

capita as compared to 36.2 revenue passengers per capita for older systems.

Consequently, systems that have been publicly owned since 1969 or earlier (six years or longer) appear to be more efficient in terms of vehicle and passenger use. Because of strong and continuing political and public support, such systems have been able both to make certain capital improvements and to implement policies that provide increasing service levels. Purchase of new buses, for example, has allowed transit systems to provide longer hours of service with fewer vehicles, whereas certain policy issues such as fare stabilization have helped to assure continued patronage.

If we consider only the financial efficiencies, however, those systems that have been public since 1969 (less than six years) appear to be more cost efficient. Table 6 shows that operating expense per vehicle, on the average, is lower (\$33 512) than it is for older systems (\$42 231). Not only can these systems operate at lower unit costs, but they also appear to be more revenue efficient; revenue per passenger is \$0.08 more than it is for the older systems (Table 6). In general, the revenue efficiency of younger systems may be explained by a fare policy that reflects the momentum of the profit-making objective of privately operated transit systems.

It should be noted that, for each of the performance measures presented in Table 6, the  $R^2$ -values (which reflect the extent of explanation of variation in transit performance) range between 0.104 and 0.157. These values indicate, for example, that only 10.4 percent of the variation in vehicle use (as measured by vehicle hours per vehicle) can be explained by stratifying 51 transit systems according to system age. These results are as expected, and they suggest that other environmental and policy variables might be more useful in explaining variation in urban transit performance when considered together with system age.

#### CONCLUSIONS

In this paper, a method has been developed by which certain environmental and policy variables have been found useful in explaining the biases inherent in transit performance measurement. Through the example presented, the extent of influence on transit resource use of the elements of wage rate, average operating speed, and population has been identified.

Since such a procedure appears to explain performance variation adequately, its usefulness in

comparative evaluation is evident. Such evaluations lend themselves to direct comparison of systems within their respective cells. Bus system performance can be compared against the mean cell values of performance indicators of similar properties. These mean values constitute a par against which comparisons can be made, primarily by managers of a transit property.

Stratification is therefore useful in explaining the possible bias in making assessments and comparisons of bus transit systems. However, it is important to stress that the stratification scheme presented here is only a beginning. Subsequent analyses that use additional environmental and policy factors will undoubtedly improve the reliability and validity of the stratification scheme. The stratification approach to comparing the performance of alternative systems holds promise of being a powerful program-analysis and system-evaluation tool.

#### ACKNOWLEDGMENT

Financial support for this research was provided by a grant from the Urban Mass Transportation Administration. We are solely responsible for the results and opinions expressed in the paper.

#### REFERENCES

1. G.J. Fielding and others. Development of Performance Indicators for Transit: Interim Report. Univ. of California, Irvine, July 1977.
2. Uniform System of Accounts and Records and Reporting System--Project FARE, Task V, Volume 1: General Description. Urban Mass Transportation Administration, U.S. Department of Transportation, July 1976.
3. Proc., 1st National Conference on Improving Transit System Performance, Norfolk, Virginia. Urban Mass Transportation Administration, U.S. Department of Transportation, Oct. 1978.
4. B.S. Pushkarev and J.M. Zupan. Public Transportation and Land-Use Policy. Indiana Univ. Press, Bloomington, 1977.
5. M.M. Bakr and others. Role and Effectiveness of Contract Management in the Transit Industry. Urban Transportation Program, Marquette Univ., Milwaukee, WI, 1975.

*Publication of this paper sponsored by Committee on Public Transportation Planning and Development.*

## Effects of Small-Scale Transit Improvements on Saving Energy

DANIEL K. BOYLE

The effects of small-scale transit improvements on saving energy in New York State's eight metropolitan planning organization (MPO) areas are examined. Actions included in the transportation system management (TSM) plans of the eight MPO areas are analyzed for their effects on ridership, mode shifts, and energy savings, as well as on the energy costs of development, implementation, and operation. Each of 11 transit-related TSM actions is analyzed separately.

These transit improvements result in average annual energy savings of more than 25 million equivalent L of gasoline over the period 1978-1980. This is about 0.1 percent of the total annual gasoline consumption in New York State but is 2.6 percent of transit energy consumption in the eight MPO areas. When demand-responsive services, which have high energy costs, are excluded, the average annual saving increases to 3.1 percent of transit energy consump-

tion. Small-scale transit improvements can thus play a role in the energy conservation efforts in New York State but cannot be expected to have a major impact on the state's energy situation.

