OPPORTUNITIES FOR ENERGY CONSERVATION IN TRANSPORTATION PLANNING AND SYSTEMS MANAGEMENT

by

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ABSTRACT

This report is a summary, based primarily on a literature review, of the energy-savings potential of the elements in the transportation planning process and systems management. Within the scope of long-range planning, the energy aspects of land use and mode of transportation were investigated, whereas for the short range the energy potential of the various transportation systems management strategies were considered. The role of the Virginia Department of Highways and Transportation in energy-saving activities was also considered. The report should be of value to transportation planners and traffic engineers as an overview of the energy-use characteristics of activities within transportation planning and systems management and as a resource document for detailed energy analyses.

SUMMARY

Since the 1973 Arab oil embargo, the utilization of energy in the United States has been the subject of many discussions, debates, and detailed studies and analyses, and the energy issues and their ramifications have affected the populace to some extent on practically a daily basis. As one of the major users of energy, especially energy derived from petroleum, the transportation sector is often the focal point of discussions and studies. The federal government has taken positive steps to conserve energy in the transportation sector, as evidenced by the 55 mph speed limit and the fuel efficiency standards for new cars. State and local governments also have an important role in energy conservation, and, as the Commonwealth's largest agency and the predominant one in transportation, the Department of Highways and Transportation can play a lead role.

The Department's interests in energy lie in two broad areas — how to reduce the amount of energy used in its own operations and how to best spend its dollars to attain an overall reduction in the use of energy for the transportation system and still maintain satisfactory levels of service. It was with the latter area that the investigation reported here was concerned.

Short-Range Planning

Within the transportation planning process, the development of the short-range element, consisting essentially of transportation systems management (TSM) strategies, is the activity most directly related to energy savings. Based on a subjective evaluation of the most common TSM strategies (see Table 12 in the body of the report) it appears that improvements at signalized intersections, promotion of ride-sharing activities, park-and-ride facilities, freeway bus/car pool lanes and access ramps, a shortened work week, and parking regulations offer relatively high energy savings. Of these, only the first three are judged to have a high feasibility for implementation in Virginia. Freeway bus/car pool lanes and access ramps are certainly feasible; however, primarily because of their high costs coupled with the rather limited number of locations involved they are less feasible than the first three mentioned. Due primarily to institutional problems, the remaining two strategies have limited potential for implementation. Additional strategies judged to be highly feasible for implementation in Virginia include one-way streets, traffic channel-

ization, promotion of nonvehicular modes, transit marketing, and transit shelters. The first four have at least a medium potential for energy savings. Strategies having a low potential energy savings and a low feasibility for implementation include user information/assistance, removal of stop signs or conversion of stop signs to yield signs, the urban goods movement strategies, auto-restricted zones, transit terminals, and integration of transportation services.

Transportation planners and traffic engineers should be cognizant of the energy impacts of the TSM strategies and be constantly alert for opportunities to implement the strategies that have both high savings and high feasibility for implementation.

Many of the TSM strategies derive their energy-savings potential from diverting the movement of people to modes, including transit, that are more energy-efficient than the automobile. Although transit has a large reserve capacity to accommodate a modal shift, the majority of this reserve occurs in the off-peak hours. During the peak hours when many of the TSM strategies are most beneficial, transit typically operates at or near capacity. Therefore, the potential for energy savings through increased utilization of transit is somewhat limited in the short term.

Although the need to save energy is a critical one, it is impossible to implement TSM strategies without giving consideration to the many other factors involved. Fortunately, positive energy impacts generally imply positive impacts on the other goals of TSM, such as improving air quality, reducing congestion, and reducing costs. Many other factors, generally of an institutional and economical nature, must also be considered. In planning for TSM strategies, the potential for saving energy must be kept in perspective as only one of many factors to be considered.

Long-Range Planning

Within the context of long-range planning, two factors having a significant impact on energy are land use patterns and the energy-efficiency of the various transportational modes. As regards the former factor, general land use patterns in the U. S. are not energy-efficient in terms of either residential consumption or transportation consumption, with the typical pattern of urban sprawl requiring long trips, high auto ownership, and limited usage of public transit. More compact land use patterns with high residential densities composed of multifamily units and with downtown work sites could result in significant energy savings. Obviously it is only within the long range that these land use changes can occur. Due to the interrelationship of land use and transportation, transportation planning, especially as related to new facilities, can be a valuable tool in shaping future land use patterns. Again, many factors must be considered, and the potential for energy savings by itself will likely never justify radical changes. However, transportation planners should be alert for opportunities to shape future land use into more energy-efficient patterns.

Based primarily on the review of a very comprehensive analysis of the energy consumption per passenger-mile (existing occupancy) of the various modes prepared by the Congressional Budget Office, the most energy-efficient mode is the van pool, followed closely by the bus. Automobiles with average occupancy, automobiles with single occupancy, and dial-a-ride systems require significantly higher amounts of energy, while new heavy rail systems, commuter rail systems, light rail systems, and car pools are grouped in between. If consideration is given to the source of new patronage for the various modes, an overall modal impact on energy, or potential for energy savings, can be derived. Again van pools result in the greatest net energy savings, followed closely by buses and car pools. Dial-a-ride systems result in the greatest net energy loss, while new heavy rail systems, commuter rail systems, and light rail systems are estimated to result in no energy savings or even to entail energy losses. It should be noted that these conclusions are the subject of much debate, some of which is presented in the report.

As with the TSM strategies, the selection of the mode of transportation in long-range planning activities cannot be based on energy concerns alone; however, consideration should be given to the energy consumption of the various modes in the alternative testing phases of the long-range transportation planning process.

Role of the Virginia Department of Highways and Transportation

The Department's role in energy conservation and the planning and operation of transportation systems is defined on four levels of activity. For those urbanized areas having the formal continuing, cooperative, and comprehensive (3-C) transportation planning process mandated by the U. S. Department of Transportation, the metropolitan planning organizations have the primary responsibility for plan development, with the Department being active in a support and approval role. In this capacity Department personnel should encourage and support those activities which result in high energy savings. For those smaller areas in which the Department is the lead planning agency and for the development of the statewide transportation plan, Department personnel should routinely consider energy savings in the development of the transportation plan. As day-to-day managers of the state's highway system, Department personnel should be cognizant of the potential energy savings related to the various TSM strategies and be constantly alert for opportunities to implement them. Finally, as the state's largest agency and the primary transportation one, the Department should be aware of opportunities to implement in-house actions both to conserve energy and to set an example for others to follow.

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INTRODUCTION

Since the 1973 Arab oil embargo, Americans have become increasingly aware of the energy crisis. Although many apparently remain doubtful as to its seriousness, the energy crisis has become a subject of national debate and study. As oil is the source of nearly half the energy Americans consume, [1] it is a key element of the energy problem , especially in view of this country's dependence on foreign imports. In 1976 oil imports averaged 7.3 million barrels (1.16 million M^3) per day, or 42% of U. S. oil consumption, with estimates for 1985 ranging from 12 to 16 million barrels (1.91 to 2.54 million M^3) per day.[2] Further, there is a limit on the world's supply of oil, with projections indicating that the recoverable oil resources will be exhausted by the early part of the twenty-first century.[3]

In 1975, 26% of the energy consumed in the U. S. was expended for the direct movement of vehicles, often referred to as the Total Direct Transport Energy (TDTE). If the indirect energy associated with transportation, e.g. that used in the manufacture of vehicles and parts, repairs, and construction, is included, this figure increases to approximately 43%.[4] More importantly, the TDTE, which is derived almost exclusively from petroleum and petroleum products, accounts for approximately one-half of all the petroleum used annually in the U. S.[5] As indicated in Figure 1, which shows the distribution of the TDTE among the modes, highway related modes consume approximately 75% of the TDTE, or approximately 38% of the petroleum used annually in the U. S. It is obvious, therefore, why transportation is often the focal point of discussions and studies regarding the energy situation, and of strategies for conservation.

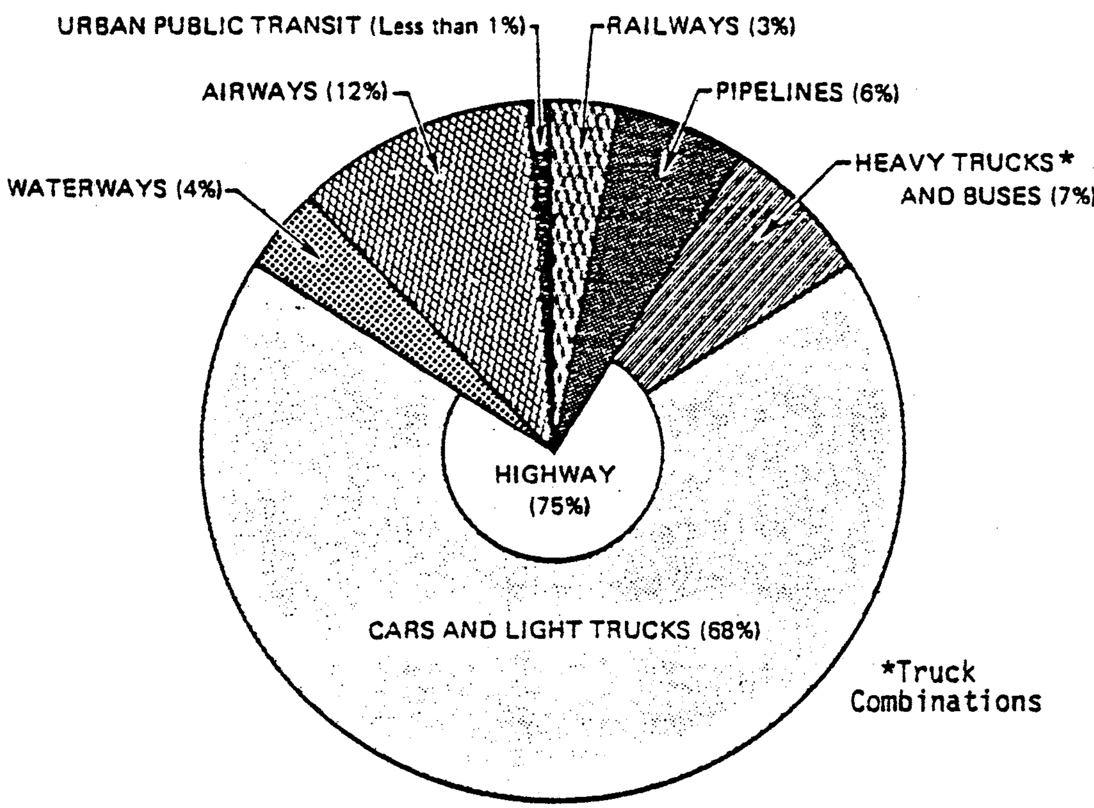

Figure 1. Components of direct transportation energy in 1972. (Source: Reference 4)

The energy crisis is a national problem and, as such, necessitates actions at the federal level of government. The federal government has responded through various policies and programs, the President's National Energy Plan perhaps being the most important. Two other important programs deserve mention — the mandated 55 mph (89 km/h) speed limit and the Energy Policy and Conservation Act of 1975, which in part mandates a fleet average fuel economy of 27.5 mpg (11.7 km/l) by 1985 for new passenger cars. The former mandate is estimated to be saving 9 million gallons (34 thousand M^3) of gasoline daily, with a potential savings of 15 million gallons (57 thousand M^3) a day at full compliance.[6] The latter mandate is expected to result in a savings of 67 million gallons (254 thousand M^3) of fuel per day by 1985.[7] See Table 1 and Figure 2 for additional information.

