ENERGY SAVINGS FOR WORK TRIPS: ANALYSIS OF ALTERNATIVE COMMUTING PATTERNS FOR NEW JERSEY

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This paper analyzes energy consumption for work trips in New Jersey. Prepared as an aid to the New Jersey Task Force on Energy, it develops a methodology to quantitatively compare alternative transportation policies intended to reduce energy consumption. Data were obtained on work trip distribution, transit patronage, and modal split for each of the 21 counties in New Jersey for 1970. From these data, work trip lengths and automobile and transit occupancy rates were calculated. Based on these as inputs to a model that predicted total work trip energy utilization, the total daily energy consumption was computed for work trips of New Jersey residents. Modal split, energy per vehicle mile (kilometer), and vehicle occupancy rates were then varied to test alternative strategies for reducing energy consumption. In general, the results of this analysis showed that, given current work trip patterns, greater savings in energy could be achieved by using automobiles than by increasing public transit patronage. Specific policy recommendations were then outlined for automobile and public transit planning.

•DURING the winter of 1973, America faced its first major gas shortage since World War II. At the height of the crisis, many public agencies rushed to develop plans to deal with the problem by encouraging car pooling, rationing fuel, and by implementing short-term improvements to transit systems. In some cases, services were instituted that never would prove useful or feasible. Some well-conceived plans helped ease the immediate crisis, but later, when fuel became more plentiful, old habits and patterns of travel returned.

In New Jersey, as in other states, the need was recognized for more long-range planning that could deal rationally with future crises by developing policies and bureaucratic mechanisms to coordinate and regulate energy supply and demand. Therefore, an energy policy task force was drawn together from personnel of several state agencies and local universities, under the auspices of the New Jersey State Energy Office. The task force was charged with the responsibility of preparing a report for the governor on the major problems of energy supply and demand in New Jersey. The task force was to make specific policy recommendations for the state's role in energy management. What follows is an analysis of journey-to-work energy consumption to examine potential energy savings under different transportation policies for the New Jersey Task Force on Energy.

Data were obtained on work trip distribution and modal split for each of 21 counties in New Jersey from the 1970 census. Work trip lengths and automobile occupancy rates were calculated from these data. From data obtained from the New Jersey State Department of Transportation, transit vehicle occupancy rates were calculated. Based on these as inputs to a model that predicted total work trip energy

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utilization, it was possible to compute the total daily energy consumption for work trips by New Jersey residents in 1970. Modal split, energy per vehicle mile (kilometer), and vehicle occupancy rates were then varied to test alternative strategies for reducing energy consumption. The results of this analysis were quite surprising. In general, it was found that much greater energy savings were possible by using automobiles rather than by increasing public transit patronage. This led to some specific policy recommendations that are discussed in this paper.

NATIONAL TRANSPORTATION SITUATION

Transportation accounts for about 25 percent of all energy consumed in the United States, and this percentage may be even higher if indirect consumption is included (1). Because so much transportation energy is expended in Interstate and interregional movement, it is difficult to isolate one region and quantify the total transportation energy consumption within its borders. Consequently, the following discussion of overall patterns of energy consumption must be based on the national level, since statewide statistics are unavailable. In Figure 1, the nationwide distribution of energy consumption among the various modes is shown for 1970. From this, it is clearly seen that the major consumers of transport energy are the highway users—automobiles and trucks.

The automobile alone consumes over one-half of all energy consumed by the transportation sector. The following table gives the percentage of automobile miles (kilometers) traveled.

Purpose	Percent
Earning a living	40.6
Family business, including shopping	20.0
Educational, civic, and religious	4.9
Social and recreational, including vacations	33.3
Other	1.2
Total	100.0

Trips for earning a living account for 40 percent of all vehicle miles (kilometers) traveled daily. Travel to work and back alone accounts for 32.9 percent of all vehicle miles (kilometers) daily. The first priority in reducing transportation energy consumption, therefore, is reducing the level of highway travel.

TRANSPORTATION IN NEW JERSEY

In 1970, vehicle registration in New Jersey reached 3.79 million vehicles, giving a ratio of 1 vehicle for every 1.9 people (7). In 1972, trucks accounted for about 9 percent of all registrations. Together, these vehicles accumulated 40 billion vehicle miles (64 billion km) of travel on 32,000 miles (51 500 km) of roads in New Jersey in 1970. Within this extensive system of roads are 440 miles (708 km) of expressways, 543 miles (874 km) of divided highways, and 1,267 miles (2040 km) of undivided state highways (7).

