0	Decrease	PR	NE	NE	NE	Minor
	Improve efficiency of urban goods movement	0 - 1.5	Decrease	PR/G	NE	Minor	NE	Minor/major
7. Measure to Restrict Traffic	Auto-free or traffic limited zones	0.5 - 2.5	Increase	G	Improve	Minor	NE-Minor*	Major
	Limiting hours or location of travel	0 - 3.0	Increase	G	Improve	Minor/major	Minor/major	NE-Major
	Limiting freeway usage	0 - 1.0	Increase	G	Improve	Minor	NE	NE
8. Transportation Pricing Measures	Bridges and highway tolls	1.0 - 5.0	NE	PU	NE	NE-Minor	NE-Minor	NE
	Congestion tolls and road cordon tolls	1.0 - 5.0	NE	PU	NE	NE-Minor	NE-Minor	NE
	Increased parking costs	0.5 - 3.0	NE	PU/PR	NE	NE-Minor	Minor	NE
	Fuel tax	2.0 - 6.0	NE	PU	NE	NE	NE-Minor	NE
	Mileage tax	2.0 - 6.0	NE	PU	NE	NE	NE-Minor	NE
	Vehicle-related fees	2.0 - 10.0	NE	PU	NE	NE	NE-Minor	NE
9. Measures to Reduce the Need to Travel	Four-day work week	1.0 - 6.0	NE	PR	NE	Major	Minor	Major
	Zoning	1.0 - 10.0	NE	G/PR	NE	Major	Major	Major
	Home goods delivery	0 - 1.0	NE	PU/PR	NE	Minor	NE	Minor
	Communications substitutes	0 - 1.0	NE	G/PR	NE	Minor	Minor	Minor/major
10. Energy Restriction Measures	Gas rationing without transferable coupons	10.0 - 25.0	NE	PU/G	NE	Major	Minor/major	NE
	Gas rationing with transferable coupons	10.0 - 25.0	NE	PU/G	NE	Major	Minor/major	NE
	Restriction of quantity of sales on a geographic basis	5.0 - 20.0	NE	PU/PR/G	NE	Major	Major	NE
	Ban on Sunday and/or Saturday gas sales	2.0 - 10.0	NE	PU/PR/G	NE	Major	Minor/major	NE
	Reduced speed limits	0 - 2.0	Increase	G	Improve	Minor	NE	NE

EXHIBIT 4

SUMMARY TABLE: ACTIONS TO REDUCE ENERGY CONSUMPTION AND THEIR INDIRECT ENVIRONMENTAL EFFECTS

Action Group	Action	Regional Energy Reduction (%)	Environmental			
			Air Pollution	Noise	Congestion	Land Use Patterns
1. Measures to Improve Flow of High Occupancy Vehicles	Bus-actuated signals	0 - 0.5	Decrease	Decrease	Decrease	NE
	Bus-only lanes on city streets	0 - 2.0	Decrease	Decrease	Decrease	NE-Minor
	Reserved freeway bus or bus/carpool lanes and ramps	1.0 - 3.0	Decrease	Decrease	Decrease	NE-Minor
	Bus priority regulations at intersections	0 - 0.5	Decrease	Decrease	Decrease	NE
2. Measures to Improve Total Vehicular Traffic Flow	Improved signal systems	1.0 - 4.0	Decrease	Decrease	Decrease	NE
	One-way streets, reversible lanes, no on-street parking	1.0 - 4.0	Decrease	Decrease	Decrease	NE-Minor
	Eliminate unnecessary traffic control devices	0 2.0	Decrease	Decrease	Decrease	NE
	Widening intersection	0 - 1.0	Decrease	Decrease	Decrease	NE-Minor
	Driver advisory system	0 - 0.5	Decrease	Decrease	Decrease	NE
	Ramp metering, freeway surveillance, driver advisory display	0 1.0	Decrease	Decrease	Decrease	NE
	Staggered work hours	0	Decrease	Decrease	Decrease	NE
3. Measures to Increase Car and Van Occupancy	Carpool matching programs	3.0 - 6.0	Decrease	Decrease	Decrease	NE
	Carpool public information	2.0 - 4.0	Decrease	Decrease	Decrease	NE
	Carpool incentives	4.0 - 6.0	Decrease	Decrease	Decrease	NE
	Neighborhood ride sharing	0 1.0	Decrease	Decrease	Decrease	NE
4. Measures to Increase Transit Patronage	Service improvements	1.0 - 3.0	Decrease	Decrease	Decrease	NE
	Fare reductions	4.0 - 6.0	Decrease	Decrease	NE	NE
	Traffic-related incentives	1.0 - 5.0	Decrease	Decrease	Decrease	NE
	Park/ride with express bus service	0.5 - 2.5	Decrease	Decrease	Decrease	Minor
	Demand-responsiveness service	0 - 1.0	Decrease	Decrease	Decrease	NE

EXHIBIT 4, Continued

5. Measures to Encourage Walk and Bicycle Modes	Pedestrian malls	0.5 - 2.5	Decrease	Decrease	Decrease	Minor/major
	Second level sidewalks	0 - 0.5	Decrease	Decrease	Decrease	Minor
	Bikeway system	0.5 - 2.0	Decrease	Decrease	Decrease	Minor
	Bicycle storage facilities	0 - 1.0	Decrease	NE	NE	NE
	Pedestrian-actuated signals	0 - 0.5	NE	NE	Decrease	NE
	Bicycle priority regulations at intersections	0 - 0.5	NE	NE	Decrease	NE
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement	Improve efficiency of taxi service	0 - 2.0	Decrease	Decrease	Decrease	NE
	Improve efficiency of urban goods movement	0 - 1.5	Decrease	Decrease	Decrease	Minor
7. Measure to Restrict Traffic	Auto-free or traffic limited zones	0.5 - 2.5	Decrease	Decrease	Decrease	Minor/major
	Limiting hours or location of travel	0 - 3.0	Decrease	Decrease	Decrease	Minor/major
	Limiting freeway usage	0 - 1.0	Decrease	Decrease	Decrease	Minor
8. Transportation Pricing Measures	Bridges and highway tolls	1.0 - 5.0	Decrease	Decrease	Decrease	NE
	Congestion tolls and road cordon tolls	1.0 - 5.0	Decrease	Decrease	Decrease	NE
	Increased parking costs	0.5 - 3.0	Decrease	Decrease	Decrease	NE
	Fuel tax	2.0 - 6.0	Decrease	Decrease	Decrease	NE
	Mileage tax	2.0 - 6.0	Decrease	Decrease	Decrease	NE
	Vehicle-related fees	2.0 - 10.0	Decrease	Decrease	Decrease	NE
9. Measures to Reduce the Need to Travel	Four-day work week	1.0 - 6.0	Increase/Decrease	Increase/Decrease	Decrease	NE-Minor
	Zoning	1.0 - 10.0	Decrease	Decrease	Decrease	Major
	Home goods delivery	0 - 1.0	Decrease	Increase/Decrease	Decrease	NE
	Communications substitutes	0 - 1.0	Decrease	Decrease	Decrease	Major
10. Energy Restriction Measures	Gas rationing without transferable coupons	10.0 - 25.0	Decrease	Decrease	Decrease	Minor/major
	Gas rationing with transferable coupons	10.0 - 25.0	Decrease	Decrease	Decrease	Minor/major
	Restriction of quantity of sales on a geographic basis	5.0 - 20.0	Decrease	Decrease	Decrease	Major
	Ban on Sunday and/or Saturday gas sales	2.0 - 10.0	Decrease	Decrease	Decrease	Minor
	Reduced speed limits	0 - 2.0	Decrease	Decrease	NE	NE

Symbol NE = No Effect

CHAPTER III
PROCESS FOR FORMULATING PACKAGES

INTRODUCTION

The previous chapter presented a list of low cost, quickly implementable transportation actions. The purpose of this chapter is to present a process for selecting a number of actions to formulate a transportation energy reduction package for an urban area.

A flowchart of the process is presented in Exhibit 5. As shown, the basic inputs to the process are (1) the interrelationships of the actions and (2) an evaluation methodology, based on a set of criteria for selecting suitable actions for a given urban area. A sample matrix of interrelationships is presented in this chapter (Exhibit 6), as are sample evaluation tables, according to selected criteria, for generalized small, medium, and large urban areas. (Exhibits 7, 8, and 9).

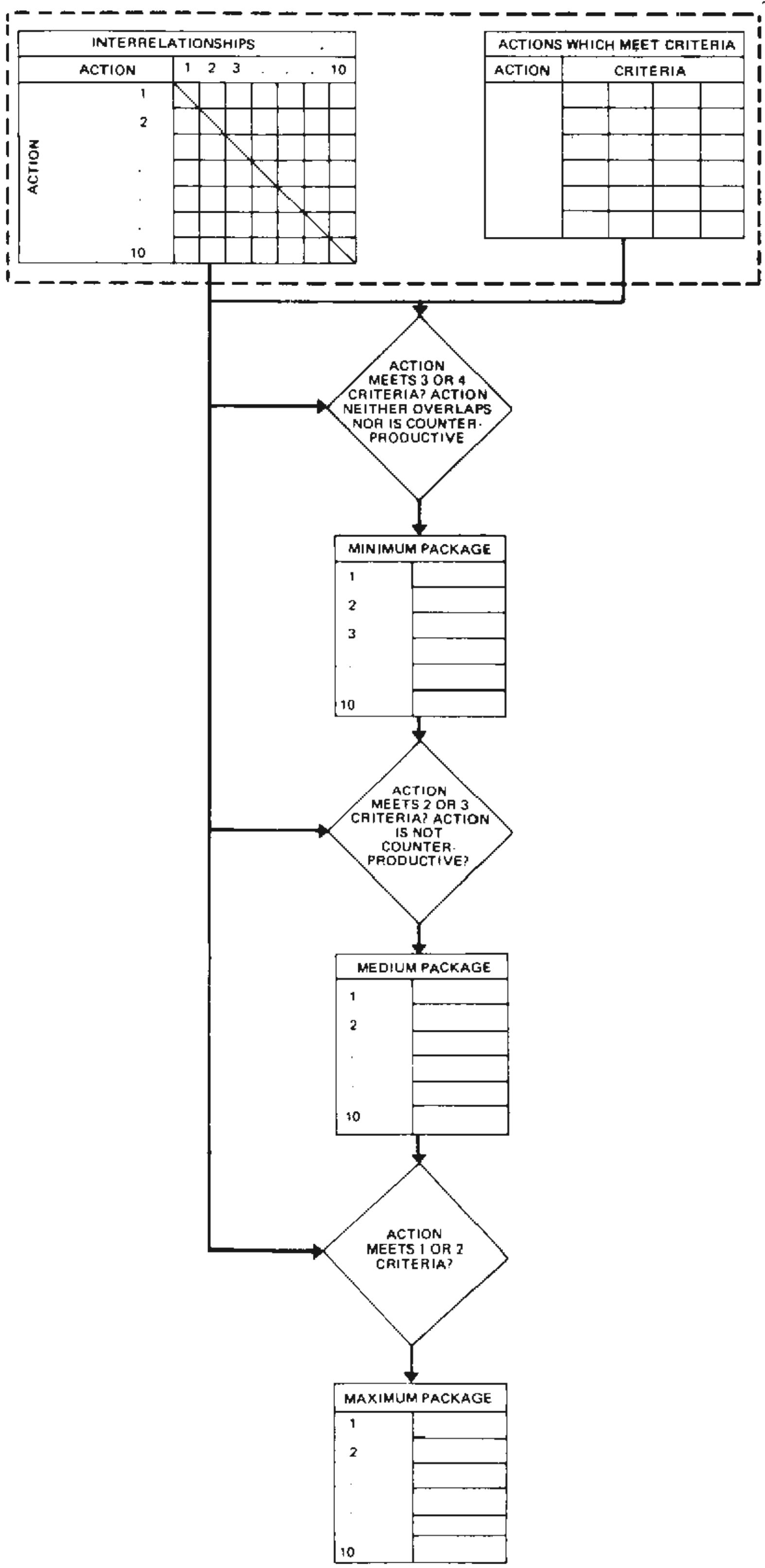
Using these inputs, packages are formulated based on an incremental approach whereby actions, that are favorable according to most criteria and at the same time interrelate satisfactorily with other actions, are selected first. These requirements are gradually relaxed in selecting additional actions until enough actions are chosen to form a package with the desired level of energy reduction.

The process is illustrated in the development of nine sample packages--minimum, medium, and maximum energy reduction packages for small, medium, and large urban areas. (Exhibits 10, 11, and 12). It should be emphasized that the sample tables and packages are for "typical" small, medium and large urban areas and thus may not be appropriate to a given area. Their primary purpose is to illustrate the process which may be adapted for conditions in that locality.

A package tailored to a specific area would vary due to one or more of the following: 1) selection of different or more evaluation criteria as significant to the area, 2) evaluation of different actions as favorable according to the selected criteria, due to local conditions, 3) variation in the matrix of interrelationships due to local conditions, and 4) variation in the size of the transportation energy reduction desired.

EXHIBIT 5

PROCESS FOR FORMULATING PACKAGES



Furthermore, it should be stressed that in many urban areas a considerable amount of transportation-related planning work has already been done. Specifically, an urban area may have one or more of the following plans which involve low cost, short-term transportation actions: short-range transit development plans, TOPICS programs, carpooling plans, transportation control plans to achieve air quality standards, and pending air quality maintenance area plans. These plans may be in varying stages of implementation. Efforts to achieve energy reduction from low cost short-term transportation actions should naturally take into account the actions already planned or being implemented, and development of an energy reduction plan should be coordinated with existing plans and ongoing planning processes of agencies within the urban area. In fact, one of the criteria selected for use in evaluation might be whether or not the action has already been programmed for the area.

EVALUATION OF INTERRELATIONSHIPS

Most transportation-related actions are not totally independent of each other, but may have positive or negative impacts on each other's energy reduction potential. In formulating an energy reduction package, it is very important to consider the impact of each action on other actions in the package and, insofar as possible, to incorporate actions which interact well with each other. This is particularly important if an incremental program is being considered in order that each step will be a logical and cost-effective basis for implementing succeeding portions of the program. In order to evaluate the impacts of one action on another, it is necessary to understand the interrelationships among actions, where "interrelationship" is narrowly defined as the impact of one action on the potential for energy reduction of another action.

The interrelationships can be divided into two categories: 1) interrelationships *between* action groups and 2) interrelationships *within* an action group. The interrelationships which will be discussed below are those between action groups. They are most important because they reflect basic differences in the ways actions achieve reductions in energy consumption--ways which may help or conflict with each other. The interrelationships of actions within an action group, on the other hand, are less well defined and more dependent on specific local conditions, as some actions may not even be applicable to a given area.

The sample matrix of interrelationships that was developed is given in Exhibit 6. Four types of interrelationships, referred to by the symbols A, I, O, and C, were defined as follows:

A - The two action groups *assist* each other either by facilitating implementation or increasing the effectiveness of actions within the other group.

I - The two action groups are *independent* of each other--actions within one group will neither enhance nor mitigate the effectiveness of actions within the other group.

O - The two action groups may *overlap* in the ways they reduce energy consumption, thus tending to reduce the effectiveness of each other to some extent.

C - The two action groups may be *counterproductive* because the objective of one might work against the objective of the other.

To illustrate the thought process that went into developing the matrix, a few examples are discussed:

1. Group 1 measures (improve flow of high occupancy vehicles), such as reserved bus/carpool lanes, *assist* the effectiveness of Group 3 measures (increase carpooling) by increasing the incentive to carpool--therefore, "A".

2. Group 2 measures (improve total vehicular traffic flow) are *counterproductive* to Group 4 measures (increase transit patronage) because they usually increase the relative attractiveness of auto mode over transit mode, thus decreasing the number of choice transit users and the concurrent reduction in energy consumption

EXHIBIT 6

INTERRELATIONSHIP OF ACTION GROUPS

ACTION GROUP \ ACTION GROUP	1 Measures to Improve Flow of High Occupancy Vehicles	2 Measures to Improve Total Vehicular Traffic Flow	3 Measures to Increase Car and Van Occupancy	4 Measures to Increase Transit Patronage	5 Measures to Encourage Use of Walk and Bike Modes	6 Measures to Improve the Efficiency of Taxi Service and Goods Movement	7 Measures to Restrict Traffic	8 Transportation Pricing Measures	9 Measures to Reduce the Need to Travel	10 Energy Restriction Measures
1. Measures to Improve Flow of High Occupancy Vehicles		C	A	A	A	I	A	I	I	I
2. Measures to Improve Total Vehicular Traffic Flow			I	C	C	I	C	C	C	I
3. Measures to Increase Car and Van Occupancy				O	I	I	I	A	I	A
4. Measures to Increase Transit Patronage					A	I	A	A	I	A
5. Measures to Encourage Use of Walk and Bike Modes						I	A	I	I	A
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement							I	I	I	A
7. Measures to Restrict Traffic								I	I	A
8. Transportation Pricing Measures									I	O
9. Measures to Reduce the Need to Travel										A
10. Energy Restriction Measures										

LEGEND:
- A - Action Groups which assist each other in reducing energy
- I - Action Groups which are independent of each other in reducing energy
- O - Action Groups which may overlap or pre-empt each others effectiveness in reducing energy
- C - Action Groups which may be counterproductive to each other in reducing energy

that can be expected from Group 4 measures. Conversely, Group 4 measures may obviate the need for Group 2 measures because they improve traffic flow by reducing the number of automobiles used--therefore, "C".

