

reductions in use through price alone. In the aggregate, these effects are likely to cancel out and result in growth in VMT of 40-50 percent higher than during the 1975-1995 period.

Other important demographic and economic factors could significantly change these projections. Trends toward greater automobile ownership per household but declining household size could add as much as 23 percent to travel projections over the same period; decreasing urbanization could add another 9 percent. But double-digit inflation, higher unemployment rates, and periodic energy supply shortages could more than cancel out these effects. The net direction of all of these factors is difficult to determine, but on the whole, our assessment is that, in spite of higher prices, the likelihood of a stagnant economy, and possible supply shortages, travel is likely to grow, albeit at a slower rate than in the 1960s and 1970s. Gasoline use (already down since 1979) is likely to continue to fall slowly.

U.S. energy policy, which so far has focused on new car efficiency and price decontrol, is generally correctly placed. Specific actions to reduce transportation demand (and hence energy use) through modal diversion or decreased travel have been historically cost-ineffective and will probably remain so. Such actions may be justifiable for other reasons, however.

In general, more attention needs to be placed on such factors than has been the case previously. Projections of travel made in the 1970s are not likely to include most, if any, of these concerns, particularly car efficiency, price rises, and inflation. Some of this work can be done with existing tools, but most of it cannot. New methods are needed that are sensitive to the joint interaction of these variables. Such methods need not be complicated: In fact, simplicity and ease of use are highly desirable attributes. We hope that this paper contributes to that effort.

#### ACKNOWLEDGMENT

I wish to express thanks and appreciation to those members of the New York State Department of Transportation who provided input to this document. By its nature this document is preliminary. Errors of interpretation, fact, or omissions remain with me. I also wish to recognize the assistance of Karen Rapp and Diana Davis in preparing this manuscript.

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## The Shape of the 1980s: Demographic, Economic, and Travel Characteristics

FRANK SPIELBERG, EDWARD WEINER, AND ULRICH ERNST

Forecasts of economic and demographic conditions are the base for all forecasts of travel demand. During the 1970s many changes were observed in the demographics of the nation. This paper reviews the trends in pertinent demographic measures and projects the directions of these measures through the 1980s. The objective is to determine how transportation demand is likely to change.

Transportation analysis is based on the premise that demographic, social, and economic factors are major

determinants of travel demand. For the past 25 years, metropolitan planning organizations throughout the world have conducted surveys of travel, performed analyses, and estimated models of travel demand, distribution, and mode choice. The projections of future conditions forecast by these models have been used to guide decisions on investments in new and improved transportation facilities.

Transportation planners have devoted extensive effort to ensuring that their models were statistically valid, replicated base-year conditions, and produced reasonable forecasts for future years. However, the validity of the forecasts of travel produced by any of these models can only be as good as the forecasts of the basic parameters on which the models depend (e.g., population and workers). Projections of these factors have most often not been the responsibility of the transportation professional; rather, they are most often developed by other staff members and used with only cursory review as inputs for the transportation forecasts.

Fawcett and Downes (1) showed that the projections of travel obtained by use of the carefully developed models are far more sensitive to changes in the values of the social and demographic parameters than to misspecification of the model or slight variation in the model coefficients.

During the past decade, significant changes have occurred in many of the social and demographic characteristics of the U.S. population. As we enter the 1980s, it is useful to identify these national trends in factors related to transportation and to examine some conjectures as to their likely effect.

#### APPROACH

To obtain a picture of trends in 1980s, a wide range of existing forecasts and analyses was reviewed. Evaluations were made of the most reasonable forecasts based on the methodology used, consistency with other information, historical trends, and forecasts of other factors.

Travel information was developed by tabulating data from the 1977 national personal transportation survey (NPTS). These data were stratified by household size and location. Average weekday trip rates by mode were calculated for each cell.

#### Economy

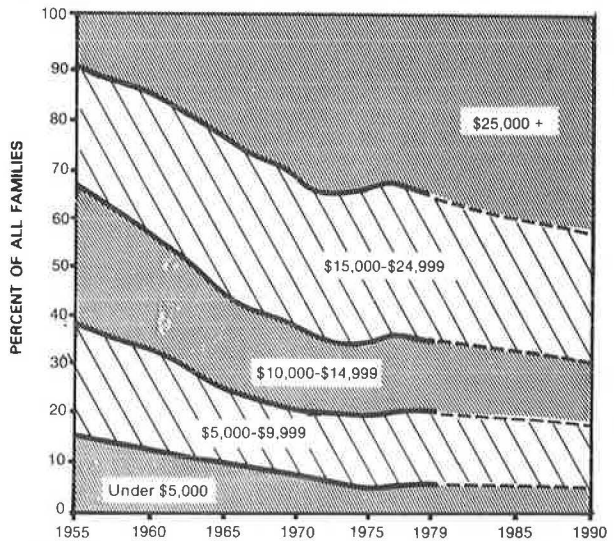
At the base of any projection of travel, explicit or implicit assumptions are made about the economic conditions of the area under study. Projections of economic growth and its characteristics typically are no more than attempts to explore the implications of a particular set of assumptions about various key factors. Changes in population, labor force, productivity, hours worked, tax policies, and exports are the forces that determine changes in the gross national product (GNP), personal income, and investments.