In recent years, the focus of attempts to improve public transportation systems has been on small-scale improvements designed to make transportation systems more efficient. Although energy has not usually been a stated criterion in evaluating such improvements, it has been generally assumed that public transit can play a major role in any conservation effort.

This paper is part of a broader study undertaken by the Planning Research Unit of the New York State Department of Transportation (NYSDOT) in conjunction with the New York State Energy Office to quantify expected energy savings for the years 1978-1980 for all elements of the state energy conservation plan. Specifically, this paper analyzes several categories of transportation systems management (TSM) actions related to mass transit to determine energy savings and costs.

#### METHOD

Determination of statewide energy savings by category and by area is the goal of the analysis; this requires an aggregate approach. Transit-related energy savings come primarily from a reduction in automobile vehicle kilometers due to mode shifts to mass transit. Energy costs are incurred by increased vehicle kilometers of travel (VKT), increased bus maintenance, and construction of transit equipment or system facilities. Savings and costs are expressed in equivalent liters of gasoline. The following formulas are used to calculate savings and costs:

Savings = (change in transit ridership x proportion of automobile drivers who divert to transit x average automobile trip length x factor for car left home)/automobile fuel efficiency.

Cost = (change in transit kilometers traveled/bus fuel efficiency) x 1.104 + construction costs + 0.105 (change in transit kilometers traveled).

In the cost formula, 1.104 is the factor that converts liters of diesel fuel to equivalent liters of gasoline and 0.105 is the factor that takes into account increased maintenance costs that arise from increased VKT (1). Average automobile trip lengths are 13.4 km upstate (2) and 15.9 km in the Tri-State area (3). Average automobile fuel efficiency in New York State was 5.06, 5.23, and 5.40 km/L in 1978, 1979, and 1980, respectively (4). Average fuel efficiency for buses has been studied by the U.S. Department of Transportation and the U.S. Environmental Protection Agency (5). Average figures are 1.70 km/L for local transit buses and 2.13 km/L for express buses. Finally, a study on the use of the car left at home has indicated that energy savings should be reduced by 40 percent to take into account such use. The factor for the use of the car left at home is therefore 0.6.

Since only 34.6 percent of workers in the New York City metropolitan area drive an automobile for the journey to work as compared with 65.7 percent in upstate metropolitan areas (6), the proportional diversion potential in the New York City metropolitan area is about half the diversion potential upstate. When diversion rates for small-scale transit TSM actions are estimated, the rate for the Tri-State area was one-half the diversion rate for upstate areas. Where appropriate, the outlying counties (Putnam, Orange,

and Dutchess) of the 12-county Tri-State area are treated in the same manner as are upstate areas. For this study, diversion rates will express the proportion of new transit riders who formerly drove an automobile.

For most types of actions, case studies provide estimates for ridership increases. A review of the literature reveals appropriate percentage increases for systemwide actions such as passenger amenities, marketing, and passenger information. Finally, for routing and scheduling improvements, a typical ridership change is estimated from averages of documented ridership changes that result from such improvements.

#### RESULTS

##### Routing and Scheduling Improvements

Average ridership and VKT changes were obtained from actions in which such information was available or easily estimated, and these averages were applied to projects from which no data were available. The average ridership increase was 40 000, whereas the average bus VKT increase was 46 000. Two projects considered separately were a Tri-State action that involved a ridership increase of 5 million and a Rochester action that involved a VKT decrease of 390 000.

Other studies (7) have indicated that from 33 to 50 percent of new riders drawn to transit by improvements in frequency of service would otherwise have driven an automobile. The 33 percent figure is used except in cases in which new service is provided to areas not already served. In those cases, the 50 percent diversion rate is used. The diversion rate is halved for the nine inner counties in the Tri-State area.

Routing and scheduling improvements result in annual savings of between 1 325 000 and 1 500 000 L; over 80 percent of the savings occurred in the Tri-State area. Three upstate areas show negative figures; in these cases, the energy costs from increased bus operation and maintenance outweigh savings from new passengers diverted to transit.

##### Express-Bus Service

A study of express-bus service in New York City revealed that the rate of diversion from driving an automobile to riding an express bus was only 4.1 percent (8). This low diversion rate can be explained by the fact that in general the trip time to Manhattan was longer by express bus than by automobile. The fact that any diversion occurred in this situation indicates the important role that comfort can play as an inducement to using mass transit.