3. Group 3 measures (increase carpooling) and Group 4 measures (increase transit patronage) are working towards the same objective--raising vehicular occupancies. Therefore, they are not directly counterproductive. However, insofar as they attract the same user market, they may *overlap*. For instance, for work trips, if the same people would be attracted to a carpool as to a park-and-ride system, it would be redundant to institute both a carpooling program and a park-and-ride system in the same area. However, if different types of people are attracted to the two systems it would not be redundant. The likelihood is that the truth lies somewhere between--therefore, "O". (For non-work trips, the degree of overlap is likely to be much less because carpooling is primarily aimed at work trips.)

4. Group 4 measures (increase transit patronage) and Group 5 measures (encourage use of walk and bike modes) mutually *assist* each other because the modes are often complementary. For instance, access to pedestrian malls is often provided by transit. As another example, good bicycle storage facilities at transit stations enable trips to be made by a combination of bicycle and transit modes that might otherwise be made by automobile--therefore, "A".

5. Group 7 measures (restrict traffic) *assist* Group 1 measures (improve flow of high occupancy vehicles) by reducing or eliminating low occupancy travel in certain locations or hours, thus reducing congestion and improving flow for the unrestricted high occupancy travel--therefore, "A".

6. Group 2 measures (improve total vehicular traffic flow) are *counterproductive* to Group 9 measures (reduce the need to travel) because the "need to travel" is often a function of conceptual options. For instance, improving traffic flow may make it marginally more desirable to make a trip rather than use a communications substitute. As another example, improved traffic flow may contribute to encouragement of development patterns which require more automobile tripmaking and thus added energy consumption--therefore, "C".

7. Group 9 measures (reduce the need for travel) may reduce the total number of transit trips made. However, the potential for reduction in energy consumption of Group 4 measures (increase transit patronage) is derived from the number of "choice" rider trips diverted from auto rather than from the total number of new transit trips generated. Group 9 measures are not likely to affect the diversion of auto trips to transit trips--therefore, they are independent, "I".

The most *significant* interrelationships identified in this matrix are:

1. Actions to improve total vehicular traffic flow tend to be counterproductive to many other actions, especially actions to shift travel away from auto to non-auto modes. This is because traffic flow improvements tend to encourage more, rather than less, vehicle miles of travel.

2. Carpooling actions and transit actions may overlap and thus preempt some of each other's effectiveness, depending upon how and where they are applied. This is because both action groups have the same market for vehicle miles of travel reduction--the single occupant vehicle. The degree of overlap depends on whether there is existing transit service and whether the same kinds of people are attracted to carpools as to improved transit service. The degree of overlap is larger for work trips than for non-work trips.

3. Energy restriction actions and transportation pricing actions have similar effects and tend to overlap or preempt each other's effectiveness. A clear example of this is gasoline rationing versus higher fuel taxes for gasoline, often considered as alternatives to one another. (A side aspect to this is that pricing actions tend to be less equitable than restriction actions.)

4. Taxi service- and goods movement-related actions are generally independent of other actions. This is because their potential for reduction in energy consumption is derived from more efficient energy usage within each mode.

5. Traffic restriction actions, transportation pricing actions, and energy restriction actions are disincentive actions which tend to increase the effectiveness of incentive actions, such as transit improvements, walk and bike actions, and carpooling programs. At the same time, incentive actions provide services which can meet the travel demand discouraged from low occupancy automobile mode by disincentive actions, thus facilitating implementation of disincentive actions. Therefore, they are complementary and mutually assist each other.

An analysis of interrelationships is necessary in formulating a logical transportation energy reduction package for an urban area. A matrix of interrelationships is a way of organizing analysis results for input into formulation of an energy reduction package. The sample matrix presented here gives basic relationships between action groups which hold true for most urban areas. For a specific area, a similar analysis based on local conditions should be made, and a slightly different matrix may result. Interrelationships within action groups should also be considered, especially when the precise combination and extent of application of actions within groups for a specific area is determined, although this is not made explicit in describing the formulation process.

Another interrelationship that should be considered is not between actions or action groups but between the twin goals of reducing energy consumption and improving air quality. For most actions, these goals are supportive of each other, with the possible exception of emission control devices on vehicles. Formulation of an energy reduction package should be coordinated with air pollution reduction planning, and the transportation control strategies being planned or implemented in many urban areas should be taken into account.

EVALUATION OF ACTIONS ACCORDING TO SELECTED CRITERIA

An evaluation of individual actions for a given urban area requires 1) determination of the applicability of an action to that area, and 2) evaluation of applicable actions according to selected criteria.

With regard to the applicability of an action to an area, the generalization can be made that the larger the area, the greater the number of actions available to it. For instance, taxi and truck-related actions probably do not apply or would be of little benefit in all but the largest cities. As another example, reserved freeway lanes or ramps for buses are not usually appropriate for small urban areas. Therefore, separate sample evaluation tables were developed for generalized small, medium, and large urban areas, where small urban areas are defined as having a 50,000-250,000 population, medium urban areas as having 250,000-1,000,000 population, and large urban areas as having 1,000,000 or more population. However, there may be a great deal of variation in applicability of actions to specific areas within the small, medium, and large urban area categories.

With regard to the evaluation of applicable actions according to selected criteria, care must be exercised in selecting criteria which reflect both areawide objectives and the constraints and concerns of those agencies which would be responsible for implementing the energy reduction package. The criteria of short lead time, minimal institutional obstacles, favorable public reaction, and high potential for reduction in energy consumption, were chosen for use in the sample evaluation as they include considerations most urban areas would have. However, a specific area might use a slightly different set of criteria. For instance, minimum legislative requirements, minimum funding requirements, or favorable impact on air quality might also be considered as evaluation criteria to be applied in place of or in addition to those used in the example.

The process used in developing the sample evaluation tables for small, medium, and large urban areas was the following:

1. Each action group was examined to determine those actions within the group which are likely to be applicable to urban areas of that size. Action groups are shown as row headings in the table.

2. Applicable actions were evaluated according to each of the four selected criteria which are the column headings in the table.

3. Those applicable actions which were evaluated as "favorable" according to a given criterion were listed in the table under the appropriate column heading.

The criteria used in this evaluation process are:

1. *Short lead time* -- Although all of the actions considered are short term, some can be implemented very quickly, whereas others may take up to two years because of requirements for legislative action, institutional change, or construction. An action which can be implemented in 0-6 months is considered highly favorable according to this criterion.

2. *Minimal institutional obstacles* -- Administrative, legal, and funding problems with regard to implementation exist to some degree for all actions, but some may encounter fewer or less significant obstacles. Administrative problems refer to such questions as whether a new agency or branch of an agency is required to implement the action; whether coordination between agencies of several levels of government is necessary; whether the effort has to be monitored or enforced; etc. Legal problems refer to such questions as whether legislative action by local, state, or Federal government is required; whether authority to implement the action exists, whether the action is likely to be challenged in court; etc. Funding problems refer to issues such as whether or not a source of money exists or can be diverted to pay

for the action; how much local money is required; whether a referendum to raise money is required; etc. An action is considered favorable according to this criterion if both a funding source and an administrative and/or operating agency with authority to implement is already in existence or could be established fairly easily.

3. *Favorable public reaction* -- The general public usually approves of those actions perceived to be in the "public good" which do not restrict personal mobility. However, some actions may be opposed by specifically impacted groups. Also, public reaction to a given action may vary considerably from city to city, depending on local conditions, perception of the need to reduce energy consumption, or even the manner in which proposed actions are presented to the public. An action is considered favorable under this criterion if it is likely to be approved of by the general public in most urban areas of a given size.

4. *High energy reduction* -- Some actions or combinations of two or three actions within a group can achieve a sizable energy reduction by themselves, whereas other actions may make only marginal contributions. Of course, the effectiveness can be increased or decreased by implementation of other actions. An action or combination of actions which can achieve an energy reduction of more than 3 percent *alone* is considered to be highly favorable under this criterion.

The sample evaluation tables are given in Exhibits 7, 8, and 9.

It should be pointed out that the results of evaluation are not always clear cut. Specifically, an action which is not generally applicable to urban areas of a given size may be applicable to a specific area of that size, or the facts about the likely effects of or public reaction to an action may not be known.

EXHIBIT 7

ACTIONS WHICH MEET EVALUATION CRITERIA IN MEDIUM-SIZED URBAN AREAS (250,000 - 1,000,000 POPULATION)

ACTION GROUP	CRITERIA Short Lead Time	Minimal Institutional Problems	Favorable Public Reaction	High Energy Reduction Strategy
1. Measures to Improve Flow of High Occupancy Vehicles	Bus only lanes on streets, bus priority regulations at intersections	Bus only lanes on streets, pedestrian and bus-actuated signals		
2. Measures to Improve Total Vehicular Traffic Flow	Eliminate unnecessary traffic control devices, staggered work hours	Eliminate unnecessary traffic control devices, improved signal systems, widening intersections, implement one-way streets, etc.	Eliminate unnecessary traffic control devices, improved signal systems, widening intersections, staggered work hours	
3. Measures to Increase Car and Van Occupancy	Carpool Program: Public information encourage employer programs, carpool matching guidance, areawide coordination, costs and convenience incentives Neighborhood ride sharing	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost and convenience incentives	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination Neighborhood ride sharing	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost and convenience incentives
4. Measures to Increase Transit Patronage	Fare reduction, traffic-related incentives	Service improvements, traffic-related incentives	Service improvements, fare reduction, demand responsive service	Fare reduction in combination with service improvements
5. Measures to Encourage Use of Walk and Bike Modes	Bicycle storage facilities, bicycle priority regulations at intersections	Bicycle storage facilities	Bicycle storage facilities, bikeway system, pedestrian mall(s)	
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement				
7. Measures to Restrict Traffic			Auto-free zone(s) of pedestrian mall type	
8. Transportation Pricing Measures	Parking-related actions, fuel tax			Bridge and/or highway tolls or road cordon tolls, fuel tax or mileage tax, parking-related actions, vehicle-related fees
9. Measures to Reduce the Need to Travel	Four-day work week			Four-day work week, zoning-related changes
10. Energy Restriction Measures	Restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales, reduced speed limits, gas rationing with or without transferrable coupons			Gas rationing with or without transferrable coupons, restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales

EXHIBIT 8

ACTIONS WHICH MEET EVALUATION CRITERIA IN SMALL URBAN AREAS (50,000 - 250,000 POPULATION)

ACTION GROUP	CRITERIA			
	Short Lead Time	Minimal Institutional Problems	Favorable Public Reaction	High Energy Reduction Strategy
1. Measures to Improve Flow of High Occupancy Vehicles		Pedestrian and bus actuated signals		
2. Measures to Improve Total Vehicular Traffic Flow	Eliminate unnecessary traffic control devices, staggered work hours	Eliminate unnecessary traffic control devices, improved signal systems, widening intersections, implement one-way streets, etc.	Eliminate unnecessary traffic control devices, improved signal systems, widening intersections	
3. Measures to Increase Car and Van Occupancy	Carpool Program: Public information, encourage employer programs, carpool matching guidance, possibly cost and/or convenience incentives Neighborhood ride sharing	Carpool Program: Public information, encourage employer programs, carpool matching guidance, possibly cost and/or convenience incentives	Carpool Program: Public information, encourage employer programs, carpool matching guidance Neighborhood ride sharing	Carpool Program: Public information, encourage employer programs, carpool matching guidance, possibly cost and/or convenience incentives
4. Measures to Increase Transit Patronage		(Perhaps service improvements)	Service improvements, fare reduction, demand responsive service	Fare reduction in combination with service improvements
5. Measures to Encourage Use of Walk and Bike Modes	Bicycle storage facilities Bicycle priority regulations at intersections	Bicycle storage facilities	Bicycle storage facilities, bikeway system, pedestrian mall	
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement				
7. Measures to Restrict Traffic			Auto-free zone(s) of pedestrian mall type	
8. Transportation Pricing Measures	Parking-related actions, fuel tax			Some form of road pricing, fuel tax or mileage tax, parking-related actions, vehicle-related fees
9. Measures to Reduce the Need to Travel	Four-day work week			Four-day work week, zoning-related changes
10. Energy Restriction Measures	Restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales, reduced speed limits, gas rationing with or without transferrable coupons			Gas rationing with or without transferrable coupons, restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales

EXHIBIT 9

ACTIONS WHICH MEET EVALUATION CRITERIA IN LARGE URBAN AREAS (1,000,000 OR MORE POPULATION)

ACTION GROUP	CRITERIA: Short Lead Time	Minimal Institutional Problems	Favorable Public Reaction	High Energy Reduction Strategy
1. Measures to Improve Flow of High Occupancy Vehicles	Bus only lanes on streets, bus priority regulations at intersections, reserved lanes or ramps on existing freeways	Bus only lanes on streets, reserved lanes or ramps on existing freeways, pedestrian and bus-actuated signals		Combination of bus only lanes on streets with reserved lanes or ramps on existing freeways.
2. Measures to Improve Total Vehicular Traffic Flow	Eliminate unnecessary traffic control devices, staggered work hours	Eliminate unnecessary traffic control devices, ramp metering and freeway surveillance, improved signal systems, widening intersections, implement one-way streets, etc.	Eliminate unnecessary traffic control devices, improved signal systems, widening intersections, driver advisory systems, staggered work hours	Combination of several traffic flow improvements
3. Measures to Increase Car and Van Occupancy	Carpool Program: Public information encourage employer programs, carpool matching guidance, areawide coordination, costs, convenience and travel time incentives Neighborhood ride sharing	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost, convenience and travel time incentives	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination Neighborhood ride sharing	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost, convenience, and travel time incentives
4. Measures to Increase Transit Patronage	Fare reduction, some traffic-related incentives	Service improvements, traffic-related incentives	Service improvements, fare reduction, park/ride facilities with express bus service, demand responsive service	Fare reduction in combination with service improvements, park/ride facilities with express bus service
5. Measures to Encourage Use of Walk and Bicycle Modes	Bicycle storage facilities, bicycle priority regulations at intersections	Bicycle storage facilities	Bicycle storage facilities, bikeway system, pedestrian mall(s)	
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement	High Occupancy, taxi operation, restrict taxi cruising, truck loading zones	High occupancy taxi operation	Most taxi service-related measures, most goods movement related measures	Combination of several truck and taxi-related actions
7. Measures to Restrict Traffic	Limiting freeway usage		Auto-free zone(s) of pedestrian mall type	
8. Transportation Pricing Measures	Parking-related actions, fuel tax			Bridge and/or highway tolls, congestion, or road cordon tolls, fuel tax or mileage tax, parking related actions, vehicle-related fees
9. Measures to Reduce the Need to Travel	Four-day work week			Four-day work week, zoning-related change
10. Energy Restriction Measures	Restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales, reduced speed limits, gas rationing with or without transferable coupons			Gas rationing with or without transferrable coupons, restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales

Some qualifications made in the process of evaluating actions for generalized urban areas are:

1. Bus-only lanes on streets are applicable primarily to medium and large urban areas; reserved lanes or ramps on existing freeways are applicable primarily to large urban areas.

2. Traffic flow improvements are applicable to all size areas but are significant only where traffic flow is presently congested. In general, larger urban areas tend to have more traffic congestion than smaller areas.

3. Carpool programs are applicable to all size areas, but areawide coordination is likely to be more useful in medium and large areas. Travel time incentives are primarily applicable to large areas.

4. Implementing a transit improvement program in some small urban areas may require substantial capital outlays and administrative action if there is presently minimal or no transit service.

5. As a generalization, carpooling programs require a shorter lead time than transit improvements, especially where new buses or a public referendum are required for the latter.

6. Walking and bicycling-related actions are unlikely to achieve a sizable energy reduction by themselves.

7. Incentive actions are more popular than disincentive actions.

8. Small scale auto-free zones, such as pedestrian shopping malls, may receive favorable public reaction, but large scale auto-free zones, where greater restraints are placed on auto travel, probably will not.

9. The four-day work week may have considerable energy reduction potential depending on whether or not a great deal of extra weekend recreational travel would be generated. However, the four-day work week may not be economically feasible.

10. Zoning-related changes may be implemented in the short range, if the local political realities permit, and thus are included in the list of actions. While they have considerable potential for reducing energy consumption, the impact from these actions is likely to take longer to materialize in comparison with most other actions.

11. Energy restriction actions are very powerful tools to reduce energy consumption. If implemented, they would serve as the driving force behind other actions, while other actions would be necessary to make them palatable.

12. Staggered work hours will tend to be effective in assisting in better utilization of transit service but may interfere with effectiveness of carpooling programs by making it more difficult to find carpool mates with compatible hours. However, "flexible" work hours could eliminate this difficulty.

FORMULATION OF PACKAGES

In order to formulate a logical package tailored to the specific conditions of an urban area, choice of actions to go into the package should be based on the following: 1) how well an action meets criteria selected as significant to the area, 2) how well an action interrelates with other actions in that area, and 3) what level of energy reduction is desired for the area.

As stated in the introduction to this chapter, the method for formulating a package is based on an incremental approach, where the first actions selected are those which are favorable according to most criteria and concomitantly interrelate satisfactorily with other actions.