The period from 1950 through 1973 (during which time the data used for most U.S. travel models were collected) was a time of steadily increasing affluence combined with steadily decreasing costs for automobile travel. Continuous increases in per capita travel were observed in almost all groups in the U.S. population. The direction of economic trends has been less clear in the last half of the decade. The rate of increase in the GNP has been reduced, and for individual households, the primary issue has been how to increase or maintain real income in the face of significant inflation. GNP growth rates are expected to fluctuate about the average of 3.6 percent/year through the 1980s in real terms. The growth rates for personal income will mirror this pattern. Inflation, as measured by the consumer price index, is projected to continue at 8-9 percent/year throughout the decade.

#### Family Income

During the 1970s the relative growth of the upper-income brackets that occurred in the 1960s slowed

Figure 1. Family income distribution (in 1978 dollars).



down [Figure 1 (2)]. Since 1975, there has been an increase in the percentage shares of the two higher income categories. Changes in the lower-income brackets were almost negligible. Trends over the last two decades and current economic prospects suggest that the income distribution will change little during the 1980s. The percentage share of the highest income group is likely to increase slightly. Smaller upward shifts should affect the other categories. But, overall, the experience of the 1970s appears a better-suited model than the rapid gains of the 1960s. The income distribution forecast for the 1980s shows that close to 40 percent of U.S. families will have incomes below \$15 000. These families are apt to be severely affected by real increases in fuel costs.

#### Total Population

The total population of the United States will grow at a modest rate during the 1980s. In the second half of the 1970s, the average annual growth rate was 0.73 percent--a full percentage point below the rate for the late 1950s. Current census projections for 1990 imply average annual growth rates between 0.6 and 1.3 percent, depending on assumptions about fertility trends. Most experts expect that fertility will rise slightly from its current low to the replacement level (the level at which the population would exactly replace itself in the absence of net immigration). At that level the U.S. population is projected to grow at a rate of 0.9 percent/year, from 220.5 million in 1979 to 243.4 million in 1990.

#### Population Change

Of the three components of change in the total population (live births, deaths, and net immigration into the country), fertility trends have been the key to recent growth patterns [Figure 2 (3)]. Mortality rates have been relatively stable over the last few decades. There has been a recent downturn that has been broadly sustained since 1973. Death rates for persons 65 years old and over (who account for about 90 percent of all deaths) declined much more from 1973 to 1978 than from 1960 to 1973, primarily as a result of a reduction in mortality from major cardiovascular diseases. This change reflects improvements in health care as well as changes in lifestyle.

Figure 2. Components of population change.

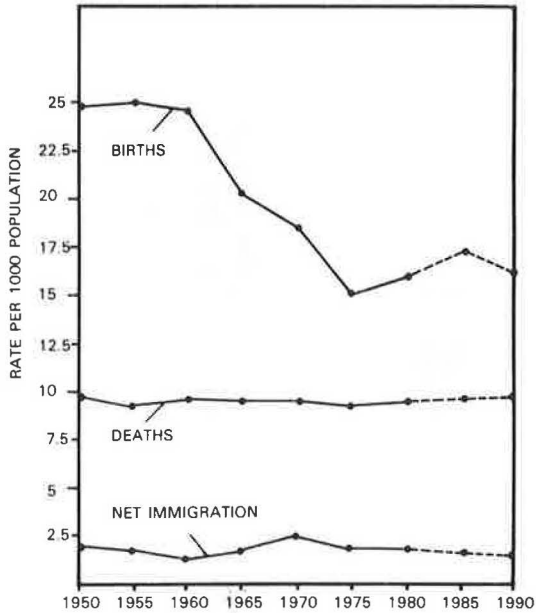
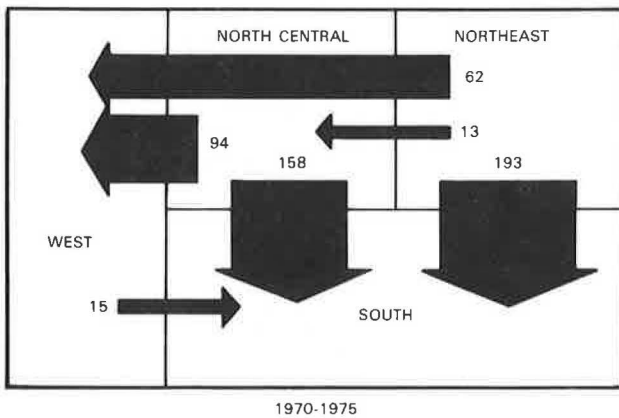
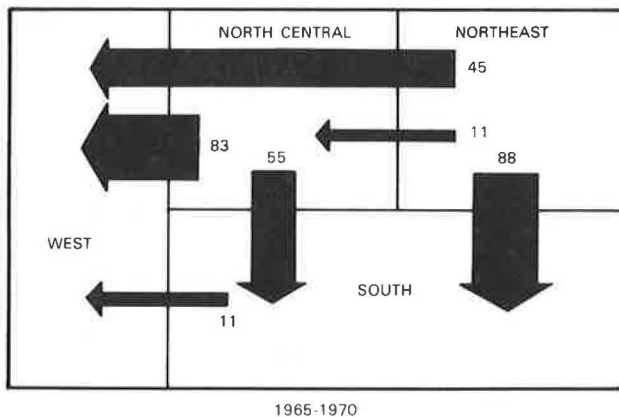