Fifteen of New Jersey's 21 counties are presently served by rail passenger service. Five companies operate a combined total of 467 route miles (752 km), carrying a weekday average of 166,130 commuters (7). In addition to rail transit, the state has extensive bus service, 4,700 buses operated by 274 companies. New Jersey's bus companies carry 313 million passengers each year (7). Figure 2 shows a map of the 21 counties in New Jersey.

Figure 1. Energy consumption by transport mode.

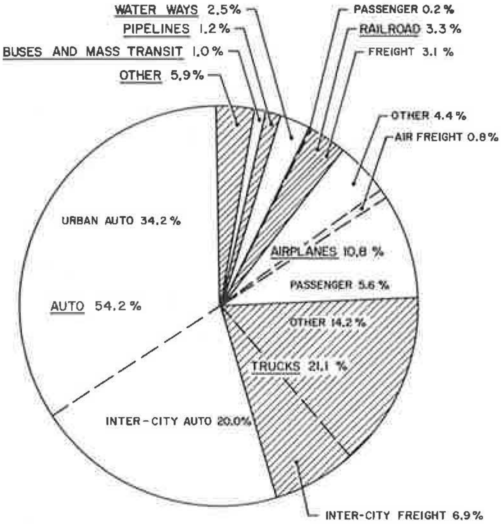


Figure 2. Counties in New Jersey.

Table 1. Distribution of mode of travel to work.

County	Automobile (percent)	Bus (percent)	Rail (percent)	Walking (percent)	Other[a] (percent)
Atlantic	74.0	8.9	0.4	10.3	6.4
Bergen	75.4	12.2	3.4	5.5	3.5
Burlington	73.4	3.2	0.8	18.3	4.3
Camden	75.7	9.7	5.0	5.2	4.4
Cape May	77.9	1.5	0.9	11.0	8.7
Cumberland	86.7	0.8	0.2	6.2	6.1
Essex	63.6	22.0	3.6	7.7	3.1
Gloucester	84.0	4.5	0.7	4.6	6.2
Hudson	48.5	28.0	7.3	13.9	2.3
Hunterdon	82.8	0.8	2.1	6.0	8.3
Mercer	79.1	5.8	1.9	8.7	4.5
Middlesex	82.9	5.5	3.4	6.4	1.8
Monmouth	77.4	5.3	5.2	7.5	4.6
Morris	83.3	2.0	5.3	5.3	4.1
Ocean	86.4	2.7	1.2	4.4	5.3
Passaic	77.9	10.6	0.9	7.8	2.8
Salem	86.3	0.5	0.1	6.0	7.1
Somerset	73.5	14.5	4.3	4.4	7.2
Sussex	85.2	1.2	0.9	5.5	7.2
Union	76.4	7.6	5.8	7.1	3.1
Warren	82.2	0.7	0.3	9.1	7.7
Avg	74.1	10.5	3.6	7.8	4.0

[a] Includes working at home.

ANALYSIS OF ENERGY CONSUMPTION

Automobile travel consumed more than one-half of all transportation energy in 1970 (Figure 1), and over 40 percent of all automobile travel was expended in earning a living (Table 1). It is clear, therefore, that about 20 percent of all transportation energy is expended in driving to work. Much of the passenger traffic carried by rail and bus is also comprised of home-to-work travelers. In fact, half of all rail passenger traffic is commuter service (8). Consequently, an examination of commuting patterns can lead to a revealing cross-sectional view of the way transportation energy is expended in New Jersey. In addition to examining energy expended in work trips alone, it is possible to extend the examination to other travel behavior as well, since the way people travel to work is strongly correlated with the travel patterns shown by their entire households. To better observe the pattern of transportation energy consumption in New Jersey and to determine the policies that will be most effective in reducing the consumption of energy, an analysis of 1970 work trips of New Jersey residents was made according to the amount of energy consumed.