Choice of additional actions is based on a gradual relaxation in the requirements for meeting criteria favorably and interrelating satisfactorily, until enough actions are selected to form a package with the desired reduction in energy consumption. Although development of only one package per area is likely to be necessary, the incremental approach allows for implementing additional actions should further reduction in energy consumption be desired.

The method of formulating these packages is illustrated by the development of nine sample packages. These are derived from the three sample evaluation tables for different size urban areas in combination with the matrix of interrelationships. For each sample urban area, minimum, medium, and maximum packages, representing increasing levels of reduction in energy consumption, are developed.

The guidelines for the formulation of the sample packages are:

1. *Minimum Package* -- includes those applicable actions which are evaluated as favorable according to 3 or 4 of the sample criteria and which neither overlap with nor are counterproductive to other actions.

2. *Medium Package* -- based on the minimum package; in addition, includes those actions which meet 2 or 3 of the sample criteria and are not counterproductive to other actions.

3. *Maximum Package* -- based on the medium package; in addition, includes those actions which meet 1 or 2 of the sample criteria. The interrelationships constraint is dropped so that all actions which would result in some increment to reduction in energy consumption are included.

These guidelines are examples and may, of course, be modified in application to a specific urban area. For instance, a given urban area may wish to achieve an energy reduction between that of the medium and maximum packages. This could be accomplished by inserting an additional guideline to establish a cutoff point in choosing some of the more marginal actions.

The sample action packages are presented in Exhibits 10, 11, and 12.

Some of the conclusions made in developing the sample packages are:

1. Carpool-related actions are good candidates for implementation in most urban areas, regardless of urban area size or the percentage of reduction required.

2. Some level of restriction of quantity of sales of gasoline or other energy restriction measures would be likely to enhance the effectiveness of any size package.

3. For a low level of reduction, it may not be necessary to implement both carpooling-related actions and transit-related actions which tend to overlap. Carpooling-related actions were selected for most urban areas because, in general, they may be quicker to implement. However, in many localities some transit improvements might might be attainable quickly.

4. Incentive-type actions which result in a sizable energy reduction tend to be selected before disincentive-type actions because they usually are more favorable for two of the sample criteria--minimal institutional obstacles and favorable public reaction.

5. Improvements to total vehicular traffic flow should be carefully screened because they tend to be counterproductive to several other groups of actions.

6. Taxi and truck-related actions are suggested only in large urban areas where they are more applicable.

7. The reduction in energy consumption that can be expected from implementation of an action or a number of actions depends on several local factors, such as extent of expected application, institutional and policy framework, existing degree of implementation of transportation control strategies, and local attitudes toward energy conservation.

EXHIBIT 10

PACKAGED ACTIONS TO REDUCE ENERGY CONSUMPTION IN A SMALL URBAN AREA (50,000 - 250,000 POPULATION)

ACTION GROUP	PACKAGES		
	Minimum Package	Medium Package	Maximum Package
1. Measures to Improve Flow of High Occupancy Vehicles			
2. Measures to Improve Total Vehicular Traffic Flow			Eliminate unnecessary traffic control devices, improved signal systems, widening intersections [1-4%]
3. Measures to Increase Car and Van Occupancy	Carpool Program: Public information, encourage employer programs, carpool matching guidance, possibly cost and/or convenience incentives [5-10%]	Carpool Program: Public information, encourage employer programs, carpool matching guidance, possibly cost and/or convenience incentives [5-10%]	Carpool Program: Public information, encourage employer programs, carpool matching guidance, possibly cost and/or convenience incentives [5-10%] Neighborhood ride sharing
4. Measure to Increase Transit Patronage		Fare reduction in combination with service improvements [4-7%]	Fare reduction in combination with service improvements, demand responsive service [4-7%]
5. Measures to Encourage Use of Walk and Bike Modes		Bicycle storage facilities, bikeway systems [1-3%]	Bicycle storage facilities, bikeway system, pedestrian mall [1-4%]
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement			
7. Measures to Restrict Traffic			Auto-free zone of pedestrian mall-type [0-1%]
8. Transportation Pricing Measures		Parking-related actions [1-2%]	Parking-related actions, possibly vehicle-related fees [1-8%]
9. Measures to Reduce the Need to Travel			Possibly four-day work week, possibly zoning-related changes [1-14%]
10. Energy Restriction Measures	Low level of restriction of quantity of sales on a geographical basis [2-6%]	Restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gasoline sales [5-15%]	Gas rationing with or without transferrable coupons restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gas sales, reduced speed limits [10-25%]
CUMULATIVE PACKAGE ENERGY REDUCTION (PERCENT)	5-10%	10-16%	16-30%

*The figures given in the boxes in the upper right hand corners are expected percent regional energy reductions if only the measures in the box are implemented.

EXHIBIT 11

PACKAGED ACTIONS TO REDUCE ENERGY CONSUMPTION IN A MEDIUM SIZED URBAN AREA (250,000 - 1,000,000 POPULATION)

	PACKAGES		
ACTION GROUP	Minimum Package	Medium Package	Maximum Package *
1. Measures to Improve Flow of High Occupancy Vehicles		Bus only lanes on streets [0-2%]	Bus only lanes on streets [0-2%]
2. Measures to Improve Total Vehicular Traffic Flow			Eliminate unnecessary traffic control devices, improved signal systems, widening intersections, staggered hours [1-5%]
3. Measures to Increase Car and Van Occupancy	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost and convenience incentives [6-11%]	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost and convenience incentives [6-11%]	Carpool Program: Public information, encourage employer programs, carpool matching guidance areawide coordination, costs and convenience incentives Neighborhood ride sharing [6-11%]
4. Measures to Increase Transit Patronage		Fare reduction in combination with service improvements, traffic-related incentives [5-8%]	Fare reduction in combination with service improvements, traffic-related incentives, demand responsive service [5-10%]
5. Measures to Encourage Walk and Bicycle Modes		Bicycle storage facilities, bikeway system [1-3%]	Bicycle storage facilities, bikeway system, pedestrian mall(s) [1-5%]
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement			
7. Measures to Restrict Traffic			Auto-free zone(s) of pedestrian mall type [0-2%]
8. Transportation Pricing Measures		Parking-related actions [1-3%]	Parking-related actions, possibly bridge and/or highway tolls, possibly vehicle-related fees [1-10%]
9. Measures to Reduce the Need to Travel			Possibly four-day work week, possibly zoning-related changes [1-14%]
10. Energy Restriction Measures	Low level of restriction of quantity of sales on a geogreaphical basis [2-6%]	Restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gasoline sales [5-15%]	Gas rationing with or without transferrable coupons, restriction of quantity on a geographical basis, ban on Sunday and/or Saturday gas sales, reduced speed limits [10-25%]
CUMULATIVE ENERGY REDUCTION (PERCENT)	6-11 %	11-18 %	18-32 %

*The figures given in the boxes in the upper-right hand corners are expectd percent regional energy reductions if only the measures in the box are implemented.

EXHIBIT 12

PACKAGED ACTIONS TO REDUCE ENERGY CONSUMPTION IN A LARGE URBAN AREA (1,000,000 OR MORE POPULATION)

ACTION GROUP	PACKAGES: Minimum Package *	PACKAGES: Medium Package *	PACKAGES: Maximum Package *
1. Measures to Improve Flow of High Occupancy Vehicles		Bus only lanes on streets, reserved lanes or ramps on existing freeways [1-5%]	Bus only lanes on streets, reserved lanes or ramps on existing freeways [1-5%]
2. Measures to Improve Total Vehicular Traffic Flow		Staggered work hours [1-2%]	Eliminate unnecessary traffic control devices, ramp metering and freeway surveillance, improved signal systems, widening intersections, staggered work hours. [2-6%]
3. Measures to Increase Car and Van Occupancy	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost, convenience and travel time incentives [6-12%]	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, cost, convenience, and travel time incentives [6-12%]	Carpool Program: Public information, encourage employer programs, carpool matching guidance, areawide coordination, costs convenience and travel time incentives Neighborhood ride sharing [6-12%]
4. Measures to Increase Transit Patronage		Fare reduction in combination with service improvements, park/ride facilities with express bus service, traffic-related incentives [7-10%]	Fare reduction in combination with service improvements, park/ride facilities with express bus service, traffic-related incentives, demand responsive service [8-12%]
5. Measures to Encourage Use of Walk and Bike Modes		Bicycle storage facilities, bikeway system [1-3%]	Bicycle storage facilities, bikeway system, pedestrian mall(s) [1-5%]
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement	High occupancy taxi operation [1-2%]	High occupancy taxi operation, restrict cruising, truck loading zones [1-3%]	• Combination of several truck and taxi-related actions [1-5%]
7. Measures to Restrict Traffic			Auto-free zone(s) of pedestrian mall type [0-2%]
8. Transportation Pricing Measures		Parking-related actions [1-3%]	Parking-related actions, possibly bridge and/or highway tolls, possibly vehicle-related fees [1-10%]
9. Measures to Reduce the Need to Travel			Possibly four-day work week, possibly zoning-related changes [1-14%]
10. Energy Restriction Measures	Low level of restriction of quantity of sales on a geographical basis [2-6%]	Restriction of quantity of sales on a geographical basis, ban on Sunday and/or Saturday gasoline sales [5-15%]	Gas rationing with or without transferrable coupons, restriction of quantity on a geographical basis, ban on Sunday and/or Saturday gas sales, reduced speed limits [10-25%]
CUMULATIVE PACKAGE ENERGY REDUCTION (PERCENT)	7-12 %	12-20 %	20-35 %

* The figures given in the boxes in the upper-right hand corners are expected percent regional energy reductions if only the measures in the box are implemented

Thus a range of reduction in energy consumption is given.

8. The total reduction in energy consumption that can be expected from a package of actions may be somewhat less than the sum of the energy reduction ranges given for individual actions in the package. This is because the reduction in energy consumption range for each individual action is stated exclusive of other actions. The greater the number of actions implemented, the more the energy reduction potential of an incremental action may be diminished.

The sample nature of the packages presented should be emphasized. Using this process, a somewhat different package from any one of the samples given may be developed for a specific urban area. The extent of application as well as level of impact of each action may also vary, depending on local conditions, energy reduction goals, and attitudes toward energy conservation.

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3. GCA Corporation, assisted by Alan M. Voorhees & Associates, Inc., prepared for the United States Environmental Protection Agency. Studies of transportation controls to reduce motor vehicle emissions in a number of cities. December 1972.

4. INTERPLAN Corporation. *Reducing the Need for Travel*, Report 7226R. July 1973.

5. R. H. Pratt Associates, Inc. *A Study of Low Cost Alternatives to Increase the Effectiveness of Existing Transportation Facilities - Results of Case Studies and Analysis of Busway Application in the United States*. January 1973.

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APPENDIX A

ACTIONS TO REDUCE ENERGY CONSUMPTION

INTRODUCTION

Identification of low cost (non-capital intensive) transportation actions which can be implemented within a short time includes describing the technology, the potential cost, the availability of resources to implement, administrative and legal aspects, and the indirect socioeconomic and environmental effects. The numerous transportation actions which could be implemented to reduce energy consumption are described in this Appendix. For ease in analysis they have been arranged into ten "Action Groups:"

1. Measures to Improve Flow of High Occupancy Vehicles
2. Measures to Improve Total Vehicular Traffic Flow
3. Measures to Increase Car and Van Occupancy
4. Measures to Increase Transit Patronage
5. Measures to Encourage Walk and Bicycle Modes
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement
7. Measures to Restrict Traffic
8. Transportation Pricing Measures
9. Measures to Reduce the Need to Travel
10. Energy Restriction Measures

Individual actions within each group are described in terms of the implementation requirements and the potential energy reduction. Institutional, legal, socioeconomic, and environmental aspects are summarized for the action group as a whole.

MEASURES TO IMPROVE THE FLOW OF HIGH-OCCUPANCY VEHICLES

Most traffic flow improvement measures tend to produce an initial decrease in fuel consumption due to an increase in average operating speed from low to middle range and a decrease in delays and excessive queuing. However, past experience has shown that the effects of the measures often promote an increase in vehicle miles of travel (VMT) over the long run. This can result in additional energy consumption and may eventually negate the energy reduction goal. One can generalize that most traffic flow improvements should not be undertaken without concomitant measures to improve and encourage the use of high-occupancy modes.

However, some traffic flow improvements that are oriented towards bus and carpool modes can be very beneficial. Among these are:

- Bus preempted traffic signals
- Reserved bus lanes on urban streets
- Exclusive bus/carpool lanes on streets and freeways
- Exclusive bus ramps

The implementing agency would be either the city traffic department or the state highway department, which generally have the legal authority, the manpower, and the financing capability to implement these relatively inexpensive actions within a period ranging from two months to a year.

Bus Actuated Signals

Bus priority signal systems involve the preemption of a normal signal cycle to permit buses to progress along a corridor with minimal delay. Generally, this is accomplished through properly located sensing devices which detect the presence of a bus and preempt the signal sequence, either extending an existing green phase or terminating an existing red one, in order to permit the bus to clear the intersection. This has an important advantage of moving large numbers of people in relatively fewer vehicles. Studies have shown that, in general, more time is spent by buses waiting at traffic signals than in picking up and discharging passengers.

Reserved Lanes or Dedicated Streets for Buses

This covers a range of actions such as: (1) eliminating a parking lane on arterials and reserving it for buses and right-turn movements, during peak hours or all day; (2) reserving an existing traffic lane for buses; and (3) setting aside a crosstown street or a street section for exclusive bus operations.

The advantage of this strategy is its attempt to segregate buses from autos. Buses in mixed traffic are severely handicapped because they suffer from all the street congestion while being an inherently slower mode of operation. The effectiveness of the strategy depends on the level of enforcement and concomitant service improvements.

An estimate made for the Baltimore area suggests that reserved bus lane improvements, in conjunction with transit service improvements, could result in a three percent reduction in VMT within central areas and a two percent energy reduction in urban fringe areas. (7) In Pittsburgh, a travel time ratio reduction from 1.7 to 1.1 was estimated, leading to a VMT reduction of about two percent in the CBD and one percent for the region. (10)

Based on VMT reduction, the energy impact is generalized as follows: 1-2 percent energy reduction in central city areas, 0-1 percent in urban fringe and suburban areas. Factors that affect energy consumption reduction are the present level of congestion and expected future level of transit service.

In general, designation of reserved bus lanes and streets does not require any legislative action other than local approval. In many jurisdictions, the designation of lanes for special uses is within the standing authority of the local traffic engineering agency. There are no significant obstacles involved in the use of Federal aid system streets for reserved bus lanes. Similarly, there do not appear to be obstacles to implementation of these measures at the state level although the experience varies from state to state.

Enforcement is essential to the effective operation of reserved lanes and streets. Compliance with this type of measure has proven to be good when accompanied by consistent enforcement.

Exclusive Bus or Bus/Carpool Lanes and Ramps

This energy conservation measure covers a range of actions including reserved lanes on bridge and tunnel approaches, reserved lanes on freeways, special bus ramps, etc. They can be implemented in several ways: by changing the vehicle size for a lane previously used by mixed traffic; by utilizing a contraflow lane for peak-hour travel (possibly reverse lane operation), or by constructing a special lane. Both of the first two methods are relatively inexpensive to implement, involving mostly striping, signing, and improvements such as portable delineators or cones, bus platforms, etc. Generally, contraflow operation is preferred because it utilizes lanes which have light traffic volumes during peak hours. Street widths should be sufficient to allow continued two-way traffic when a contraflow operation is implemented. Constructing special bus lanes involves a substantial capital cost and cannot be accomplished in a short-term period.

Enforcement of reserved lanes for such use is essential to the effectiveness of this type of measure. In some instances, local law enforcement agencies have expressed reservations concerning the feasibility of enforcing this type of freeway operation, especially when carpools are permitted.

In most urban areas, state initiation or at least state approval would be required for the implementation of reserved or contraflow lanes on freeways. In some instances, Federal cooperation would also be required for implementation. Depending on the extent of the program, the energy reduction could vary from 1-3 percent.

Institutional/Legal Considerations

The local traffic departments would have the authority to implement most of the measures in this group and therefore legal constraints would be limited to the feasibility of enforcing the exclusivity inferred by such measures.

The technology currently exists to implement these measures and in cases where no new construction is required, the capital expenditure is small.

An important consideration is the interaction of these measures with other programs. For example, greater effectiveness of exclusive bus lanes can better be achieved if employed in conjunction with the development of fringe parking lots. There can also be negative effects; for example, if traffic volume is not reduced by the availability of the bus service, exclusive lanes can create additional congestion.

Federal and state aid may be available to share the cost of such measures.

Indirect Effects

Socioeconomic -- A major benefit of these measures is the reduction in travel time expected for the high-occupancy vehicle or bicycle. However, if traffic volume along the route is not reduced, congestion and a resulting increase in travel time will ensue for all other vehicles.

Many measures related to grade separation for pedestrians and bicycles could be considered safety improvements, although exclusive bike lanes can present bicycle/vehicle conflicts at intersections if intersection priorities are not clearly marked.

Although some change in driving route may be expected from exclusive or reserved lane measures, the impact of lifestyle would be minimal and could be considered beneficial.

Environmental -- Improvement of flow for high-occupancy and low-energy consuming travel modes would probably have beneficial impact on the environment if the total level of congestion is reduced. Introduction of these priority-group measures alone, without concurrent VMT reduction measures, could possibly induce further congestion and subsequent air and noise pollution. For instance, implementation of reserved or exclusive bus lanes could induce congestion on surrounding streets from traffic trying to avoid these areas.