Figure 3. Net migration among census regions (annual averages, 000s).



The slowdown in population growth reflects a drop in birth rates. This drop is primarily the result of a decline in fertility rates for women across all age categories. The general consensus is that changing aspirations of women and couples have caused this decline in fertility rates. A popular

assumption is that the decline in fertility rates in the younger age groups is the result of the postponement of childbearing and that the birth rate could rise again in the near future as many young women begin to make up desired births delayed from previous years. It is doubtful, though, whether the effect would lead to a substantial increase in the birth rate over the next few years. All indications are that fertility rates will increase slightly and approach the level at which the population replaces itself (in the absence of net immigration). This projection is consistent with most recent survey data of the birth expectations of young married women.

Regional Redistribution

The key factor in the regional redistribution of the U.S. population has been migration. The 1970s brought a radical shift in several long-term migration trends. First, the net out-migration from the South reversed. The South became the region with the largest in-migration. At the national level, however, total net annual regional change amounts to only 0.25 percent of the total population [Figure 3 (4,5)]. Second, the historical trend toward expanded urbanization reversed. Each past decennial census up to and including the 1970 count showed that a greater percentage of the population lived in urbanized areas. In the 1970s, for the first time, the number of migrants from urban to nonmetropolitan areas exceeded the number who moved in the opposite direction. Third, the rate of migration into the central cities from the suburbs increased in the second half of the 1970s. Migration from the suburbs to the central cities in the three years from 1975 to 1978 reached almost the level for the five-year period 1970-1975--3.6 versus 3.8 million. This relative acceleration may be an indication that the often-cited return to the city is more than a series of isolated phenomena.

As with regional migration, however, the net rate of migration is still quite small compared with the total population. In fact, in absolute terms, the annual rate of migration from central cities to suburbs was stable throughout the decade. The rate of turnover has increased, new groups that have smaller household size are moving to central cities, and larger households continue to seek the suburbs.

Population Growth by Type of Residential Area

Although the parameters of migration among types of residential areas have begun to change, the relative magnitude of migration flows implies a continuation of current growth trends through the 1980s. The full impact of these changes will be felt in the years that follow the next decade.

The projections shown here identify the suburbs as still the key growth area. Population in the suburbs (the noncentral portions of metropolitan areas) is projected to increase from about 63 million in 1975 to 86 million in 1990. This growth results in an increase in the share of the suburbs of the total population--from less than 30 percent in 1975 to more than 35 percent in 1990 [Figure 4 (6)]. Central cities are projected to show an absolute increase in the population--from 67 million in 1975 to 72 million in 1990. Their share in the total U.S. population, however, will decrease slightly--from 31 to 30 percent.

The population living in small-urban areas (cities that have a population between 2500 and 50 000) is expected to remain stable. Consequently, the percentage share of this category will decrease. The rural population is projected to decrease in ab-

Figure 4. Distribution of population by area.