Source of Work Trip Data

In the 1970 census, 15 percent of all households tabulated were asked specific questions on the mode of transportation used by each household member for the journey to work and on the address of the place of work. Tabulations of these data are available for each county in New Jersey and were used to determine the modal split for work trips (i.e., the number of people who went to work by car, bus, train) for each county (2). In addition, tabulations of numbers of workers commuting to selected cities and counties were available for each county. It was therefore possible to obtain an approximation of the average work trip length for each county.

Existing Commuting Patterns

Table 1 (2) gives the modal split for work trips in 1970 by county. For every county, the automobile carries the majority of all workers, an average of 74.1 percent for the state. All public transit, rail and bus together, carry only 14.1 percent of all workers. Of all counties, Hudson County has the largest share of transit riders, 35.3 percent, and the smallest percentage of automobile travelers, 48.5 percent. Salem County has the smallest percentage of transit riders, 0.6 percent, and Cumberland County has the largest share of automobile work trips, 86.7 percent. Burlington County has the largest percentage of walkers, 18.3 percent. This figure may reflect the contribution of three large military bases in the county, containing large numbers of resident workers.

Many New Jersey residents commute from their counties of residence to work in adjacent counties or neighboring states. In fact, according to the census, 182,000 New Jerseyites commute to New York, and 74,000 commute to Pennsylvania each day; they make up approximately 9 percent of the New Jersey labor force. A significant proportion of out-of-state residents commute into New Jersey each day, equal to about one-half of the total outbound New Jersey commuters. These calculations do not include those workers residing outside New Jersey. Table 2 gives a county-by-county tabulation of the percentage of out-of-county commuters. Only 4 counties have fewer than 25 percent commuting, and two-thirds of the counties have more than 30 percent commuting to work out of county.

The results of the wide dispersal of homes and jobs are reflected by the distance one must travel to work. In Table 3, the approximate average one-way work trip lengths for each county are given. The data in Table 3 are based on county-to-county work trip tables from New Jersey Department of Labor and Industry 1970 census data. These trip tables only contained data about work trips to the first 20 selected locations for each county, ranked by number of trips to each location. In most cases, these locations

Table 2. Percentage of residents commuting to out-of-county jobs.

County	Percent
Atlantic	14
Bergen	43
Burlington	37
Camden	40
Cape May	16
Cumberland	12
Essex	29
Gloucester	47
Hudson	36
Hunterdon	40
Mercer	14
Middlesex	36
Monmouth	29
Morris	38
Ocean	35
Passaic	35
Salem	26
Somerset	48
Sussex	43
Union	36
Warren	33
Avg	36

Table 3. Average work trip length (one-way).

County	Trip Length (miles)
Atlantic	10.9
Bergen	9.1
Burlington	12.8
Camden	8.3
Cape May	14.4
Cumberland	10.8
Essex	6.4
Gloucester	10.7
Hudson	6.6
Hunterdon	13.7
Mercer	9.4
Middlesex	12.0
Monmouth	14.1
Morris	13.1
Ocean	15.7
Passaic	7.8
Salem	11.6
Somerset	13.6
Sussex	18.0
Union	7.9
Warren	15.5
Avg	9.9

Note: 1 mile = 1.6 km.

Table 4. Average vehicle occupancy for work trips by automobile and public transit.

	Occupancy (persons per vehicle)	
County	Automobile	Public Transit
Atlantic	1.17	6.9
Bergen	1.15	17.8
Burlington	1.14	15.6
Camden	1.19	16.2
Cape May	1.15	8.0
Cumberland	1.18	4.9
Essex	1.19	25.0
Gloucester	1.17	14.7
Hudson	1.24	31.8
Hunterdon	1.12	10.6
Mercer	1.19	20.6
Middlesex	1.15	25.7
Monmouth	1.15	7.4
Morris	1.13	11.8
Ocean	1.14	6.2
Passaic	1.17	13.4
Salem	1.24	10.6
Somerset	1.13	23.3
Sussex	1.15	3.4
Union	1.17	19.2
Warren	1.17	3.4

accounted for >90 percent of all work trips for the county. The work trip tables had origins disaggregated by municipality. For each county, a theoretical center of population was assigned based on the population distribution among all municipalities. All out-of-county trips were assumed to begin at this location. For trip ends, a center of employment was assumed for each destination. Distances were obtained from the Offical Map and Guide 1972 of the New Jersey State Department of Transportation. Intracounty trip lengths were calculated by using an assumed average trip time of 20 min and speeds averaging about 20 mph (32 km/h), but varying with the urban or rural nature of the county. Finally, the average trip length for each county was computed by weighting each tabulated trip length by the number of workers traveling that distance. The average trip lengths for the more rural counties are generally longer than those for more urbanized counties (Table 3). Sussex County, for example, has an average trip length nearly three times that of Essex County. Overall, the 9.9-mile (15.9-km) average work trip length in New Jersey is quite close to the national average of 9.4 miles (15.1 km) (6).