MEASURES TO IMPROVE TOTAL VEHICULAR TRAFFIC FLOW

Traffic flow improvements derive energy saving capabilities by increasing vehicle operating speeds from low to medium. The long run effect may be increased VMT which uses more energy if other methods to encourage non-automobile modes of travel are not implemented.

Some possible traffic operational actions are:

- Improve the signal system and its operational and physical maintenance
- Implement one-way streets, reversible lanes, intersection turning movement restrictions, etc., where they would decrease congestion
- Eliminate unnecessary traffic control devices
- Provide driver advisories for parking
- Widen intersections
- Provide ramp metering, freeway surveillance, driver advisory displays
- Stagger working hours

Most of these actions could be undertaken by a state department of transportation or highway department and/or traffic departments of individual jurisdictions. They are inexpensive and can be implemented in a short time period.

One method of funding for such improvements is through Federal programs, such as the Highway Safety Program, or through Federal Aid Urban System funding.

Improved Signal Systems

Improving signal systems may mean any number of interrelated actions including:

- Computerizing the signal system allowing better allocations of green time and greater flexibility of adjustment

- Timing signals to result in signal progressions in the direction of heavy traffic

- Making the signals traffic responsive, allowing the signal cycle to change based on traffic flows

- Upgrading maintenance

The following initial travel time decreases on affected roads resulting from improved signal systems were found in various cities: (11)

	Percent
Kansas City	12
New York	20-40
London	9
Toronto	8-37
Glasgow	12
San Jose	10-12
Louisville	1-24

This results in an average of 5-15 percent improvement in travel time which includes an average 10-30 percent reduction in stop/go cycles and a 2-6 mile per hour speed improvement. On the average, a 5-15 percent improvement in travel time could result in about an 8-20 percent energy reduction during congested periods for an area where traffic congestion is a problem, such as downtown areas. Over the region, this might mean an energy reduction of 1-4 percent.

Implement One-Way Streets, Reversible Lanes, Intersection Turning Movement Restrictions, Intersection Channelization

These are improvements to increase the capacity of existing street systems and decrease congestion. Most cities have one-way streets which increase the vehicular capacity of the street by 15-30 percent and result in fewer delays than two-way operation. Washington, D.C., is an example where reversible lanes are used during morning and evening peak hours. This type of operation can increase capacity 20-50 percent and increase speeds 2-6 mph.

The initial energy reduction resulting from improved operating speeds and decreased delays depends on the extent of the programs and the current degree of congestion. A comprehensive program in a downtown area might result in an energy reduction of 1-4 percent.

Traffic flow at intersections is frequently restricted because of a lack of adequate channelization to handle the volumes of traffic desiring to make various turning movements. Improved channelization can often result in decreased congestion and decreases in air pollution and energy consumption.

Eliminate Unnecessary Traffic Control Devices

Most established urban areas contain numbers of traffic control devices, particularly traffic signals and stop signs, that do not meet warrants for such devices adopted by the Federal and state agencies. Frequently, unwarranted traffic control devices result from changing traffic patterns and as the result of special interest pressure.

Removal of unwarranted traffic control devices accomplishes, in general, the same result as other traffic engineering improvements, i.e., reduced congestion, reduced "stop and go" cycles and increased operating speeds. In addition, the elimination of a single unwarranted traffic signal yields an electrical energy reduction of over 5,000 KWH annually.

Local and state traffic engineering agencies generally have standing authority to remove unwarranted traffic control devices. In some urban areas, local legislative concurrence is also required for the removal of such devices. Obtaining this approval can be a formidable obstacle in implementing this type of action.

Staggered Working Hours

This energy conservation action is one which requires considerable coordination, particularly with major employers within the urban area. There are many large employment centers that have the same work hours for all employees. This creates extremely high peak hour traffic flows and results in delays and congestion because the demands cannot be met by the existing street system.

A staggered working hours program would tend to spread the number of vehicles using the street system over a longer time period, thereby reducing the high peaking characteristics within a shorter time period. This would result in increased efficiency of traffic flow through the reduction of delays and improved travel times along the transport system.

Staggered work hours may be achieved by varying starting and quitting times on a company-wide basis, for example, or by allowing flexible hours for the individual employee. Staggering work hours can be beneficial to transit service by reducing the peak period demand and spreading it to times when transit vehicles are operating at lower capacity. Staggered work hours can have the opposite effect on carpooling, however, by making it more difficult to arrange convenient times.

Ramp Metering, Freeway Surveillance, Driver Advisory Displays

These are all measures to reduce traffic congestion on freeways:

- Ramp control measures entail the limiting of vehicle entry onto the freeway at a given ramp in order to maintain a desired level of service.
- Freeway surveillance techniques are designed to identify and then locate the points from which slow downs and stoppages emanate. Once identified and located, corrective action can be quickly taken and smooth flow restored.
- Driver advisory displays are designed to help motorists by providing information on congestion conditions, hazardous conditions, or to guide them to destinations such as parking facilities by the best route available.

These measures achieve some energy reduction as a result of smoother traffic flow and higher speeds. On the other hand, they do not tend to reduce vehicle miles of travel and may actually increase it. Because of these mixed effects, no energy reduction is estimated.

Institutional/Legal Considerations

In general, this group of actions has a negligible impact on the institutional or legal systems. The capital expenditures required are minor and legal authority to implement and enforce the measures exists within the local jurisdictions.

Indirect Effects

Socioeconomic -- These actions result in travel time savings to automobile users, at least initially, and safety is usually improved.

Environmental -- Vehicular traffic flow improvements can have a limited short-term effect on air pollution. However, if additional VMT is generated, the long-term effect can be detrimental.

MEASURES TO INCREASE CAR AND VAN OCCUPANCY

A combination of measures is necessary to develop a successful carpool program. The combination should include: (1) carpool rides matching techniques, (2) an informational program to make people aware of the program, and (3) incentives to carpooling and/or disincentives to driver only cars.

The purpose of carpool matching is to give people better knowledge of whose travel patterns are similar to theirs and to bring them together. There are both manual and computerized matching techniques. Many situations can employ simple manual methods, especially where the program is being developed by small to medium size employers with less than 1,000 personnel. This category includes the vast majority of employers. Computerized techniques and programs are useful for large companies or agencies and for matching on an areawide basis. The most widely used program is one developed by the Federal Highway Administration.

Public information activities are used to promote carpooling, to inform people about available programs, and to help people understand how to use the program. These activities include: publicity through local radio, television, and newspaper, promotional bumper stickers and displays, seminars, and involvement of volunteer groups within business and government.

Incentives to carpooling and/or disincentives to driver only cars include the following:

- *Cost-Related Incentives*
  - Removal of present parking cost subsidies employers may provide to their auto commuting employees
  - Parking cost subsidization where employer pays for all or part of the cost of parking for carpoolers, but not for driver-only cars
  - Provision of company-owned or sponsored cars or vans (example: 3M Company, Minneapolis)
  - Books of trading stamps (for example: Walter & Dunlop, Washington, D. C.)
  - Allocating preferential parking places based upon car occupancy without increasing parking costs for the carpoolers

- *Convenience-Related Incentives*
  - Allocating closer-in or preferential parking spaces to carpoolers
  - Special park-ride lots for carpoolers and bus-poolers
  - Early work departure privileges
  - Banning of low occupancy autos in selected areas
  - Parking supply reductions with special permits for high-occupancy vehicles
  - Allocating closer-in or preferential parking spaces to carpoolers
  - Special park-ride lots for carpoolers and buspoolers
  - Early work departure privileges
  - Banning of low occupancy autos in selected areas
  - Parking supply reductions with special permits for high occupancy vehicles

- *Improved Travel Time Incentives*
  - Reserved lanes on freeways for buses and carpools, either with-the-flow or contraflow
  - Priority ramp metering for buses and carpools
  - Reserved toll plaza lanes for buses and carpools

The majority of previous carpool programs were organized by individual employers for their employees, often motivated by parking shortages or severe traffic congestion. This kind of activity could be an integral part of areawide carpool planning. However, in attempting to achieve energy reduction and other benefits through carpooling, a major sponsor or coordinating agency would be needed. Depending upon local conditions, the agency could be the city traffic department, a transit authority, the regional council of governments, the state department of transportation or highways, a business or civic group, or the media. This agency would develop information related to where people live and work, identify potential employers who would be interested in establishing carpool/vanpool programs, and coordinate carpool planning with transit planning. Such a program is presently being sponsored by the U. S. Department of Transportation.

The potential for reduction in energy consumption due to carpooling is substantial. The exact percentage reduction depends on factors such as the current auto occupancy, the expected level that could be obtained, and the percent of VMT due to work trips (the trips most affected). A Los Angeles study shows that, if the commuting auto occupancy could be raised from 1.1 to 1.7 and the total average auto occupancy from 1.4 to 1.7, there would be a 10 percent reduction in VMT which roughly translates into a 10 percent reduction in transportation energy consumption. (26) A carpool study done for the Seattle in the downtown area estimated a potential of 11 percent.

A formula for calculating percent reduction is: (12)

$$100 - \frac{\text{old work occupancy}}{\text{new work occupancy}} \times 100 \times \frac{\text{work trip VMT}}{\text{total trip VMT}}$$

$$100 - \frac{\text{old non-work auto occupancy}}{\text{new non-work auto occupancy}} \times 100 \quad \frac{\text{non-work trip VMT}}{\text{total trip VMT}}$$

An average energy reduction that could be expected from a comprehensive carpooling program would be 8-12 percent.

An important consideration about carpooling is the extent to which it detracts from transit usage. In corridors served by transit, carpools could be competing for the same "auto-driver only" work trips. But to some extent they may appeal to different types of people. Carpooling programs are primarily directed towards work trips whereas transit improvements are generally oriented towards a wider variety of trips. However, in some areas transit may not be as feasible as carpooling. Although they may detract from each other somewhat, the cumulative impact is likely to be greater than that of either one alone.

In some ways transit, taxis, and carpools can be coordinated to achieve mutual benefits. Also, transit and taxis are likely to benefit by serving mid-day trips for which autos will be less available.

Two assets of a carpooling program are its ease in implementation and the relatively low capital cost required. Current transit systems do not have enough peak hour capacity to handle much diversion from commuter autos. Most transit improvement programs require additional buses, and annual bus production capability is limited and takes time to expand. Thus, over the short-term, carpooling is likely to play a primary role in efforts toward energy reduction through this readily available higher occupancy mode.

The Department of Transportation has numerous reports on carpooling which describe in detail various aspects of carpooling including manual and computerized matching, incentives to carpooling, carpool organization, legal and institutional issues, transit/taxi coordination, back-up systems, buspools, etc. These reports may be obtained from the U. S. Department of Transportation in Washington, D.C. (31)

Neighborhood Ride Sharing

This includes such pooled actions as taking a number of children to Scouting or Little League activities. The concept may be broadened to include shopping trips, trips to various churches or similar informal activities which are not covered under carpooling. Conceivably, this could become a coordinated program with a central phone bureau and posters and advertisements. However, informal sponsorship by groups which require meetings might be a more likely possibility.

No attempt is made to estimate energy reduction impact of neighborhood ride sharing.

Institutional/Legal Considerations

Costs of carpooling programs, either to employers or to government agencies, are likely to be small. For an areawide carpool program, establishing an effective organizational structure in the responsible agency would be an institutional constraint.

Legal questions may arise involving (1) the legality of offering incentives to carpooling, (2) the regulatory status of carpools, (3) the insurance status of carpools, (4) liability of sponsors of carpool programs, (5) competition with regulated for-hire modes of travel, etc. However, these questions are by-products of carpooling and are unlikely to become impediments to a carpooling program.

Indirect Effects

Socioeconomic -- Carpooling generally reduces out-of-pocket costs to the auto traveler. However, travel time is usually increased somewhat, unless travel time incentives are employed. If a successful areawide program is implemented, travel time improvements may automatically occur due to the reduction in the number of vehicles traveling on the transportation system.

Environment -- A decrease in air and noise pollution may result. Depending on the trip-type mix for the area and how much carpooling competes with transit operations in decreasing auto miles of travel, a reduction in mobile source air pollution of up to 10 percent can be achieved.

MEASURES TO INCREASE TRANSIT PATRONAGE

A number of measures to increase transit patronage may be considered. These include service improvements, fare reductions, park-and-ride facilities, demand-responsive systems, bus priority traffic flow improvements, etc. Generally, a number of these measures would be employed in a transit improvement program. The improvements to be emphasized would naturally depend on the type of present services of the urban area involved.

An important consideration is that many cities have ongoing Transit Development Programs, which should be analyzed for their energy reduction impact and incorporated into any energy reduction package.

Energy reduction estimates resulting from transit improvements are actually based on reductions in automobile VMT, and thus on changes in modal split. For most transit improvements, the additional bus VMT generated is assumed to be negligible.

Bus, Subway, and Commuter Rail Service Improvements

Service improvements on urban transit systems can encourage greater ridership by making transit usage more attractive.

Service improvements include:

- *Scheduling* -- more frequent service, greater reliability of service
- *Routing* -- expansion of service to more areas, direct routes to reduce or eliminate transfer requirements
- *Information* -- better information services for fares, routes, and schedules
- *Marketing* -- advertising, direct mail, radio, television
- *Passenger Shelters* - including benches, shelters, and bus loading zones or pull-outs
- *Equipment* - new and cleaner buses, cars, or stations; air conditioning
- *Fare Collection Methods* -- convenient token or ticket schemes, eliminate transfer fees
- *Safety Improvements* -- police protection, better lighting

- *Special services* such as:
  - service to job centers not served by areawide transit
  - service for handicapped persons
  - off-peak shopping specials
  - service to sports events and parks
  - express services
  - service to medical care centers

All of the above would be implemented by the transit operator, whether private or public. Some would require public monies in the form of Federal capital grants supplemented by local matching funds. In some cases, referenda would be required to pay for the local share of costs through bonds or other actions; however, most can be implemented at very little cost and will yield increased ridership. Most of these actions will be included in short-range Transit Development Programs presently being studied or implemented in many urban areas.

The purchase of additional buses can be a constraint, as many cities are presently attempting to purchase buses and production is limited. Therefore, an expansion-of-service-related improvement program may be more difficult to implement in the short-range.

The reduction in energy consumption as the result of transit service improvements may be estimated from VMT reduction caused by a change of mode from automobile travel. Some estimates of VMT reduction due to service improvements which were developed for Transportation Control Strategies to reduce air pollution follow:

Area	Percent VMT Reduction	Comments
Salt Lake City, Utah (11)	1-2	Downtown and peak corridors
Baltimore, Maryland (7)	3	Central city and urban fringe suburbs
Los Angeles, California (26)	3	Region

Fare Reductions

In some cases, fare reduction appears to have been a significant element in attracting increased transit ridership, both from old and new patrons. In Atlanta, a reduction of fare from $.40 to $.15 resulted in a 28 percent increase in ridership, of which about half were previous auto users. Other experiments are being conducted in Boston; Denver, Marin County, Orange County, San Diego, San Francisco, Santa Cruz, California; Seattle; and Toronto. Some no-fare experiments are also being conducted, as in downtown Seattle. Promising increases in ridership have been reported. Generally, these fare reductions have been accompanied by some service improvements. In part, the value of a fare reduction program may be the publicity it attracts to transit. In general, increased ridership has not offset lower fares in terms of revenue generation, resulting in a net revenue loss. Thus, fare reductions as well as service improvements generally require some type of public subsidy. Some studies indicate that if the cost needed for a fare reduction program were applied to service improvements, a greater diversion from auto use would occur. The combination of a fare reduction with service improvements, however, seems to be a promising tool.

Traffic-Related Incentives to Ridership

These actions have been generally described above. They include:

- Bus-priority ramp metering
- Exclusive bus ramps to freeways
- Reserved bus lanes on freeways and at toll plaza approaches
- Bus lanes on city streets
- Bus-actuated signal systems

The energy reduction potential of these improvements is derived from decreased VMT due to change in modal split from auto to bus. This increase in bus usage occurs because of decreased travel time by bus accomplished through the bus-oriented traffic improvements.

By analogy with other actions, if a comprehensive program of bus priority or bus exclusive traffic actions was undertaken, energy consumption reductions of 4-8 percent in corridors, 2-6 percent in the CBD area, and 1-5 percent regionwide would be a generalized estimate. For example, an estimate for the Shirley Highway on I-95 in Virginia busway project gives a corridor VMT, or energy consumption, reduction of approximately 6 percent. (21)

Park/Ride Facilities with Express Bus Service

Park-and-ride actions for transit users may utilize existing facilities or require construction of new parking lots. Existing facilities that might be utilized are stadium and shopping mall parking lots to be accompanied by express bus service and/or reserved bus lane operations Traffic and highway departments would be involved if buses were given special roadway privileges; city and regional government agencies would be involved in coordination, and implementation funding can come from local, state and Federal sources. In general, unless exclusive bus lanes are specially constructed or new parking facilities built, costs are relatively low.

VMT reductions due to the park-and-ride strategy translates into a relatively small energy consumption reduction, because the park-and-ride strategy reduces the straight running portion of the ride as opposed to the "cold start" portion of a trip. Since the "cold start" portion of a trip requires more BTU/VMT than the running portion of the trip, the percent reduction in energy consumption is decreased slightly from percent decrease in VMT.