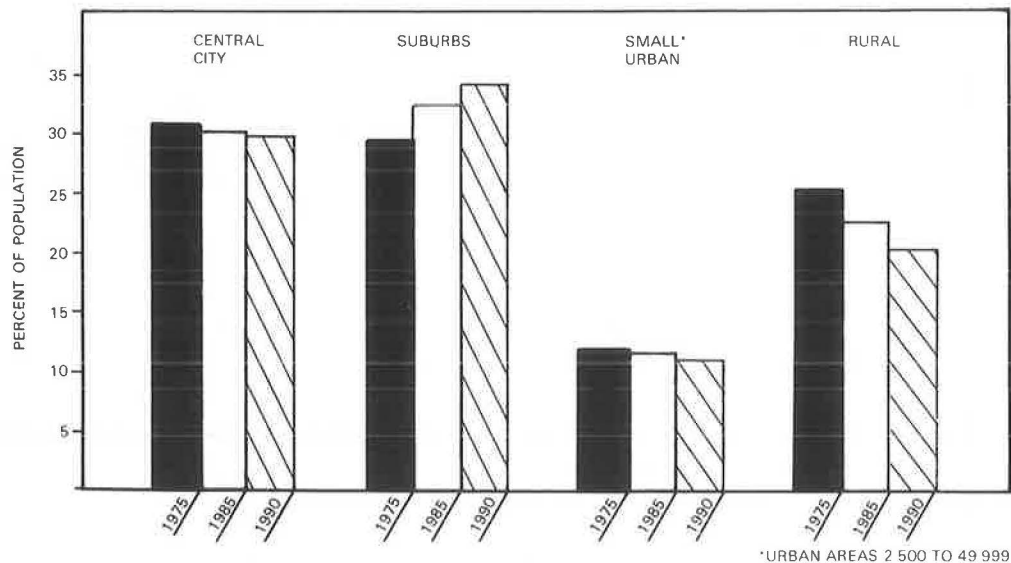
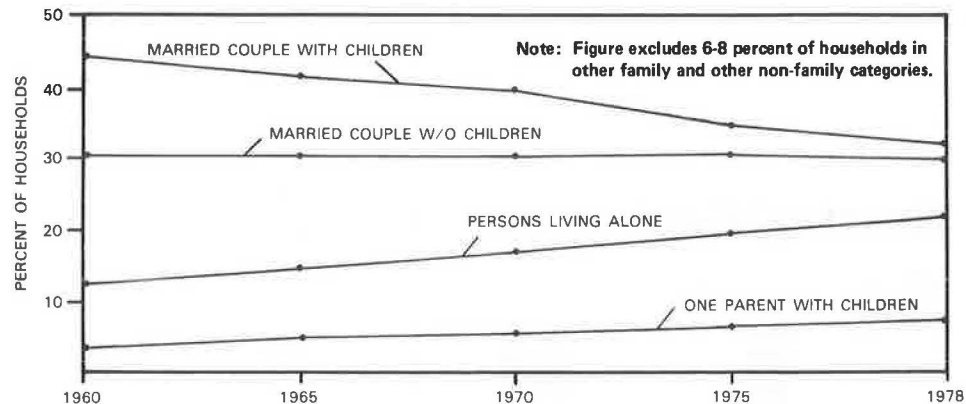


Figure 5. Trends in household composition.



solite terms. The percentage share of rural areas in the total population is projected to decline from more than 25 percent to under 22 percent. If recent shifts in migration patterns continue throughout the 1980s, this decline in the relative importance of the rural areas is likely to be milder.

Throughout the next decade the suburbs will continue to be the residence of the largest segment of the population.

#### Trends in Household Composition

The percentage of households that contain married couples who have children has declined from 44 percent in 1960 to 32 percent in 1978 [Figure 5 (7,8)]. Over the same period, the percentage of all households that consists of married couples who do not have children has remained constant at about 30 percent. The most significant gain has been in the category of single-person households. In 1960, persons who lived alone accounted for 13 percent of all households. By 1978 this percentage had increased to 22 percent. In the 1980s the growth in single-person households is likely to slow down only marginally, because the number and proportion of elderly in the population (who account for a large fraction of single-person households) will continue to increase.

Households that do not contain children have increased substantially since 1960 and are expected to represent an even larger proportion of all house-

holds by 1990. Such households place less emphasis on schools or the availability of play space in their decisions about residential location. Higher-density, central living will be more acceptable for this group.

This conjecture is supported, in part, by preliminary data from the 1980 census that show that, although central cities are experiencing a loss of population, they are, at the same time, showing growth in the number of households. Thus, we expect that in the 1980s the central cities will retain their relative share of households, but the suburbs will contain the larger proportion of population.

#### Labor Force

The total U.S. labor force is projected to increase from 102 million in 1980 to 114 million in 1990, which corresponds to an average annual growth rate of 1.1 percent/year. The major driving force behind this increase in the total labor force is the growth in the female labor force. From 1970 to 1980 the male labor force has grown at an average annual rate of 1.6 percent. Over the same time period, the female labor force has grown at a rate of 2.8 percent/year [Figure 6 (2)]. The growth in the labor force is expected to slow down for both groups during the 1980s--to a rate of 0.8 percent/year for the men and 1.5 percent/year for the women.