Table 1

Effect of Speed on Fuel Consumption Rates
in Rounded Miles Per Gallon (Source: Reference 6)

	Speed (MPH)		
Vehicle Type	55	60	70
Subcompact	32	31	23
Compact	18	17	15
Standard	17	16	15
Luxury	15	14	13

Note: 1 mph = 1.61 km/h
1 mpg = 0.425 km/l

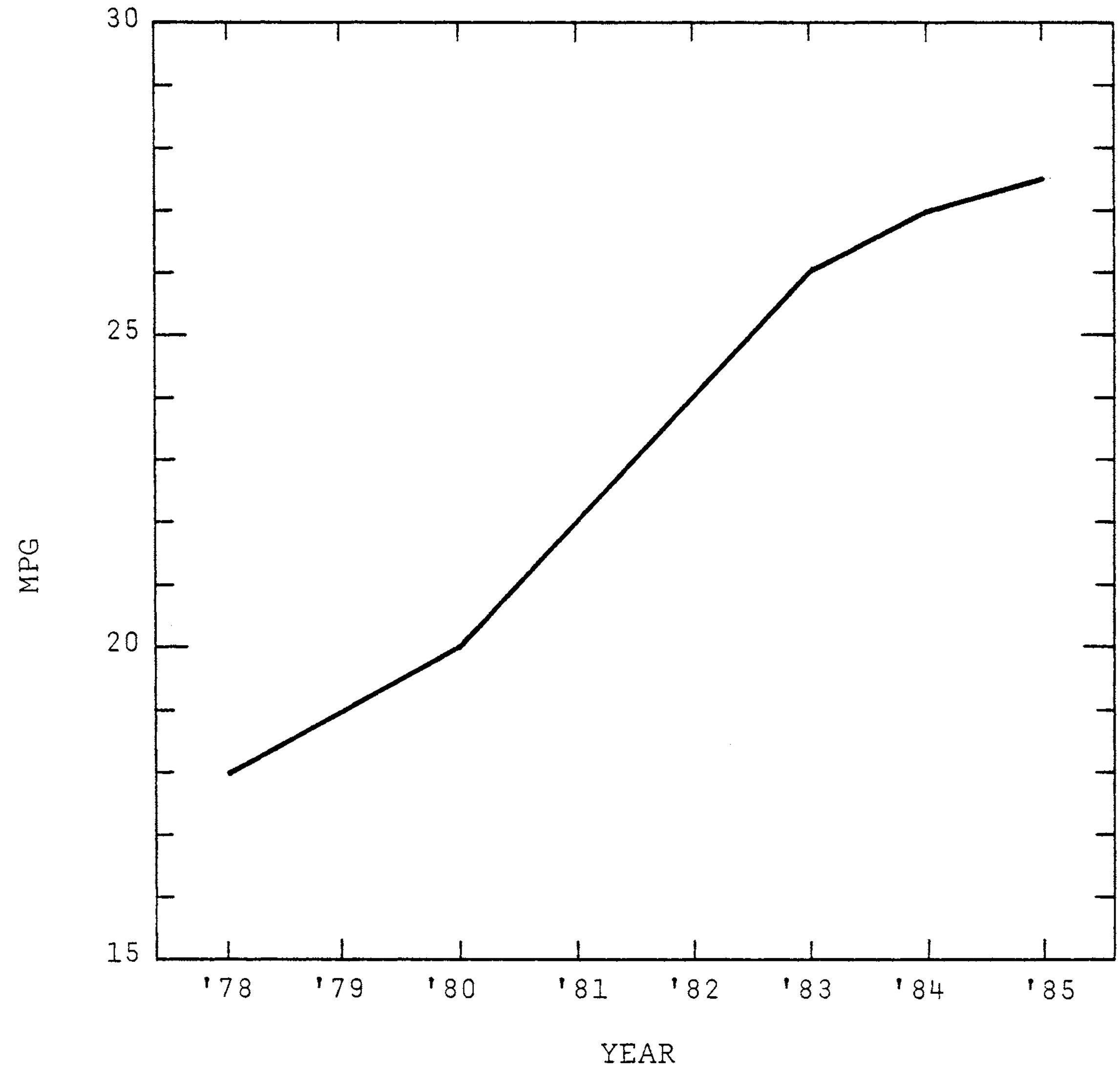

Figure 2. Federally mandated fuel economy standards for new passenger cars. (Source: Reference 6)

Note: 1 mpg = 0.425 km/l

State and local governments also have an important role in energy conservation, and as the Commonwealth's largest agency, the Virginia Department of Highways and Transportation can play a leading role in conserving energy. Further, in view of the aforementioned large utilization of petroleum by the transportation sector, especially the highway related travel modes, it is most appropriate that the Department be cognizant of energy savings in its policies and daily operations. Other studies described in a series of reports for the Department have investigated or will investigate the energy savings associated with highway construction and maintenance, highway lighting, and the operation of Department facilities.(8)

PURPOSE AND SCOPE

The purpose of the study reported here was to investigate energy savings in the area of transportation planning and systems management. As the Department's initial study in this area, the scope is limited primarily to an overview of energy as related to planning and planning associated issues with the primary emphasis being on the energy savings potential of the Transportation Systems Management (TSM) strategies. By considering energy savings in the planning stages through TSM and the long-range planning element, the broad question of how the Department can best spend its dollars to attain an overall reduction in the use of energy for the total transportation system and still maintain satisfactory levels of service can be addressed. As a traffic engineering tool, TSM translates the planning into immediate energy savings in system operations.

TRANSPORTATION PLANNING IN VIRGINIA

The Virginia Department of Highways and Transportation is the Commonwealth's primary transportation agency, and places major emphasis on highways and transit. The Department also has certain coordinative responsibilities for the rail, air, and water modes; however, the State Corporation Commission's Division of Aeronautics and the Virginia Port Authority have major responsibilities for the last two modes. Accordingly, detailed planning activities are related mainly to the highway and transit modes. All rail planning required by the Federal Railroad Administration is being performed by the Department, whereas the primary effort in air and water transportation planning is the coordination of the plans prepared by the above mentioned agencies with highway and transit plans. The Director of Planning has responsibility for all planning activities, with a staff consisting of personnel in the Transportation Planning, Public Transportation, and Transportation Coordination Divisions and the Research Council.

The state's responsibilities for the continuing, cooperative and comprehensive (3-C) transportation planning process mandated by the U. S. Department of Transportation (U. S. DOT) in urbanized areas with populations over 50,000 are under the auspices of the Director of Planning. Further, formal transportation plans are developed for all small urban areas with a population greater than 3,500; and, finally, the Department is the lead agency in the development of Virginia's statewide multi-modal transportation plan.

OVERVIEW OF ENERGY SAVINGS AND TRANSPORTATION PLANNING

Within the framework of the formal 3-C planning process required by the U. S. DOT for urbanized areas, the element that directly addresses energy savings is transportation systems management (TSM). The TSM element, or short-range element of the planning process, is designed to address the short-range transportation needs through improving efficiency in the use of existing transportation facilities. A primary benefit of improved efficiency is direct energy savings. The energy-savings potential of TSM strategies is discussed in the next section.

Whereas the TSM element offers an immediate potential for energy conservation, the long-range element of the planning process, which is aimed at identifying new transportation facilities or major changes in existing facilities, can provide for energy savings in the future. Two important issues in the long-range planning appear to offer the most potential for energy savings — consideration of the interrelation of land use and transportation and consideration of the most efficient mode of travel (especially in the case of a major new facility). Both of these issues are discussed in detail in later sections.

Although not within the scope of this report, it would be improper to address energy and transportation planning without mentioning the difficulty, if not impossibility, of predicting future travel within the framework of the constraint on the use of energy. The conventional travel simulation process of trip generation, trip distribution, trip assignment, and modal split, which was developed in the 1950's and 1960's when energy was abundant, generally is not capable of forecasting the impact or change in travel resulting from an energy policy or constraints upon the use of energy. The process is often capable, however, of measuring the sensitivity of various travel related indices to an assumed change in travel. For example, if a certain work trip car pool policy were to be implemented, the process cannot forecast how travel would change, i.e., how much auto occupancy for work trips would change. However, different assumed auto occupancy levels could be tested to determine their sensitivity or impact on such parameters as fuel consumption, vehicle miles of travel, etc.(9) Recognition of this weakness in the current planning process is important in order to avoid overestimates of future transportation facilities and investments. As exemplified above, however, the sensitivity analysis capabilities can be an important tool in determining how energy consumption changes due to various proposed energy policies.

POTENTIAL FOR ENERGY SAVINGS IN THE TSM STRATEGIES

As indicated in the previous section, TSM is a term used to describe the short-range element of the required urbanized area's transportation plan, having been introduced in the U. S. DOT guidelines issued in September 1975. TSM involves management or control strategies which have the goal of improving the utilization of existing transportation systems in order to relieve congestion, reduce costs, improve air quality, and conserve energy. These strategies are generally considered in the short-range, although some are long-range, and they are generally considered to require minimal or no capital expenditure, although some are very capital-intensive. Many of these strategies have been employed for years by the traffic engineering profession to attain elements of the goal mentioned above. TSM is a valuable energy-saving tool in small urban areas, and possibly even rural areas, as well as the larger areas where the 3-C process is required. Being alert to this potential is an important role of the Department in its day-to-day operations and its planning functions.

Since 1975 when the term TSM was introduced, there have been many studies which have identified the various strategies. Likewise, there have been various categories or groupings of strategies by general purpose and, basically, for this study, the particular categories defined in reference 25 are used. These categories, along with the various strategies described in this report are listed in Table 2. Although the list of strategies investigated is not all inclusive, it does contain those strategies most typically considered under TSM. It is noted that some strategies might logically fall under several categories; however, for purposes of this report these strategies are discussed in detail under only one category.

Table 2

TSM Strategies Investigated

I. Strategies Relating to Improved Vehicular Flow

- Improvements in signalized intersections
- Freeway ramp metering
- One-way streets
- Removal of on-street parking
- Reversible lanes
- Traffic channelization
- Transit stop relocation
- User information/assistance
- Removal of stop signs or conversion of stop signs to yield signs

II. Strategies Relating to Preferential Treatment of High-Occupancy Vehicles

- Freeway bus and car pool lanes and access ramps
- Bus and car pool lanes on city streets and urban arterials
- Bus preemption of traffic signals
- Toll policies

III. Strategies Relating to Reduced Peak Period Travel

- Work rescheduling
- Congestion pricing

IV. Strategies Relating to Urban Goods Movement

- Spatial separation of trucks and truck activities
- Temporal separation of trucks and truck activities
- Truck route and facility consolidation

V. Strategies Relating to the Promotion of High-Occupancy and Nonvehicular Travel Modes

- Ride sharing
- Nonvehicular travel modes
- Auto-restricted zones

VI. Strategies Relating to Transit and Paratransit Service Improvements

- Transit marketing
- Security measures
- Transit shelters
- Transit terminals
- Transit fare policies and collection techniques
- Extension of transit with paratransit
- Integration of transportation services

VII. Strategies Relating to Transit Management Efficiency Measures

- Route evaluation
- Vehicle communication and monitoring techniques
- Maintenance policies

VIII. Strategies Relating to Parking Management

- Parking regulations
- Park-and-ride facilities

Within the literature several types of studies and resulting data are available, with the data being applicable to the TSM category or group, to the TSM strategy in general, or to a TSM project specifically. To be as comprehensive as possible, data from all three types of studies are presented. The results are also presented in various frameworks, i.e. annual or daily gallons or barrels of gasoline saved, percentage of national or regional energy saved, and percentage of national or regional transportation energy saved. As different base data were used, often without details as to the source, it is impossible to convert all reported results to a common framework. Accordingly, the consumption statistics presented in Table 3 should provide the reader with some perspective for comparison. A summary section regarding TSM describes a comprehensive study which does address the above concerns.

Strategies Relating to Improved Vehicular Flow

Strategies in this category have the general effect of decreasing congestion, increasing average speeds, and reducing travel times. Within the range of typical urban driving speeds a uniform speed of 30 mph (48 km/h) is generally the most economical on fuel consumption, with speeds of 15 mph (24 km/h) or 52 mph (84 km/h) consuming 19% more fuel. Fuel consumption also increases greatly with stop-and-go traffic with one stop-start cycle per mile requiring 19% more fuel than a uniform speed of 30 mph (48 km/h). This last figure does not include the approximately 1 gallon (3.8 l) of fuel required for every 20 minutes of idling.(10) One study has estimated that a 50% reduction in the number of accelerations results in energy savings of approximately 10% for urban driving, which nationwide would amount to an annual savings of 2 billion gallons (7.6 million M^3) of gasoline or 91 million barrels (14.5 million M^3) of crude petroleum.(11) Relating these statistics to travel time results in a generalization that a 50% increase in driving time due to highway congestion may result in a 100% increase in fuel consumption.(12)

It is important to note that the potential for fuel savings is offset somewhat by improving these travel characteristics. Additional travel may, in fact, be induced, or motorists may switch from a more energy-efficient mode such as transit or ride sharing to the single-occupant automobile.

Improvements in Signalized Intersections

Several different aspects of signal operation can be addressed to effect an energy savings, probably the most comprehensive being the installation of computer controlled signal systems. Based on varying assumptions, there is a maximum savings potential of 32 to 63 thousand barrels (5.1 to 10.0 thousand M^3) of fuel per day from nationwide improvements to signal systems.(13)

Table 3

Summary of Estimated Energy Consumption

I. Total Energy Consumed (U. S. - 1976)

- Annual:	74.2	quadrillion (10^{15}) Btu's
	12.8	billion equivalent barrels of oil
- Daily:	0.2	quadrillion (10^{15}) Btu's
	35.0	million equivalent barrels of oil

II. Total Direct Transportation Energy Consumed[a] (U. S. - 1976)

- Annual:	3.5	billion barrels of fuel
	147.8	billion gallons of fuel
- Daily:	9.6	million barrels of fuel
	404.9	million gallons of fuel

III. Total Direct Highway Energy Consumed[b] (U. S. - 1976)

- Annual:	2.7	billion barrels of fuel
	111.7	billion gallons of fuel
- Daily:	7.3	million barrels of fuel
	306.0	million gallons of fuel

IV. Total Highway Gasoline Consumed (U. S. - 1976)

- Annual:	2.5	billion barrels of gasoline
	105.8	billion gallons of gasoline
- Daily:	6.9	million barrels of gasoline
	289.9	million gallons of gasoline

V. Total Highway Gasoline Consumed (Virginia - 1976)

- Annual:	61.2	million barrels of gasoline
	2569.3	million gallons of gasoline
- Daily:	0.2	million barrels of gasoline
	7.0	million gallons of gasoline

Sources: Energy in Focus: Basic Data, Virginia Energy Office, June, 1977; "Monthly Motor Gasoline Report by States - Year End 1976", Federal Highway Administration; and Reference 4.