Figures from six express-bus studies across the country were used to determine a rate of diversion from driving an automobile to riding an express bus for upstate areas. These figures ranged from 16 percent in Seattle, Washington, to 55 percent in San Bernardino, California. Most rates fell in the 40-50 percent range. Because most of these studies considered additional service changes such as park-and-ride lots, exclusive bus lanes, and signal preemption, a 33 percent diversion rate is a reasonable estimate for express-bus service in upstate metropolitan areas and express-bus projects in the Tri-State region that operate outside New York City.

The effect of express-bus service on energy consumption is somewhat surprising. The energy costs from the increase in bus VKT are significantly greater than energy savings from increased

ridership. Statewide, this results in an annual cost of 550 000 equivalent L of gasoline. It appears that the most energy-efficient change in service is the conversion of an existing bus line to express service, since this involves no change in bus VKT. This type of change, however, tends to attract a great proportion of riders of the local transit service. Provision of express-bus service may fare less well as an isolated project than do other transit-related TSM actions. This suggests that express-bus service should be packaged with other complementary actions.

#### Park-and-Ride Service and Transportation Corridor Parking

In considering transportation corridor parking, there are two basic types of park-and-ride lots: (a) remote park-and-ride service, which involves parking in outlying areas and using public transportation for the major portion of the journey to work, and (b) peripheral park-and-ride service, which involves (as the name suggests) parking on the outskirts of the central business district (CBD) and using public transportation for final trips within the CBD. In general, lots more than 4.8 km from medium-sized downtown areas are classified as remote, and lots within 2.4 km are classified as peripheral (9). This analysis uses a distance of 4.8 km as the dividing line between the two types.

Four areas in the state are using or constructing park-and-ride lots--the Tri-State region, the Capital District, Syracuse, and Rochester. All these areas could provide data on either the number of new spaces or the change in bus ridership associated with the park-and-ride lots. To complete the data necessary for the energy calculations, average figures for annual number of cars and passengers per space in a park-and-ride lot and the average occupancy of a car that used the lot were needed. These averages were obtained from park-and-ride studies in six cities across the country (10,11) and from recent surveys in Albany. The annual number of cars per space is 200, or 80 percent of full capacity (250 cars/space is the equivalent of full capacity, since there are 250 workdays in a year). Average automobile occupancy differs for remote and peripheral lots. It is 1.15 for the former and 1.33 for the latter. The difference can be readily explained by the assumption that more carpooling takes place for the long automobile trip to a peripheral lot than for the essentially local trip to a remote lot. From these two averages, we can compute the annual number of passengers per space, which is 230 for remote lots and 266 for peripheral lots.

Since park-and-ride lots capture automobiles on their way to work and save the energy formerly expended on that portion of the trip between the lot and the CBD, the distance between the lot and the CBD is used as the average automobile trip length in the energy calculations for this section. This average distance is estimated at 19.3 km for the Tri-State region.

To determine diversion rates, averages from a five-city park-and-ride study were used (10). For remote lots, the rate of diversion from automobile driver to transit user averaged 45 percent, whereas for peripheral lots the figure was 70 percent. In the Tri-State region, the diversion rate is halved. Some areas used existing lots for park-and-ride service. In these areas, there were obviously no energy costs for construction.

The results of the energy calculations show that park-and-ride service can have a positive effect on energy consumption in the state. On the average,

park-and-ride service saved 6 400 000 equivalent L of gasoline annually during 1978-1980. Although the diversion rate is higher for peripheral lots, use of remote lots has a more-pronounced effect on energy savings because of a greater reduction in automobile VKT.

#### Shuttle-Transit Service

Shuttle-transit service can link two activity centers or can operate as a circulator within the CBD. Shuttle-transit service is being provided or planned in Westchester County, the Capital District, Syracuse, and Rochester. Free downtown bus service in Albany and Syracuse has resulted in an increase of 1000 riders/day (2.0 percent). This number can serve as an estimate for Westchester County's program. For future projects in Westchester and Albany, a conservative estimate of an additional 500 passengers/day is used.

The assumption is made that such service does not divert automobile trips made into the CBD to other modes but that it does divert some automobile trips within the CBD. The automobile trip length used in the energy calculations must be adjusted accordingly. An average trip length of 1.6 km for trips within the CBD is appropriate. For shuttle service between two activity centers, the distance between centers can serve as a measure of trip length.

Based on figures from two studies on free-fare CBD transit service (12,13), a 25 percent rate of diversion from driving an automobile to using shuttle-transit service is used for all projects in the state. Shuttle-transit service can result in modest energy savings of 150 000 equivalent L of gasoline annually in New York State. The most energy-efficient programs in the category are those that do not require an increase in bus VKT. When new service has been provided, the energy costs of increased bus operation and maintenance outweigh the energy savings. Free-fare programs within the CBD that use existing transit lines are the most promising type of shuttle-transit service in terms of saving energy.