The fast overall growth in the past decade was largely attributable to the entry of the baby boom

Figure 6. Percentage of husband-wife families with a working wife.

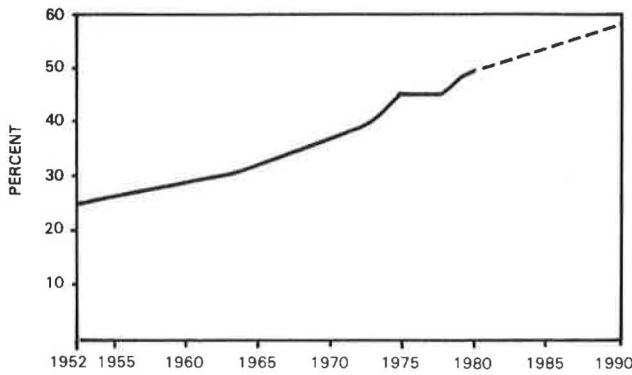


Table 1. Effect of female employment on household trip rates in 1977.

Household Size	Employed Persons		Weekday Trips/Household	Increase In Trip Rate
	Male	Female		
2	1	0	4.33	1.65
2	1	1	5.98	
3	1	0	5.73	1.64
3	1	1	7.37	

generation. This group no longer plays a role in the growth of the labor force. Significant growth in the 1980s is primarily due to the increased participation by women in the labor force.

Rate of Participation in the Labor Force

The long-term decline in the rate of participation in the labor force for men is expected to taper off in the 1980s. This rate is projected to stay virtually constant. In contrast, the rate of participation in the labor force for women is projected to continue its recent climb throughout the first half of the 1980s and to level off somewhat during the second half. By 1990, more than 51 percent of all women are expected to be in the labor force, which is up from 43 percent in 1970.

The growth of female participation in the labor force is the result of a series of complex factors. The implications for the social and economic fabric of our society and for changing demands on public services are only partially understood. The addition of another wage earner in existing households and the continued formation of small households as a result of greater economic independence of women require a reassessment of current notions about the travel behavior and transportation needs of households.

Working Wives

The proportion of married women who enter the labor force is projected to increase. This trend results not only from a change in attitudes regarding working wives but also from economic reasons, an expanding economy, equal-opportunity laws, increased female levels of education, and a corporate climate that provides women with improved wages and seniority.

Household Trip Rates

The effect of increased female employment on trip rates has been an open question during the 1970s.

Some have suggested that the result of devoting many hours each day to employment would be to reduce the overall household trip rate. Data from the 1977 NPTS [Table 1 (9)] suggest that the results of increased participation in the labor force by married women is an absolute increase in travel. It appears that devoting time to employment does not suppress nonwork travel--rather, roughly 1.65 trips/weekday are added. This is almost exactly the number of work trips expected per employed person.

Migration of the Work Force

During the 1970s, heavily populated areas (the central counties of metropolitan areas that have a population of 2 million or more) experienced a net out-migration of jobs at a rate of almost 100 000/year. The situation was different for the smaller central counties. Those that have a population of 1 to 2 million people experienced a net in-migration of workers from other areas. Between 1970 and 1973, central counties that had a population between 500 000 and 1 million registered substantial job in-migration; by 1973-1976, this situation had changed to net out-migration.

The primary beneficiary of this change was the category of central counties that have a population under 500 000. The net in-migration of jobs almost tripled from 1970-1973 to 1973-1976, to a rate of about 50 000 workers/year. The remaining two categories, noncentral counties in metropolitan areas and nonmetropolitan counties, show a net in-migration in both periods. In both cases, total net in-migration increased. The relative increase is particularly significant for the nonmetropolitan counties.

These trends in geographical changes in job location are likely to continue into the 1980s. The dispersal of residential location has been followed by the dispersal of the location of the place of work. Although this change is gradual (less than 0.5 percent of the total labor force), it could begin to affect work travel patterns. The centers of metropolitan areas could continue to lose importance as a destination for the work trip.

Real Cost of Gasoline

In the absence of any new crises, such as those in Iran, total petroleum production during the 1980s is projected to increase from about 50 million barrels/day. The gap between world production and demand is projected to be small (about 200 000 barrels/day in 1980) but to rise steadily through the decade. Sporadic restriction of supply should also be expected during the 1980s.

Since demand will exceed supply, the price of a barrel of oil will continue to increase and reach almost \$70/barrel by 1990. The price differential between domestic and imported crude will be eliminated by 1982. The increase in petroleum prices is expected to be accompanied by continued inflation. In the early fall of 1979 projections were that the 1990 barrel price (in 1979 dollars) would be on the order of \$32. Subsequent events suggest that this projection might be low.