Note: 1 barrel = 0.159 m^3
1 gallon = 0.003785 m^3
1 Btu = 1056 Joules

(a) Includes gasoline, diesel fuels, kerosene jet fuel, marine diesel, and naphtha jet fuel for all modes

(b) Includes gasoline and diesel fuels for autos, trucks, buses, and motorcycles

Interconnected signals also produce savings. A computer analysis of a 4.5-mile (7.2-km) project in Atlanta in which 21 noninterconnected, volume-density controllers were replaced with actuated controllers that were interconnected indicated fuel consumption was reduced by 22%, a savings of 750 thousand gallons (2.8 thousand M^3) of gasoline per year.[14] Changing from pre-timed signals to fully actuated signals may result in energy savings as the red signal delay is minimized. The savings is inversely proportional to the amount of cross-street traffic; relatively low volumes on the cross street mean maximum energy savings, whereas equal volumes on both the main line and cross street mean essentially no savings from actuated signals. A computer simulation study of a District of Columbia intersection where the main line carried seven times the volume of the cross street resulted in a 25% increase in fuel consumption efficiency with actuated equipment.[15] Signal timing also affects the energy consumption characteristics. As the cycle length increases, a fuel savings results because the numbers of stops and accelerations/decelerations decrease; however, a point is reached where fuel consumption from queuing and idling is more than these savings. Hence there is an optimum cycle length from an energy standpoint as well as from a delay standpoint, with several studies having indicated that the optimum energy cycle is longer than the optimum delay cycle, which has serious implications as to public acceptance.[16] For example, a computer analysis for a total intersection volume of 1,400 vehicles per hour resulted in an optimum delay cycle length of 95 seconds, a delay of 33.7 vehicle hours per hour, and incremental fuel consumption of 126 gallons (0.5 M^3) per hour. At the optimum energy cycle length of 222 seconds, the delay was 47 vehicle hours per hour while the incremental energy consumption was 109 gallons (0.4 M^3) per hour.[17] Obviously, a compromise is necessary to accommodate both goals for intersection performance. The relatively new right-turn-on red laws offer potential for fuel savings, with estimates ranging from 0.13% to 0.25% of direct fuel consumption if 80% of all intersections in the U. S. are under a permissive right-turn-on-red rule.[18] A study conducted in Virginia estimated that 3.6 million gallons (14 thousand M^3) of gasoline were saved in 1977 as a result of the right-turn-on-red regulation.[19] One final scheme is to eliminate pedestrian interference with vehicular turning movements by including an all-red phase in the cycle. A computer simulation study, however, concluded that the lack of interference by pedestrians did not offset the additional idling caused by a 25 second all-red phase.[20]

Freeway Ramp Metering

Signalizing freeway ramps effects an energy savings by increasing vehicular flow on the freeway and decreasing total travel time; however, the savings are partially offset by increased vehicle idling at the ramp. It is estimated that 30 thousand barrels (4.8 thousand M^3) of fuel per day could be saved nationwide if all freeway ramps were metered.(21) As for specific case studies, a program of ramp metering involving 851 ramps in the Los Angeles region is estimated to save 24 million gallons (91 thousand M^3) of fuel annually.(22) Finally, a computer simulation study during the morning peak period of a 12.6-mile (20.3-km) inbound section of the Santa Monica Freeway in Los Angeles indicated a 3% reduction in fuel consumption by vehicles on the freeway when non-priority entry control techniques were applied to 6 ramps.(23)

One-Way Streets

Conversion to one-way streets can potentially save energy by improving vehicular flow characteristics, primarily by eliminating potential conflicts at intersections from opposing turning movements. The effectiveness of a progressive signal system is also increased. Additional travel distance can, however, slightly offset the energy savings. By utilizing a computer simulation technique, it was found that the conversion of several two-way streets to one-way streets in the District of Columbia resulted in an 11% and 13% increase in fuel consumption efficiency for off-peak and peak period conditions, respectively.(24)

Removal of On-Street Parking

The capacity of a roadway is increased significantly by removing the parking and this results in an energy savings from improved vehicular flow. Also, delays from vehicles maneuvering in and out of spaces or simply seeking a space are eliminated. A serious problem with implementing this strategy is the reaction of merchants who depend on customer access; therefore, replacement parking should be provided. No specific energy-savings data were found in the literature surveyed; however, a 5 mph (8 km/h) improvement in traffic speeds and a 50% reduction in traffic delays and stops have been attributed to on-street parking restrictions.(25)

Reversible Lanes

When there is heavy flow in one direction, e.g. inbound in the morning peak period, on an urban street, there is a potential for saving energy by increasing the capacity and improving vehicular flow with a reversible lane or lanes. If only a single lane is provided in the off-direction of travel, however, some energy can be wasted through increased queuing and idling resulting from left turn movements. Further, there is a real potential that demand will shift to the improved facility, and in the long term the fuel consumed on that facility will actually increase due to increased volumes. For example, a computer study of installing reversible lanes on a 5-mile (8-km) section of Wilshire Boulevard in Los Angeles found an initial 3.3% reduction in fuel consumption but an increase of 4.2% in the long term. Fuel savings resulting from possible improved flow on existing parallel facilities were not addressed.(26)

Traffic Channelization

Channelization techniques which direct traffic into defined paths on the roadway result in increased fuel economy through improved vehicular flow. Channelization, which generally requires traffic islands or pavement markings, includes such techniques as providing separate turning movement lanes and even turn restrictions to separate traffic flow and reduce conflicts and driver confusion. No specific energy-savings data were found in the literature surveyed; however, effective channelization can increase traffic speed by up to 10 mph (16 km/h).(27)

Transit Stop Relocation

In urban areas the loading and unloading of transit passengers seriously disrupt vehicular flow, especially at intersections and during peak periods. As transit stop location has an effect on the level of interference, it is possible that relocating the stop could improve vehicular flow and thus result in an energy savings. Although generally not feasible, especially in the downtown area, transit loading bays or turnouts which remove the interface point from the traffic flow probably offer the most potential for improvement. A midblock transit stop improves flow by locating the interface point away from the intersection; however, midblock stops require significantly more valuable curbside space. The most popular locations for transit stops are at the end of the blocks, either near-side or far-side. Generally it has been found that near-side transit stops cause the least interference when the intersection approach traffic is lighter than the exit traffic, the cross street is one-way from right to left, and the volume of right turns is low. The opposite characteristics apply to far-side transit stops.

Relocating the transit stop to the far side may also increase the effectiveness of right-turn-only lanes and allow implementation of right-turn-on-red regulations. No specific energy-savings data were found in the literature surveyed.

User Information/Assistance

Included under this strategy are actions or programs which result in energy savings primarily through improving the flow of vehicles. These would include such items as pre-trip traffic condition information, system condition broadcasts, traffic flow condition signs, route advisory signs, progressive speed advisory signs, incident detection and management, and motorist aid. No specific energy-savings data were found in the literature surveyed.

Removal of Stop Signs or Conversion of Stop Signs to Yield Signs

Although not very significant, there is a potential for energy savings through reduced acceleration/deceleration at stop sign controlled,low volume, rural road crossings by removing the stop sign or converting the stop sign to a yield sign. Utilizing computer simulation and assuming a minor road average daily traffic of 100 vehicles and a major road volume of less than or equal to 200 vehicles per hour, an estimated annual savings for the state of Indiana of 5.7 million gallons (22 thousand M^3) of gasoline was obtained if the stop signs were removed at 120,000 intersections.(28) This figure represented the maximum savings because stop signs could not be removed at all intersections for other reasons, primarily from a safety aspect. Another study estimated that 0.3 to 2.9 thousand barrels (50 to 460 M^3) of fuel per day nationwide could be saved by converting stop signs to yield signs at feasible locations.(29)

Strategies Relating to the Preferential Treatment of High-Occupancy Vehicles

The travel time savings and improved transit service levels resulting from strategies in this category enhance the attractiveness of the more energy-efficient high-occupancy modes. Accordingly, the primary energy savings are derived from the fact that users of low-occupancy, energy-inefficient travel modes are encouraged to shift to the more efficient modes. Minor energy savings are also derived from the improved vehicular flow of the high-occupancy modes themselves and the improved vehicular flow of the low-occupancy modes which may result from significant user shifts. Energy savings may be offset slightly by new induced trips or possibly even shifts from high-occupancy to low-occupancy modes due to improved flow for low-occupancy modes. If existing heavily traveled lanes are converted to preferential treatment lanes, overall travel on the facility may degrade to the point where energy consumption increases. It is noted that transit and ride sharing are discussed in more detail in later sections.

Freeway Bus and Car Pool Lanes and Access Ramps

Generally there are five distinct types of priority treatment for buses and car pools involving freeways; namely, separated facilities, concurrent flow reserved lanes, contra-flow reserved lanes, priority access-bypass lanes on metered ramps, and priority access-exclusive use ramps. Typically the priority treatment is in effect only during the peak periods of commuter travel, and frequently projects include more than one of the aforementioned types of treatment. For example, the Santa Monica Freeway Diamond Lane project between Santa Monica and Los Angeles consisted of a 12.6-mile (20.3-km) reserved bus and car pool lane coupled with preferential bypass lanes at 12 of 30 metered on-ramps. Although the project was abandoned after 21 weeks, the California Department of Transportation estimated a daily average savings during the 8 peak hours of 11,345 gallons (43 M^3) of fuel, or 7.6% over the period immediately prior to the project, by the end of the 18th week.[30] Another study estimated a significantly less savings of 185 gallons (0.7 M^3) per hour, or 0.8% over pre-project levels.[31] A computer simulation study of the Santa Monica Freeway resulted in energy-savings estimates of 3% with priority operation at 6 entry controlled ramps, 3% with preferential bus only lanes, and 6% with preferential bus and car pool lanes.[33] In late 1974, 3.8 miles (6.1 km) of high-occupancy vehicle (HOV) lanes were opened to buses only on Route 101 north of San Francisco, the northbound lane being an extension of a previously established contra-flow bus only lane, and in 1976 the HOV lanes, with the exception of the contra-flow lane, were opened to three or more person car pools. Fuel savings were estimated at approximately 1,000 gallons (3.8 M^3) per day.[32] In 1974 priority access bypass lanes were opened on 9 metered ramps entering I-35 W. south of Minneapolis with analyses approximately one year later estimating fuel savings of 1,000 gallons (3.8 M^3) of gas per day.[34] The San Bernardino busway, which extends 11 miles (17.7 km) from Los Angeles eastward to El Monte, is a separated 2-lane facility for the exclusive use of buses, and is responsible for an estimated fuel savings of 5,000 gallons (19 M^3) per day.[35] Based strictly on the number of car pools in the exclusive lanes in November 1976, the Shirley Highway reversible bus and car pool lanes were estimated to be conserving over 2 million gallons (7.6 thousand M^3) of gasoline per year.[36] This is obviously a conservative estimate since only car pool data were utilized.

Bus and Car Pool Lanes on City Streets and Urban Arterials

There are basically two types of priority treatment for buses and car pools on local roadways — (1) concurrent flow reserved lanes, and (2) contra-flow reserved lanes. The HOV lanes are most frequently found in the curb lane, probably because implementation is relatively easy and inexpensive and requires the least change in bus operations. If local bus operations are involved, it is very important to prevent queuing of buses and/or car pools by removing the loading and unloading of passengers off the traveled way. Bus lanes in the median have the capability of being able to accommodate directional flow, and contra-flow bus lanes are most frequently established on one-way street systems when there is heavy directional traffic. When freeway HOV lanes can be extended onto urban streets or arterials, optimum results of the preferential treatment are realized. Although seldom found in the U. S., bus streets represent the maximum utilization of local streets for HOV treatment. No specific energy-savings data were found in the literature surveyed.

Bus Preemption of Traffic Signals

Signal preemption is a technique by which HOV operators can electronically or optically activate a special device within the signal head which causes the phase selector, within certain constraints, to lengthen the green phase or shorten the red phase so that the HOV can proceed through the intersection. The premise for this technique is that approximately 10% to 20% of bus travel time on downtown routes is spent waiting at traffic signals.[37] In progressive signal systems, the timing could be set so as to favor buses; however, this is very difficult due to the variability in the number of loading and unloading passengers. Although preemption is a valuable supplement to reserved lanes, it can be employed effectively as a measure by itself. Bus preemption may cause increased auto delay at the intersection, which results in increased fuel consumption, and downstream cross street traffic may back up in the intersection such that buses may be stopped even if the signal is preempted. Preemption on contra-flow bus lanes on one-way street systems may prove most effective if cross street traffic is light. A combination of priority treatment involving preemption of 35 signals and a reversible exclusive bus lane along a 10-mile (16-km) section of NW 7th Avenue in Miami resulted in an estimated reduction in fuel consumption of 10%.(38) This reduction is attributable only to the operation of 30 buses and does not include analysis of mode shifts.

Toll Policies

Toll collection points often create bottlenecks in the traffic stream, especially during the peak hours, and thereby afford opportunities for priority treatment. Techniques usually involve exclusive or possibly nonexclusive passage for HOV's through the toll facility either with no toll or a reduced toll being collected. In addition to facilitating the travel of the HOV, this strategy offers a readily perceived economic incentive. No energy-savings data were found in the literature surveyed.

Strategies Relating to Reduced Peak Period Travel

Strategies under this category are designed specifically to reduce the congestion or the amount of travel that occurs in urban areas during the two periods of the day that coincide with home-to-work or work-to-home trips. It is during these two rush-hour periods that the transportation systems are most severely taxed, and during which the most problems occur, with unacceptable service levels occurring during the peak hours on about 19% of all urban freeways and principal arterials. During the hours 7 to 8 a.m. and 4 to 5 p.m., the urban roadway must carry 9% to 10% of the total daily traffic, compared to about 5% per interpeak hour and 2% to 4% in the evening, night, and early morning hours.(39) The potential for saving fuel by reducing congestion has been discussed previously, whereas the savings from reducing travel or the number of trips is apparent. As with the other categories, the amount of energy saved may be offset somewhat from induced trips or modal diversion due to resulting improved flow characteristics.