#### Passenger Amenities

Passenger amenities can be described as those characteristics that contribute to the comfort, convenience, or attractiveness of the transit user's environment (other than the commonly measured attributes of travel time, fare, frequency, and schedule).

All areas in the state include actions for such amenities as bus shelters, new buses, modification of existing transit vehicles, rehabilitation of transit stations, and bus or transfer terminals. In general, many studies (7,14-19) indicate that provision of passenger amenities has a small but positive effect on transit ridership. A federal study indicates that an optimistic estimate of the change in ridership that results from a major program of providing bus shelters, transfer stations, and other amenities is an increase of 5 percent (20). None of the state's metropolitan areas can be said to be undertaking a major program of providing passenger amenities, which suggests the figure of 2 percent as an estimate of the increase in ridership.

This figure of 2 percent applies to the entire state program of amenities and is not an annual figure. For computing annual changes, this figure of 2 percent will be adjusted according to the proportion of actions for amenities being taken in the specific year involved. In all cases, the base

for computing ridership changes is the 1977-1978 fiscal-year ridership data.

#### Fare-Collection Improvements

A review of the literature about fare-collection improvements indicates that many such actions either have no effect on ridership (21-24) or do not induce mode shifts from automobile to transit (13). Consequently, only actions within New York State that produce documented ridership increases or could reasonably be expected to produce such increases were included in the analysis of energy savings.

For purposes of analysis, these actions can be divided into three types--the Uniticket program, transfer actions, and fare-structure modifications. The Westchester County Department of Transportation has published a detailed report on the Uniticket program (25), which shows that the rate of diversion from driving an automobile as a result of the Uniticket program is 13.5 percent. Because of a limited marketing budget, the program has thus far attracted primarily commuter rail users to the suburban bus; automobile commuters to Manhattan have not been induced by the Uniticket program to use commuter rail. The average length of the diverted trip must therefore be adjusted. The Westchester report indicates that 3.2 km is a good estimate of average automobile trip length from home to the commuter rail station.

Among transfer programs, Syracuse reports a 0.5 percent ridership increase. This figure of 0.5 percent can be used to calculate bus-ridership increases in New York City and Rockland County as a result of transfer programs. A 50 percent rate of diversion from automobile driver to transit user is assumed in Syracuse and Rockland and a 25 percent diversion is assumed in New York City.

Binghamton's metropolitan planning organization (MPO) staff estimates an 8 percent ridership increase due to the modified fare structure. This 8 percent increase can be applied to Elmira. A 50 percent rate of diversion from automobile driving is assumed.

Energy costs for improved fare collection come from new fare boxes. Net annual energy savings from improved fare collection average slightly less than 1 500 000 equivalent L of gasoline statewide. Approximately 85 percent of the savings are realized in the Tri-State area.

#### Passenger-Information Improvements

Passenger-information improvements can be defined as those actions that increase understanding of how to use a transit system. Passenger-information improvements usually do not provide the initial impetus for using public transit. However, once a potential new rider has decided to use public transit, passenger information becomes an important aspect in translating the decision into behavior and in retaining a first-time rider as a transit user. All areas in the state are undertaking programs to improve passenger information. The most common involve signs and map revisions. There is conflicting evidence on the effect of improved passenger information on ridership. One study suggests that there has been no effect (26). There is evidence that information programs are affected by the law of diminishing returns within a fairly short period of time (7). One study suggests that the maximum increase in ridership that would result from a major marketing effort of informational and promotional programs would be from 2 to 4 percent (20).

No area in New York State is undertaking a major

program to improve passenger information that leads to an assumption of a 0.5 percent increase in ridership. This figure of 0.5 percent applies to the entire program of improved information and is not an annual figure. To determine annual changes, this figure must be adjusted according to the proportion of information improvements taken in a specific year. This analysis is similar to that performed for passenger amenities.

Energy savings that resulted from improved passenger information averaged slightly less than 3.5 million equivalent L of gasoline annually. Once again, energy savings in the Tri-State region account for most of the savings in the state.

