Energy. Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA, Rept. DOT-TSC-OST-75-22, 1975.
2. Energy Primer: Selected Transportation Topics. Transportation Systems Center, U.S. Department of Transportation, Cambridge, MA, 1978.
3. Energy Effects, Efficiencies, and Prospects for Various Modes of Transportation. NCHRP, Synthesis of Highway Practice No. 43, 1977, 57 pp.
4. Joint Strategies for Air Pollution Reduction and Energy Conservation. Interplan Corporation, Santa Barbara, CA, 1974.
5. J.M. Gross and others. Energy Impacts of Transportation Systems Management Actions in New York State, 1978-1980. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 151, 1979.
6. T.M. Downs and R.H. McManus. Action--Energy Contingency Plans. Federal Highway Administration and Urban Mass Transportation Administration, March 29, 1979.
7. D.T. Hartgen and others. Guidelines for Transportation Energy Contingency Planning. New York State Department of Transportation, Albany, May 29, 1979.
8. D.T. Hartgen. Transportation Energy: An Overview with Emphasis on New York State. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 141, 1978.
9. Transportation Energy: Summary of Analysis Procedures. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 147, Oct. 1978.
10. N.S. Erlbaum, G.S. Cohen, and D.T. Hartgen. Automotive Energy Forecasts: Impacts of Auto Efficiency, Price, and Supply. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 142, 1978.
11. Baseline Transportation Energy Forecasts for New York State. Planning Research Unit, New York State Department of Transportation, Albany, draft rept., March 19, 1979 (as revised June 1979).
12. 1977 Census of Transportation, Truck Inventory, and Use Survey. Bureau of the Census, U.S. Department of Commerce, 1979.
13. Highway Statistics. Federal Highway Administration, FHWA-HP-HS-S75, 1975.
14. Highway Statistics. Federal Highway Administration, FHWA-HP-HS-76, 1976.
15. Highway Statistics. Federal Highway Administration, FHWA-HP-HS-77, 1977.
16. Highway Statistics. Federal Highway Administration, FHWA-HP-HS-78, 1978.
17. N.S. Erlbaum. NYS CAFE: Monitoring Changes in 1979 New Car Registrations and Their Effect on Fuel Use. New York State Department of Transportation, Albany, June 18, 1979.
18. N.S. Erlbaum. Sensitivity of Passenger Car Fuel Forecasts to Price Increases and Price Elasticities. New York State Department of Transportation, Albany, April 16, 1979.
19. Sensitivity Analysis of Passenger Car Fuel Forecasts. New York State Department of Transportation, Albany, March 30, 1979.
20. Sensitivity of Passenger Car Fuel Forecasts to Improvements in Vehicle MPG Beyond 1985. New York State Department of Transportation, Albany, June 25, 1979.
21. Sensitivity of Passenger Car Fuel Use: Revised Price Projections, Different Levels of Gasoline Price Elasticity, and Improvements in Vehicle Efficiency Standards Beyond 1985. New York State Department of Transportation, Albany, July 12, 1979.
22. Charles River Associates. Price Elasticity of Demand for Transportation Fuels. Office of Transportation Research, Federal Energy Administration, May 1976.
23. Aviation Forecast for Fiscal Years 1979-1990. Office of Aviation Policy, Federal Aviation Administration, U.S. Department of Transportation, Sept. 1978.
24. Regional Energy Conservation Data Book: Air Cargo. Oak Ridge National Laboratory, Oak Ridge, TN, Sept. 1978.
25. Handbook of Airline Statistics: 1973 Edition, Civil Aeronautics Board, Washington, DC, March 1974.
26. New York State Statistical Yearbook: 1977 Edition. New York State Division of the Budget, Albany, Sept. 1977.
27. G.S. Cohen, N.S. Erlbaum, and D.T. Hartgen. Intercity Rail Travel Models. TRB, Transportation Research Record 673, 1978, pp. 21-25.
28. A.B. Rose. Energy Intensity and Related Parameters of Selected Transportation Modes: Freight Movement. Oak Ridge National Laboratory, Oak Ridge, TN, Jan. 1979.
29. Waterborne Commerce of the United States. Corps of Engineers, Department of the Army, 1977.
30. NYS Energy Consumption and Supply Statistics, 1960-1976. New York State Energy Office, Albany, 1978.

Publication of this paper sponsored by Committee on Energy Conservation and Transportation Demand.

Use of Disaggregate Data to Evaluate Gasoline Conservation Policies: Smaller Cars and Carpooling

MARTIN E. H. LEE AND MATTHEW F. GLOVER

A microdata base of vehicle ownership and use characteristics was built from 7581 interviews of Michigan applicants for renewal of driver's licenses taken throughout the state in 1976. Analyses of gasoline efficiency in occupant kilometers per liter suggested that the greatest potential for conservation policy was to be found in commuter carpooling and a shift to smaller cars. Six scenarios for carpooling and smaller cars were defined in sufficient detail to exclude types of trips or classes of vehicle users for which these policies would present significant difficulties. The scenarios were run against the 1976

data to calculate the gasoline savings and improvements in occupant kilometers per liter obtainable in the best case. Smaller reductions in liters were found than would be predicted from gross estimates, but considerable consistency was found in the pattern of hypothetical responses of different subgroups of drivers distinguished by income or the urbanization of their home area, despite large differences in gasoline consumption. It is suggested that suburban drivers could provide 25 percent more gasoline savings than the statewide per capita average under the most optimistic scenarios analyzed. It is also suggested that the microdata techniques be calibrated to externally measured behavioral data on travel and conservation choices.