Work Rescheduling

Actions within this strategy incorporate one of two basic methods — variable work hours or the shortened workweek — with the former action being established as either staggered or flexible. The more structured staggered work hour programs have starting and finishing times fixed according to a prescribed schedule in which the working hours of groups of employees are staggered, typically by 15-minute intervals. Under flexible work hour programs employees select their own starting and quitting times within preestablished limits and work the minimum number of hours. Further, all employees are typically required to be present during a fixed or core time. The purpose of the variable work hour programs is to relieve congestion by distributing the work trips over a longer period such that travel at any given time during the traditional peak is lessened, with the primary energy savings resulting indirectly from improved traffic flow, increased speeds, and reduced idling time. As variable work hour programs frequently decrease peak-period congestion on transit facilities, minimal energy savings may result from commuters diverting to transit; however, transit ridership may decrease if transit scheduling is not coordinated with the new work schedules. If implemented on a regional or city-wide basis, variable work hour programs must be coordinated very closely to avoid creating bottlenecks or congestion at points far removed from the place of employment, which may actually increase energy consumption. Finally, care must be taken in implementing programs to minimize disruption to energy-efficient ride-sharing activities. No specific energy-savings data related to variable work hour programs were found in the literature surveyed; however, it was generally agreed that the savings are minimal.

The second basic method, the shortened workweek, generally involves working the same number of hours but in fewer days, with the typical arrangement being four 10-hour days. The schedule can be arranged such that all employees have the same day off or it can be staggered to enable a 5-day or even 6-day business week. The primary purpose of shortened workweek programs is to reduce the vehicle miles of travel. Full compliance nationwide with a 4-day workweek would theoretically reduce by 20% the number of work trips and hence result in a 20% fuel savings for commuters. More realistically, by assuming 25% of those commuting to and from work by car could be placed on a 4-day schedule, approximately 125 thousand barrels (19.9 thousand M^3) of fuel could be saved per day.[40] These savings are likely to be offset somewhat by increased recreational travel, the attractiveness of living farther from work because of the reduced travel needs, and the potential for second jobs. Since the extra work hours are generally added at the beginning and end of the day, shortened workweek programs also spread out the rush hour and thus exhibit characteristics similar to those of variable work hour programs. Widespread regional diversion to shortened workweeks may simply change the rush hours to an hour earlier and an hour later.

Congestion Pricing

Contrary to most TSM strategies, congestion pricing is a relatively new traffic management technique, with few practical examples, especially in the United States. With the increased emphasis on the goals of TSM, however, much discussion has been generated recently concerning the viability of pricing as a tool to reduce the rush hour problems in urban areas. From an economic standpoint the underlying justification for congestion pricing is that it provides a method to equitably distribute the external costs of congestion, e.g. air pollution, noise, discomfort, and petroleum depletion, to those who actually cause the required expenditures. Basically, congestion pricing involves the imposition of direct charges on the peak period users of the transportation system. Actions would include such schemes as increased toll charges during the peak periods at existing toll collection points, increased transit fares during peak periods, parking surcharges on long-term parking, and supplementary licensing for entry to congested areas. Results of such actions would include the substitution of nonpeak travel for the peak period travel, alteration of routes or destinations to avoid the congested areas, diversion to more efficient modes, and the elimination of unnecessary travel. It is obvious that energy savings occur because of the decrease in congestion, reduction in travel, and diversion to less energy-consuming modes.

Congestion pricing has received much criticism as a management strategy, primarily from downtown merchants who foresee the decline of business as a major problem. It is also argued that low income people will pay a disproportionate share of the cost, either directly or in the loss of jobs, mobility, etc. Finally, based on many studies of the elasticity of gasoline cost which indicate that demand is relatively inelastic to price increases, it is debatable whether congestion pricing per se would have significant impacts in the U. S.

Strategies Relating to Urban Goods Movement

In recent years there has been increased emphasis on the movement of freight by trucks in the transportation planning process. Although the percentage of trucks in the traffic stream is relatively small, their impact is quite significant, especially during the peak hours, with the primary impact being the disruption of traffic flow from loading and unloading operations. A secondary impact occurs because of the generally slower operating characteristics of trucks. Accordingly, the majority of the energy savings associated with strategies under this category are derived from managing goods movement activities such that decreased congestion, increased speeds, and reduced idling occur for the main traffic flow. There is also the opportunity from several strategies to effect a fuel savings by improving the efficiency of the trucking operations. With a few exceptions, strategies related to goods movement are only being proposed or discussed and have not been implemented.

Spatial Separation of Trucks and Truck Activities

The most beneficial action under this strategy for reducing congestion and hence decreasing fuel consumption is to provide off-street loading and unloading facilities. In most urban areas existing off-street facilities are already being used wherever possible, and it is practical only within the long term to increase this activity through urban zoning requirements for new construction or in planning for new towns. Most loading and unloading operations occur at curb-side loading zones, and there are several actions which can improve the efficiency and utilization of the loading zone. These include imposing time limits on a per truck basis, locating the zones on lesser traveled streets, and ensuring the zone is used as intended and not just for merchant or customer parking. Although not feasible in most cases, it has been suggested that existing or new traffic lanes be dedicated to exclusive truck usage. This concept has more merit if it is applied to high-occupancy vehicle lanes or other HOV priority treatments. A final technique to separate truck traffic, one that has widespread use already in urban areas, is to establish specific truck routes which restrict trucks from congested areas.

Temporal Separation of Trucks and Truck Activities

Actions under this strategy result in energy savings by reducing the congestion caused primarily by the loading and unloading operations. Many cities have temporal restrictions on truck deliveries; however, the hours allowed for delivery are intended to accommodate the merchants and hence include the peak congestion periods. The most advantageous action would be to encourage or require night deliveries; however, both merchants and truckers object to this policy because of additional manpower expense, nighttime truck noise, and security problems. An alternative action which seems more feasible is to restrict deliveries to off-peak times such that the worst congestion times are avoided.

Truck Route and Facility Consolidation

The primary energy savings from this strategy results from restructuring the trucking industry to improve the efficiency of operation. In the extreme case, all deliveries going to the city would be consolidated at a main terminal outside the city. Goods would be delivered to smaller terminals at the periphery of the central business district, and then be delivered by small trucks to the individual businesses. This system would be extremely costly and most difficult to implement due to private competition. Certain aspects of the concept are more feasible; e.g. deliveries to several businesses located in a single building could be consolidated at one particular delivery point. A trucking firm can often improve its own particular routing and scheduling and thus improve efficiency, and some benefits might result from decreased downtown congestion if the delivery procedures are improved. It has been estimated that a nationwide reduction in direct transportation fuel consumption in 1972 of 0.9% would have resulted from increased load factors and decreased mileage due to more careful routing.[41]

Strategies Relating to the Promotion of High-Occupancy and Nonvehicular Travel Modes

The basic result of promoting, and thereby increasing the use of high-occupancy and nonvehicular travel modes, is a reduction in the total vehicle miles traveled, with the accompanying reduction in fuel consumption. Minor savings also result from the improved flow conditions which occur if significant diversion to high-occupancy and nonvehicular modes takes place. The strategies under this category are typically applied only to the twice-daily commuter traveler; however, the concepts are certainly applicable to more general cases of travel needs. Savings may be offset somewhat by additional trips, such as for shopping, induced by the increased availability of the automobile to certain households. It is estimated that a 10% reduction in the work related vehicle miles of travel would result in a national savings of 90 thousand (14.3 thousand M^3) barrels of fuel per day. Further, when traffic conditions are congested, reducing traffic volumes by 10% can cause a 2 mpg (0.9 km/l) improvement in fuel efficiency, which results in an estimate of 30 thousand barrels (4.8 thousand M^3) of fuel saved per day nationally.[42]

Ride Sharing

If it is assumed that travel demand on a transportation system is represented by a fixed number of person-trips over a fixed period of time, then an obvious method of saving energy is to share rides, or increase the vehicle occupancy (passenger-miles per vehicle-miles). Travel demand can be categorized by purpose by work trips and non-work trips. Since non-work trips have a wide dispersion of origins and destinations and are made over a wide range of time, ride sharing is considerably more feasible for the twice-daily work trips, primarily in the large urban areas where the size and concentration of employment activities and residential densities increase the potential for ride sharing. It is generally agreed that ride-sharing programs offer more potential for energy conservation than any of the other TSM strategies, primarily because of the relatively low cost and ease of implementation and the magnitude of travel involved. (A formal comparison of the energy efficiency of ride-sharing modes with other modes is presented in a later section.) This view is supported by the federal government through the many programs of the Departments of Transportation and Energy and the Environmental Protection Agency. Ride-sharing programs, however, are not without their critics and problems. Probably the most significant concern is that such programs may reduce transit usage as potential markets for ride sharing and transit frequently are identical; however, this concern can be resolved by close coordination with the local transit company from the outset of efforts to establish ride-sharing programs. In lightly populated areas where transit routes are underutilized and unprofitable, ride-sharing programs can complement transit by improving its efficiency through the elimination of routes. Another important consideration in estimating energy savings is to account for additional mileage caused by more indirect travel to pick-up and discharge riders. A final problem often associated with ride-sharing programs involves institutional issues such as legal questions, insurance liability, and regulation.

Of the various types of ride-sharing programs, commuter car pooling offers the greatest potential for fuel savings, primarily because it is the easiest and least expensive to implement and, due to its flexibility, it has by far the greatest potential market. Studies have indicated that the national average automobile occupancy for work trips is 1.4 persons per car, with specific case studies reporting occupancies ranging from 1.1 to 1.6.(43) By raising occupancy by 30% from 1.6 to 2.1 people, 5% of the total highway fuel consumed and 3% of the nation's total direct transportation fuel consumption can be saved.(44) The literature contains many cases of successful car pool programs. A cross section of documented programs involving 197,000 auto commuters for which follow-up data were available indicated that ride sharing had eliminated the use 33,200 commuter cars with an estimated annual fuel savings of over 11 million gallons (42 thousand M^3).[45] As a specific example, the areawide program in Portland, Oregon, eliminated the use of over 13,000 autos per day with an estimated annual fuel savings of 6 million gallons (23 thousand M^3) of gasoline.[46]

Van pools and bus pools (often referred to as subscription bus service) are actually more energy-efficient than car pools due to the higher load factors; however, they do not offer the potential for savings that car pooling does. This is primarily because these ride-sharing activities are best suited for longer trips, are applicable in more densely populated areas, and often require participation by parties additional to the riders. With these restrictions, the potential market is considerably less than that for car pooling activities. The van pooling program initiated by the 3M Company was estimated to be saving 108.3 thousand gallons (0.4 thousand M^3) of fuel per year as of late 1974, while a subscription bus service in El Segundo, California, utilizes eight buses to save an estimated 250 thousand gallons (0.9 thousand M^3) per year.[47]

As indicated by the category title for this group of strategies, the TSM strategies involve the promotion of the ride-sharing activities cited above. Promotional techniques frequently include manual or computer matching of potential participants, providing an informational clearinghouse for interested participants, and providing newspaper and other local media advertising. Van pool programs in particular require commitments and preferably funding from employers to be successful. Incentives to encourage ride sharing are often used to complement promotional techniques. In addition to the incentives discussed previously under preferential treatments, preferential parking privileges, parking subsidies, or even arranging for fringe lots as staging areas are often utilized as ride-sharing incentives.

Nonvehicular Travel Modes

Actions under this strategy encourage and promote diversion from auto travel to either bicycling or walking, with fuel savings being a direct consequence. Diversion to bicycling or walking appears to offer a significant fuel savings potential as over 62% of all auto trips are less than 5.5 miles (8.9 km) in one direction, with over 24% being less than 1.5 miles (2.4 km); however, these figures represent only about 15% and 2%, respectively, of the VMT.[48] If all trips less than 5.5 miles (8.9 km) were converted to bicycling and walking, a 10% savings of direct transportation energy would result.[49] Due to inclement weather and personal travel needs, such as the need for carrying packages and other items, it is not realistic to assume 100% diversion. Accordingly, if various percentage diversions ranging from 0.1% to 5.0%, depending on the trip length, are assumed, the fuel savings would amount to approximately 40 thousand barrels (6.4 thousand M^3) of fuel per day.(50)

Various actions can be undertaken to encourage and promote bicycle usage, the most significant of which is the provision of safe, unobstructed, and convenient travel for the bicyclist. The development of bikeways, ranging from completely separate facilities to signs indicating a bike route, is probably the most common action taken to encourage bicycling. Other techniques are media promotion, "piggyback" arrangements to encourage bicycling as part of a longer trip, and secure facilities for storing bicycles.