An estimate for Seattle indicates a four percent energy consumption reduction in corridors to the CBD and a two percent reduction in the CBD, resulting in a 1-2 percent reduction overall from park-and-ride actions. An estimate for Pittsburgh gives a one percent travel decrease in corridors to the CBD and in the CBD. For Los Angeles, a regional reduction of 2.5 percent is estimated for a hypothetical busway system on all freeways with extensive park-and-ride facilities. (12, 10, 26)

Thus, the impact of this strategy varies with the extent of the park-and-ride-express bus service system and with the amenability of the area to such service. A generalized figure for the CBD would be 3-5 percent energy consumption reduction and .5-2.5 percent for the region.

Demand-Responsive Systems

Potential actions include:

- Demand-responsive operation of feeder bus routes
- Demand-responsive high occupany operation of taxis
- Demand-responsive operation of a pool of vehicles for all social service agencies in the area including hospitals, welfare agencies, day care centers, etc.; this pool could have vehicles and operators tailored to needs of elderly and handicapped persons
- Dial-a-bus systems with manual or computerized dispatching systems, usually for low to medium density areas, can provide special services and be equipped to handle needs of elderly and handicapped persons

These would be implemented by the transit operator, taxi operators, and the agencies involved. All require some initial funding, with some systems requiring costly computerized systems, as well as good organization and management. In general, on bus demand-responsive systems revenues generated are not sufficient to cover costs.

The energy consumption reduction potential is related to the new riders diverted to the transit feeder routes. Consolidation of agency services can also reduce fuel usage as fewer trips are made by agency vehicles.

Overall Energy Impact

To some extent, the various transit improvements do complement each other, for example, fare reductions generally require some service improvements, and park-and-ride-express bus service are enhanced by reserved or priority bus traffic operations. However, the cumulative energy reduction may be somewhat less than the sum of the individual reductions.

There is also a limit to the amount of energy reduction potential possible from "incentive-type" strategies alone, such as transit improvements, without concomitant "stick-type" disincentives to automobile use. All of the estimates above have been made under the assumption of no particular auto disincentive strategies. These strategies would naturally enhance the impact of the "incentive-type" strategies to higher vehicle occupancy modes.

A rough estimate of the maximum energy reduction from transit improvements without disincentives to auto use is 8-10 percent. As discussed earlier, a concomitant carpooling program might reduce the potential energy reduction of transit improvements; however, the cumulative reduction of the two would be greater than either alone.

Institutional/Legal Considerations

In general, measures to increase transit patronage have minimum institutional or legal constraints. The legal authority exists in the local highways or transit operations departments and they require no enforcement. The technology is currently available and the only question is one of cost-effectiveness. However, local referenda may be required to approve taxation or allocation of funds to pay for local shares of some improvements.

Major increases or improvements in service will require additional buses or transit vehicles which requires some capital expenditure and lead time for procurement and manufacture.

Demand-responsive systems can have special value for particular groups in the population, e.g., handicapped, elderly, or sick persons.

Indirect Effects

Socioeconomic -- Travel time savings to transit riders may result from service and travel time improvements. Fare reductions would result in some cost redistribution. If substantial patronage is generated due to a particular new facility, economic development around the facility may occur.

Environment -- Increases in transit patronage can provide a 1-10 percent decrease in automotive emissions, again providing the interaction with carpooling is considered.

The park-and-ride facilities present some question as to their resultant local versus regional environmental impact. On a regional scale, they provide some benefit; however, they can create local congestion and resultant pollution problems and should be carefully located. The proliferation of very large lots or bus terminals would be an extreme example of a detrimental effect of such measures.

MEASURES TO ENCOURAGE WALK AND BICYCLE MODES

Walking and bicycling are modes that, until recently, have received little attention as alternates to the use of automobiles. Experience with these alternate modes of travel suggests that cost-effective measures to promote their use can be undertaken.

Four measures to encourage walking and the use of bicycle can be identified:

- Provision of facilities for pedestrians and bicyclists
- Modification of regulations to encourage walking and bicycling
- Enhancement of the "image" of these modes as desirable, healthful, and enjoyable activities
- Emphasis of the cost savings involved in the use of bicycles and walking

Some of the more specific measures included in these categories are described in the following sections.

Pedestrian Malls in High Activity Centers

Pedestrian malls have generally been designed to create areas where the pedestrian was free to leisurely stroll or to move more purposefully in a pleasant and safe environment. The malls range in types from those in large regional shopping centers to existing streets from which all vehicular traffic has been banned. In the latter case, benches, trees, and other plantings have been added to enhance a parklike atmosphere without detracting from the opportunities for access to commercial properties which bound the mall.

Well designed malls can be created with relatively low capital outlay where existing streets are utilized or they can be expensive depending upon the degree of refinement of the environment with benches, trees, and plantings.

The shopping center and other types of malls are usually created as an integral part of a major commercial development where the pedestrian environment is a primary concern. The evolution of underground walkways in cities such as New York and Philadelphia into mall-like areas has also proven to be highly successful and an inducement to the pedestrian to use them in short CBD trips.

Second Level Pedestrianways

Probably the most costly of the methods for the encouragement of pedestrian activities, these systems are finding application in many large cities. New York City, Montreal, and Philadelphia have extensive underground systems of pedestrianways connecting major CBD buildings with underground transportation terminals. In addition, the pedestrianways are lined with small shops and even department stores and theaters to create a mall atmosphere completely sheltered from weather and vehicular traffic. Cincinnati and Minneapolis have connected many large CBD buildings with above ground pedestrianways which run above the existing sidewalk or simply building to building at midblock points.

Pedestrian Actuated Traffic Signals

Pedestrian actuated traffic signals are in widespread use in urban areas. Their use can be expanded to new intersection locations and midblock locations, where warranted, to increase efficiency of traffic flow in areas of high pedestrian concentration.

Bicycle Priority Regulations at Intersections

This would give the bicyclist the priority at intersections. Specific measures include enactment of a "Yield to Bicycle" ordinance at selected locations, traffic signal equipment capable of being actuated by bicycles or their riders, or "All-Red" signal intervals to permit bicycle crossings in all directions. These measures would require special lanes and/or ordinances in order to adequately enforce such operation. They could be incorporated into a program to encourage bicycling within the urban area.

Bikeway Systems

Many cities are currently engaged in a process of seeking locations where bikeways can be developed. The assignment of existing street space is one possibility that appears to have the best likelihood of success despite institutional, safety, and technical problems now being examined.

Construction of new facilities on utility rights-of-way or easements is a possibility that is being considered in areas where such routing may serve the demand. Paving costs for such facilities tend to be low compared to street and highway paving but presently there are no methods for assessing user costs other than through licensing fees.

Bicycle Storage Facilities

The provision of bicycle storage facilities in the vicinity of major trip end locations in CBDs and at transit stations is one important method for encouraging bicycle use. Some European cities have provided bicycle racks on buses, an added inducement to bicycle users.

Energy-Impact of Walk/Bicycle Measures

As yet, there is little experience to indicate the potential for converting automobile tripmaking to walk or bicycle modes in the U.S. In Holland and China, bicycling is the predominant mode in urban areas. In some countries, walking is the predominant mode. However, urban areas in the U.S. have lower densities in general and have automobile-oriented land use patterns which are not as amenable to walk and bicycle tripmaking. The magnitude of the facilities and the change in public orientation indicates a relatively small impact over the short-term--perhaps 0-2 percent.

Second level sidewalks can also be considered as traffic flow improvement methods but with slight energy reduction possibilities.

Institutional/Legal Considerations

Within this group of measures, the vehicle-free or pedestrian mall concept and creation of bikeways are the elements with the greatest impact on the institutional/legal system.

The mall concept may create litigation problems by denying vehicular access to the area. It may also create problems with the goods delivery system, auto-oriented business, and transit service. Although there are no technical problems with the creation of the mall, the inadequacy of side streets to handle the diverted traffic may create problems. Some capital costs are incurred with the creation of a mall.

Bikeways create problems only to a very minor extent during the initial stages when local regulations may have to be altered and some capital cost may be incurred by the necessity to improve local streets to make them safe for bikeways. The negative reaction of motorists to the creation of bikeways can be alleviated by careful planning and construction to avoid vehicle/bicycle conflicts.

Indirect Effects

Socioeconomic -- If bikeways and pedestrian facilities are poorly planned, they can create additional vehicle conflicts and congestion.

The creation of pedestrian malls could induce economic dislocation for some auto-oriented business; however, experience has shown they are generally favorable to retail establishments in the area in terms of sales.

Environment -- In general, implementation of walk and bicycle-related measures will result in reduction in noise and air pollution.

IMPROVE THE EFFICIENCY OF TAXI SERVICE AND GOODS MOVEMENT

These actions are generally related to trips in congested downtown areas where efficiencies can be implemented to reduce vehicle idling cruising, or miles of travel per person trip.

Taxi Service

Fuel efficiencies may be effected for taxicabs by:

- Requiring or encouraging more fuel efficient vehicles
- Restricting cruising, thus reducing VMT
- Encouraging higher occupancy of taxis
- Encouraging jitney or similar para-transit services

Promoting more fuel efficient taxis could include encouraging or requiring taxi owners or companies to drive smaller, more efficient vehicles. In some areas this would require a change in regulations. The impact of this action would probably take several years to fully materialize, as the measure would most likely apply only to new vehicles. However, taxi turnover is more rapid than the private auto population.

Another approach being employed in several urban areas, to reduce air pollution, is the conversion of taxis or other fleet vehicles to gaseous fuels such as liquified natural gas (LNG), liquified petroleum gas (LPG), or compressed natural gas (CNG). For fleet operations these propellants have proven to be cost-effective; they are, however, in short supply in many urban areas.

In some cities a taxi regulation restricting the time or place of cruising (which means a taxicab driver is merely driving around waiting to be hailed by a passenger) has been imposed. Such a restriction will, of course, reduce VMT but should be accompanied by provision of adequate taxi stands or staging areas in which an empty cab is required to wait, unless the area is fully occupied.

Another approach is to enforce a limit of the ratio of total mileage to service mileage. The success of such schemes requires careful planning, discussion, and involvement of taxi owners and drivers, as well as enforcement.

A related measure would be to prohibit taxis from idling, or running the engine while awaiting a fare. Generally drivers do idle the engine for heat or air conditioning, or to listen to the radio, thus this measure would also require enforcement to be effective.

In some cities taxis are not permitted to pick up additional passengers while servicing a customer. Permitting and even encouraging this practice can be effective in reducing VMT. Permitting higher occupancy may result in a somewhat lower level of service; also, people will often refuse to share a cab with strangers, particularly if the time or cost will be extended to serve additional passengers. Fare schedules may require adjustment to accommodate this practice; in general the driver would have higher earnings.

In cities where transit service cannot be rapidly expanded or where there is an intensive travel corridor along a main arterial, jitney service may be encouraged to respond to latent demand. Jitneys have more flexible stops than transit and are generally privately owned and operated. Usually a single fare is charged no matter what the distance and the user is assured of frequent service. In many areas there may be objections to jitney services as competition to both taxis and transit. Most cities require licensing of such services; however, some operate on a "black market" basis.

Similar paratransit reduction impact of taxi-related strategies depends on whether taxis are a significant mileage factor in the area under consideration and on the current type of operation. Generally, the most significant impact would be in downtown areas of large cities. Any restriction of taxicab operations will likely bring opposition from taxi operators.

On a regional level, the generalized estimate of energy consumption reduction developed by taxi-related strategies would be 0-2 percent.

Urban Goods Movement

Goods movement related actions include:

- Changing the hours of goods delivery
- Instituting more or longer truck loading zones
- Providing terminals for consolidating merchandise
- Rerouting of through trucks where VMT would be reduced
- Providing rail or utility channels in subway utilization where possible

All of the above apply most specifically to downtown areas of larger cities.

Adjusting the hours of goods delivery, particularly restricting such delivery to night time hours could result in considerable fuel savings by reducing idling time and affording more direct routes. However, merchants and truckers generally view this as an onerous measure. One modification that is more pallatable and has been applied in many areas is to restrict loading hours to the off-peak daylight hours.

Several of the measures, such as loading zones and routing, are related to TOPICS type improvements, and should be considered in conjunction with other traffic flow improvements. Provision of terminals and other techniques require a longer implementation time and direct participation of the private sector.

A generalized estimate of the energy consumption reduction of goods movement measures is 0-1 percent.

Institutional/Legal Considerations

These measures are generally most effective for high density urban areas; therefore, implementation, operation, and cost would be at the local level, with some Federal funding assistance for TOPICS type measures. Although legal authority for these measures generally exists at the local level, some changes in regulations would be required to implement specific measures and opposition may be expected from special interest groups. If regulations are issued as restrictions, enforcement would be difficult.

Indirect Effects

Socioeconomic -- Measures requiring more fuel efficient taxis represent a savings to the taxi driver or company and if implemented at the point of turnover, may meet little opposition. Taxi companies may also oppose some taxi efficiency measures such as encouraging jitney service and restricted cruising as being detrimental to their business.

Increasing the efficiency of urban goods movement could have a significant improvement on travel time in cities where delivery vehicles are unloaded on the local streets. However, questions of safety and economic disruptions to the drivers of such vehicles are posed by such measures as nighttime goods delivery. It should be noted that goods movement improvements can be an adjunct to achieving higher transit ridership in the downtown area.

Environmental -- Taxi efficiency and goods movement improvement measures have been proposed as a means of reducing air pollution in major cities. By removing delivery and construction truck traffic from rush hour traffic periods, congestion may be relieved and some noise reduction could be achieved. Nighttime goods delivery measures, however, may shift the localized noise problem to the evening delivery hours, thus disturbing residential areas.

MEASURES TO RESTRICT TRAFFIC

This category described measures to discourage vehicle miles of travel by restraints on where and when the vehicles themselves are permitted to travel. Three types of measures to restrict traffic are:

- Creating zones where auto usage is banned or limited
- Limiting hours and location of travel
- Limiting freeway usage

Vehicle-Free or Traffic Limited Zones

Vehicle-free zones generally refer to closing off a limited area in a heavily trafficked commercial district to autos and trucks. There are over 100 cities in the world which have banned traffic from portions of their central cities. Most of these cities are in Europe where population densitites are higher and people are more accustomed to using bicycle, pedestrian, and transit modes. In the U.S., the major examples of such zones have been shopping malls.

The impetus behind most of these zones is to eliminate an ever-increasing level of traffic congestion which leads to high air pollution, noise, safety, and unpleasantness levels. There were questions as to whether the pedestrian malls would result in less sales and therefore commercial viability in the area. Experience indicates that the economic viability has not been threatened and has in fact improved in many locations. (3)

Provisions need to be made for rerouting of through traffic, necessary goods movement in the area, improved transit access to the area, and in some cases parking structures on the fringes.

The size of such zones has been fairly small. It is argued that their impact is also small except with regard to preservation of their own environment.

Gothenburg, Sweden, is an example of an area where an attempt was made to restrict unnecessary traffic. In this case, autos were not banned, but the city was divided into sectors, and vehicles were not allowed to cross sector lines. Through traffic was rerouted. This resulted in: elimination of traffic congestion, less travel in the area, more distance traveled by through traffic at higher speeds, and better performance by transit vehicles in the CBD. However, it is significant that Gothenburg is a relatively small city which is well served by transit.

It is important to realize that auto restricted zones can vary widely in scale and need not mean a total ban on cars.

What is the energy saving potential? Prohibiting or discouraging the use of the auto in certain zones would reduce VMT and therefore energy consumption in that zone. This energy reduction must be counterweighed with increased VMT due to rerouting of through traffic in the area and shifts in tripmaking to non-restricted areas. Experience indicates that, however, tripmaking to the area does not decrease, but may result in a resurgence in the popularity of the area. This would depend on the provision of better transit service or parking areas on the periphery. As to increased VMT due to rerouting of traffic, experience indicates that this need not be significant if the rerouting is designed well. However, energy consumption is usually improved due to less idling and stop-and-go-traffic.

In Los Angeles, a reduction of 0.6 percent regional VMT from making part of the downtown business area into an auto-free zone is estimated. This would require extensive changes in parking and land use patterns. If several downtown areas in the region were involved, however, the regional energy reduction would be greater. (26)

The potential for energy reduction through small scale auto-free zones is small, whereas large scale auto-free zones in the U.S. might require a great deal of land use or institutional change, unless attitudes toward the change are favorable. Therefore, the generalized estimate for energy consumption reduction potential through auto-restricted zones is 0.5-2.5 percent.

Limit Hours and Location of Travel

Limit Vehicle Travel to Certain Hours -- Under this measure, vehicle travel would be limited to certain hours. This measure would be enforced by identification of vehicles by means of stickers, license tag designations, and others.

It is not likely that this measure would achieve significant reductions in total VMT; however, this measure could be effective in shifting some VMT from high-congestion time periods to those of lower congestion, thus reducing peak period travel.

Major implementation obstacles related to this measure include the establishment of priority for the issuance of permits, and the enforcement of the travel restrictions.

In the absence of any such program, estimates of energy reduction effectiveness are difficult. Such a program would tend to be more effective as a part of a comprehensive vehicle limitation/transit improvement program.