During 1979, the President and the U.S. Congress made numerous attempts to agree on national policies to conserve gasoline. Emergency rationing legislation was enacted, but the guidelines for standby rationing were made the subject of a plan to be submitted later by the President to the Congress for approval. Even less progress was made toward development of an ongoing plan for reducing oil use. In the political debates, many assertions have been made about the need to maintain certain types of travel, notably commuting. Given that almost all automobile uses are defended by some interest group or region, interest is increasing in improving efficiency rather than in reducing kilometers traveled.

An exploration of candidate policies for improving efficiency is even more difficult than an exploration of methods for inhibiting travel because it requires detailed information on vehicle fleet mix and fuel performance, kilometers traveled, and passenger load. Moreover, it is highly desirable to know variations in the relationships between these factors among different population subgroups and among different regions: Differential impacts of policies may result from these variations.

This paper describes the development of a microdata base on vehicle ownership and use throughout Michigan. We use it to identify some of the characteristics of inefficient travel and to develop a rationale for two policies (use of smaller cars and commuter carpooling) that the data suggest are appropriate responses to inefficiency. We then use the microdata to calculate the best-case changes in gasoline consumption and efficiency of use that would result from the full or partial implementation of these policies. These analyses use highly detailed personal trip data to limit hypothetical adherence to these policies to favorable conditions.

Various levels of travel data aggregation have been used in previous efforts to compare these and other conservation policies. For example, Lutin (1) used 1970 census data on work trips aggregated at the county level and applied hypothetical load factors and fuel-efficiency factors to estimate energy savings from carpooling and smaller cars (as well as some modal shift considerations). Erlbaum (2) used household survey data on annual driving distance by vehicle class and the age and sex of the owner; observed trends in vehicle kilometers and hypothetical fleet mixes were applied to the owner age and sex groupings to estimate future demand for gasoline. In a later paper, Erlbaum and others (3) forecast more detailed impacts of conservation scenarios by manipulating average trip rates, lengths, and occupancy; vehicle efficiency; and household automobile ownership from daily data in the same survey. Inputs to the models were aggregated over different combinations of location, trip purpose, and automobile ownership level. This study differs from these approaches in that it individually queries the characteristics of each trip reported by a large number of respondents on a designated day, applies conservation factors if conditions are met, and then aggregates the results by population sector.

DESCRIPTION OF THE SURVEY AND DATA BASE

The Michigan Driving Experience Survey (MDES), a microdata base on vehicle ownership and use, was built from 7581 personal interviews of applicants for renewal of driver's licenses conducted throughout Michigan during 1976. It used a controlled selection procedure for random selection of sites within two dimensions--level of urbanization and gasoline sales per capita (the latter is the only indicator available of gross personal travel activity). Because of the scarcity of rural trip-making data, rural areas were deliberately oversampled. All data are capable of being weighted to compensate both for sampling rates and for variations due to the day of week of the interview and the level of nonresponse. Overall response was very high--85 percent of those asked to participate. The number of usable interview forms (7581) represents 72 percent of the number of interviews predicted from the work load of the 30 local driver license bureaus selected for the survey. The difference between the two percentages primarily represents some continuity gaps inevitable in the conduct of a decentralized survey that operated over an entire year.

Within the 30 sites, a random number system, beyond the control of the employees, was used to select seven or eight interviewees per office per week from among all applicants for renewal of driver's licenses. Because the system used a meaningless sequence number that becomes a transaction identifier in an audit trail, it was possible to verify later that none of the (unannounced) eligible drivers had been missed. Follow-up procedures, which were more time consuming than an interview done at the time the driver was in the local bureau, helped keep administrative response very high. Overall, this provided a representative sampling of the Michigan driver population; however, drivers under the age of 19 are not represented because they are not old enough to renew a driver's license.

Interviews were conducted by the managers of the local license bureaus, who generally have excellent public contact skills and who received training in the interview procedures in a seminar and on site. The emphasis of the survey was on the careful reconstruction of a recent trip day (usually the previous day) and on the complete set of vehicles to which the respondent had access.

The survey was designed to yield a series of measures of the amount and type of driving undertaken, aggregated over the entire trip day. Thus, the total time and distance driven by each respondent are expressed in terms of the travel under different trip regimes, purposes, light conditions, road types, vehicles used, and passenger load. The vehicles owned and used are identified at the level of make, model, and year, and this information is available for each trip made during the day.

The survey data have been integrated with the individual accident and traffic conviction records from the files of the sponsoring agency (individual identity has been deleted). Cross-reference capability has been established with selected socioeconomic characteristics of the traffic zones (used by state transportaton modelers) in which the respondents resided. Certain socioeconomic characteristics are also available by zip code of residence. In addition, the interview itself provides basic biographical information on the respondent and her or his household.