Calculation of Transportation Energy for Work Trips

The following expression was used to determine the total energy consumed by work trips (3):

$$E = \sum_{c} \left\{ W_c L_{cw} \left[\sum_{j} \alpha^{w}_{cj} \left(\epsilon_j / \lambda_{cj} \right) \right] \right\} \tag{1}$$

where

E = total work trip energy,
W_c = number of one-way work trips made in the c th county,
L_{cw} = average work trip length for the c th county,
α^{w}_{cj} = percentage of work trips by the j th mode,
ϵ_j = energy per vehicle mile (kilometer) for the j th mode, and
λ_{cj} = load factor for the j th mode in the c th county.

L_{cw} is assumed to be constant for all modes for a given county. Most likely, average trip length would vary with mode, particularly with respect to rail trips. Since automobile trips tended to dominate all other modes in the base year 1970 and trip length distributions were unavailable for each mode, a constant value assumed for L_{cw} did not appear unreasonable.

The load factor λ_{cj} for each mode by county required estimation for input into the model. For automobiles, λ was known since the 1970 journey-to-work data specified automobile driver or automobile passenger as separate modes. Automobile occupancy was calculated as the total automobile users (drivers + passengers) divided by the number of automobile drivers. For buses, however, λ was estimated from data provided by the New Jersey State Department of Transportation. Annual bus route statistics for 1973 were obtained. These contained total number of trips, total passengers carried, and total vehicle miles traveled for each route. In addition, a description of each route was obtained to determine which counties were traversed. Average vehicle occupancy was based on the total number of passengers multiplied by the assumed average trip length and divided by the total number of vehicle miles (kilometers) traveled for each route. Because of the method by which load factors were calculated, the factors provided here should be considered as approximations rather than absolute values. In this analysis, they were included primarily for use relative to other assumed load factors. Table 4 gives the load factors obtained for automobiles and buses for 1970. It should be noted that, although the census data aggregate the bus and the streetcar, all travel in this category was assumed to be by bus, since the only streetcar line presently operating in New Jersey (Newark) is generally considered to be a subway. Later, all other commuter rail travel was aggregated with bus travel. Although railroad cars hold more people per vehicle than buses, in actual operation, their occupancy ratios and energy consumption per passenger-mile (kilometer) were similar. Consequently, it was decided to consider both bus and rail as one mode, transit.

The automobile occupancy for work trips is about 1.2 persons per car (Table 4). This indicates that about 5 out of every 6 workers who drive to work travel alone. Bus occupancy fluctuates widely, from 31.8 passengers in Hudson County to 3.4 passengers in Sussex and Warren Counties.

Energy Consumption per Mode

The energy consumption parameters ϵ_j were obtained from the work of Fels (4). Although Fels included the energy cost of manufacture for both the vehicle and the guideway, only operating energy was used in these calculations. Assessment of only the energy savings achieved by presently available alternatives was desired, considering both the vehicles and the guideway as sunk energy costs. Obviously, any consideration of future alternatives or of an increase in the supply of transportation facilities to meet increases in demand would have to account for energy of manufacture for new components. The following table (4) gives the energy requirements in kilowatt-hours (joules) per vehicle mile (kilometer) for each mode under consideration (1 kW-h = 3.6 MJ):

Mode	Energy Required (kW-h)
Automobile	3.19
City bus	8.66
Rail rapid	15.50

[The 1973 automobile had an internal-combustion engine and weighed 3,600 lb (1630 kg).]