#### Demand-Responsive Service

In New York State, demand-responsive service includes dial-a-bus operations and services for the elderly, the handicapped, or both provided by vehicles under the Urban Mass Transportation Administration's Section 16(b)(2) program. Little research has been done into the mode of travel previously used by riders of demand-responsive service. Two studies report a rate of diversion from automobile (driver and passenger) of 50 percent (27,28), whereas two other studies indicate an 11 percent rate of diversion from driving an automobile (29,30). It is reasonable, given this variation in diversion rates, to assume that 20 percent of the users of demand-responsive service in New York State formerly drove an automobile. Since most of the demand-responsive service provided in the Tri-State region is in suburban areas in which conventional transit service is not extensive, the 20 percent diversion rate is used for the entire state.

Energy costs come from the operating and maintenance costs involved in provision of service and to a lesser extent from the manufacture of the necessary minibuses. These costs outweigh the energy savings. On the average, the annual energy cost of demand-responsive service is more than 3.8 million equivalent L of gasoline. A relatively large number of vehicle kilometers is required by the nature of demand-responsive service. Demand-responsive service is meant to improve the mobility of groups unable to get around by automobile or conventional transit and so result in more induced trips than do most other programs.

#### Maintenance Improvements

All areas in the state report programs to improve maintenance. There are three basic ways in which improved maintenance can lead to energy savings. If buses are given regular maintenance, they will run more efficiently, which increases average mileage. According to transportation officials working with the Metropolitan Transit Authority for New York City, an increase of 0.042 km/L can be expected from improved maintenance. This mileage improvement will not occur instantly but can be expected to increase more quickly with time. An increase over the base-year figure of 0.021 km/L for the first year of the maintenance program, 0.032 km/L for the second year, and 0.037 km/L for the third year is assumed. Transit bus kilometers per liter for each MPO area can be used to calculate energy savings:

$$\text{Energy savings} = (\text{bus VKT}/\text{bus kilometers per liter}) - [\text{bus VKT}/(\text{bus kilometers per liter} + \Delta \text{ bus kilometers per liter})] \times 1.104,$$

where 1.104 is the factor that converts liters of diesel fuel to equivalent liters of gasoline.

Improved maintenance extends the life span of



buses. If improved maintenance programs statewide can extend transit bus life spans from 12 to 13 years, only one-thirteenth of an area's bus fleet will be replaced per year as opposed to one-twelfth. Savings will come from the energy required for bus construction:

$$\text{Energy savings} = (\text{number of buses in fleet}/12) - (\text{number of buses in fleet}/13) \times 1.08 \times (10^{12} \text{ J/bus}) \times (2.87 \times 10^{-8}),$$

where  $1.08 \times 10^{12}$  J/bus is the energy needed to manufacture a bus (1) and  $2.87 \times 10^{-8}$  is the factor that converts joules to equivalent liters of gasoline.

Energy costs will increase as a result of an increased amount of maintenance. A figure is available for the energy needed per dollar spent on maintaining equipment (31); this figure has been adjusted for the Tri-State area to reflect different operating conditions. An increase in the amount allocated to maintenance in an authority's operating budget can indicate the existence of a program to improve maintenance. In the Tri-State region, it is assumed that the amount of money allocated for maintenance will increase by 0.25 percent annually. Two formulas for energy costs can be constructed. For the Tri-State region:

$$\text{Energy costs} = \text{proportion of operating budget assumed to go to improved maintenance} \times 1977 \text{ operating expenditures} \times 0.333,$$

where 0.333 is the energy in equivalent liters of gasoline per dollar spent for maintaining equipment in the Tri-State region. For upstate areas:

$$\text{Energy costs} = (\text{maintenance forecast}_{\text{year } i} - \text{maintenance forecast}_{\text{year } i-1}) \times (\text{CPI}_{\text{year } i} / \text{CPI}_{\text{year } i-1}) \times 0.443,$$

where CPI is the consumer price index and 0.443 is the energy in equivalent liters of gasoline per dollar spent for maintaining equipment in upstate areas.

Calculations show that savings of more than 1 800 000 equivalent L of gasoline can be gained annually from improved maintenance. This assumes that bus mileage improves more quickly with time and that the life span of the bus is extended immediately.

#### Monitoring Transit Operations

The types of transit actions being taken in New York State include real-time monitoring (by two-way radio and other communications systems) of specific situations and broader systemwide monitoring to increase and standardize data collection on transit operations and to improve the internal efficiency of the transit system.