The primary goal of actions to encourage and promote walking is to reduce the conflicts between pedestrian and natural or man-made elements so as to upgrade the pedestrian environment and increase safety. Pedestrians and autos can be physically separated by providing sidewalks, skywalks, overpasses, underpasses, and malls. Improvements in existing pedestrian circulation systems include removing or relocating impediments, changing signal phasing or installing "walk" signals, providing crosswalks, widening sidewalks, improving lighting, and installing people mover systems. In a study of short, high capacity rail lines proposed for the high density areas of six cities, it was determined that these six downtown people mover systems will use more operating energy than the modes they replace. That is, people mover systems appear to have a net negative impact on energy consumption.(51)

Auto-Restricted Zones

For purposes of this report, an auto-restricted zone (ARZ) is interpreted to mean the actual physical restriction of automobiles from certain areas — typically a highly developed central business district of a large city. Fuel savings come from reduced travel resulting primarily from diversion to a more efficient mode or possibly the elimination of unnecessary trips. Experience with ARZ's is extensive in European countries; however, due to transit's high share of the modal split in European cities, it is doubtful whether parallel conclusions can be drawn for the U. S. In the U. S. the use of ARZ's is generally limited to pedestrian and transit malls, which were generally established to recapture the amenities and thus stop the decline of downtown areas. Since these areas are typically very small in area, minimal fuel savings are likely to be achieved. If the restricted area is sufficiently large, fuel savings in the range of 4% to 7%

can be expected.(52) The question of economic impacts on merchants and businesses must be answered satisfactorily before the establishment of large ARZ's becomes commonplace.

Strategies Relating to Transit and Paratransit Service Improvements

There is currently much discussion and controversy concerning the true energy savings potential of transit. (A formal comparison of the energy-efficiency of transit modes with other modes is presented in a later section.) Places having a viable transit service exhibit smaller energy use in transportation in terms of average weekly gasoline purchase per licensed driver than do those places not having such a service; e.g. Manhattan at 4.43 gallons (16.8 l) versus Bridgeport, Connecticut, at 17.84 gallons (67.6 l).(53) Theoretically, the energy-savings potential of transit is quite large, with an estimated 5% savings of total national energy consumption and 24% savings of gasoline consumption possible for a 100% diversion of auto journey-to-work trips to transit.(54) Such savings, however, are valid only in a long-range time frame. Existing transit accounts for a very small percentage of urban passenger miles of travel, in the range of 3%,(55) and typically operates at or near capacity during the peak commuting hours. Accordingly, existing transit systems cannot accommodate the massive increase in patronage required for a 100% diversion of auto journey-to-work trips. It has been estimated that existing systems can accommodate 15% more ridership, which reduces the aforementioned savings to approximately 1% of the total national energy consumption and 4% of gasoline consumption.(56) To further illustrate the long-range nature of the transit potential, a 20% shift of commuters, as opposed to the aforementioned 100% shift, would require an estimated 26,500 additional vehicles, 73,400 additional employees, $530 million additional for storage and maintenance facilities, and $330 million additional in support from local communities.(57) Another source indicates that approximately 3.5% of highway fuel would be saved by a shift of 10% of the auto mileage to buses.(58)

As indicated by the category title for this group of strategies, the actual TSM strategies involve transit and paratransit service improvements. Strategies under this category have the primary goal of attracting transit ridership by expanding transit service areas, improving service to existing service areas, increasing personal amenities for transit patrons, and promoting transit. The fuel savings potential is derived from the diversion of users of low-occupancy, inefficient travel modes to highly energy-efficient transit. Apparent fuel savings indicated by increased ridership must be modified to reflect new induced travel, especially in the case of expanded service, and possible diversion from more energy-efficient modes. Further, increased service generally requires increased fuel consumption by the transit system. Transit service improvements described in this section generally have minimal effect on the modal switch. The maximum potential is realized when these service improvements are used to complement other strategies, primarily those relating to auto disincentives, where adequate alternative service is absolutely necessary for success.

Transit Marketing

Marketing as a management tool is relatively new to the transit industry, and is one of the more promising approaches for improving transit. Modern marketing as applied to transit implies not only the selling of transit to the public but also having a total concern for and responsiveness to the service needs of current and potential transit patrons. The basis of a marketing program is the marketing plan, which consists of six basic elements - 1) systematic, large-scale consumer research, 2) service planning to develop routes, service modes and other operational elements, 3) pricing policies and fare structures, 4) user information and communications, 5) promotional elements, and 6) monitoring and evaluation.[59] A comprehensive marketing plan such as that just described provides the background and impetus for essentially all service improvements. No specific energy-savings data were found in the literature surveyed.

Security Measures

The perceived exposure to crime for transit users and potential users is generally agreed to be a factor affecting transit ridership, particularly during nighttime and possibly off-peak hours and on rail systems. Based on attitude surveys, however, there is no agreement on the relative importance of this factor to riders, on its impact on ridership, nor on how much ridership could be increased with improved security. Typical security actions include police or security force patrol and surveillance, various alarms and signals, automatic vehicle monitoring systems, two-way radio systems, closed circuit television surveillance, aerial surveillance, and design features such as adequate lighting. No specific energy-savings data were found in the literature surveyed.

Transit Shelters

A passenger shelter which provides protection from inclement weather and offers seating facilities at transit stops is an important amenity to current and potential patrons. The amount of time spent getting to a pickup point and/or waiting for the vehicle is a factor in modal choice. Studies have shown that the amount of time waiting for transit is generally perceived to be at least twice the value attached to actual travel time,[60] and, accordingly, any amenities attached to this waiting time enhances the attractiveness of utilizing transit. No specific energy-savings data were found in the literature surveyed.

Transit Terminals

Transit terminals, which serve collection, distribution and transfer functions in the transit system, can be classified into the two broad categories of downtown terminals and outlying transfer terminals.[61] Usage of both categories of terminals results in an efficient transit operation by facilitating route consolidation. Downtown terminals are a means to facilitate the use of transit, decrease travel time, and aid passenger transfer and distribution in the downtown area. Further, traffic congestion caused by buses in the curb lane may be decreased if the transfer and distribution operations are located off the street. Outlying transfer terminals function as collection and transfer centers and are generally located at park-and-ride lots, at points near the end of routes, and at points where routes intersect. By consolidating collection in outlying areas, vehicular traffic destined for the downtown area is reduced. No specific energy-savings data were found in the literature surveyed.

Transit Fare Policies and Collection Techniques

Prior to the era of massive public takeover of transit companies, the fare policy was rather straightforward — the fare box revenues should cover expenses and allow for a profit margin. The provision of transit service is now considered more of a public service, often being compared to garbage collection and fire and police protection. Further, as evidenced by the TSM goals and objectives, transit is being considered as a viable tool for decreasing congestion, air pollution, and energy consumption. Coupled with this new emphasis has been increased financial support for transit, including operating subsidies, with the end result being a change in attitudes regarding the role of the fare box. Simply stated, more and more transit operators are experimenting with fare policies and collection techniques with the primary goal of attracting ridership and providing essential services, even if there is a substantial risk that deficits will increase.

Fare reduction programs are frequently initiated to increase ridership, being based on the premise that the standard estimate of a 0.33% loss in bus ridership for each 1% increase in fare appears generally to hold in the reverse case of fare decreases.[62] Atlanta and San Diego are examples of two cities which have implemented fare reduction programs, along with some service improvements. Estimated fuel savings are 9,300 gallons (35 M^3) per day, or less than 0.5% of regional consumption, and 5,000 gallons (19 M^3) per day, or less than 1% of regional consumption, for Atlanta and San Diego, respectively.[63] Fare free programs, particularly in downtown or other highly congested areas, have also been implemented. In such programs the loss in revenue is partially offset by improved operating efficiency resulting from eliminating the delays due to fare collection. The Seattle fare free program is estimated to be conserving approximately 460 thousand gallons (1.7 thousand M^3) of gasoline and 20 thousand gallons (76 M^3) of diesel fuel per year, which is about 0.2% of the annual gasoline consumption in Seattle.[64] Other fare policies include peak/off peak hours fare differentials and special rates for the elderly and handicapped.

Techniques are also employed to simplify and speed up the collection process, to provide financial incentives through discounts, and to reduce the perceived high cost of transit by eliminating the actual transfer of money every time transit is utilized. Examples of techniques include exact fare systems, prepaid fare systems (tickets, tokens, punch cards, passes, permits, etc.), postpaid fare systems, and no barrier fare systems. Recent innovations in fare collection equipment have also improved the efficiency of fare collection.

Extension of Transit with Paratransit Services

In addition to attracting riders from low-occupancy modes, paratransit services frequently can save energy through increasing the efficiency of the regular transit operation by eliminating the necessity for some services. The elimination of nonproductive transit routes or service saves energy in two ways, the most apparent being the reduction in required transit fuel. Further, by increasing the availability of vehicles, service on heavily patronized and productive routes can be improved. Paratransit can be utilized to complement transit services by providing line-haul feeder services, additional peak period capacity, short-haul transit within the central business district, low demand density services, service at low demand times, suburban auto travel alternatives, and mobility for nondrivers.[65] Although no specific energy-savings data relating directly to this strategy were found in the literature surveyed, the energy-savings potential of several of the paratransit modes themselves are discussed elsewhere in the report.

Integration of Transportation Services

The purpose of integrating and coordinating transportation services is to increase the efficiency of the transportation system in an area and to facilitate its utilization by the public. Although this particular strategy is directed more toward the integration of transit systems, integration as envisioned in the TSM concept involves all modes of transportation. Integration of transit systems is approached at three levels — (1) the institutional level, i.e., the organizational structure under which the operators function; (2) the operational level, i.e., the services provided; and (3) the physical level, i.e., the facilities and equipment used.[66] Integration at the institutional level is generally the most difficult and time-consuming to implement. No specific energy-savings data were found in the literature surveyed.

Strategies Relating to Transit Management Efficiency Measures

Strategies under this category have the primary goal of improving the internal efficiency of transit operations, with fuel savings being derived from induced modal shift and decreased fuel consumption by the transit system itself. As mentioned previously, due to the small demand being met by transit, very large and impractical increases in transit ridership must occur to effect significant fuel savings. The potential for direct energy savings by the system itself is even less because of the practically insignificant amount of fuel consumed by transit systems when compared to national consumption. As shown in Figure 1 earlier in the report, urban public transit consumes less than 1% of the direct transportation energy.

Route Evaluation

Periodic route evaluation by transit management should be undertaken to determine changes in demand. The evaluation should include route spacing, transit stop spacing, headways, route layout, and vehicle loading. A computer simulation study of the bus operations on a street in Minneapolis showed an estimated 23% improvement in fuel efficiency if the number of bus stops was reduced from eight to four and the stops were relocated.(67) Based on case studies of average route speed versus fuel consumption an estimated 23% reduction in fuel consumption results from increasing the average speed from 10 mph (16 km/h) to 20 mph (32 km/h).(68) Energy-savings data regarding the other aforementioned evaluation parameters were not found in the literature surveyed.

Vehicle Communication and Monitoring Techniques

Fleet-to-base information exchange with two-way radio systems, automatic vehicle monitoring systems, or transit "checker"/ street supervisor systems provides for efficient control of fleet operations. This exchange increases driver and passenger safety and improves customer service. Systems can be used for reporting vehicle breakdowns, accidents, traffic conditions, schedule changes and reroutings, overloads, lost and found articles, and transit and nontransit emergencies.(69) No specific energy-savings data were found in the literature surveyed.

Maintenance Policies

Vehicle maintenance is important not only from an internal efficiency standpoint because system performance is improved, but also from an external standpoint because the public image of the system is enhanced through reliability and dependability of the vehicles in service. Elements of a coordinated and comprehensive maintenance program include improved scheduling of maintenance and adequacy of the maintenance facilities and equipment. No specific energy-savings data were found in the literature surveyed.

Strategies Relating to Parking Management

The urban transportation system can be viewed as being composed of three distinct elements — the vehicle, the right-of-way, and the terminal — with the last element consisting of parking and loading facilities.(70) As a key element in the system, parking, or, more specifically, parking management, has the potential of being a valuable tool for achieving the objectives associated with transportation systems management, including energy conservation. Specifically, strategies related to parking management can result in energy conservation by improving vehicular flow, primarily by removing on-street parking which previously has been discussed; encouraging modal shift from the auto to more efficient modes; and reducing travel by discouraging trips to certain areas. It is primarily because of the last noted action that the private parking industry, merchants, building developers, city officials, automobile user groups, and manufacturers frequently oppose the implementation of parking controls. Accordingly, with a few exceptions, parking management strategies are not being utilized to the extent appropriate based on their potential for saving energy.

Parking Regulations

Parking management strategies involving regulation can be separated into actions regulating the supply of parking and regulating the price of parking. The actions included under the general strategy of parking regulations are discussed briefly under the following subheadings.(71)

Allow Short-Term, On-Street Parking Only

Time restrictions on the duration of curb parking, which are widely used in cities throughout the U. S., are imposed to discourage long-term parking in order to provide space for shoppers and other short-term users. Long-term parkers are typically auto driving commuters who would be encouraged to shift to more energy-efficient modes, which would also reduce peak period congestion.

Enforce Parking Regulations

Strict enforcement of parking regulations is absolutely critical for the successful attainment of the energy-saving goals. Enforcement programs are the most common parking management action utilized by U. S. cities.

Reserve Parking for Priority Vehicles

As mentioned previously, the provision of preferential parking for high-occupancy vehicles is a method of encouraging car pooling and van pooling.

Restrict Parking Time at All Facilities

Primarily aimed at the commuter, limiting the duration of parking at on-and off-street parking facilities essentially requires the commuter to shift to transit. Use of this action is somewhat limited in scope because many of the parking facilities typically utilized by commuters are privately owned and operated.

Require Residential Parking Permits

If the central business district is located within close proximity of residential areas, commuters frequently use the residential streets for all day parking. Requiring bona fide residents to have permits would discourage this practice and possibly force commuters using the auto into more energy-efficient modes.