Journey-to-Work Energy

The total energy expended in work trips for 1970 is given in Table 5. In addition to total energy, per capita energy and the ratio of transit energy per passenger-mile (kilometer) to automobile energy per passenger-mile (kilometer) are given. Per capita consumption varies considerably by county. Sussex County consumes about 4½ times as much energy per capita as Hudson County. What accounts for the difference? As determined earlier, energy consumption depends heavily on modal split, average trip length, and average vehicle occupancy. All of these variables are correlated with the overall population density of the respective counties, which is shown for 1970 in Figure 3. Where densities are higher, trip lengths are shorter, more people ride public transit, and the buses and trains are fuller. Even automobile occupancy is higher. Figure 4 shows the correlation between energy consumption and population density by county for New Jersey in 1970.

ALTERNATIVE PATTERNS OF ENERGY CONSUMPTION

Based on the model of energy consumption developed here, the energy savings achievable through the adoption of different policies will now be examined. Several policies will be considered, including car pooling, increasing the efficiency of automobiles, and encouraging people to use public transit.

Table 5. Transportation energy for 1970 work trips.

County	kW-h per Capita	Total Energy (kW-h × 10^3)	Ratio of Transit to Automobile Efficiency
Atlantic	16.9	2,967.8	2.2
Bergen	16.6	14,920.0	5.7
Burlington	21.9	7,086.7	5.0
Camden	13.2	6,061.4	5.0
Cape May	20.7	1,236.3	2.6
Cumberland	19.1	2,324.0	1.5
Essex	8.9	8,343.4	7.8
Gloucester	18.1	3,126.2	4.6
Hudson	7.2	4,394.4	9.4
Hunterdon	25.6	1,783.0	3.5
Mercer	16.4	5,010.7	6.4
Middlesex	22.3	12,993.0	8.2
Monmouth	23.4	10,823.0	2.4
Morris	24.6	9,453.6	3.8
Ocean	34.9	5,149.7	2.0
Passaic	13.9	6,415.0	4.2
Salem	19.7	1,189.8	3.2
Somerset	27.1	5,371.1	7.6
Sussex	32.3	2,505.9	1.1
Union	14.4	2,825.4	6.0
Warren	27.1	2,007.9	1.0
Avg	16.8	120,988.3	5.3

Note: 1 kW-h = 3.6 MJ.

Figure 3. County population density for New Jersey.

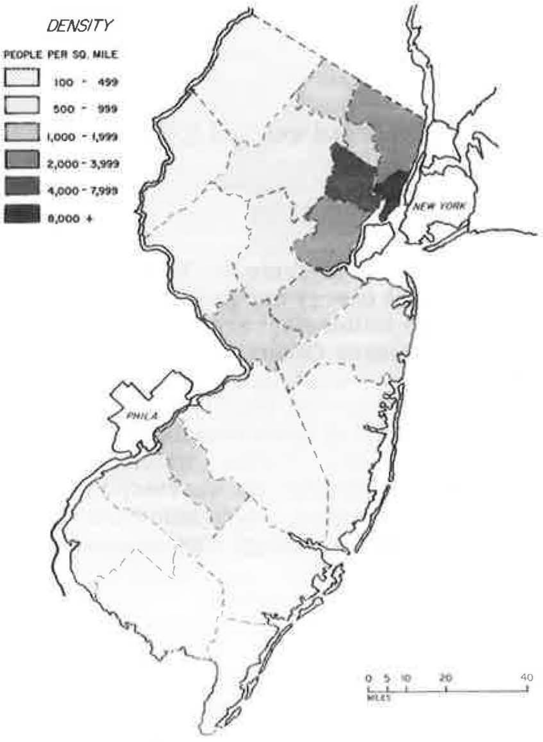
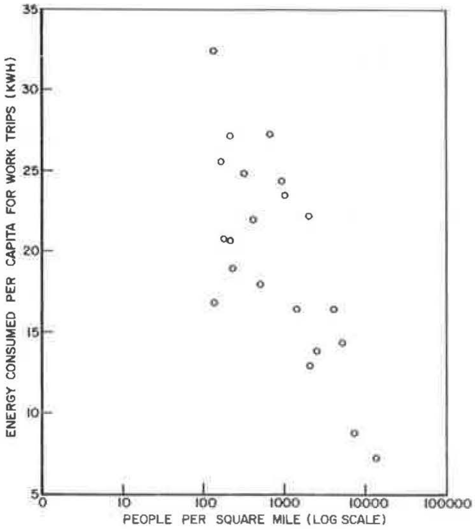


Figure 4. Per capita work trip energy consumption versus county population density for New Jersey.