Daily License System -- This refers to a form of road pricing whereby vehicles would be banned from a given area, such as a CBD unless a license valid for one day only had been purchased. Licenses would be sold at certain types of stores or from vending machines. Differential prices could be charged to different kinds of vehicles. The purpose of such a scheme would be to discourage travel in the area; however, it might result in additional travel in circumventing the area. It would have no predictable energy reduction impact and would be very hard to implement.

Limiting Freeway Usage

Freeway Ramp Use by Permit Only -- The operation of this measure would be similar to that of ramp metering, discussed previously in this appendix. An added degree of sophistication can be attained, since freeway entry by permit would allow some establishment of priority among potential freeway users. For example, permits could be issued first to those who could demonstrate the greatest need (inflexible working hours, no transit service alternative, etc.). Major drawbacks of this measure include difficulties in establishing permit issuance priorities and in enforcement of an on-going program.

Another example would be permitting only high occupancy usage (buses and/or carpools) on freeways during morning and/or evening peak hours. Major drawbacks here would be public acceptance and enforcement. Effectiveness of this type of measure is similar to that of freeway metering with priority bus operation, discussed elsewhere in this appendix.

Close Freeway Ramps During Certain Hours -- This measure is, in reality nothing more than freeway metering, with the closed ramps having a metering rate of zero vehicles per hour. Effectiveness is the same for the freeway metering, and costs are somewhat less, since sophisticated speed and volume sensing equipment is not required. This measure could actually increase VMT as a result of circuitous travel by motorists to find freeway access.

Institutional/Legal Considerations

The impact of vehicle-free zones or pedestrian malls on the institutional structure is minimal if they are restricted to small-scale areas. Subarea or regional scale restrictions of vehicles would have marked institutional and socioeconomic ramifications. Long-term planning for adequate, efficient transportation and goods movement could make larger vehicle-free areas more realistic; however, the capital investment would be major and would require a major reassessment of community priorities.

Limitations of vehicle travel by location or time can only be effective if alternative modes of travel are provided. In the absence of sufficient alternative modes, vehicles would attempt to circumvent the restrictions creating travel pattern disruption, congestion and enforcement problems. If permit systems are used to limit vehicle travel, the major problem becomes one of determining a justifiable priority system for issuing permits.

Indirect Effects

Socioeconomic -- Travel restrictions can have severe socioeconomic implications in terms of life-style alterations, travel pattern disruption, possible economic dislocation where income is dependent on travel, etc. However, when combined with transit improvements, alternative mode incentives, and an adequate public information system, the severity of impact can be markedly reduced. If these restrictions are limited to downtown areas and alternatives are not adequate, this would be an inducement for more downtown businesses to flee to the suburbs, removing the tax base which would support transit improvements.

Environmental -- It is likely that the air quality and noise level in the restricted area or time period would be improved, but to the extent that restrictions encourage circumvention, the problem would simply be relocated or spread over other time periods. Where additional VMT or trips are generated, or side street congestion is increased, the regional impact of such restrictions could be detrimental.

TRANSPORTATION PRICING MEASURES

Transportation pricing can lead to a reduction of vehicle miles of travel in basically two manners:

- By reducing the cost of other modes, relative to that of the automobile

- Raising the relative cost of automobile operation

The first category of measures is discussed elsewhere in this appendix, particularly in the sections on promoting higher occupancy modes. The measures discussed in this section deal primarily with increasing the cost of automobile operation.

Pricing measures can apply to the journey, to the cost of parking, or to the auto. Pricing can affect the direct out-of-pocket cost of travel, or be in the form of one-time or annual charges.

In general, automobile pricing measures represent a powerful means of altering travel behavior. At the same time, these measures tend to be highly unpopular and, consequently, tend to have serious implementation obstacles.

Bridge and Highway Tolls

The most direct method of attempting to influence travel behavior through pricing is through the application of tolls. A limited number of tolls have been implemented expressly for the reduction in traffic. The experience with these tolls suggests that they can produce meaningful shifts of travel to carpools and transit modes.

Disadvantages in the use of tolls as a means of reducing travel include:

- *Limited Application Opportunities* -- Some facilities do not lend themselves well to toll operation. Furthermore, toll operation is not permitted on some highways.

- *Traffic Diversions* -- These can be unpredictable and may actually involve an increase in total vehicle miles of travel.

- Undesirable long-range land use patterns may be encouraged.

Bridge and tunnel tolls may be more effective in appropriate corridors because it is difficut to circumvent them by transferring to a non-toll route.

The energy reduction impact of bridge and highway tolls is derived primarily from diverting trips from auto to transit mode and, secondarily, from discouraging tripmaking. With regard to modal split, typical models indicate a 0.2-0.4 percent increase in transit use for each cent of toll for CBD and fringe CBD travel. As an example of a toll/pricing situation: when bridge tolls on the San Francisco-Oakland Bay Bridge were reduced for 3 or more person carpools, the number of such carpools during peak periods increased from 1,000 to 1,800.

A generalized estimate for energy reduction impact is 5-10 percent in suitable freeway corridors, and 1-3 percent on a regional level.

Congestion Tolls

In a congestion toll scheme, rates vary according to the level of congestion present on the facility. This level is constantly being measured and reported. Further variations can include price differentials by vehicle type and vehicle occupancy.

Congestion tolls are the most sophisticated device available to deal with excessive peaking and the resultant congestion problems. Of all VMT reduction strategies, the congestion toll is the only one focusing on the peak period traveler as the source of a disproportionate amount of energy consumption.

Congestion tolls are a specific type of highway toll. Obstacles to congestion tolls are generally the same as those described above for the typical highway tolls. However, congestion tolls suffer the drawback of not currently being in use and perhaps being more cumbersome to administer.

Energy reduction impact of congestion tolls would be similar to that of highway tolls.

Vehicle Fee for Crossing Cordon Line

This measure refers to setting up toll stations and charging fees on all routes going in and out of a specified area enclosed by a cordon line.

The energy reduction impact would be similar to that of highway tolls, except that the tolls would be more widespread and diversion to other, toll-free facilities would not be possible. However, this measure would be very expensive and difficult to implement.

Increased Parking Charges and Parking Supply Management

Parking charges can be a powerful factor in choice of travel mode. For example, a 5.3 percent decrease in local CBD vehicle miles of travel was projected to accompany a $.87 daily increase in parking rates in Pittsburgh. (10)

It has been proposed by EPA that such increased parking charges be imposed as a surcharge on an areawide basis; with the fees collected to be used for transit improvements; however, this was not well received and has since been rescinded by the EPA Administrator.

As a part of a parking rate increase program, it is desirable to reduce the number of free spaces available. Removal of some on-street parking spaces may accomplish the dual purpose of restricting the parking supply and also improving traffic flow. However, there are usually few on-street spaces remaining in locations such as the CBD.

Implementation of parking charges in suburban areas that traditionally have had free parking at employment and shopping locations is a major undertaking, and serious obstacles would probably be encountered. Without areawide programs of parking cost increases, a strong program oriented exclusively to the CBD could have the effect of dispersing traffic to other parts of the urban area. As an example of energy reduction impact, in Baltimore a combination of increased parking charges with improved bus service and carpooling efforts could produce a 2-3 percent VMT reduction in the CBD, while the reduction in other areas of the city would be negligible. (7)

The program might consider zoning changes to prohibit new parking structures in specific areas, or provisions that no permit be issued for a lot or garage if it will result in an increase of VMT in the area. This has been promulgated as part of the transportation control plans to reduce air pollution in several urban areas.

Generally all forms of parking management--rates, regulations, permits, and allocations--should be coordinated by a special local government authority or department.

Impose Additional Gasoline Tax

This is, in effect, a tax on VMT that, in addition to discouraging total VMT, also tends to shift travel to more efficient vehicles.

Administration and collection of this tax would be relatively simple, due to the existing administrative structure for the collection of gasoline taxes. Any gasoline tax undertaken primarily to dampen demand for fuel can be expected to incur strong popular opposition, particularly at a time when gasoline prices are escalating rapidly.

The VMT reduction impact of higher gasoline prices, either from additional tax or inflation, is not as direct as other pricing measures, such as tolls, that must be paid daily or during each trip. Preliminary data related to the current situation indicates a VMT reduction of 5-8 percent in response to fuel cost increases of 30-75 percent and problems in obtaining fuel.

The feasibility of any fuel pricing measure is enhanced by the simultaneous implementation of measures such as transit improvements, carpooling incentives, etc.

Impose Mileage Tax

A mileage tax means application of a tax based directly on vehicle miles of travel. Major implementation obstacles to this measure are the reporting of VMT and administration or collection of the tax. Essentially the same result can be achieved by additional fuel taxes or vehicle taxes.

Differential Fee to Promote Fuel-Efficient Vehicles

This refers to the imposition of an annual fee at registration, graduated on the basis of weight and/or on the basis of "luxury" item energy consumption.

The two main vehicle characteristics which adversely affect fuel consumption are vehicle weight and "luxury" add-on devices like power steering, power brakes, automatic transmission, and air conditioning.

In Europe, differential taxes on cylinder displacement (a surrogate for weight) have helped cause the predominance of small-engined, fuel-efficient cars.

Average fuel economy in urban driving is 10 miles per gallon, and in regional driving is 12 miles per gallon. This corresponds to an average vehicle weight of about 4,250 pounds. (36) If a differential vehicle fee could help change the average weight of the vehicle mix, this would result in a percent energy reduction of:

Average Weight	Percent Energy Consumption Reduction
4,000	3-6
3,500	20-25
3,000	32-36
2,500	40-45

One source suggests that a conversion to 50 percent "small cars" in the vehicle mix would result in a 14 percent conservation of auto fuel on a nationwide basis. (17)

Air conditioning in use decreases efficiency an average of 1.5 miles per gallon; automatic transmission decreases efficiency an average of 1.6 miles per gallon; power steering decreases efficiency about 0.1 miles per gallon, etc. (35) No attempt is made to isolate the energy reduction impact of increased fees charged for cars with these items.

Change in mix of vehicles with respect to fuel consumption characteristics can be affected by a number of other measures such as increased gas taxes, gas rationing, or simply rising fuel prices. It is difficult to isolate the impact of any one measure. However, should an annual differential fee system be set up, it would definitely add to the impetus towards smaller cars. A generalized estimate of energy reduction impact would be 2-10 percent.

This action could be implemented by the motor vehicle bureau and could be an add-on to the annual registration process.

Tune-Up Requirements

A feasible measure to promote fuel efficiency is to require engine tune-ups every 5,000 miles. The better tuned the car, the more fuel-efficient it is. This measure could be implemented through the state inspection system. One method would be to require the presentation of receipts for tune-up services in order to pass inspection, with or without imposition of a fine for cars that have not been tuned up every 5,000 miles. A generalized estimate of energy reduction impact would be 0-1 percent.

Tax on Second or Third Car Ownership

This would mean a progressively greater tax on the nth car owned in the household above the one-car or two-car level. This tax would be hard to implement. The probable agency would be the motor vehicle bureau through the registration process. It would also probably be very unpopular, even considered "un-American." No attempt is made to estimate the energy reduction impact.

Tire Tax

This refers to increasing the tax on new or retreaded tires. The purpose of this tax would be to discourage VMT. The impact on energy consumption would be negligible unless scarcity conditions existed, as in World War II. This measure might have the undesirable side effect of encouraging usage of worn out tires.

Institutional/Legal Considerations

Pricing measures can be implemented at the local or state level or, in the case of taxing measures, also at the Federal level. Many such measures are already in effect to some extent and therefore technical problems are manageable. However, public opposition to imposition of such measures is strong. Furthermore, from the equity viewpoint these measures impact the poor more severely than the rich because of the regressive nature of flat taxes or other cost increases.

Indirect Effects

Socioeconomic -- As discussed earlier, any of the toll gate or ramp metering type measures will provide improved flow on the control arterial; however, local congestion problems at the point of entry could lead to an increase in travel time.

The objective of these pricing measures is to divert the automobile operators to more efficient modes or to force the user to pay a higher cost and transfer this benefit to the users of alternative modes. The cost of administering such programs will, however, diminish the amounts transferred to alternative modes.

The objective of many of the measures appears to be a restriction of mobility. However, mobility within the restricted or taxed areas should be improved. Driving patterns might be altered by motorists attempting to circumvent the taxed areas.

The preferential pricing of low-energy consuming vehicles would accelerate the trend to smaller vehicles with increased disruption and dislocation in the auto industry. These problems could be reduced if production shifts to energy-efficient vehicles or transit vehicles.

Environment -- The reduction in vehicle miles of travel achieved by such pricing schemes would yield an environmental benefit. The reduction in pollutant emissions would be approximately proportional to the reduction in VMT. Again, where ramp pricing or toll gates are employed, localized "hot-spots" could form due to congestion.

MEASURES TO REDUCE THE NEED TO TRAVEL

This heading includes several unrelated actions, such as:

- Implementing the four-day work week
- Zoning:
  - against "urban sprawl"
  - to promote mixed land use development with closer proximities of residence to work place
- Encouraging home goods delivery from stores
- Encouraging substitution of telephone and communications services for face-to-face contact requiring auto travel
- Encouraging neighborhood ride sharing

Four-Day Work Week

The four-day work week refers to a schedule of 10 hours of work, 4 days a week, or some similar arrangement, which permits a full work week and at least one week day of leisure. With respect to reducing energy consumption this measure may be expected to reduce the work trip one day a week. However, it may also be anticipated that additional fuel consumption could result from increased leisure travel. The four-day work week has been implemented in both production industries and office occupations with varying degrees of success. It tends to be less successful in those situations which require daily communication to transact business.

The four-day work week is advantageous for reducing air pollution as it tends to spread the daily peak travel period for work and to reduce the total number of work trips. Problems similar to those associated with staggered work hours may be encountered in implementing the four-day work week in conjunction with carpooling.

Assuming a range of 15-70 percent of the work force on a four-day work week and no additional recreation travel, it is estimated that energy consumption could be reduced 1.25 to 6.5 percent.

Zoning and Other Land Use Controls

Zoning measures can be an effective tool to reduce VMT; however, the effects of zoning controls are generally not felt in the short-term. Implementation of zoning measures is accomplished at the local level.

Two approaches towards zoning to encourage less VMT are: (1) zoning against types of development which are totally auto-dependent, i.e., for which it would be very difficult to provide adequate transit (generally described as unplanned "urban sprawl"), and (2) zoning to encourage mixed-use land development with closer proximity of residence to work place and other activity centers, e.g., new towns, apartment houses in downtown business areas, and Planned Unit Developments (PUDs).

In the long run, the effectiveness of zoning measures would be enhanced by energy restriction measures; they could yield up to 10 percent energy consumption reduction.

Home Goods Delivery

Home delivery of goods has declined in practice, at least for small consumer goods, with the increase in cost for such services. Also, the need for such service has diminished as people have gained more personal mobility and shopping center development has brought goods and services together for convenience.

The energy reduction potential arises from the difference between each customer making an individual trip back and forth and the delivery service making a longer trip to service many customers. There are, however, increased labor costs associated with taking orders, selecting merchandise, billing, loading, etc. The few remaining delivery services, such as dairy trucks, carry a selection of items, thus tending to reduce the cost of the service somewhat.

The energy reduction impact is difficult to estimate and would be negligible on the short-term. However, increased availability of free or low cost delivery might stimulate utilizaton of the service, thus reducing auto trips, especially where transit or paratransit services are not available. Local agencies and media could encourage pooled delivery much as they have done for carpooling.

Substitution of Communication Facilities

Communications can be substituted for transportation and face-to-face contact by usage of telephone, telegraph, computer, or even more exotic devices. With the present energy situation and the cost of obtaining fuel and other travel costs increasing, many businesses are finding it a better and cheaper means to utilize communications media as a substitute for travel. The impact of this measure is negligible in the short run.

Institutional/Legal Considerations

Implementation of many of the measures described above has already been attempted to some degree on a voluntary basis by individual employers or other groups. Four-day work weeks could be imposed by local or regional regulations; however, many industries or businesses may have to be exempted because their processes cannot be interrupted or they depend on the work schedule of other groups or businesses.

Land use control measures impose the legal problems of reversing or replacing many existing local zoning regulations and policies. For example, current policies encouraging low density, "urban sprawl" may need to be reversed to promote land use development with closer proximity of residence to work place.

The technology to implement measures such as home goods delivery or substitution of communications for travel does exist and has been applied on a voluntary basis to a limited degree; however, until the "stick" is applied forcing the need to reduce travel, many of these measures might not be sufficiently utilized to be cost-effective.

Indirect Effects

Socioeconomic - Changes in lifestyle would be induced by extensive implementation of many of these measures. For example, four-day work weeks tend to encourage recreational and social activities which could increase VMT, if not controlled by other restrictions or alleviated by transit. Many of these changes could be beneficial; however, the implications of lifestyle change require detailed study and planning to determine the effects on employment, transit usage, and other urban problems.

The cost of implementing technological amenities to reduce the need to travel would eventually be borne by the user; however, this cost could be a trade-off for the cost in dollars or time which would have been incurred by travel.

Many socioeconomic questions are posed by the use of zoning to reduce "urban sprawl" by promoting high density "clustering." For example, clustering may limit the worker to the job-types or industries available within the cluster.

Environmental -- The four-day work week tends to reduce detrimental air pollution effects by spreading travel over a longer daily time frame if a 10-hour day is assumed and allowing pollutants to disperse. The reduction of one day's travel will also tend to reduce pollutants unless leisure travel is substituted. The other measures suggested will probably have a positive environmental impact by reducing concentrations of pollutants.