Considerable effort has been made to build two verified summary files:

1. In a driver file, all time and distance information has been aggregated over the trip day for

all trip attributes, including algorithm-assigned travel by purpose in multipurpose trips.

2. In a second file, each trip is treated as a separate case, and driver descriptors are repeated.

The files were built primarily with OSIRIS.IV software for use with both the OSIRIS and the MIDAS software packages on the University of Michigan computing system.

SOME CONSIDERATIONS FOR THE ANALYSIS OF GASOLINE USE

Because MDES is a carefully drawn sample of the entire Michigan driver population (19 years and over), the total amount of gasoline consumed by different sectors of the population may be calculated. One problem is in the definition of the size of the active driving population, since some drivers retain a license essentially for identification or to permit only very limited travel, such as to assist a spouse on a vacation trip. (This sampling problem may be disregarded for analysis of policies, such as rationing, that use driver licensing in the allocation of gasoline.) In order to realistically represent those who would be targets for improving efficiency, we decided to consider those respondents who reported that they drive 322 km/year or less as inactive. This led us to reduce the estimated number of drivers for 1976 by 2.4 percent. From the result (6 150 000), gasoline consumption based on vehicle size, and a trip rate based only on trips in automobiles, vans, and pickups, we calculated the overall 1976 gasoline consumption for the state to be 17.20 billion L. Taxation data yields a sales figure of 18.57 billion L, and most of the difference is explained by the exclusion of gasoline-burning large trucks and buses from the analysis. Sales to out-of-state vehicles and inaccurate constants for fleet kilometers per liter would also affect this estimate. Nevertheless, we wish to compare the relative effect of conservation policies on this total.

EXPLORATORY ANALYSIS OF EFFICIENT VERSUS INEFFICIENT DRIVING

On the grounds that in 1979 it is easier to promote fuel-efficient driving than to encourage people to drive less, we examined the personal and travel characteristics of those above and below the median of a measure of efficiency. That measure was defined as

$$OKPL_i = \sum_j (PT_{ij} * KT_{ij} * KPL_{ij}) \Big/ \sum_j KT_{ij} \quad (1)$$

where

$OKPL_i$ = occupant kilometers per liter for the ith respondent,

PT_{ij} = number of occupants (including driver) for the ith respondent on his or her jth trip,

KT_{ij} = kilometers driven for the ith respondent on his or her jth trip, and

KPL_{ij} = fuel efficiency (in kilometers per liter) of vehicle used for the ith respondent for his or her jth trip.

This measure was applied only to the driving of automobiles, vans, and pickups in the driver file and, by definition, assigns the value zero to those who did not drive on their designated trip day.

The median value of OKPL for the use of these vehicles was found to be 8.06. We compared the distributions of respondents above and below the median across age; sex; marital status; number of drivers, nondriving adults, preschool children, and school children in the household; employment; occupational class; level of education; income group; length of time at current address; type of residence; and population density of residence location.

By examining the percentage of respondents above and below the median OKPL within each stratum on these 14 variables (e.g., all those age 25 to 34 or all males), we found few distributions that differed substantially from a 50-50 split. Only 2 of the 75 population subgroups analyzed showed more than 60 percent above. Those subgroups that showed a distribution greater than 52.5-47.5 percent in either direction are listed below. Note that these analyses treat each variable stratum (i.e., subgroup) independently.

Subgroup	Characteristics
Low efficiency	
More than 60 percent below	Widowed, living alone
55-60 percent below	Over 45 years old, no other drivers in household, middle-status occupation, 8-11 grades of education
52.5-55 percent below	Male, no children in household, employed full time, household income over $25 000, divorced or separated, same address for 6-11 months
High efficiency	
More than 60 percent above	Two preschool children in household, unemployed or houseperson, postgraduate education
55-60 percent above	Under 35 years old, one or more nondrivers in household, one preschool child or one to three school-aged children in household, student, very high-status occupation, household income under $5000, less than seven grades of education, same address one or two years
52.5-55 percent above	Female, four or five drivers in household, employed part time, live in small rural community, same address less than six months or more than 20 years

The lack of a clear relationship with income, sex, and age contrasts with large differences in kilometers driven across these variables. Altogether we infer a weak pattern of gasoline inefficiency among lower-middle status, older drivers, who typically live alone or in childless households; but the small concentrations of low-efficiency drivers hardly identify them as the major target groups for efforts to reduce gasoline consumption.

In the area of travel characteristics, we examined the number of kilometers driven for various purposes to determine whether certain purposes were relatively less efficient than others and, therefore, logical targets for conservation efforts. In the table below, all respondents who reported driving on their assigned day were divided into two groups: those whose OKPL (averaged over the day's driving) was below the median of 8.06 and those whose OKPL was above. As the table (based on 1976 travel figures) shows, the more-efficient drivers of automobiles, vans, and pickups average a much higher number of kilometers per day in all purpose categories, except for commuting to work or school and travel on the job; and, although the more-efficient drivers also do more driving to and from school, the difference is much smaller.