The effects of monitoring actions are indirect in terms of impact on ridership. However, improvements in the efficiency of the transit system can lead directly to energy savings by reducing overall bus VKT. Field tests of the RUCUS package (a set of computer programs designed to expedite and improve the efficiency of scheduling for mass transit) in four cities nationwide showed a decrease in vehicle hours on the order of 1.3-4.8 percent (32). If it is assumed that average speed is approximately the same on all transit systems and that average speed is not changed by RUCUS, these figures can serve as the percentage decrease in vehicle kilometers that results from increased scheduling efficiency. It is assumed that reduction in vehicle kilometers

realized from use of RUCUS comes from elimination of duplicate service and therefore does not affect ridership levels.

The formula for calculating savings from monitoring actions is

$$\text{Energy savings} = (\text{decrease in bus VKT/average bus mileage}) \times 1.104,$$

where average bus mileage can be obtained for each system and 1.104 is the conversion factor for diesel fuel to equivalent liters of gasoline.

Installation or improvement of communications systems and implementation of computer-based programs such as RUCUS involve energy costs. A study has provided a figure for energy costs per dollar spent on electrical equipment (31). The formula for calculating energy costs for monitoring actions is

$$\text{Energy costs} = \text{cost in dollars of communications system or computer-based program} \times 0.112 \text{ equivalent L of gasoline per dollar.}$$

Energy costs outweigh energy savings in two of the three years covered in this study, with an average annual net cost of 110 000 equivalent L of gasoline. Monitoring actions may have a more-positive effect on energy in the long run as the increased internal efficiency of the transit system gradually increases the operating efficiency of the system.

#### Marketing

Marketing actions are defined as efforts to publicize the existence of the transit system itself or of various special programs. All areas in New York State are taking marketing actions, which include promotional advertising campaigns, tie-ins with local merchants, and barter arrangements. The evidence regarding to what extent ridership actually increases is conflicting. Some studies report no lasting gains (7,33), whereas others suggest that there is a definite positive effect (13,23,34,35). The general consensus is that marketing actions result in a slight increase in ridership but that it has been a short-term effect, which suggests the need for ongoing marketing programs.

A federal study cites an upper limit of 2-4 percent for ridership increases that result from a major marketing campaign. Since no metropolitan area in the state is undertaking a major marketing campaign, a 1 percent increase in ridership can be expected from the existing and proposed marketing programs. In comparison to ridership assumptions made for other TSM actions, marketing has twice the impact of passenger information on ridership and half the impact of passenger amenities.

This 1 percent ridership increase is not an annual figure but rather applies to the entire marketing program over the three years with which this study is concerned. To compute annual changes, this figure of 1 percent must be adjusted according to the proportion of the marketing budget spent in a specific year.

A 50 percent diversion rate from driving an automobile to using transit is estimated for marketing actions (25 percent for the Tri-State area).

Marketing actions can save a sizeable amount of energy: By 1980, more than 8.3 million equivalent L of gasoline will be saved annually through marketing actions. Approximately 95 percent of these savings are realized in the Tri-State area. It should be emphasized that, for maximum effectiveness,

**Table 1. Energy effects of small-scale transit improvements in New York State by category.**

Category	Net Energy Savings (L 000 000s gasoline)		
	1978	1979	1980
Routing and scheduling improvements	1.55	1.49	1.35
Express-bus service	-0.56	-0.56	-0.57
Park-and-ride service	5.41	6.57	7.26
Shuttle-transit service	0.16	0.15	0.13
Passenger amenities	10.68	10.42	14.14
Fare-collection improvements	1.64	1.42	1.37
Passenger-information improvements	2.75	2.94	4.11
Demand-responsive service	-4.45	-4.86	-6.98
Maintenance improvements	1.17	2.40	2.87
Monitoring	0.29	-0.09	-0.53
Marketing	2.41	5.30	8.60
Total	21.05	25.18	31.75

marketing actions should be taken as part of a continuous and ongoing marketing program.

#### DISCUSSION AND CONCLUSION

Table 1 summarizes the energy effects of 11 transit-related categories of TSM actions in New York State. Total energy savings from transit-related actions amount to 21.0, 25.2, and 31.7 million equivalent L of gasoline in 1978, 1979, and 1980, respectively. According to Federal Highway Administration monthly state gasoline reports, in 1977, gasoline consumption in New York State was 23.5 billion L. In the overall state energy situation, transit-related TSM actions result in annual savings of only 0.1 percent of total gasoline consumption.

There are several reasons for considering the energy savings reported here as conservative projections. First, factors such as energy costs due to construction and maintenance of transit equipment and facilities are included in the calculations; also included are second-order effects such as use of the car left at home. However, potential second-order savings like decreased maintenance requirements for automobiles due to decreased use and the elimination in some cases of the need for a second car in the household are not addressed. In other words, although second-order energy costs are considered fairly thoroughly, second-order savings are not, because the complexities of such calculations are beyond the scope of this paper. In addition, energy savings have been claimed only for new transit riders diverted from driving an automobile, and no credit has been given for current riders who might otherwise divert to the automobile.