Freeze Number of Spaces, Limit Parking Garage Construction, Utilize Zoning to Limit Number of Spaces

The actions cited here all have the goal of restricting parking such that increased commuter parkers resulting from future growth will be encouraged to utilize the more energy-efficient modes.

Charge High Parking Rates for Single-Occupancy Vehicles

Obviously aimed at encouraging the utilization of more energy-efficient modes, this action is limited in scope because the majority of commuters do not pay for parking.

Charge Low Rates for Short-Term Parkers and High Rates for Long-Term Users

This action has the same purpose as the aforementioned action concerning time restrictions, i.e., to encourage utilization of spaces by shoppers and other short-term users and discourage the auto commuter. Use of this action also is limited in scope due to the availability of free parking for commuters.

Increase All Parking Rates

With the objective of decreasing congestion by penalizing everyone, this action is obviously not popular with downtown merchants who foresee customers shopping more at suburban or outlying shopping centers.

Reduce Parking Costs for Priority Vehicles

As a complement to reserving spaces for high-occupancy vehicles, reducing the cost or possibly subsidizing the cost can encourage the utilization of the more energy-efficient modes. Due to the availability of free parking, this action probably has less potential than reserving spaces.

Impose Parking Tax on Users or a Parking Stall Tax on Garage Owners

These actions are simply another method of raising parking rates in order to reduce travel in the congested central city area.

Summary of Parking Regulations

Although several of the actions discussed in the preceding paragraphs have had widespread use in U. S. cities, their utilization has not been in the context of parking management as a TSM strategy. Further, many of the specific actions are new concepts and have minimal or no examples of implementation. Accordingly, little information regarding the impacts of parking management strategies is available; however, the energy impacts are being addressed in recently developed urban parking programs. For example, a computer study of four geographic areas in the Washington D. C. region estimates a savings of 42 thousand gallons (160 M^3) of gasoline per day from implementing a parking program which includes residential parking permit systems, removal of free on-street commuter parking, increased parking rates, preferential car pool parking, additional park-and-ride lots, and zoning and land use controls.[72]

Park-and-Ride Facilities

The provision of parking facilities at modal transfer points in outlying or fringe areas is a commonly employed strategy in U. S. metropolitan areas. By facilitating the transfer from low-occupancy modes to high-occupancy modes, a modal shift to more energy-efficient travel is encouraged. Further, fringe parking causes a reduction in travel and congestion in the urban activity centers by shifting the parking away from the area. Park-and-ride lots are generally more successful if coupled with premium public transportation service. No specific energy-savings data were found in the literature surveyed.

Summary of the Potential for Energy Savings in the TSM Strategies

As mentioned at the outset of this part of the report on TSM strategies, the information presented represents such a wide range of study efforts and statistical results that direct comparisons of the various TSM strategies are made extremely difficult. One particular study prepared for the U. S. DOT did investigate actions to reduce energy consumption within the common framework of regional energy conserved.(73) In keeping with the nature of this present report, it is felt that a summary of the U. S. DOT report is appropriate. Accordingly, Tables 4 through 9 duplicate summary tables from that report. The study was conducted during the early years of the energy crisis; therefore, the reader should consider recent developments and local issues in evaluating the validity of the results. Finally, it is noted that the majority of the actions listed have been discussed in detail in this report; however, the actions are categorized differently and several additional actions are addressed.

Tables 4, 5, and 6 list the transportation actions with estimates of the potential regional reduction in energy use, and relate these action to institutional/legal considerations, indirect socioeconomic effects, and indirect environmental effects, respectively. The information on these considerations and effects is somewhat beyond the scope of this present report; however, it is certainly pertinent to implementation of the various actions.

Tables 7, 8, and 9 summarize the estimated potential regional reductions in energy use based on various "packages" of transportation actions for small urban areas, medium-sized urban areas, and large urban areas, respectively. In formulating the packages, consideration was given to whether the actions were favorable according to most criteria and whether the actions complemented each other. The four criteria considered were short lead time, minimum institutional obstacles, favorable public reaction, and high energy reduction. Regarding the interrelationships of various actions, some actions reinforce each other, some have contrary effects, and some overlap. Several of these interrelationships were mentioned in the previous discussions, and obviously it is best to design packages with actions which complement each other. As defined in the DOT report, a minimum package includes actions which are

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TABLE 4 (SOURCE: REFERENCE 73)

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
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. Measures 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 - 6.0	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 - 6	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

SUMMARY TABLE: [illegible] TO REDUCE ENERGY CONSUMPTION AND THEIR INDIRECT SOCIOECONOMIC EFFECTS

Action Group	Action	Regional Energy Reduction (%)	Travel Time	Cost Distribution	Safety	SOCIO-ECONOMIC: Life-style Change	SOCIO-ECONOMIC: Economic Dislocation	SOCIO-ECONOMIC: 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, 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 improvement	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-responsive service	0 - 1.0	Decrease	PU/G	Improve	NE	NE	Major
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. Measures 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

SYMBOLS: Cost Distribution: G = Government
PU = Public
PR = Private
NE = No Effect

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-responsive service	0 - 1.0	Decrease	Decrease	Decrease	NE
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. Measures 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

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TABLE 7 (SOURCE: REFERENCE 73)
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. Measures to Increase Transit Patronage		Fare reduction in combination with service improvements 4-7%	Fare reduction in combination with service improvements 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-relation 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 transferable coupons, restriction of quantity 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%	18-30%

* 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.

TABLE 8 (SOURCE: REFERENCE 73)

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

ACTION GROUP	PACKAGES		
	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, cost and convenience incentives [6-11%] Neighborhood ride sharing
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, possible 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 transferable 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 expected percent regional energy reductions if only the measures in the box are implemented.

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TABLE 9 (SOURCE: REFERENCE 73)
PACKAGED ACTIONS TO REDUCE ENERGY CONSUMPTION IN A LARGE URBAN AREA (1,000,000 OR MORE POPULATION)

ACTION GROUP	PACKAGES		
	Minimum Package *	Medium Package *	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, 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, cost, convenience and travel time incentives [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 transferable 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.

favorable according to three or four of the criteria and which do not overlap or work counter to each other. A medium package includes the minimum package plus actions which are favorable to only two or three of the criteria and which are not counter-productive in their relation to each other. A maximum package includes the medium package plus actions meeting only one or two of the criteria with all interrelationship constraints being dropped.

Other Activities Related to Transportation Systems Management

Although they will not be discussed in detail, several other activities need to be briefly mentioned in order to provide an overview of energy and transportation in Virginia and to provide as complete a resource document as possible. As these issues relate primarily to the TSM strategies, they are being presented at this point.

The first activity is a result of the Clean Air Act Amendments of 1977, which basically require that states submit plans or programs to the Environmental Protection Agency for attaining the national ambient air quality standards for those pollutants designated as nonattainment. In Virginia's urbanized areas having a population greater than 200,000, it is intended that these plans be developed by the Metropolitan Planning Organization in close cooperation with the Department of Highways and Transportation and the State Air Pollution Control Board. For other areas the plan development is the responsibility of the State Air Pollution Control Board. Included in the requirements is a consideration of certain transportation control measures, the majority of which are TSM strategies. Generally, strategies which have a high potential for energy savings will also improve air quality; however, the two distinct goals should be kept in perspective when programs are being developed.

The second activity is a result of the Energy Policy and Conservation Act of 1975, which empowered the Federal Energy Administration (now the Department of Energy) to fund state energy conservation programs. A program must provide for a 5% reduction in energy consumption by 1980, and include certain specific conservation measures in order to qualify for federal funding. Several of these required measures — including right-turn-on- red, promotion of car pools and van pools, and promotion of transit — are TSM strategies. In Virginia, the organization designated to develop the program is the Division of Energy, which is part of the Office of Emergency and Energy Services. Based on the projected energy use in Virginia in 1980, the program anticipates energy savings of 0.69% from a statewide promotion of car pools, 0.11% from increased use of bicycles, 0.33% from right-turn-on-red, 0.19% from fringe parking lots, and 0.004% from promotion of van pools.[74]

The third activity relates to several studies noted in the literature review that present methodologies for analyzing the energy conservation potential of several of the TSM strategies. Specific reference to these documents may prove of benefit to readers of this report. The first document, which was prepared for the then Federal Energy Administration (FEA), provides worksheets and a set of simple procedures for analyzing the energy conservation potential of transportation related measures being considered to increase car pooling, van pooling, and transit.(75) The second report, soon to be published under the auspices of the National Cooperative Highway Research Program (NCHRP), is a synopsis of current information on the energy related aspects of transportation systems. It includes recommended procedures for performing analyses of transportation energy consumption along with a rational method of presentation of the results of an energy analysis.(76) The third document is another soon-to-be published NCHRP report which contains a practical application of the methodology presented in the aforementioned FEA report.(77)

POTENTIAL FOR ENERGY SAVINGS IN LAND USE

Historically, transportation technology has played a major role in the development of the nation and, in particular, the land use patterns in metropolitan areas. Early development in our cities occurred along the routes of mass transportation facilities because walking and the railroads, the horse cars, or the cable cars were the only means of accessibility and mobility. As the automobile emerged as the predominant mode, the patterns in urban development began to change to the patterns that exist today. In view of the energy situation, especially as related to transportation, there is a need to consider changes to the existing patterns, and long-range transportation planning can be employed to a degree to implement these changes.

Land use configurations require varying levels of energy consumption, with reliable data being available for the residential sector and the transportation sector. Based on several studies, conservative but realistic estimates indicate that a 10% savings of energy in the residential sector could be realized by replacing single-family detached housing with single-family attached housing. A 30% savings could be realized with a low-rise multifamily housing unit, and a 35% savings with a high-rise multifamily unit.(78 Regarding the land use impact in the transportation sector, higher residential densities are characterized by both lower automobile ownership, and consequently fewer miles traveled, and a lower percentage of trips using the more energy-intensive automobile.

Compared to a residential density of 2 dwelling units (DU's) per acre (5 DU's/h), a residential density of 10 DU's/acre (25 DU's/h) is estimated to use 17% less transportation energy while a density of 30 DU's/acre (74 DU's/h) uses 42% less transportation energy.(79) If the above savings are combined with estimates of savings involving downtown versus spread work sites, and accounting for their relative weights in the national energy picture, a more general summary of the impacts of land use can be derived. Compared to a base residential density of 2 DU's/acre (5 DU's/h), all single-family detached, and spread work sites, the following percentage reductions in net national energy consumption are estimated:

1. Ten DU's/acre (25 DU's/h), 20% single-family detached and 80% attached and spread work sites - 7% reduction.

2. Ten DU's/acre (25 DU's/h), defined as above and downtown work sites — 17% reduction.

3. Thirty DU's/acre (74 DU's/h), 50% low-rise multi-family and 50% high-rise, and spread work sites — 19% reduction.

4. Thirty DU's/acre (74 DU's/h), defined as above, and downtown work sites — 27% reduction.(80)

Another study, which used computer simulation to analyze the energy consumption of 37 hypothetical cities with varying configurations and characteristics, supports the above data by concluding that sprawling land use patterns have larger energy requirements than do compact structures. Further, both population and employment distributions are important factors in explaining differences in energy consumption.(81)

Obviously, today's urban structures and land use policies and practices are not conducive to the potentials for energy savings described above and, in fact, the opposite appears to be the case. Based on such underlying forces as lower costs for land in suburban fringes, a preference for single-family housing and open space, and the availability of roads, automobiles, and fuel, the nation's metropolitan areas are becoming more dispersed. Between 1960 and 1970, metropolitan areas experienced a 17% growth, mostly in the suburbs. The population of the central cities increased only 7%, while that of the suburbs increased by 26%. Between 1970 and 1973, the central cities lost 1% of their population while the areas outside gained 6%.(82) This urban sprawl is characterized by longer trips, higher auto ownership, more miles traveled, and limited usage of energy-efficient public transportation.

Due to the interrelation between land use and transportation, new transportation facilities or major modifications to the existing system definitely influence land use patterns. As suggested by the underlying forces mentioned above, however, transportation is not the only factor in the establishment of land use patterns. Other factors are often behavioral or institutional in nature and, as such, are extremely difficult to change. Within these limits, therefore, transportation planning, coupled with land use controls and policies, can structure future systems which encourage a change to the energy-efficient land use described previously.

POTENTIAL FOR ENERGY SAVINGS IN THE URBAN TRANSPORTATION MODES

The transportation planning process consists basically of estimating the future travel demand and selecting the transportation system that will accommodate that demand. In recent years energy has become an increasingly important variable in the analysis of future transportation system alternatives. From an energy standpoint only, and assuming the forecasting deficiencies mentioned previously have been taken into account, the planning effort would select that transportation system, or combination of modes, that would satisfy the demand with the minimum energy consumption. Accordingly, many studies have been conducted which have attempted to quantify the energy used by the various urban transportation modes. Although several of the modes can be considered in the short range, it is only within the long range that planning for and comparison of all the modes are applicable. In fact, energy considerations for several of the modes described in the following narrative have been discussed in previous sections.

The energy efficiency of the different urban transportation modes is a subject of much controversy throughout the country. Due to the energy situation, there are serious implications on future funding for and implementation of the various modal systems, and different interest groups are quick to criticize any reports that do not favor their mode. An example of such a report is the recent publication by the Congressional Budget Office (CBO) on the potential savings of different urban transport modes.[83] This publication is a comprehensive review of the research to date on the modal energy subject, and, at the same time, is quite controversial. In keeping with the scope of this present report, the remainder of this section summarizes the results of the CBO study and related discussions. The reader is referred to the CBO report for the many details which have been omitted from this summary.