Trip Purpose	Low-Efficiency (below median OKPL) (km/day)	High-Efficiency (above median OKPL) (km/day)
Commute to and from work	19.5	11.3
On the job	10.1	3.5
Commute to and from school	1.6	2.4
Personal business	2.6	5.1
Shopping	4.7	8.9
Social purposes	5.5	13.2
Recreation	2.6	12.1
Interchange modes	0.05	1.0
Other	4.5	11.6

It is to be expected that it would be difficult to substantially change vehicle kilometers per liter or occupancy for driving on the job, but commutes to work (and also school) are trip purposes that seem to hold promise for decreased consumption by increased efficiency. Because most commuting (unlike other purposes) has regular trip ends and regular times, there is a logical case for carpooling within the existing vehicle fleet. This analysis confirms a finding of the 1969-1970 Nationwide Personal Transportation Survey (4) that nonwork travel is relatively efficient and contrasts with the political appeal of "save our journeys to work".

The analysis also suggests that if efficiency is to be increased in a high proportion of nonwork travel (which represents about 70 percent of all driving according to MDES) it will require a change in vehicle, more than passenger, load. It would seem prudent, therefore, to promote a consumer shift to the purchase and use of smaller cars.

Commuter carpooling and smaller cars were thus selected for further analysis. Both are subject to a variety of constraints. For example, only people who can afford to replace automobiles can shift to smaller cars, and carpooling is only possible when a sufficient number of people have similar working hours.

These constraints can only be explored with detailed travel data. We have built a number of reasonable constraints into a series of scenarios for smaller cars and commuter carpooling and applied the scenarios retroactively to 1976 automobile, van, and pickup travel in Michigan. From this, we measured the maximum possible benefits in the form of changes in liters consumed per driver and in OKPL. These scenarios are arbitrary. The consequences of many sets of assumptions, other than those described below, could be compared by means of this technique.

SCENARIOS FOR COMMUTER CARPOOLING AND SMALLER CARS

We have attempted to describe for both of these policies one likely situation in which limited shifts toward carpooling or smaller cars occur and one maximum scenario in which all eligible travel is shifted into the most-efficient configuration. Eligibility is defined as a series of prohibitions on the improvement of efficiency because of unfavorable conditions; these represent the reasonable constraints and apply equally to the likely and the maximum scenarios.

Carpooling

Our reasoning in limiting additional commuter carpooling to three occupants is based largely on the observation that the logistics of ridesharing are reasonably manageable at this level, especially in a situation in which many more motorists are pressed to participate than currently do so voluntarily. It is reasonable to assume that current pooling behavior represents the exploitation of the most-attractive opportunities by the most-willing motorists [we note that in a 1978 survey of state employees in Albany, New York, about 25-30 percent of commuter carpools had occupancies greater than three (5)]. We postulate the likely scenario of adding one passenger, aware that for most commuters this means giving up solo driving and that the addition of a second passenger may well be less traumatic than the addition of the first. No adjustment was made for additional travel distance to pick up or drop off passengers:

1. Scenario 1--likely pool--any trip by a vehicle carrying less than two passengers (excluding driver) adds one passenger and
2. Scenario 2--maximum pool--any trip by a vehicle carrying less than two passengers (excluding driver) increases its passenger load to two (excluding driver).

Rules and prohibitions of scenarios 1 and 2 are as follows:

1. Trips of less than 10 min in duration are ineligible;
2. Trips to work that commence outside the time period 6:00-9:00 a.m. are ineligible;
3. Trips from work that commence outside the time period 3:00-7:00 p.m. are ineligible;
4. Trips made by persons from households that have more drivers than automobiles are subject to a penalty of 30 percent of the reduction in gasoline use for each additional day that the car is left at home;
5. For trips that involve chauffeuring someone to work and a return home without serving any other purpose, additional savings accrue due to the reductions in distance traveled and increase in available seats;
6. Trips for respondents in small villages and remote areas are ineligible; and
7. Rules 1-3, 5, and 6 do not apply to trips to and from school.

On the prohibitions, our 10-min minimum is close (with startup and shutdown time) to the poor-potential market segment derived in the analyses by Brunso and others (5). The constraints on time periods allow commuter carpooling during most normal working hours. As noted by Atherton and others (6), people who join pools leave their cars at home part of the time and, if other drivers are available to use them, gasoline savings due to ridesharing may be reduced. We calculated the proportion of the time a car would be left at home under both scenarios and arbitrarily applied a reduction of 30 percent for that proportion of the savings. Chauffeured commutes (trips in which someone is driven to work) may yield extra savings under ridesharing. In MDES, we were able to identify chauffeured work commutes specifically and to test that the driver returned home without serving any other purpose. In these cases, one-half of the gasoline was counted as saved, in addition to a reduction of the other half, dependent on the scenario. The elimination of small villages and remote areas for work commuting was perhaps the most crude prohibition; a more detailed approach would be to use the MDES data to investigate the prevalence of existing commuter ridesharing in different types of residential locations and to derive a more precise rule. Finally, all of these rules and prohibitions were applied to work commuting, but only number 4 (car left at home) was applied to school commuting. Chauffeured trips were ignored for school commutes, because most of these trips carry nondrivers as passengers, and the remaining prohibitions were ignored on the grounds that school commuting has higher passenger loads now and that the flexibility and social relationships that facilitate pooling seem more likely in school than at work.