A final reason for considering these energy savings as conservative projections is the synergistic effect that can be obtained by packaging actions together. Express-bus service and park-and-ride lots, marketing and passenger information, and passenger amenities and maintenance are examples of complementary pairs of actions. In these and other cases, the effect of the package of actions is greater than the sum of the effects of the individual actions.

In conclusion, minor transit improvements in the eight MPO areas of New York State result in average energy savings of more than 25 million equivalent L of gasoline over the three years 1978-1980. This represents 2.6 percent of total energy consumed by transit in these eight areas. If demand-responsive service is excluded, savings rise to 3.1 percent of total energy consumed by transit. These energy

savings are conservative projections. Although minor transit improvements cannot be expected to make a major impact on New York State's energy situation, such improvements can contribute positively to the state's conservation efforts.

#### ACKNOWLEDGMENT

I wish to thank David T. Hartgen, Janis M. Gross, Michael A. Kocis, and Gerald S. Cohen for advice and assistance in the preparation of this report. Special thanks are due Linda Unangst for typing the paper.

#### REFERENCES

1. J.A. Apostolos, W.R. Shoemaker, and E.C. Shirley. Energy and Transportation Systems, California Department of Transportation, Sacramento, Final Rept., Dec. 1978.
2. N.S. Erlbaum, G.S. Cohen, and D.T. Hartgen. Automotive Energy Forecasts: Impact of Carpooling, Trip Chaining, and Auto Ownership. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 134, Dec. 1977.
3. Journey-to-Work Trip Lengths. Tri-State Regional Planning Commission, New York City, Interim Tech. Rept. 1302, Feb. 1977.
4. N.S. Erlbaum, D.T. Hartgen, and G.S. Cohen. Automotive Energy Forecasts: Impact of Price, Availability, and Efficiency. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 133, Dec. 1977.
5. EPA Study of Potential for Motor Vehicle Fuel Economy Improvement. U.S. Department of Transportation; U.S. Environmental Protection Agency, Rept. 7, Jan. 10, 1975.
6. U.S. Bureau of the Census. Census of Population: 1970, Subject Reports.; Final Report. PC(2)-6D: Journey to Work. U.S. Government Printing Office, 1973.
7. R.H. Pratt, N.J. Pederson, and J.J. Mather. Traveler Response to Transportation Systems Changes. R.H. Pratt Associates, Kensington, MD, Feb. 1977.
8. L.J. Pignataro and others. Survey of Ridership of Express Buses in the City of New York. Polytechnic Institute of New York, Brooklyn, Final Rept., May 1976.
9. D.T. Hartgen. Forecasting Remote Park-and-Ride Transit Usage. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 39, Dec. 1972.
10. R.H. Ellis, J.C. Bennett, and P.R. Rassam. Fringe Parking and Intermodal Passenger Transportation: Operational Experience in Five Cities. Peat, Marwick, Mitchell and Company, Washington, DC, Nov. 1971.
11. C.A. Keck and G.S. Cohen. Characteristics and Attitudes of Dial-A-Bus and Park-and-Ride Users in New York State. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 74, March 1975.
12. J.F. DiRenzo and R.B. Rubin. Air Quality Impacts of Transit Improvement, Preferential Lane and Carpool/Vanpool Program. U.S. Environmental Protection Agency, March 1978.
13. Grey Advertising, Inc. Transit Marketing Management Handbook: Pricing. Urban Mass Transportation Administration, U.S. Department of Transportation, April 1976.
14. D.K. Holland. A Review of Reports Relating to the Effect of Fare and Service Changes in Metropolitan Public Transportation Systems.