Many studies of modal energy consider only the energy required to run the system, i.e. propulsion energy, which possibly has been modified based on occupancy to reflect what is commonly referred to as energy-intensiveness. There are, however, other factors which should be evaluated in a comprehensive review of energy needs per mode. To address these broader factors, the CBO study delineates nine basic energy components which are combined to form a hierarchy of four measures of energy use, each of which reflects an increasing level of comprehensiveness. This framework for evaluating energy consumption is depicted in Table 10.

Table 10

Framework for Evaluating Modal Energy Consumption
(Source: Reference 83)

1. Propulsion energy per vehicle mile	Energy-intensiveness			
2. Average number of occupants				
3. Station and maintenance energy		Line-haul energy		
4. Construction energy				
5. Vehicle manufacturing energy			Modal energy	
6. Mode of access				
7. Fraction of trip devoted to access				Program energy
8. Circuity				
9. Source of new patronage				

The first two measures of energy use and their components are self-explanatory and straightforward; however, the latter two measures require explanation. Much of the travel on public transportation modes relies on the automobile for access to the stations, and combined auto/transit trips are usually more indirect than those by auto alone. Modal energy accounts for this type of factor by increasing the line-haul energy for access energy requirements and circuity and, accordingly, is the most comprehensive energy consumption rate. The modal energy can be misleading, however, if the source of patronage is not considered. For example, if the patrons divert from a more efficient mode, the net result may be an increase in energy consumption. The final measure of energy use, program energy, is calculated by subtracting the modal energy of the new transportation service from a weighted average of the modal energies of the old transportation services from which the new patronage is drawn. A positive number indicates a net energy savings with the new system whereas a negative number indicates a net energy loss, or more consumption. Obviously, program energy is the key measure on which to base planning decisions.

To be as accurate as possible in calculating values for the various modal energy requirements, the CBO study relies on a comprehensive review of available estimates of urban transportation energy use from both theoretical and applied studies. Further, high, low, and middle estimates are prepared for each mode and each energy component, with the middle estimate being the most representative or best estimate. The results are summarized in Figures 3 through 6 and the best estimates are tabulated in Table 11. Following is a discussion of the results by mode.

Van pools exhibit the best performance characteristics in all categories of energy measures by utilizing the least energy and offering high potential for energy savings. This is not surprising, however, as by design van pools provide door-to-door, prearranged, single direction, peak hour service, and any mode operating with these characteristics would perform equally as impressively. As mentioned previously, these characteristics also tend to limit van pool applications such that the potential for energy savings on a nationwide basis is less than the potential of several of the other modes.

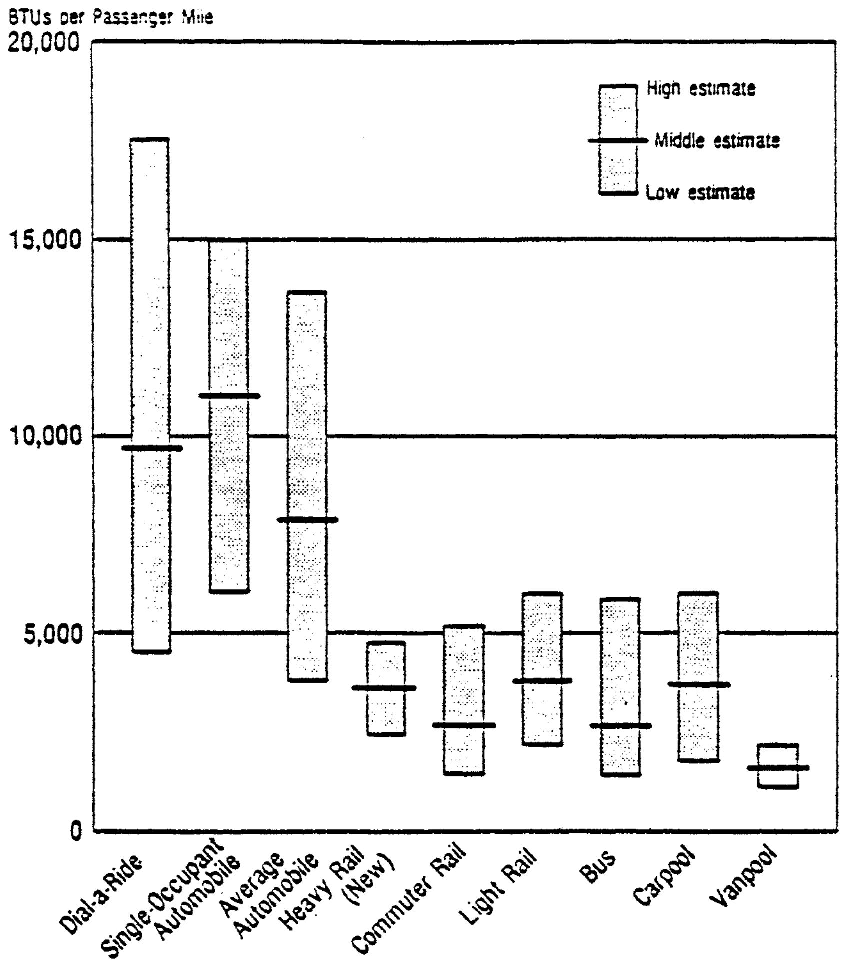

Figure 3. Operating energy.
(Source: Reference 53)

Note: 1 Btu per passenger-mile = 676 Joules per passenger-kilometer

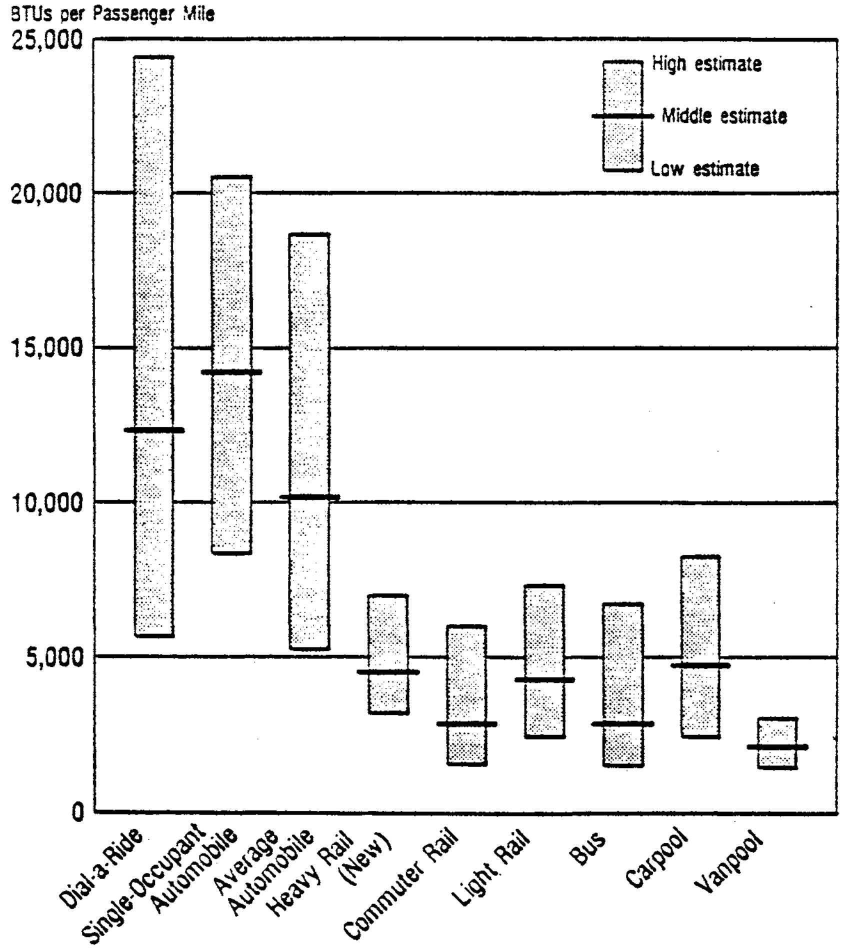

Figure 4. Line-haul energy.
(Source: Reference 53)

Note: 1 Btu per passenger-mile = 676 Joules per passenger-kilometer

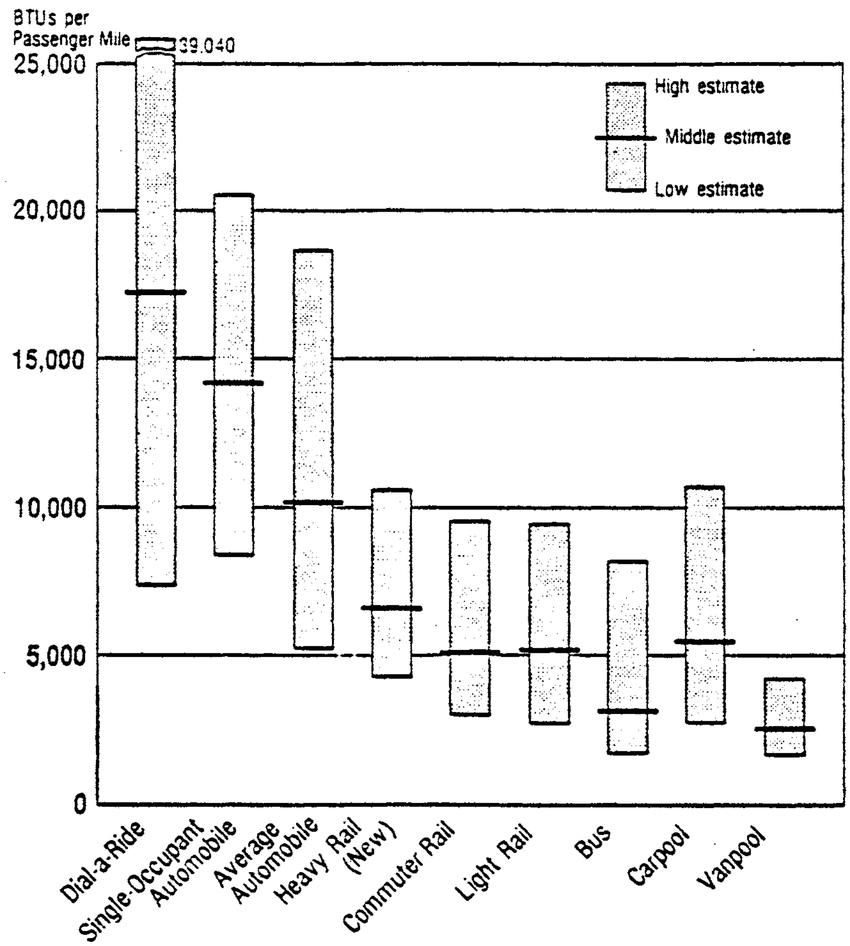

Figure 5. Modal energy.
(Source: Reference 53)

Note: 1 Btu per passenger-mile = 676 Joules per passenger-kilometer

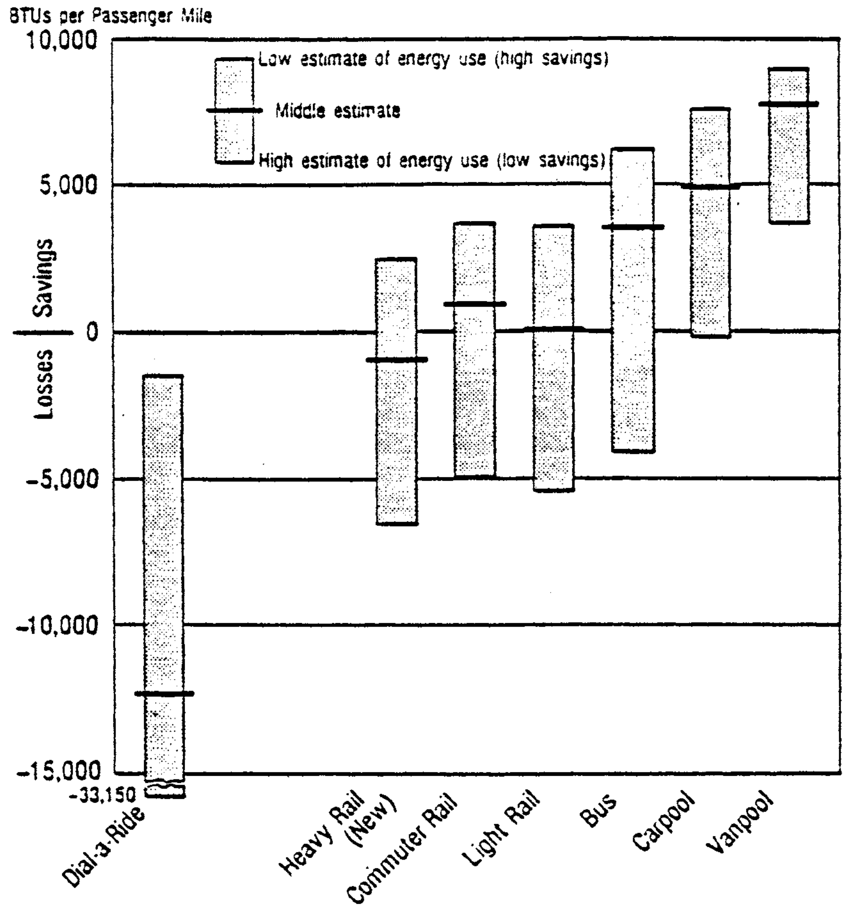

Figure 6. Program energy - net savings or losses.
(Source: Reference 53)