ENERGY RESTRICTION MEASURES

This group of measures depends on the restriction of the supply of fuel and/or on the method of vehicle operation. Specifically, the following measures are examined:

- Retail gasoline rationing without transferable coupons
- Retail gasoline rationing with transferable coupons
- Restricted allocation of gasoline on a regional basis
- Bans on Sunday and/or Saturday gasoline sales
- Speed limit restrictions

Retail Gasoline Rationing Without Transferable Coupons

Under this system gasoline would be rationed and allocated on some systematic basis. To accomplish a ration coupon program several procedures (some of which were used in World War II) have been suggested. These include:

- Rationing to licensed drivers in a household
- Rationing on the basis of occupational or other need

- Rationing on the basis of proximity to a transit system
- Rationing on the basis of number of vehicles in a household

The coupons would not be transferable under this plan, except perhaps within a household.

Rationing can yield almost any level of energy consumption reduction desired, and can do so with relative certainty, since rationed allocations can be predetermined. The cost would depend on the method of distribution and enforcement employed. Rationing would be effective only if strictly enforced over a large urban area.

Gasoline rationing can undoubtedly produce large reductions in VMT. There may be difficulties in determining an equitable distribution method, however. As witnessed during World War II, the administrative requirements in order to assure such distribution can be onerous. Also, the potential for black market, counterfeiting, and other violations of the system can result in a costly enforcement structure.

Implementation problems related to rationing may be summarized as follows:

- *Mobilization* -- the administrative machinery of a rationing system must be designed and implemented. Necessary legislation must be passed and public information programs launched.

- *Administration* -- guidelines for dealing with coupon distribution and requests for variances and exemptions must be established, and local administrative machinery implemented.

- *Enforcement* -- potential black market activity or other violations of the program would require constant policing.

Preliminary estimates by the Federal Energy Office of the cost of a rationing program give a range of one to two cents per gallon of gasoline. Fees could be collected through the rationing mechanism or through general tax programs. Rationing would be most effective if applied nationally. A regional or statewide plan would encounter serious implementation difficulties, although such plans have been proposed in some areas with severe air pollution problems.

From the equity viewpoint, rationing is a less discriminatory means of decreasing gas purchases than increasing fuel taxes or allowing prices to rise to market demand levels.

Theoretically, gas rationing can produce as large an energy consumption reduction as needed. However, a reduction of more than 25 percent from levels to which energy consumption was predicted to grow in the next few years would impair economic activity. Therefore, estimated reduction from gas rationing is 10-25 percent.

Gasoline Rationing with Transferable Coupons

This gasoline rationing procedure is identical to that described above except that coupons may be freely exchanged or sold through a market mechanism.

Rationing with transferable coupons minimizes enforcement problems due to blackmarket activities associated with nontransferable coupons; however, additional administrative problems could develop. One suggestion to alleviate this situation is to limit the effective period of the coupons to a calendar month.

Restriction of Quantity of Gasoline Sales

This action refers to gasoline allocation to service stations on a geographic basis. The system presently in effect provides allocation on a statewide basis, with some variance for specific areas. The basis for allocation is a percent of sales for the same period in 1972.

One advantage of gasoline allocation/restriction of sales over gas rationing with coupons is that it is more easily administered, since the number of units (service stations) involved is much smaller than would be in providing coupons to nearly every individual. The administrative and enforcement machinery required is considerably less than with coupon rationing, yet the procedure effectively limits supply.

At the point of sale this can result in further limitations such as the odd-even plan in which gasoline is sold only on even days of the month to vehicles whose license ends in an even number. Sales may also be restricted to a dollar amount or to a specific number of gallons.

This system suffers from several defects. One possible defect is long waiting lines for gas, resulting in unproductive time losses, hazards to traffic and gas station operators, and a shift in energy consumption from tripmaking to unproductive searching for gas and idling.

Restriction of quantity of sales can be implemented together with practically any other transportation action, including coupon rationing. Restriction of quantity of sales does not have as high a maximum energy reduction potential as gas rationing with coupons because it distributes energy usage less efficiently in terms of keeping the economy productive. Therefore, the economic tolerance limit is reached at a lower percentage of energy reduction than under a system of gas rationing with coupons. However, energy consumption reduction through this system of 2-20 percent can be estimated.

Ban on Sunday and/or Saturday Gasoline Sales

Recently, there was a voluntary ban on Sunday gasoline sales. To some extent the result was merely to shift fuel purchase and travel to other days of the week. However, the trend in years past has been to increasing weekend travel, including long distance tripmaking by auto. Another popular weekend activity has been "Sunday pleasure driving." The ban apparently had an impact on these activities.

A Department of Transportation news release indicates an average decrease of 13.76 percent of VMT on Sundays immediately after the ban. Other figures were: 20 percent on rural Interstate routes, 10.93 percent on urban Interstate routes, and 10.72 percent on other urban roads and streets. Saturday traffic was also affected. On a year-to-year basis, Saturday driving in a 12-day period after the ban did not decrease. However, the increase was a negligible .51 percent compared to the increase projected by pre-gas crisis trends--5-10 percent.

Bans on Saturday as well as Sunday gasoline sales would result in even less weekend auto travel. However, it might further aggravate the development of long gas lines during weekdays. The action would be more effective if implemented on a state or national scale. The impact of Sunday and/or Saturday gasoline sale bans would be difficult to isolate from impacts due to restriction of quantity of gas sales, higher prices, etc. A generalized estimate of impact gives a range of 2-10 percent energy consumption reduction.

Implement Reduced Speed Limits

This measure refers to reducing speed limits on highways. Optimum fuel efficiency (lowest gallons per mile) is achieved in the 30-40 mph speed range. For every 10 mph increment over 40 mph the increment in fuel consumption increases at an accelerating rate. (35)

All states have implemented 55 mph speed limits in accordance with the Emergency Highway Energy Conservation Act. A decrease in average speed from 70 to 50 mph results in a 20-25 percent decrease in fuel consumed for the vehicle miles affected. This would probably affect intercity and rural travel more than urban area travel. However, almost all urban areas have high speed facilities, or freeways. Nationwide, an estimate has been made of a 1.4 percent savings in total transportation energy if there is a 50 percent success in limiting highway speed to 50 mph. A generalized estimate of the effect of this action is 2-4 percent in a freeway corridor and 0-2 percent in a regional basis for a medium size urban area. This action requires legislation on a state or Federal level, implementation by highway or transportation departments, and police enforcement. A side effect of reduced speed limits is fewer highway accidents. The current record on highways with reduced speed limits indicates 15-20 percent fewer fatalities.

Institutional/Legal Considerations

The problems associated with energy restriction measures are primarily during the initial implementation phase. Depending on the severity or regional extent of implementation, legal issues, including the questions of variances and justifiable allotment procedures; enforcement problems including the policing of black market activity and counterfeiting of coupons, etc.; and the high cost of an extensive bureaucracy to carry out the program could markedly reduce the program effectiveness and public acceptability.

Indirect Effects

Socioeconomic -- Assuming the initial implementation phase economic impacts are mitigated as inequities in supply are eliminated, a region will adjust by minor alterations in travel patterns and lifestyle, such as increased usage of carpools, alternative travel modes, etc. These alterations are seen by many as beneficial to society, although they would create some economic dislocation in auto-dependent industry or business.

Environmental -- Restricted energy expenditure is undoubtedly beneficial to the total environment. However, implementation phase disruptions can create localized pollution, traffic congestion and limited health effects. For example, gasoline stations become the local "hot-spot" for air and noise pollution, and long waiting lines create short-term exposures to high levels of carbon monoxide.

APPENDIX B

HOW TRANSPORTATION ACTIONS CAN REDUCE ENERGY CONSUMPTION

The purpose of this appendix is to provide background information on some of the relationships that were used in determining the reductions in energy consumption for transportation actions examined in the body of this document.

Transportation-related actions can cause reductions in energy consumption in one of three ways: 1) by reducing the amount of energy consumed per vehicle mile traveled; 2) by reducing the number of vehicle miles of travel per person mile of travel; and 3) by reducing person miles of travel. These may be viewed as: improving fuel economy; shifting to higher occupancy vehicles or to walk or bicycle modes; and reducing the number and/or length of trips.

IMPROVING FUEL ECONOMY

Calculations of energy reductions from actions resulting in better fuel economy involve 1) estimating improvements in miles per gallon, 2) estimating vehicle miles of travel impacted for specific subareas or for the region, and 3) conversion to energy savings on a regional level.

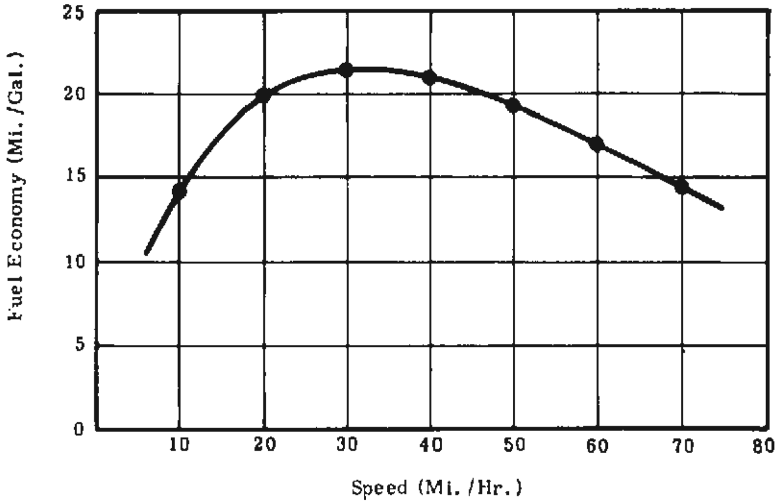
Factors which affect fuel economy are driving conditions or mode of operation (speed, stop and go cycles, and idling time), and vehicle-related characteristics such as weight, accessories, and tuning.

Operational Factors

Speed is a very important factor. The optimum fuel economy for most cars occurs at a steady speed of between 30 and 40 miles per hour. At cruising speeds above or below this level, fuel consumption goes up rapidly, as is illustrated in Exhibit B-1. Thus, energy can be saved by either decreasing speeds from high speed levels or increasing speeds from low speed levels. For instance, cruising at 50 mph instead of 70 mph results in a savings of about 25 percent. (35)

EXHIBIT B-1

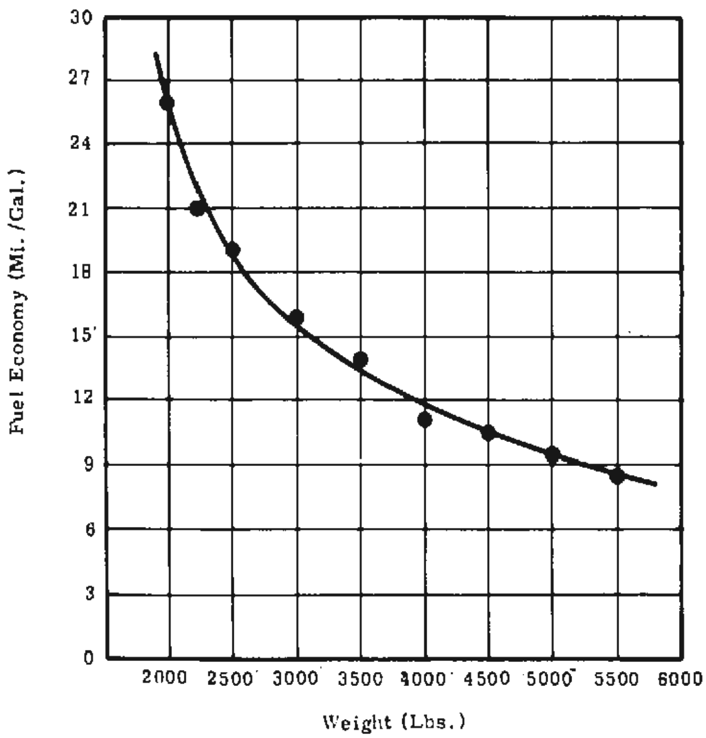
Fuel Economy Vs. Speed



Source: Based on figures from Paul J. Claffey's NCHRP Report 111: Running Costs of Motor Vehicles as Affected by Road Design and Traffic, 1971: figures assume "ideal conditions"--level roads, smooth surfaces, no acceleration and deceleration; no stop-and-go traffic.

EXHIBIT B-2

Fuel Economy Vs. Weight



Source; Based on figures from the U.S. EPA Office of Air and Water Programs: Fuel Economy and Emission Control, November 1972.

In addition, acceleration/deceleration and stop/go cycles result in increased fuel consumption over steady cruising speed operation. An acceleration/deceleration cycle from 30 mph to 10 mph and back to 30 mph results in extra gasoline consumption of about .0035 gallons. (4) Stop go cycles result in increased fuel consumption both from acceleration/deceleration and from idling. The average car consumes about .6 gallons/ hour when idling. (4) Usually, the larger the car, the greater the amount of gas consumed in idling. As an example of the composite effect of a stop/go cycle, one stop/go cycle per mile from a 30 mph level with 30 seconds of idling results in 20-30 percent extra gasoline consumed. (4)

Vehicle Characteristics

Weight is the most significant characteristic affecting fuel consumption as heavier cars require more power, and thus larger engine sizes to propel them. Larger engines, however, consume more fuel than small ones. Also, with the same engine size, a heavier car will consume more fuel than a lighter car. The approximate relationship of fuel economy to vehicle weight is illustrated in Exhibit B-2.

Convenience devices such as air conditioning, automatic transmission, power steering, and power brakes also contribute to fuel economy loss. Air conditioning results in a loss of 9-20 percent; automatic transmission results in a 2-15 percent loss; and power steering results in a 1-2 percent loss. (35) Emission control devices also increase fuel consumption. However, the fuel loss due to emission control devices varies greatly with vehicle weight, with lighter cars showing a slight gain and heavier cars showing losses of up to 18 percent. (35)

Fuel consumption is also affected by how well a car is tuned. Fuel economy improves an average of one mile per gallon after a tune-up, which is equivalent to a 10 percent improvement under urban driving conditions.

SHIFTING TO HIGHER OCCUPANCY VEHICLE OR TO WALK OR BICYCLE MODES

Calculations of energy reductions from actions causing modal shifts involve 1) estimation of changes in modal split for specific subareas or corridors; 2) conversion of modal split change to auto vehicle miles of travel reduction and to other mode miles of travel increases, if any; 3) conversion of vehicle miles of travel information to net energy savings; and 4) adjustment of energy savings to a regional basis.

Modal split models can be used to forecast modal split changes for local areas based on pricing, travel time, or service changes among modes. Local traffic data can be used to estimate affected vehicle miles of travel.

Factors which affect calculations of energy reduction impacts of actions to change modal split are: current modal split percentages, price elasticity, time elasticity, auto occupancy, transit occupancies, taxi occupancy, auto fuel mileage, transit fuel mileage, and truck load/capacity ratio. These factors vary from area to area.

Some national average figures for vehicle occupancy and fuel consumption by mode are given in Exhibit B-3.

CHANGING THE NUMBER AND/OR LENGTH OF TRIPS

Calculations of energy reductions from actions leading to reduction in number of person trips made involve: 1) estimation of reduction in number of trips made, generally by trip purpose and/or subarea; 2) conversion of number of trips reduction to person miles of travel reduction using existing trip length distribution; 3) conversion of person miles of travel reduction to vehicle miles of travel reduction using average auto occupancy; and 4) conversion of vehicle miles of travel reduction to energy savings, on a regional basis.

Factors needed for the calculations are existing trip length distribution and average auto occupancy in the local area.

COMMENT

Calculations such as those outlined above were used in deriving the energy reduction ranges for individual actions, generalized over all urban areas, given in Appendix A. Similar calculations can be undertaken to determine finer estimates of energy reduction for any specific area. If more detailed information on energy factors is desired, the reader is referred to the bibliography.

EXHIBIT B-3

VEHICLE OCCUPANCY AND FUEL CONSUMPTION BY MODE

Mode	Average Vehicle Occupancy	Type of Fuel*	Average Fuel Consumption (mi. /gal)
Auto	1.6 persons/auto		
• Urban Driving Conditions		Gasoline	10.0
• Urbanized Region Driving Conditions		Gasoline	12.0
• Nationwide		Gasoline	13.0
Bus	15.0 persons/bus		
• Urban Transit		Diesel	4.0
• Intercity		Diesel	6.2
• School		Diesel or Gas	5.0
Rapid Transit	20.0 persons/R.T. car	Electricity	2.0*
Commuter Rail	60.0 persons/train	Diesel or Electricity	2.0*
Trolley	15.0 persons/trolley car	Electricity	2.5**
Taxi	.7 persons/taxi***	Gasoline	10.0

*Conversion of gallons of fuel to unit of energy:

1 gallon of gasoline = 125,000 BTU
1 gallon of diesel fuel = 138,000 BTU

**Converted to equivalent liquid fuel using a factor of 130,000 BTU/gallon, assuming a 0.33 thermal efficiency from powerplant to transit company.

*** Driver not included

SOURCES:

Husted, Robert, United States Department of Transportation. Society of Automotive Engineers Report No. 730521. "Mass Transit Impact on Energy Consumption", 1973.