Energy Savings Through Car Pooling

As stated earlier, the average automobile occupancy for work trips in New Jersey was about 1.2 passengers per car, meaning only about 1 in every 6 drivers were in a car pool in 1970. If everyone shared a ride and the average automobile occupancy rose to 2.0, according to the figures in Table 6, the state would save about 40.7 percent of the journey-to-work energy. If average occupancy rose to 3.0, over 59 percent of the 1970 energy consumed could be saved.

More Efficient Automobiles

If a 25 percent increase in automobile efficiency were achieved, which might be accomplished by reducing average car weight to 2,400 lb (1090 kg) and by increasing fuel economy to achieve 20 miles/gal (8.5 km/liter), the overall energy savings would amount to 25.3 percent, as given in Table 7 (3). If even smaller cars were driven, weighing about 1,800 lb (816 kg) and getting about 25 miles/gal (10.6 km/liter), similar to the Honda CVCC, the savings would be almost 52 percent of the energy used in 1970. Finally, if car pooling were combined with the use of small cars, an energy savings of 70.7 percent of 1970 consumption could be achieved.

Energy Savings Through Public Transit

For evaluation of energy savings to be achieved through more effective use of public transit, the energy consumed per vehicle mile (kilometer), ϵ_j, was not varied although this is certainly possible within limits. For this analysis, α_j^w, the percentage of people using public transit for work, and λ_j, the average number of passengers, were varied. Four strategies were tested:

1. Shifting 10 percent of all automobile travelers to public transit and holding the 1970 load factors constant;
2. Shifting 30 percent of all automobile travelers to public transit and increasing the load factors to 25 (this represents approximately 50 percent bus occupancy);
3. Shifting one-half of all automobile commuters to public transit and increasing the load factors to 40 (about 80 percent of bus capacity); and
4. Shifting 50 percent of all automobile commuters to public transit (the remaining 50 percent uses small cars).

It should be noted that a shift of only 10 percent of all automobile commuters to public transit would nearly double present transit ridership, and in some counties transit ridership would have to increase tenfold. The results of this analysis are given in Table 8. A 10 percent shift results in a savings of only 8.8 percent. The 30 and 50 percent shifts to transit result in 26.5 and 46.4 percent savings respectively. The biggest savings, 72.3 percent, would be achieved through a shift of 50 percent of all automobile commuters to public transit; the remaining drivers would travel to work in small cars that are 53 percent more efficient than the cars of 1970.

POLICY RECOMMENDATIONS AND PRIORITIES

The preceding analysis has provided insight into the results of several alternative transportation policies. All of these would have a significant impact on patterns of energy consumption, but they would have profound effects on life-styles as well, perhaps in ways not altogether favorable. Now, the implications of these policies will be examined in more detail.

Table 6. Effects of car pooling on energy consumption.

	Energy Saved by Increasing Automobile Occupancy (percent)			Energy Saved by Increasing Automobile Occupancy (percent)	
County	2 People	3 People	County	2 People	3 People
Atlantic	39.2	57.6	Middlesex	41.9	60.8
Bergen	41.0	59.5	Monmouth	40.3	58.4
Burlington	42.2	61.1	Morris	42.3	60.8
Camden	39.1	58.2	Ocean	42.1	60.7
Cape May	42.1	61.0	Passaic	40.0	58.9
Cumberland	40.9	60.3	Salem	38.1	58.7
Essex	38.6	57.4	Somerset	42.2	60.4
Gloucester	41.1	60.3	Sussex	41.7	60.4
Hudson	35.2	54.5	Union	40.4	50.3
Hunterdon	43.4	61.9	Warren	40.8	60.2
Mercer	39.9	59.4	Avg	40.7	59.4

Table 7. Energy savings due to increased automobile efficiency.