Smaller Cars

A shift to the next-smallest vehicle size makes intuitive sense as the likely behavior of the market under fuel cost pressures. However, uncertainty of gasoline supply is likely to bring about more abrupt and unpredictable market shifts than incremental increases in fuel cost or taxes. For example, vehicle range may sometimes outweigh even kilometers per liter in purchase decisions if fuel is only available at certain hours or on certain days. Nevertheless, this scenario presumes incentives to shift to vehicles of higher kilometers per liter, and the maximum is therefore based on the subcompact. The kilometer per liter figures below are based on 1972 model-year cars because this was the median year in the data.

1. Scenario 3--likely size shift--all eligible trips are shifted to the next-smallest vehicle size.

Old Model	Old Kilometers per Liter	New Model	New Kilometers per Liter
Luxury	4.2	Intermediate	5.9
Van or pickup	4.7	Intermediate	5.9
Full size	5.1	Intermediate	5.9
Intermediate	5.9	Compact	6.8
Compact	6.8	Subcompact	9.3

2. Scenario 4--maximum shift to smaller automobiles--all eligible trips are shifted to subcompacts, regardless of vehicle size previously used.

Rules and prohibitions of scenarios 3 and 4 are as follows:

1. Trips in subcompacts remain unchanged,
2. Trips by households that have income less than or equal to $10 000 are ineligible, and
3. Trips that have three passengers or more (excluding driver) are ineligible.

We postulate in the prohibitions that trips currently in subcompacts are not shifted to a more-fuel-efficient subcompact. Trips by drivers from low-income households are excluded on the grounds that a size shift requires capital investment or tax incentives that are unattractive to these groups; also, they drive, on the average, about one-half to two-thirds of the statewide average driving distance. Finally, travel with an occupancy of four or more is excluded; for about 6.8 percent of all trips, this represents perhaps the most resilient demand for large cars.

Combined Scenarios

Because the carpool and size-shift policies involve independent factors, they can be simply combined to estimate joint effects.

1. Scenario 5--combined likely--combination of scenarios 1 and 3 and
2. Scenario 6--combined maximum--combination of scenarios 2 and 4.

We want to reemphasize that these scenarios are only six of a very large number of possible combinations of definitions and prohibitions: Our intention is to use the microdata to apply reasonable limitations to these two policies and to measure what, at best, they could possibly achieve.

ANALYSIS OF THE SCENARIOS

The effects of the six scenarios on gasoline consumption and efficiency of use were calculated from the MDES trip file. The scenarios were translated into sets of complex filters on trip attributes and driver characteristics in order to isolate trips that are eligible for fuel savings.

Gasoline consumed exists in the file as a variable calculated for each trip; for eligible trips, this was recalculated according to the reductions attainable by increasing passenger load or kilometers per liter. Thus, in the case of carpooling, the gasoline consumption for each eligible trip was reduced by 50 percent if a solo driver took on one passenger, by 33.3 percent if a two-person pool took on a third occupant, and so forth. The assumption was that such reductions reflected the reductions in vehicle kilometers traveled that would result from some vehicles being left unused. In the case of the use of smaller cars, the constants for kilometer per liter were simply changed according to the scenario.

The 1976 gasoline consumption figures were obtained by the formula:

$$\overline{LD}cp = \left[\overline{LT}cp * T_p \Big/ \sum_p \left(\overline{LT}_{cp} * T_p\right)\right] * (SG/N_p) \quad (2)$$

where

$\overline{LD}_{cp}$ = mean liters of gasoline consumed per driver in 1976 under the cth scenario by the pth subgroup of the driving population,
$\overline{LT}_{cp}$ = mean liters of gasoline per trip under the cth scenario by the pth subgroup of the driving population,
T_p = number of trips by the pth subgroup in 1976,
SG = statewide total gasoline consumption in 1976 (L), and
N_p = estimated number of Michigan drivers in the pth subgroup (extrapolated from sample).

The recalculated gasoline consumption figures for each trip under the various scenarios were used in the computation of the efficiency index:

$$\overline{OKPL}_{cp} = \sum_t (OT_{pt} * KT^2_{pt}/LT_{cpt}) \Big/ \sum_t KT_{pt} \quad (3)$$

where

$\overline{OKPL}_{cp}$ = mean occupant kilometers per liter under the cth scenario for the pth subgroup of the driving population,

OT_{pt} = number of occupants in the tth trip by the pth subgroup,

KT_{pt} = kilometers driven on the tth trip by the pth subgroup, and

LT_{cpt} = liters consumed under the cth scenario by the pth subgroup of the driving population.

All of these calculations were weighted for sampling- and response-rate factors. In the case of the use of smaller cars, the constants for kilometer per liter were simply changed according to the scenario.

RESULTS

We have compared the six scenarios with the measured consumption levels and efficiency of driving in Michigan in 1976. Because the kilometer per liter averages for vehicle size classes were held constant at the 1976 fleet estimates given above, it would be possible to project further reductions in gasoline consumption from the scenarios by applying recent factors for improvement of kilometers per liters.