- Federal Highway Administration, U.S. Department of Transportation, June 1974.
15. J.H. Shortreed, ed. Urban Bus Transit--A Planning Guide. Univ. of Waterloo, Ontario, May 1974.
  16. D.T. Hartgen and G.H. Tanner. Behavioral Model of Mode Choice. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 19, March 1970.
  17. B. Pushkarev and J. Zupan. Public Transportation and Land-Use Policy. Indiana Univ. Press, Bloomington, 1977.
  18. New Yorkers Evaluate Their Transportation Systems. Louis Harris and Associates, New York City, April 1978.
  19. P. Hernandez. Bus Passenger Waiting Shelters. California Department of Transportation, Sacramento, Jan. 1977.
  20. U.S. Congress, Office of Technology Assessment. Energy, the Economy, and Mass Transit. U.S. Government Printing Office, 1975.
  21. J.D. Brogan and K.W. Heathington. An Evaluation of a Complimentary Pass Package as an Acceptable Marketing Technique for Attracting New Passengers to Urban Bus Transit Lines. Purdue Univ., West Lafayette, IN, May 1973.
  22. J.D. Brogan, K.W. Heathington, and G.T. Satterly. The Use of Complimentary Passes to Improve Ridership on Bus Transit Systems. Purdue Univ., West Lafayette, IN, 1976.
  23. Urban Transportation Economics. TRB, Special Rept. 181, 1978.
  24. W.R. Hershey and others. Transit Fare Prepayment. Urban Mass Transportation Administration, U.S. Department of Transportation, Aug. 1976.
  25. The Westchester County/MTA Uniticket Program: A Status Report--November 1977 to October 1978. Westchester County Department of Transportation, Dec. 1978.
  26. Hollander, Sydney, and Associates. Transit Information Aids. Washington Metropolitan Area Transit Authority, Final Rept., 1969.
  27. T. Urbanik II. Dial-A-Ride Project in Ann Arbor: Description and Operation. In Demand-Responsive Transportation Systems, HRB, Special Rept. 136, 1973.
  28. W.F. Hoey. Dial-A-Ride in the Context of Demand-Responsive Transportation: A Critical Appraisal. TRB, Transportation Research Record 608, 1976, pp. 20-25.
  29. W.R. McDougall. Growing Demand-Responsive Systems in the United States and Canada. In Demand-Responsive Transportation, TRB, Special Rept. 147, 1974, pp. 3-16.
  30. R.F. Kirby and others. Paratransit: Neglected Options for Urban Mobility. Urban Institute, Washington, DC, 1975.
  31. J. Hurley, Jr. Feasibility of Transportation Projects--An Energy-Based Methodology. Univ. of Florida, Gainesville, Ph.D. thesis, 1975.
  32. K.R. Roberts. Vehicle Scheduling and Driver Run Cutting--RUCUS Package Overview. Mitre Corporation, Washington, DC, May 1973.
  33. Long Beach Transit Marketing Program. Cunningham, Short, Berryman and Associates, Los Angeles, CA, Jan. 1974.
  34. J. Keyania and E.S. Putnam. Transportation System Management: State of the Art. Interplan Corporation, Santa Barbara, CA, Feb. 1977.
  35. B. Morris. Marketing: A Tale of Two Cities. Mass Transit, Vol. 5, No. 2, Feb. 1978.

*Publication of this paper sponsored by Committee on Public Transportation Planning and Development.*

## Integrated Transit-Network Model (INET): A New Urban Transportation Planning System Program

ROBERT DIAL, DAVID LEVINSOHN, AND G. SCOTT RUTHERFORD

The Integrated Transit-Network Model (INET) is a new Urban Transportation Planning System (UTPS) computer program for analysis of transit systems. Its objectives are to account for the interaction of highway and transit networks, exploit existing highway network data, provide for accurate but simple and inexpensive transit-network coding, provide input for other UTPS programs, furnish useful evaluative reports, and help bridge the gap between systems and operations planning. A small transit network is hypothesized to demonstrate INET's features and explain its assumptions, mechanics, and operation. Special subjects are route layout, cruise and stop delay time, exclusive and mixed rights-of-way, scheduling, and cost and impact estimates. There is a brief discussion of INET's use with real transit and highway data; the results testify to INET's exceptional simplicity and accuracy.

The Urban Transportation Planning System (UTPS) is a set of computerized and manual tools that aid analysis of urban transportation problems; the system was developed and distributed jointly by the Urban Mass Transportation Administration (UMTA) and the Federal Highway Administration (FHWA).

The Integrated Transit-Network Model (INET) is a

new UTPS program by means of which planners can study the interaction of transit (bus) service and automobile service on shared rights-of-way. By using available highway network information, INET greatly simplifies coding. It cuts data collection costs and allows the study of more alternatives with no increase in cost.

INET needs only the simplest and most-straight-forward network description but produces detailed estimates of service, resources, and impacts. INET writes a file of the transit network for analysis by other UTPS programs that analyze the shortest path, impedance, cost, passenger loading, and other factors.

### GOALS AND CAPACITIES

INET's goals are to reveal the interaction of highway and transit systems, exploit existing highway network data, facilitate accurate but