United States Department of Transportation, Federal Highway Administration. FHWA Notice, HHP-40. Subject: Energy Related Studies Underway and "Highway Travel Forecasts Related to Energy Requirements", February 28, 1973.

FORMATS FOR CALCULATIONS OF ENERGY REDUCTION IMPACTS BASED ON CHANGES IN SIGNIFICANT PARAMETERS

Reduction in energy consumption due to a given action may be the result of one or more of the following: 1) change to driving conditions which consume less fuel, 2) change to vehicle types which are more efficient, and 3) change in vehicle miles of travel.

Exhibit B-4 is a matrix showing the relationships between the transportation action groups and each of these three types of effect.

Change to Driving Conditions Which Consume Less Fuel

The main driving conditions that can be changed by low cost, short term transportation actions to reduce energy consumption are 1) average cruising speed; 2) number of acceleration/deceleration cycles per mile, given the average cruising speed; 3) number of stop/go cycles per mile; and 4) amount of time spent in idling.

This can be expressed as a general mathematical relationship, as follows:

$$EC_1 = f\ (S, A/D, S/G, I)$$

where:

EC_1	=	energy consumption due to change in driving conditions
S	=	average cruising speed
A/D	=	number of acceleration/deceleration cycles per mile, given the average cruising speed
S/G	=	number of stop/go cycles per mile, given the average cruising speed
I	=	amount of time spent in idling.

Some research has been conducted concerning the relationships between the values of these parameters and amount of fuel consumed, and factors

EXHIBIT B-4

RELATIONSHIP BETWEEN TRANSPORTATION ACTION AND TYPE OF CHANGE

Action Group	Types of Changes		
	Driving Conditions	Efficient Vehicle Types	Vehicle Miles of Travel
1. Measures to Improve Flow of High Occupancy Vehicles, Pedestrians, and Bicycles	X		X
2. Measures to Improve Total Vehicular Traffic Flow	X		X*
3. Measures to Increase Car and Van Occupancy			X
4. Measures to Increase Transit Patronage			X
5. Measures to Encourage Use of Walk and Bike Modes			X
6. Measures to Improve the Efficiency of Taxi Service and Goods Movement	X		X
7. Measures to Restrict Traffic			X
8. Transportation Pricing Measures		X	X
9. Measures to Reduce the Need to Travel			X
10. Energy Restriction Measures	X	X	X

* Increase in VMT.

stemming from this research are available for computing reductions in energy consumption from estimates of changes in these parameters. However, such data is not readily available in all areas to make estimates of original values of each of these parameters individually or to make predictions of changes in the values of these parameters after implementation of given actions. The kind of information more likely to be available is average travel time on segments of the highway system, general type of traffic operation, and a qualitative estimate of degree of traffic congestion. Based on these, however, some assumptions can be made as to original and predicted values for cruising speed, A/D cycles, etc.

The following example presents calculations of approximate percentage energy reduction in an urban region, based on assumed changes in the above parameters. In the example, average gallons/mile figures (original and predicted) are determined. These figures do not represent "typical" gallons/mile, given a set of values for the above parameters, because parameters such as road conditions, grades, and curves have not been taken into account. However, as these other parameters will not be affected by the kinds of transportation actions under consid-ation, the percentage energy reduction in an urban region, which is calculated without adjustment for these parameters, should be fairly reasonable.

Example A:

Assume the original values for the parameters being analyzed are: 1) average cruising speed of 15 mph; 2) 3 acceleration/deceleration cycles per mile; 3) 2 stop/go cycles per mile; and 4) 2 minutes of idling per mile.

Assume the following changes in driving conditions occur: 1) average cruising speed increases to 20 mph, 2) 1 acceleration/deceleration cycle per mile is eliminated, 3) 1 stop/go cycle per mile is eliminated, 4) 1 minute of idling per mile is eliminated.

Also assume that the changes in driving conditions apply to 10 percent of the vehicle miles of travel in the region, that the total amount of vehicle miles of travel in the region remains constant, and that the distribution of travel in time and space in the region is unaffected.

Approximate percentage reduction in energy consumption in the region can be calculated as follows:

Step 1: Calculate average gallons/mile used under original driving conditions, without adjustment for road conditions, grades, curves, etc.:

equation:

$$A = B + (C)\ (D) + (E)\ (F) + (G)\ (H)$$

where:

A	=	average gallons/mile used under original driving conditions without adjustment for road conditions, grades, curves, etc.
B	=	gallons/mile associated with original cruising speed, assuming paved road, flat grade, no curves, etc.
C	=	original number of acceleration/deceleration cycles per mile
D	=	excess gallons consumed per acceleration/deceleration cycle from original cruising speed to average intermediate speed and back again
E	=	original number of stop/go cycles per mile
F	=	excess gallons/consumed per stop/go cycle from original cruising speed to stop and back again
G	=	gallons consumed per hour of idling
H	=	original fraction of hour spent in idling per mile

results:

B	≈	.056 (Ref. 35)
C	=	3

D	$\approx$	.0035, if average A/D cycle goes from 15 mph to 30 mph, to 10 mph, back to 15 mph (Ref. 35)
E	=	2
F	$\approx$	.004, if average S/G cycle goes from 15 mph to stop and back to 15 mph (Ref. 4)
G	$\approx$	.6 (Ref. 35)
H	=	1/30

thus,

$$A \approx .056 + (3)(.0035) + (2)(.004) + (.6)(1/30) \approx \underline{.0945}$$

Step 2: Calculate average gallons/mile used after changes in driving conditions, without adjustment for road conditions, grades, curves, etc.

It is assumed that the effects of the changes in each parameter are cumulative, although this may be slightly inaccurate. However, the degree of accuracy of these calculations does not require a finer analysis.

equation:

$$I = J + (C-K)\ (D) + (E-L)\ (F) + (G)\ (H-M)$$

where:

I	=	average gallons/mile used after changes in driving conditions, without adjustment for road conditions, grades, curves, etc.
J	=	gallons/mile associated with new cruising speed, assuming paved road, flat grade, no curves, etc.
C	=	defined above
K	=	number of acceleration/deceleration cycles per mile eliminated

D	=	defined above
E	=	defined above
L	=	number of stop/go cycles per mile eliminated
F	=	defined above
G	=	defined above
H	=	defined above
M	=	fraction of an hour of idling per mile eliminated

results:

J	$\approx$	.050 (see qualifications above)
C	=	3
K	=	1
D	$\approx$	.0035
E	=	2
L	=	1
F	$\approx$	.004
G	$\approx$	.6
H	=	1/30
M	=	1/60

thus,

$$I = .05 + (3-1)\ (.0035) + (2-1)\ (.004) + (.6)\ (1/30-1/60) = \underline{.071}$$

Step 3: Calculate percentage reduction in energy consumption used by vehicle miles of travel affected by changes in driving conditions:

equation:

$$N \approx \frac{A-I}{A} \text{ (100 percent)}$$

where:

N = percentage reduction in energy consumed by vehicle miles of travel affected by changes in driving conditions

A = average gallons/mile used under original driving conditions, without adjustment for road condition, etc.

I = average gallons/mile used after changes in driving conditions, without adjustment for road conditions, etc.

results:

$$N \approx \frac{.0945 - .071}{.0945} (100 \text{ percent}) \approx 25 \text{ percent}$$

Step 4: Calculate percentage reduction in automotive energy consumption in urban region due to changes in driving conditions.

equation:

$$P \approx (Q/100)(N)$$

where:

P = percentage reduction in automotive energy consumption in region due to changes in driving conditions

Q = percentage which vehicle miles of travel affected by changes in driving conditions is of total vehicle miles of travel in region

N = percentage reduction in energy consumed by vehicle miles of travel affected by changes in driving conditions

results:

$$P \approx (10/100)(25 \text{ percent}) \approx 2.5 \text{ percent}$$

Final answer:	Percentage reduction in energy consumption in region due to changes in driving conditions is 2.5 percent.

This example is summarized in Exhibit B-5.

Change to More Fuel Efficient Vehicles

Some of the vehicle characteristics that affect fuel consumption are weight, number and type of special accessories, tuning, and type of tire.

This can be expressed as a general mathematical relationship, as follows:

$$EC_2 = f(W, AC, TU, TI, \ldots\ldots)$$

where:

EC_2	=	energy consumption relative to vehicle characteristics
W	=	vehicle weight
AC	=	number and type of special accessories
TU	=	state of tuning
TI	=	type of tire

An example is given below of calculations to obtain approximate percentage regional energy reduction due to shift in the weight mix of the automobile population. Similar calculations can be performed for special accessories, tuning, etc. However, these energy reductions are not always cumulative, because of interrelationships between characteristics, and care must be exercised in calculating combined effects associated with a change to more fuel economical vehicles.

Similar sets of calculations could be performed for trucks, taxis, and other vehicle types.

EXHIBIT B-5

SAMPLE CALCULATION FOR REDUCTION IN ENERGY CONSUMPTION DUE TO CHANGES IN URBAN DRIVING CONDITIONS

Computing gal./mi. under given driving conditions, unadjusted for road conditions, grades, curves, etc.:

Driving Conditions	(1) Cruising Speed mph	(2) Gal./Mi. at Steady Cruising Speed	(3) No. of A/D Cycles Per Mile	(4) Excess Gallons Consumed Per A/D Cycle	(3)x(4) Excess Gal./Mi. Due to A/D Cycles	(5) No. of S/G Cycles Per Mile	(6) Excess Gallons Consumed Per S/G Cycle	(5)x(6) Excess Gal./Mi. Due to S/G Cycles	(7) Gallons Per Hour Consumed In Idling	(8) Fraction of Hour Spent Idling Per Mile	(7)x(8) Excess Gal./Mi. Due to Idling	[(2)+[(3)x(4)]+[(5)x(6)]+[(7)x(8)]] Total Gal./Mi. Consumed, Assuming paved road, Flat grade, No curves, etc.
Original	15	.056	3	.0035	.0105	2	.004	.008	.6	1/30	.02	.0945
Predicted	20	.050	2	.0035	.0700	1	.004	.004	.6	1/60	.01	.0710

Computing percentage reduction in automotive energy consumption in region due to change in driving conditions:

(9) Percentage Reduction on Affected VMT	(10) Percentage of Automotive VMT in Region that is Affected	(9) x (10) Percentage Reduction in Automotive Energy Consumption in Region
$\frac{.0945 - .0710}{.0945} \approx$ 25%	10%	2.5%

Example B:

Suppose the original automobile population weight mix was: 30 percent cars weighing between 2000 and 3000 pounds, 40 percent cars weighing between 3000 and 4500 pounds, and 30 percent cars weighing 4500 pounds or over. Suppose, after implementation of measures affecting automobile purchasers' attitudes, the predicted distribution by weight class is: 40 percent cars weighing between 2000 and 3000 pounds, 45 percent cars weighing between 3000 and 4500 pounds, and 15 percent cars weighing 4500 pounds or over.

Also assume the automobile population being considered is all the automobiles in the region and that the total amount of vehicle miles of travel in the region remains constant.

Approximate percentage reduction in automobile energy consumption in the region relative to change in automobile population weight mix can be calculated as follows:

$$X = \left[1 - \frac{\sum_{i=1}^{N} (A_i/100) \quad (C_i)}{\sum_{i=1}^{N} (B_i/100) \quad (C_i)}\right] \qquad (100 \text{ percent})$$

where:

X = percentage energy reduction in the region relative to change in automobile population weight mix

N = number of weight classes

A_i = original percentage of automobile population in weight class i

B_i = predicted percentage of automobile population in weight class i, based on implementation of actions affecting automobile purchasers' attitudes

C_i = average miles/gallon for cars in weight class i results:

N	=	3							
A_1	=	30	A_2	=	40	A_3	=	30	
B_1	=	40	B_2	=	45	B_3	=	15	
C_1	$\approx$	19	C_2	$\approx$	12.5	C_3	$\approx$	9	(Ref. 36)

thus,

$$X = 1 - \frac{(.3)(19) + (.4)(12.5) + (.3)(9)}{(.4)(19) + (.45)(12.5) + (.15)(9)} \text{ (100 percent)}$$

$$= 1 - \frac{12.4}{14.575} \text{ (100 percent)}$$

$$\approx 15 \text{ percent}$$

Change in Vehicle Miles of Travel

Vehicle miles of travel reduction may result from any one of the following: incentives to carpooling, incentives to transit ridership, incentives to use of walk and bicycle modes, more efficient utilization of taxi service and trucks, traffic restraint measures, pricing measures, measures to reduce the need to travel, and energy restriction measures. Some of these actions may be exclusively oriented toward vehicle miles of travel reduction, e.g. carpooling incentives, whereas others may result in energy reduction in a number of ways, e.g. energy restriction measures. Traffic flow improvements in contrast, may result in increases in vehicle miles of travel.

In general, percentage reductions in vehicle miles of travel are approximately equivalent to percentage reductions in vehicular energy consumption. However, this assumes that no significant changes occur in the trip length distribution. Trip lengths affect energy consumption because shorter trips consume more energy per mile than longer trips, as cars use more fuel right after being started than after they are warmed up. (Also a direct translation of vehicle miles of travel reduction into energy reduction assumes no significant changes in driving conditions and fuel economy characteristics of vehicle population.)

Mathematically, this can be expressed as follows:

(1) $EC_3 = f\ (VMT,\ TL)$

where:

EC_3 = energy consumption relative to vehicle miles of travel

VMT = vehicle miles of travel

TL = trip length distribution

and (2) percent $\Delta\ EC_3 \approx$ percent Δ VMT

Estimates of vehicle miles of travel reduction are usually based on estimates of change in modal split. Modal split prediction has been the subject of many transportation studies and will not be discussed in detail. Generally, modal split prediction is based on modal split models or on judgement using empirical data. Modal characteristics which are usually considered are cost, time, comfort, and convenience.

Given estimates of changes in modal split, vehicle miles of travel reduction can be approximated using the following equations:

1. Increased carpooling:

$$Z = \left(1 - \frac{X}{Y}\right)\ (100\ \text{percent})$$

where:

Z = percentage vehicle miles of travel reduction in region associated with increased carpooling

X = original average auto occupancy

Y = predicted average auto occupancy, after implementation of actions resulting in increased carpooling

It may be desirable to make separate analyses for different trip purposes or different "trip attraction" sub-areas.

2. Increased transit patronage:

$$W = \left(\frac{P}{S_1} - \frac{Q}{S_2}\right) - \left(\frac{T}{V_1} - \frac{U}{V_2}\right)$$

where:

W = percentage vehicle miles of travel reduction in region associated with shift from auto to transit

P = original percentage of person miles of travel in region made by automobile

Q = predicted percentage of person miles of travel in region made by automobile after implementation of relevant actions

S_1 = original average automobile occupancy in region

S_2 = predicted average automobile occupancy in region

T = original percentage of person miles of travel in region made by transit

U = predicted percentage of person miles of travel in region made by transit after implementation of actions resulting in increased transit patronage

V_1 = original average auto occupancy in region

V_2 = predicted average transit occupancy in region

It may be desirable to make separate analyses for different trip purposes or different sub-areas and/or corridors of the region. If more than one mode of transit is involved, the equation should be changed accordingly.

3. Shift from auto to walk and bike modes:

$$G = \frac{(H)\ (I) + (J)\ (K)}{(L)\ (M)}$$

where:

G = percentage reduction in vehicle miles of travel in region associated with shift from auto to walking

H = number of person trips in region associated with shift from auto to walking

I = average length of trip in miles associated with walk trips which replace auto trips

J = number of person trips in region associated with shift from auto to bicycle

K = average length of trip in miles associated with bicycle

L = original average auto occupancy

M = total original vehicle miles of travel in region

4. Reduction in vehicle miles of travel due to changes in taxi service, assuming same person miles of travel by taxi:

$$S = \left(\frac{B - A}{B}\right)\frac{E}{F} + \left(\frac{C - D}{F}\right)$$

where:

S = percentage reduction in vehicle miles of travel in region due to changes in taxi service

A = original average taxi occupancy

B = predicted taxi occupancy after implementation of actions to promote higher taxi occupancy

C = original taxi miles of travel due to cruising

D = predicted taxi miles of travel due to cruising after implementation of restrictions on cruising

E = taxi miles of travel in region

F = total vehicle miles of travel in region

Some adjustment may be made if there is a significant difference between average taxi fuel economy and average automobile fuel economy in a given region.

5. Reduction in vehicle miles of travel associated with a higher truck loadings, assuming a constant amount of goods moved:

$$K = \frac{F - E}{F} \left(\frac{G}{H} \right)$$

where:

K = percentage reduction in vehicle miles of travel in region associated with higher truck loadings, assuming a constant amount of goods moved

E = original average percentage of truck capacity used, either by weight or volume

F = predicted average percentage of truck capacity used, either by weight or volume

G = truck miles of travel in region

H = total miles of travel in region

Breakdowns by truck class and by trip length might provide a more accurate estimate.

In calculating energy reduction from VMT reduction, adjustment would be necessary for differences in average energy/mile consumed by trucks and by other types of vehicles.

CONCLUSION

Three types of changes leading to reduction in energy consumption, caused by transportation-related actions, have been discussed. The analysis has been oversimplified, however, since in each case it has been assumed that only one type of change occurs, while all other parameters are held constant. In the "real world", however, all of these types of changes may occur concurrently. Ideally, it would be preferable to calculate the total transportation energy reduction impact of an action or set of actions considering all three types of changes simultaneously.

APPENDIX C

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