Note: 1 Btu per passenger-mile = 676 Joules per passenger-kilometer

Table 11

Ranking of Urban Transportation Modes for Various Measures
Of Energy Requirements Based on Middle Estimates
(Source: Adapted from Reference 83)

Operating Energy Intensiveness	Line-Haul Energy	Modal Energy	Program Energy (Net Savings)
Van Pool (1560)	Van Pool (2020)	Van Pool (2420)	Van Pool (7720)
Shuttle Loop Transit (2300)	Bus (2820)	Bus (3070)	Car Pool (4890)
Heavy Rail (Old) (2540)	Commuter Rail (2890)	Heavy Rail (Old) (3990)	Bus (3590)
Bus (2610)	Heavy Rail (Old) (3100)	Commuter Rail (5020)	Commuter Rail (970)
Commuter Rail (2625)	Shuttle Loop Transit (3160)	Light Rail (5060)	Light Rail (30)
Group Rapid Transit (3330)	Light Rail (4280)	Car Pool (5450)	Heavy Rail (New) (-980)
Heavy Rail (New) (3570)	Heavy Rail (New) (4550)	Heavy Rail (New) (6580)	Dial-A-Ride (-12,350)
Car Pool (3670)	Group Rapid Transit (4600)	Average Auto (10,160)	
Light Rail (3750)	Car Pool (4740)	Single-Occupant Auto (14,220)	
Personal Rapid Transit (5500)	Personal Rapid Transit (8650)	Dial-A-Ride (17,230)	
Average Auto (7860)	Average Auto (10,160)		
Dial-A-Ride (9690)	Dial-A-Ride (12,310)		
Single-Occupant Auto (11,000)	Single-Occupant Auto (14,220)		

Note: Numbers in parentheses are Btu's/passenger-mile

1 Btu/passenger-mile = 676 Joules/passenger-kilometer

Car pools offer significant potential for saving energy on a national level due to the large percentage of auto commuting and the few constraints to forming car pools. Based on the energy measures, car pooling is a relatively high energy consumer; however, it is second to van pools when the source of patrons is considered.

Buses appear to offer the most potential of all the conventional urban public transportation modes by consistently performing well in all categories of energy measure. This is primarily attributable to their flexibility and access requirements and, as discussed previously, several innovative services offer significant energy savings at minimal additional costs. The potential is somewhat limited by existing fleet sizes and characteristic peak-hour-only utilization.

Rail systems exhibit probably the most unexpected (and hence most controversial) characteristics of the modes analyzed. When considering operating energy-intensiveness only, all the rail systems compare favorably in absolute numbers to the other modes. If line-haul energy is added, both light rail and new heavy rail systems become increasingly less energy-efficient. Commuter rail, along with light rail and new heavy rail, becomes a relatively large consumer of energy when the modal (access) energy is added. Old heavy rail systems still compare favorably because they are typically in high-density areas with walk-on access. When the overall program energy or energy savings is considered, with the exception of dial-a-ride, the rail systems offer considerably less energy savings than the other modes. Using the best estimates, light rail offers essentially no savings while a new heavy rail system actually wastes a significant amount of energy.

Automobiles perform poorly in all categories of energy consumption, even when an average occupancy is considered. The difference in consumption rates between the automobile and the other modes will decrease as the federally mandated fuel economy standards are implemented.

Dail-a-ride performs extremely poorly in all categories of energy measures, and actually wastes energy by the most optimistic estimates of energy requirements. Its performance is readily explained by the low load factors and high route circuity which are typical of existing dial-a-ride systems.

Personal rapid transit, group rapid transit, and shuttle loop transit systems compare reasonably well; however, limited operational data do not allow any significant conclusions, especially as to the most important measure of program energy.

The CBO study is quite controversial and, accordingly, following is a discussion in list form of some of the major criticisms of or comments on the study. Some of the weaknesses are indicated in the study itself while other criticisms are described in other papers or the record of the hearing held before the Subcommittee on Transportation on the CBO study.[84] The reader is referred to the report on this hearing for a detailed criticism of the CBO report.

1. In practice, no reasonable transportation policy could be based on energy alone. For example, dial-a-ride has the potential for providing specialized transportation to the elderly and handicapped, which fact may have priority over the energy issue in many instances.

2. The interrelation between land use and land use policy and transportation is ignored in the calculations, thus making long-term energy savings particularly uncertain. For example, dense, concentrated land development would tend to favor the rail systems, while continued urban sprawl would require more miles of travel which would offset the potential savings of several of the other modes.

3. An assessment of the potential for energy conservation in urban transportation modes necessitates the consideration of many technological, operational, and behavioral factors, each of which can and often does vary among urban areas and transportation systems. Hence it is not valid to formulate decisions regarding specific urban areas and systems based on averages or typical data. Policies and decisions should be made only after a detailed analysis of local conditions.

4. The source of energy, or type of fuel, is an important variable not quantified in the CBO study. Obviously, the primary concern currently is the conservation of petroleum; however, it is noted that frequently much of the electricity used by certain modes is generated by turbines that burn petroleum-based products.

5. As with any study as comprehensive as the CBO study, certain basic data are lacking and are estimated.

6. The real measure of potential energy savings is the capacity of the modal systems; therefore, the ultimate comparison should be energy per seat-mile, not passenger-mile. This very likely would reorder the modes such that the high capacity modes would be the most efficient.

Within the constraints mentioned, the long-range transportation planning process provides the mechanism for analyzing future transportation systems from an energy standpoint. The potentials for energy savings with the various modes of transportation should be considered in the alternative analysis phase of the process.

CONCLUSIONS

Based on the results of a review of the literature, conclusions of an overview nature regarding the potential for energy savings in transportation planning and systems operation can be drawn. Additionally, certain conclusions regarding the Virginia Department of Highways and Transportation's role in energy savings can be stated.

Conclusions Regarding the Potential for Energy Savings in the TSM Strategies

Within the transportation planning process, the development of the short-range element, consisting essentially of TSM strategies, is the activity most directly related to energy savings. Although the literature contains many studies of the potential energy savings through specific TSM strategies, many of the strategies have not been addressed. Further, it is essentially impossible to rank or prioritize the strategies on a quantitative basis because of the many variables involved and assumptions made in deriving the energy savings. Finally, the short-range element consists of a package of TSM strategies which support and complement each other in order to effect an overall reduction in energy use. Within the context of a package of actions, the energy savings of specific strategies may increase, or strategies having low potential may be a critical complement to other strategies. Thus the validity of comparing strategies on an individual basis is questionable. Therefore, for purposes of this study only a subjective evaluation of the strategies has been made from the standpoints of potential for energy savings and potential for implementation in Virginia. These potentials have been rated simply as low, medium, or high. As for the potentials for energy savings, several strategies appear to offer consistently high relative savings within the literature reviewed, while others seem to be consistently low in energy savings. The remainder of the strategies were generally rated as having medium potential. The feasibility of implementation is based on the author's personal knowledge and opinion regarding transportation activities in Virginia. The results of the evaluation are presented in Table 12.

Although the results of the evaluation are open to much debate, and broad utilization of the results must be tempered with personal judgments, certain specific conclusions can be made. Strategies having significant potentials for energy savings include improvements at signalized intersections, promotion of ride-sharing activities, park-and-ride facilities, freeway bus/car pool lanes and access ramps, shortened workweek, and parking regulations.

Table 12

Subjective Evaluation of the Potential for Energy Savings and Feasibility of Implementation in Virginia of TSM Strategies

	Strategy	Energy Savings Potential	Feasibility
1.	Improvements in signalized intersections	High	High
2.	Freeway ramp metering	Medium	Low
3.	One-way streets	Medium	High
4.	Removal of on-street parking	Medium	Low
5.	Reversible lanes	Medium	Medium
6.	Traffic channelization	Medium	High
7.	Transit stop relocation	Low	Medium
8.	User information/assistance	Low	Low
9.	Removal of or conversion of stop signs to yield signs	Low	Low
10.	Freeway bus/car pool lanes and access ramps	High	Medium
11.	Bus/car pool lanes on city streets and urban arterials	Medium	Medium
12.	Bus preemption of traffic signals	Low	Medium
13.	Toll policies	Medium	Medium
14.	Work rescheduling - variable work hours - shortened workweek	Medium High	Medium High
15.	Congestion pricing	Medium	Low
16.	Spatial separation of trucks and truck activities	Low	Low
17.	Temporal separation of trucks and truck activities	Low	Low
18.	Truck route and facility consolidation	Low	Low
19.	Promote ride sharing	High	High
20.	Promote nonvehicular travel modes	Medium	High
21.	Auto-restricted zones	Low	Low
22.	Transit marketing	Medium	High
23.	Transit security measures	Low	Medium
24.	Transit shelters	Low	High
25.	Transit terminals	Low	Low
26.	Transit fare policies and collection techniques	Medium	Medium
27.	Extend transit with paratransit services	Medium	Low
28.	Integration of transportation services	Low	Low
29.	Transit route evaluation	Low	Medium
30.	Transit vehicle communication/monitoring	Low	Medium
31.	Transit maintenance policies	Low	Medium
32.	Parking regulations	High	Low
33.	Park-and-ride facilities	High	High

Of these, only the first three are judged to have a high feasibility for implementation in Virginia. Freeway bus/car pool lanes and access ramps are certainly feasible; however, primarily because of the high costs and rather limited number of locations where the costs are warranted, the feasibility is less than for the first three mentioned. Due primarily to institutional problems, the remaining two strategies have limited potential for implementation. Other strategies judged to be highly feasible for implementation in Virginia include one-way streets, promotion of nonvehicular modes, traffic channelization, transit marketing, and transit shelters. The first four have at least a medium potential for energy savings. Strategies having low energy-savings potential and feasibility for implementation include user information/ assistance, removal of stop signs or conversion of stop signs to yield signs, the urban goods movement strategies, auto-restricted zones, transit terminals, and integration of transportation services.

Many of the TSM strategies derive their potentials for energy savings from diversion to more energy-efficient modes, including transit. Although transit has a large amount of reserve capacity to accommodate a modal shift, the majority of this reserve occurs in the off-peak hours. During the peak hours when many of the TSM strategies are most beneficial, transit typically operates at or near capacity. Therefore, the potential for energy savings through the increased utilization of transit is somewhat limited in the short term.

Although the need for energy savings is a critical issue, it is impossible to implement TSM strategies without giving consideration to the many other factors involved. Fortunately, positive energy impacts generally imply positive impacts on the other goals of TSM, such as improving air quality, reducing congestion, and reducing costs. Many other factors, generally of an institutional nature, must also be considered. In planning for TSM strategies, the potential for energy savings must be kept in perspective as only one of many factors to be considered.

Conclusions Regarding the Potential for Energy Savings in Land Use

General land use patterns in the United States are not energy-efficient from the standpoint of either residential consumption or transportation consumption, with the typical pattern of urban sprawl being characterized by long trips, high auto ownership, and limited usage of public transit. More compact land use patterns with high residential densities composed of multi-family units and with downtown work sites can result in significant energy savings. Obviously it is only within the long-range that land use changes can occur. Due to the interrelationship of land use and transportation, transportation planning, especially as it relates to new facilities, can be a valuable tool in shaping land use patterns. Many factors must be considered, and the potential for energy savings by itself likely will never justify radical changes.

Conclusions Regarding the Potential for Energy Savings in the Urban Transportation Modes

Within the transportation planning process, consideration should be given, primarily in the long range, to the energy efficiency of the various modes of transportation. Based primarily on the review of a very comprehensive analysis of the energy consumption per passenger-mile (existing occupancy) of the various modes prepared by the Congressional Budget Office, the most energy-efficient mode is the van pool, followed closely by the bus. Automobiles with average occupancy, automobiles with single occupancy, and dial-a-ride systems require significantly higher energy, while new heavy rail systems, commuter rail systems, light rail systems, and car pools are grouped in between. If consideration is given to the source of new patronage for the various modes, an overall modal impact on energy, or potential for energy savings, can be derived. Again, van pools result in the greatest net energy savings, followed closely by buses and car pools. Dial-a-ride systems result in the greatest net energy loss, while new heavy rail systems, commuter rail systems, and light rail systems are estimated to result in no energy savings or even in energy losses. It should be noted that these conclusions are the subject of much debate, some of which was presented previously.

As with the TSM strategies, the selection of the mode of transportation in long-range planning activities cannot be based on energy concerns alone. A wide range of factors must be considered.

Conclusions Regarding the Role of the Virginia Department of Highways and Transportation

The Department's role in the use of energy in the planning and operation of transportation systems must be defined on four levels of activity. For those urbanized areas having the formal 3-C transportation planning process mandated by the U. S. DOT, the metropolitan planning organizations have the primary responsibility for plan development, with the Department having an active support and approval role. In this capacity, Department personnel should encourage and support those activities which result in high energy savings. For those smaller areas in which the Department is the lead planning agency and for the development of the statewide transportation plan, Department personnel should routinely consider energy savings in the development of the transportation plan. As day-to-day managers of the state's highway system, Department personnel should be cognizant of the potential energy savings related to the various TSM strategies and be constantly alert for opportunities to implement them. Finally, as the state's largest agency and primary transportation one, the Department should be aware of opportunities to implement in-house actions to both conserve energy and set an example for others.

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