The statewide gasoline consumption for 1976 that would have occurred under each scenario is given in the list below.

Scenario 0--1976 baseline; gasoline consumption = 17.2 billion L/year.

Scenario 1--Commuter pool: add one passenger; gasoline consumption = 15.9 billion L/year.

Scenario 2--Commuter pool: driver and two passengers; gasoline consumption = 15.5 billion L/year.

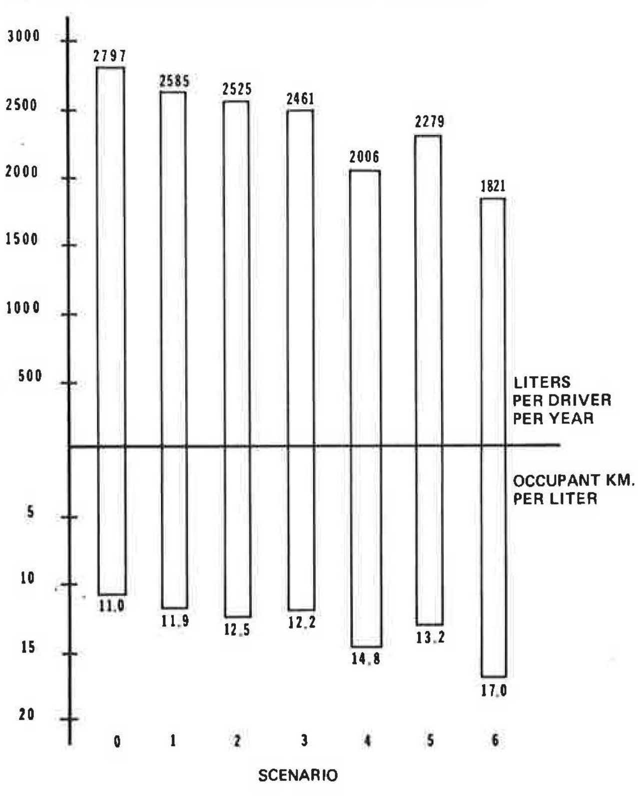
Scenario 3--Shift to next-smallest car; gasoline consumption = 15.1 billion L/year.

Scenario 4--Shift all vehicles to subcompacts; gasoline consumption = 12.3 billion L/year.

Scenario 5--Combine scenarios 1 and 3 (likely); gasoline consumption = 14.0 billion L/year.

Scenario 6--Combine scenarios 2 and 4 (maximum); gasoline consumption = 11.2 billion L/year.

Figure 1. Gasoline consumption and efficiency by scenario.



The reductions in total gasoline consumed are of the order of 8-10 percent for carpooling and 12-28 percent for smaller cars. The combined effect of the maximum scenarios would be a reduction of about 35 percent, or about 6.0 billion L. It is important to note that these reductions are less than would be estimated by a simple manipulation of kilometers per liter, vehicle kilometers traveled, and market penetration of different automobile sizes. This is primarily because small cars are being driven higher average distances than large cars, as was reported in an earlier MDES paper on gasoline rationing (7).

We believe that the moderate difference in overall gasoline savings between the scenarios to add one passenger (7.6 percent reduction) and that raising all eligible commuting trips to at least three occupants (9.7 percent reduction) is largely a measure of the tendency for current passenger loads to increase with trip length.

Figure 1 summarizes average annual liters consumed per driver and efficiency measured in occupant kilometers per liter for 1976 and the six scenarios. The pattern of reduced consumption and increased efficiency is relatively consistent across the income groups shown in Table 1 and the regional groupings of drivers shown in Table 2. This pattern prevails, except where explicitly prevented by the prohibitions in the scenario (e.g., no smaller cars for low-income respondents), despite large differences in the consumption levels of all these groupings of drivers. This parallels an important conclusion from other MDES analyses: There is considerable consistency in the proportional allocation of kilometers driven to types and purposes of travel by different population and regional subgroups, regardless of the major differences in the average number of kilometers driven.

In 1976 there was a monotonic (large) increase in consumption and decrease in efficiency with increasing income. This is despite the fact that the highest-income group looks slightly more fuel efficient if passenger load is disregarded [see Lee (7)]. When the scenarios are applied, in contrast to the very substantial differences in liters saved, there is only a slightly higher payoff in terms of percentage changes in gasoline consumption and efficiency as income increases. Low-income people, by definition, are unable to gain the financial rewards of smaller cars; hence the maximum smaller car and combined scenarios show that the $5000-$10 000 income group uses more gasoline than does the next-highest income group.

There are very substantial differences in gasoline use between drivers who reside in areas that have different levels of urbanization in Michigan. Table 2 shows the very heavy dependence of the suburbs (urban fringe) and the remote parts of the state on gasoline. Efficiency is lowest in the suburbs and the outskirts of urban areas. We should point out that these are groups of zip codes that vary largely by the density of housing; as a result, the central-city category includes the areas of affluent urban areas and medium cities, such as Ann Arbor, and the city-outskirts category includes some of the poorer neighborhoods in Detroit. Therefore, assumptions about economic factors are risky. Table 2 shows very low average consumption for the outskirts, and yet their potential improvement in OKPL through carpooling is the highest in percentage

Table 1. Annual gasoline consumption per driver and occupant kilometers per liter by income group.