As shown in Figure 7 (10,11), the cost of gasoline relative to all items declined significantly between 1960 and 1973. During the 1973-1974 embargo the cost rose sharply but then once again declined slowly in real terms until the sharp price increases of 1979. Due to the continued increase in the real price of crude oil, the price of gasoline relative to all items is expected to continue its real increase through the 1980s, although the rate of increase will slow in the later half of the decade.



Figure 7. Price of gasoline relative to all items.

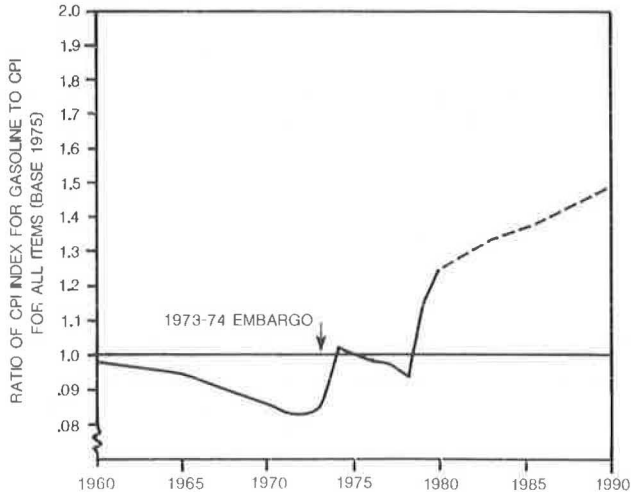


Figure 8. Automobile fleet average fuel economy.

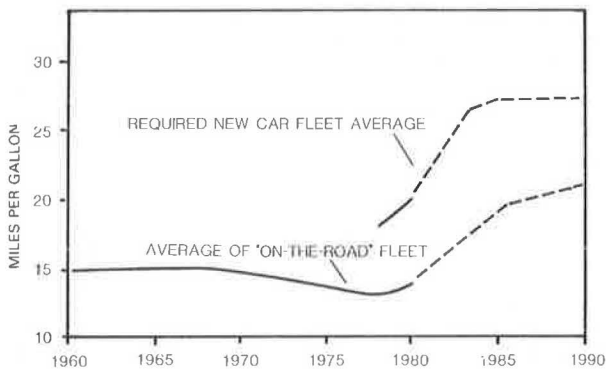
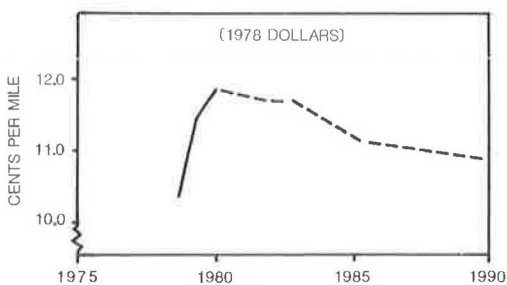


Figure 9. Automobile operating costs per mile.



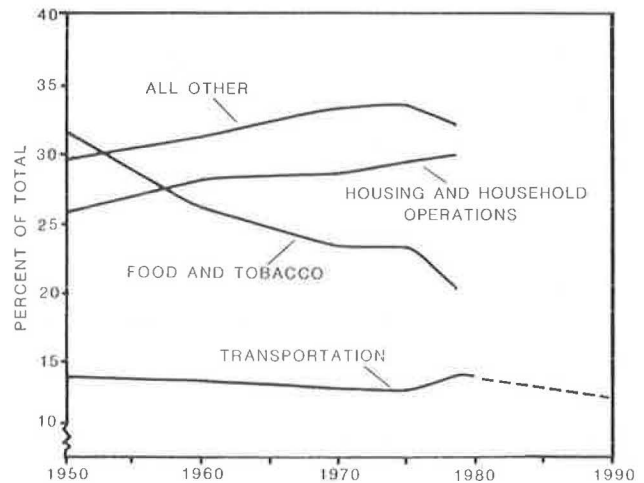
Note: Figure includes variable costs only; does not include fixed items such as cost of vehicle purchase, taxes, and licenses.

By 1990 the real cost of gasoline is projected to be approximately 1.5 times the 1979 cost. This forecast indicates that trends to smaller cars will continue in an effort to maintain existing life-style in the face of rising fuel costs.

#### Cost of Automobile Operation

The cost to a household of automobile operation depends on both the cost of gasoline and the fuel economy of the vehicles available. The fuel efficiency of the U.S. automobile fleet declined from

Figure 10. Transportation expenditures as a percentage of total personal consumption expenditures.



about 14.5 miles/gal in 1960 to a low of about 13.5 miles/gal in 1975 [Figure 8 (6)]. Mandated improvements in the fuel efficiency of new cars have begun to increase the average efficiency of the fleet. By 1980 the efficiencies of the early 1960s will be surpassed. The continued increase in new car efficiency coupled with the retirement of older vehicles will result in fleet efficiencies of 19 miles/gal by 1985 and almost 23 miles/gal by 1990.