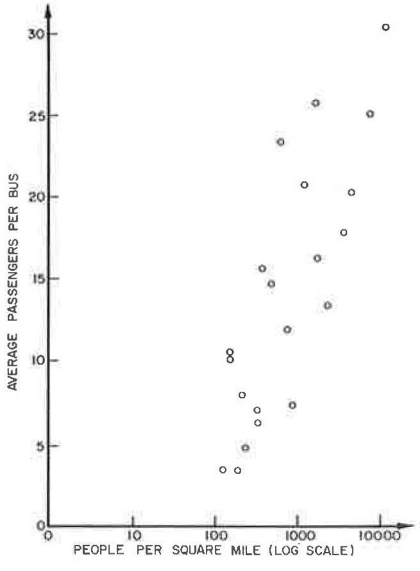
	1970 Energy Saved (percent)		
County	25 Percent More Efficient Car	53 Percent More Efficient Car	53 Percent More Efficient Car With 2 People[a]
Atlantic	23.7	50.4	68.7
Bergen	24.2	51.4	70.6
Burlington	24.8	52.7	72.4
Camden	24.1	51.3	69.6
Cape May	24.8	52.6	72.3
Cumberland	24.9	52.9	72.0
Essex	23.8	50.6	68.7
Gloucester	24.7	52.6	71.8
Hudson	23.3	49.5	65.9
Hunterdon	24.8	52.8	73.0
Mercer	24.7	52.5	71.1
Middlesex	24.7	52.6	72.2
Monmouth	23.7	50.4	69.3
Morris	24.5	52.1	71.9
Ocean	24.5	52.1	71.8
Passaic	24.2	51.5	70.2
Salem	25.0	53.2	71.0
Somerset	25.4	51.6	71.3
Sussex	24.5	52.1	71.6
Union	24.4	51.8	70.6
Warren	24.8	52.7	71.8
Avg	24.3	51.7	70.7

[a] Average.

Table 8. Potential energy savings due to public transit.

County	Energy Saved (percent) 10 Percent Shift to Transit, 1970 Load Factor	30 Percent Shift to Transit, 50 Percent Load Factor	50 Percent Shift to Transit, 80 Percent Load Factor	50 Percent Shift to Transit, Use of Small Cars
Atlantic	5.1	28.7	48.0	73.2
Bergen	8.0	26.3	46.4	72.1
Burlington	8.9	26.3	46.3	72.6
Camden	7.7	26.5	46.5	71.9
Cape May	6.0	26.8	46.5	72.8
Cumberland	3.5	26.6	46.3	72.8
Essex	8.3	24.8	45.6	70.9
Gloucester	7.7	26.4	46.3	72.6
Hudson	8.3	24.9	44.0	68.7
Hunterdon	7.0	26.6	46.5	72.8
Mercer	8.3	26.0	46.0	72.2
Middlesex	8.7	25.6	46.0	72.3
Monmouth	5.5	28.6	48.2	73.2
Morris	7.2	26.9	46.2	72.7
Ocean	4.9	27.4	47.0	73.0
Passaic	7.4	26.9	46.7	72.5
Salem	6.8	26.0	45.9	72.5
Somerset	8.4	25.7	46.0	71.8
Sussex	0.8	27.6	47.1	73.2
Union	8.1	26.1	46.2	72.1
Warren	0.6	26.9	46.5	72.9
Avg	8.8	26.5	46.4	72.3

Figure 5. Average public transit load factors versus county population density for New Jersey.



Car Pooling

It is clear that significant energy savings can be achieved through car pooling, especially if smaller automobiles are used. It would seem that this method of energy conservation would have the least impact of all on current life-styles. Current patterns of residence and employment are not affected, and most people could continue to drive larger cars if they preferred. The difficulties with car pooling are several. First, if car pools are to be effective, large numbers of individuals would have to voluntarily agree to car pool since there seems to be slight chance of imposing enforceable and effective car pool regulations. Second, many people do not live close to individuals with whom they share similar work destinations. Third, many people do not find car pooling acceptable because of incompatibility with other riders, lack of privacy, and schedule constraints. Fourth, the energy savings achieved through car pooling may not be extendable to other trip purposes since many other types of trips now have higher automobile occupancy rates and are not amenable to further increases.

On the whole, however, significant energy savings from car pooling could be achieved in relatively short time through incentive policies such as preferential parking, exclusive lanes, reduced tolls, and automobile insurance subsidies.

Automobile Efficiency

Of all policies examined, the most dramatic savings were achieved through increasing the energy efficiency of the automobile. Although most Americans seem to prefer larger cars, this policy seems to offer the least need for readjustment of patterns of living and traveling. Technologically, efficiency increases of the magnitudes used in this analysis are possible today, and some current car models meet the standards of the most efficient automobile tested here. It is certain that the automobile industry would be opposed to regulations requiring smaller, more efficient cars, as might some automobile safety advocates since smaller cars sustain more damage in collisions with stationary obstacles and larger cars. The energy savings, however, are great, and unlike those of car pooling could be extended uniformly to other trip purposes.