		Income Group					
Scenario	Item	<$5000 (N = 516 000)	$5 000-10 000 (N = 1 089 000)	$10 000-15 000 (N = 1 536 000)	$15 000-25 000 (N = 1 952 000)	>$25 000 (N = 1 058 000)	All (N = 6 150 000)
0	Annual liters per driver	1647	1984	2582	3062	4013	2797
	OKPL	12.4	11.9	11.3	10.8	10.4	11.0
1	Annual liters per driver	1552	1843	2370	2828	3676	2585
	OKPL	13.0	12.7	12.1	11.7	11.3	11.9
2	Annual liters per driver	1548	1817	2317	2767	3592	2525
	OKPL	13.1	13.3	12.7	12.3	12.0	12.5
3	Annual liters per driver	1647	1984	2211	2620	3399	2461
	OKPL	12.4	11.9	12.8	12.4	11.9	12.2
4	Annual liters per driver	1647	1984	1736	2006	2559	2006
	OKPL	12.4	11.9	15.9	15.6	15.3	14.8
5	Annual liters per driver	1552	1843	2044	2423	3131	2279
	OKPL	13.0	12.7	13.9	13.3	13.0	13.2
6	Annual liters per driver	1548	1817	1579	1813	2302	1821
	OKPL	13.1	13.3	18.2	17.9	17.8	17.0

Notes: N = estimated number of Michigan drivers in category.
1 L = 0.264 gal; 1 km/L = 2.352 miles/gal.
Table is based on 1976 fleet kilometers per liter figures.

Table 2. Annual gasoline consumption per driver and OKPL by residential density.

		Type of Residential Area						
Scen-ario	Item	Central Cities (N = 1 015 000)	City Outskirts (N = 934 000)	Urban Fringe (N = 2 511 000)	Rural Towns (N = 988 000)	Small Villages (N = 507 000)	Remote Areas (N = 195 000)	All (N = 6 150 000)
0	Annual liters per driver	2339	1999	3210	2790	2986	3187	2797
	OKPL	11.2	10.2	10.7	11.7	11.6	12.7	11.0
1	Annual liters per driver	2131	1779	2953	2567	2964	3146	2585
	OKPL	12.2	11.4	11.6	12.7	11.7	13.2	11.9
2	Annual liters per driver	2071	1726	2881	2510	2960	3078	2525
	OKPL	12.9	12.3	12.3	13.3	11.7	13.3	12.5
3	Annual liters per driver	2040	1772	2801	2487	2665	2911	2461
	OKPL	12.5	11.3	11.9	12.8	12.7	13.6	12.2
4	Annual liters per driver	1700	1457	2218	2075	2218	2563	2006
	OKPL	14.6	13.6	14.8	15.2	15.4	15.9	14.8
5	Annual liters per driver	1862	1582	2582	2290	2638	2843	2279
	OKPL	13.6	12.8	13.1	14.0	12.8	14.2	13.2
6	Annual liters per driver	1522	1276	1999	1874	2173	2449	1821
	OKPL	17.1	16.6	17.3	17.6	15.6	16.5	17.0

Notes: 1 L = 0.264 gal; 1 km/L = 2.352 miles/gal.
Table is based on 1976 fleet kilometers per liter figures.

terms. The city outskirts are also the only area in which the maximum carpool scenario has more effect in total gasoline consumption than the likely smaller-car scenario. Recall that carpooling was declared impossible (except for to and from school) for those in the small villages and remote areas. Of the four categories to which the pooling scenarios were applied, the city outskirts achieved better gasoline savings and improved efficiency than did the others. The best improvement in efficiency from smaller cars is achieved by rural towns, followed by the suburbs. The greatest percentage improvement in liters used under all of these scenarios, however, is consistently found in the suburbs.

Together these policies have the potential to bring suburban and rural consumption down to current urban levels. Because more than 40 percent of Michigan's drivers live in the urban fringe, their having the highest per capita consumption and the largest potential reduction under these scenarios amounts to enormous savings in the best case--as much as 3.0 billion L of gasoline on 1976 standards. For comparison, their share of the maximum benefits shown in Table 1 if it were proportionate to population would be about 2.5 billion L annually. We also note that, under the maximum combined scenario, OKPL becomes more homogeneous throughout the state than it was in 1976, which could be considered a desirable change in addition to overall improvements in average efficiency of gasoline use.

CONCLUSION

The analysis of logically reasonable conservation scenarios by using microdata suggests that the differing levels of consumption between income and regional subgroups provides a scale against which similar percentage reductions could be predicted if commuter carpooling and shift to smaller cars were promoted to reasonable limits. From a policy standpoint, it would be useful to take the present consumption levels of those who use less gasoline (lower-income groups and urban dwellers) as a goal for the rest of the state, especially the suburbs. However, apart from unwelcome precedents, the most remotely located drivers could be allowed extra gasoline supplies with little impact on state consumption because of their small number.