The rate of increase in fleet efficiency is projected to be greater than the rate of increase in the real price of gasoline for the 1980s. Although the real cost of gasoline may rise more rapidly than shown in these projections, increases in fleet efficiency would compensate for price increases of 4 percent/year. The combined effect on automobile operating costs will be an increase through 1980, followed by stabilization in 1981-1982, and a decline in real terms for the remainder of the decade [Figure 9 (10)]. Real operating costs per mile in 1990 may be slightly less than in 1979.

Automobile operating costs in the 1990s will again increase. By 1985 new cars will have achieved fuel economy standards that can be easily implemented. Major technological innovation will be required to obtain additional efficiency. The gap between petroleum demand and production is also expected to widen more rapidly in the 1990s and lead to either higher real prices or supply restrictions.

Although the 1980s may be a period of relative stability, actions taken during the 1980s must recognize the likely problems of the next decade.

#### Transportation Budget

Between 1950 and 1970 the proportion of personal consumption expenditure devoted to transportation declined only slightly (from roughly 13 percent to 12 percent), even though the cost of travel in real terms fell substantially. A slight rise in the proportion of the budget devoted to transportation in 1974 was followed by a major increase from 1975 to 1977, when it reached a 20-year high of 14.3 percent [Figure 10 (12)].

How transportation expenditure will change in the 1980s is unclear. The conjecture shown in Figure 10 suggests that household travel expenditure will decline slightly during the 1980s, and households will seek to reestablish the historical values of 12-13 percent:

1. Studies have suggested that households over a wide range of urban areas and living conditions have a cost budget for transportation, and

2. Although the costs of gasoline will increase in real terms during the 1980s, the cost per mile of automobile travel will decline slightly as fleet efficiency improves.

The post-1974 increase in the transportation budget reflects the fact that households require some time to change dwelling locations and trip patterns. During the 1980s long-term decisions about residential location and activity patterns will be made that reflect travel costs. However, 80 percent of the housing units that will exist in 1990 are already in place. The availability and cost of certain types of transportation were implicit in the development of this housing. The residents of this housing will be forced to live with the economic and mobility consequences.

Nominal price increases or occasional supply restrictions during the 1980s may lead to some household adjustments. Households that do not change patterns in the 1980s should be able to maintain their transportation budgets within the historic range if household income keeps pace with inflation. Beyond 1990, due to real increases in operating cost, these households will need to either increase the proportion of income devoted to transportation or reduce travel. Within limits, the latter option is easier and more likely to be chosen. Some trips must be made, however, and in the 1990s a growing proportion of households will be seeking cheaper travel alternatives.

Gasoline Expenditures

The amount of money spent on gasoline is a direct function of travel. As would be expected, larger households make more trips and, therefore, have higher gasoline expenditures [Figure 11 (9)]. Similarly, higher-income households travel more and spend more on fuel, although the percentage of income devoted to gasoline expense shows a rapid decline with increasing income. Above the median income, gasoline expenditure increases more slowly than does income. Other factors, such as the amount of time available to travel, serve to constrain trip rates. These higher-income households could absorb

significant real increases in gasoline prices without exceeding the average amount of the budget devoted to transportation.

The evidence, however, also suggests that lower-income households are already constrained by the cost of operations. The mobility of this group could be even more restricted as real costs increase.

CONCLUSIONS

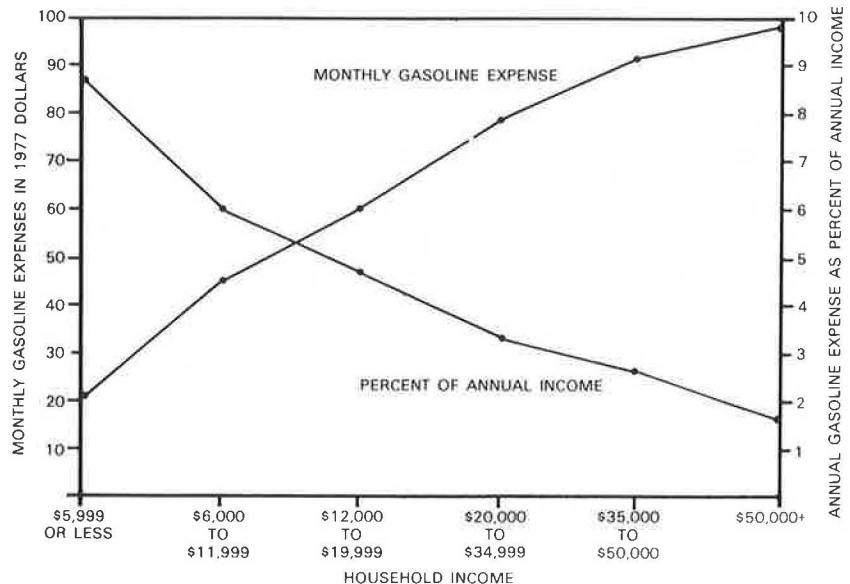
Based on analysis of trends observed during the 1970s and their projection to the next decade, the following findings are particularly significant:

1. Continued inflation will result in a halt in the rise of real income;
2. Growth in population will continue to slow;
3. Family size will decrease and the proportion of single-person households will increase;
4. Although some smaller households will seek dwelling units in higher-density areas (central cities and older suburbs), the majority of growth in both population and households will occur in areas characterized as suburban;
5. The proportion of women employed will continue to increase; and
6. Continued increases in the real cost of gasoline will be coupled with significant increases in vehicle fuel efficiency so that the per mile cost of automobile operation will be stable for the population as a whole.

Perhaps most significant, however, is that, in spite of definite trends in migration to the South, to nonmetropolitan areas, and, to a lesser degree, to central cities, the absolute magnitude of the net changes will be small compared with the total population. The vast bulk of the U.S. housing stock is in place. Substantial net change in residence locations over the decade is impractical.

Our view of the 1980s may be summarized as follows. Population in the South and West will continue to grow at a faster rate than will the nation as a whole, and most of this growth will occur in the lower-density developments that characterize new housing areas. The bulk of the population will live in suburban locations, dependent for travel on automobiles. Fuel costs will continue to increase in real terms so that households will take a variety of

Figure 11. Characteristics of household gasoline expenditure.



actions to maintain their transportation budgets within the historical range. The most popular action will be the purchase of more fuel-efficient vehicles. As a result, vehicle miles of travel in all areas will continue to increase, although the rate of growth will be slower than that observed in the past. Nonetheless, lower-income groups will face increased restrictions on their mobility.

Households that do not include children will increase as a proportion of the total. These households will find higher-density living more acceptable, and many will choose locations within the central city or older suburbs. These households, which frequently have two working adults, will find transit acceptable for many trips. As a result, transit ridership as a proportion of total travel will stabilize and grow in absolute numbers.

From a transportation viewpoint, these trends and forecasts indicate that the northeastern and midwestern regions will have to adapt to a low-growth future and concentrate on selective revitalization and rehabilitation of existing highway and transit facilities. The southern and western regions will need to encourage new development to occur at higher densities so that they can better serve travel with transit. Nationwide, extensive areas of low-density development will still exist, where paratransit options will be the only stable alternatives to single occupant use of the automobile. Ridesharing in carpools, vanpools, or taxicabs will be the most cost-effective transportation option. New institutional arrangements will be needed so that providers of such services can enter the market.

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## Estimating Vehicle Miles of Travel: An Application of the Rank-Size Rule

WAYNE R. UGOLIK

This paper suggests a simplified approach to the problem of estimating annual vehicle miles of travel without the need for extensive vehicle count data. By using detailed data on vehicle miles of travel per highway section of the New York State touring route system, it is shown that, when the highway sections are ranked in decreasing order of their section vehicle miles of travel, the vehicle miles of travel of the individual sections can be closely approximated by a function of section rank value. An approximation of the total sum of vehicle miles of travel on all highway sections is then obtained by integrating this function over all the rank values. The approach has potential for use as a forecasting tool. Tests on data for 1968, 1974, and 1976 show that the method can produce surprisingly accurate results.

In 1970 Zahavi (1) noted that, when certain transportation-related quantities are ranked in decreasing order of value, a certain level of stability is attained in the relationship between rank and value that enables analyses that might not otherwise be possible. This relationship, well known in the sciences, is called the k-distribution. In this paper we explore a similar pattern of stability that is exhibited by a ranking (in decreasing order) of

the annual vehicle miles of travel per section of the New York State touring route highway network. This stability enables us to develop a method for estimating annual vehicle miles of travel on the state route system by a simple scheme that has the potential to circumvent the costly and extensive vehicle-counting procedures that are currently in wide use. The method is based on what we term the rank-size rule. Its utility for producing accurate estimates is illustrated by an application to New York State vehicle miles of travel data for 1968, 1974, and 1976.

#### RANK-SIZE RULE

The rank-size rule can be described mathematically as follows:

1. Let  $a_1, a_2, a_3, \dots, a_n$  be a listing of positive numbers with  $a_1 \geq a_2 \geq a_3 \geq \dots \geq a_n$ ; that