In promoting fuel efficiency rather than efforts to reduce personal travel through traffic restraint or taxation, it must not be assumed that this is necessarily a more equitable approach for lower-income groups just because we found them to be more fuel efficient now. The mechanisms for promoting these policies (tax incentives and pool subsidies) may be out of reach, and lower-income groups may be trapped (especially with older cars) at efficiency levels that will become more burdensome as gasoline goes up in price.

A further development of this policy-analysis technique would be to introduce independently measured factors into the scenario definitions, such as the personal characteristics of those revealed by marketing studies to be willing to buy a smaller car or certain trip attributes that are associated with successful carpools of different sizes. The MDES data base has been constructed to facilitate this. In our view, the collection of sample data of this kind should become a routine matter in the monitoring of energy use and the planning of energy-conservation policy.

ACKNOWLEDGMENT

The Michigan Driving Experience Survey was initiated by Lee at the request of the Michigan Department of State while he was on the staff of the University of Michigan Highway Safety Research Institute (HSRI). HSRI assisted in the early stages of the survey under joint sponsorship from the department and the Michigan Office of Highway Safety Planning, which later provided funds under the U.S. Department of Transportation's 402 program. We gratefully acknowledge the review of this paper and suggestions of Richard H. Shackson of Carnegie-Mellon Institute of Research. The views presented in this paper are ours and do not necessarily reflect those of the Michigan Secretary of State, the Michigan Office of Highway Safety Planning, or the U.S. Department of Transportation.

REFERENCES

1. J.M. Lutin. Energy Savings for Work Trips: Analysis of Alternative Commuting Patterns for New Jersey. TRB, Transportation Research Record 561, 1976, pp. 23-36.
2. N. Erlbaum. Gasoline Demand by Owner Characteristics. TRB, Transportation Research Record, 561, 1976, pp. 37-44.
3. N. 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.
4. Nationwide Personal Transportation Survey. Federal Highway Administration, April 1972. NTIS: PB-242884-SET/ST.
5. J.M. Brunso, M.A. Kocis, and W.R. Ugolik. Factors Affecting Ridesharing Behavior. Planning Research Unit, New York State Department of Transportation, Albany, Prelim. Res. Rept. 165, Aug. 1979.
6. T.J. Atherton, J.H. Suhrbier, and W.A. Jessiman. Use of Disaggregate Travel Demand Models to Analyze Car Pooling Policy Incentives. TRB, Transportation Research Record 599, 1976, pp. 35-40.
7. M.E. Lee. Gasoline Rationing Based on Licensed Drivers or Vehicles: Potential for Coupon Sales Between Income Groups in Michigan. TRB, Transportation Research Record 731, 1979, pp. 29-32.

Publication of this paper sponsored by Committee on Energy Conservation and Transportation Demand.

Abridgment

How Much Fuel Does Vanpooling Really Save?

DONALD A. MAXWELL AND DENNIS V. WILLIAMSON

Opinions vary as to how much fuel is actually saved by vanpools. Estimates range from an optimistic 49 210 L/year (13 000 gal) to a conservative estimate of 5700 L/year (1500 gal). A reliable estimate is required by policy planners so that preferential treatment for vanpools with regard to fuel allocation can be justified. During the fall of 1978, drivers of 211 vans provided the information necessary to compute values for average trip length by van and automobile and vehicle occupancy rates for the van and automobile. Late in the following spring, 211 van passengers responded to a questionnaire designed to obtain estimates for van and automobile fuel-efficiency rates and the use of vehicles formerly used for commuting. Fuel savings were determined by substituting the values into a modified version of a model developed for the U.S. Department of Energy. The results indicate that the most probable saving per van is 17 400 L/year (4600 gal). This is based on 11.2 occupants/van, a previous vehicle occupancy of 1.47, an 86.6-km (53.8-mile) commute distance, vehicles left at home being driven 9.8 km/day (6.1 miles/day), 4.25 km/L (10 miles/gal) for the van, and 6.8 km/L (15.9 miles/gal) for the previous vehicle. If the vanpoolers formerly drove by themselves in gas guzzlers that were disposed of immediately, the optimistic savings estimate is 30 280 L/year (8000 gal). If they drove the average fleet, carpooled some, and gave their previous cars to teenagers, a more pessimistic estimate of savings is 5700 L/year (1500 gal).

In Texas, vanpooling is a highly visible, and somewhat controversial, energy-conservation measure under the State Energy Conservation Plan (SECP). Because of their energy-saving potential, vanpools were given some preferential treatment during the gasoline shortage in the summer of 1979 and will be given higher priority during future emergency situations. In order to justify this position, fuel-allocation officials and conservation planners need reliable estimates of the fuel demand and the fuel savings created by the vanpool fleet. This study grew out of a need to establish a reliable estimate to replace current rules of thumb.

Almost everyone agrees that vanpools save gasoline, but opinions vary as to exactly how much. The Texas vanpool program has previously used 18 900 L (5000 gal) per van annually to make savings estimates. Most Texas vanpool programs (1) claim savings between 18 900 and 30 300 L (5000 and 8000 gal). The original SECP, which used guidelines developed by the Stanford Research Institute (SRI) (2) for the Federal Energy Administration (3), used a conservative figure of 5700 L (1500 gal) per van annually. The enthusiastic support given to the