To obtain energy savings from small-car ownership, the state would necessarily require rigid automobile efficiency standards or high registration fees for large cars or both. Higher taxes on gasoline would also deter large-car ownership but probably not sufficiently to achieve great savings. Taxes paid at the time of purchase, however, have the effect of stimulating both consumer and producer to alter the sales market for automobiles in favor of smaller cars. In fact, one of the major recommendations of the task force on energy was the restructuring of the present automobile registration fee schedule to encourage the purchase of more efficient automobiles. A formula was developed in which the registration fee for an automobile would be proportional to its weight and engine displacement and inversely proportional to its age and passenger capacity.

Public Transit

Public transit, although much more efficient per vehicle mile (kilometer) than the automobile, could not provide an energy savings comparable to that achieved through more efficient automobiles and car pooling. There are several reasons for this. First, the automobile currently accounts for so large a share of work travel that even slight increases in automobile efficiency or automobile occupancy have a large impact on total energy consumption. Conversely, public transit carries so few riders on work trips that only large increases in ridership have a significant effect in reducing energy consumption. Second, transit load factors are generally quite low, compared to vehicle capacity. Full buses are much more energy efficient than those with only a few passengers. Average load factors depend on a number of characteristics of the system and the region served. Transit routes that pick up large numbers of people at one point and that transport all of them to a common destination will have high load factors. Routes that have many stops and offer frequent service will have lower load factors. Routes that offer frequent service in off-peak hours will also have lower load factors. In general, routes that serve areas of low population density will have low load factors. The relationship between population density and public transit load factors for 1970 is shown in Figure 5. There is a strong correlation between the two measures.

Because of the strong relationship of transit load factors to population density, one may conclude that the greatest energy savings from public transit could be achieved in those counties of greatest population density. Public transit would also be most energy efficient for longer trips between highly concentrated areas.

In recommending improvements to our public transit system to achieve savings in transportation energy, one must quickly point out that such improvements are costly and that provision of transit service is influenced by other factors such as the provision of service to specific social groups, the reduction in congestion and localized pollution, and the stimulation of economic activity. These factors may work to reduce energy efficiency but are often socially desirable.

Trip Length

In this analysis, strategies to reduce trip length were not treated primarily since it is not clear how to achieve this fundamental way of reducing travel. That a great deal of cross-commuting occurs between counties and states leads one to suspect that improvements in dissemination of information on local employment opportunities might help people find jobs nearer their homes. It might also be possible to encourage a more diversified range of housing opportunities in each community so that workers of all classes would have more chance to find housing in the communities in which they work. In the final analysis, the greatest savings that can be achieved require an overall state land use policy that shapes development into higher density clusters rather than continuous low-density sprawl. Higher densities mean shorter trip lengths and greater effectiveness for public transit systems.

Policies With Potential Negative Impact

Two correlated policies frequently mentioned in energy conservation strategies are restriction of urban parking and increased suburban bus service. These policies are singled out here because they may actually lead to increases rather than decreases in long-term patterns of energy consumption. The probable result of disincentives to parking in urban areas will be an increase in the already significant competitive advantage of suburban shopping and employment centers and the long-run encouragement of more dispersed trip patterns. Increased suburban bus service to low-density areas, unless it is carefully planned to ensure high vehicle occupancy, will most likely result in transit service with low load factors and inefficient utilization of energy.

CONCLUSIONS

Based on this analysis of work trip energy consumption, it is clear that New Jersey must adopt a multimodal approach to transportation planning, which stresses the most desirable aspects of each mode. First priority should be given to the implementation of policies designed to encourage the use of smaller, more economical cars. Second priority should be given to the development of public transit in the areas in which it is most effective: high-density urban areas and heavily traveled corridors. In many areas, rail should be given priority over bus, since rail can better serve longer trips and achieve higher loadings. In addition, electrification of rail systems, although it does not significantly reduce energy consumption, will allow future flexibility in choice of fuels, as petroleum resources diminish. Third priority should be given to the reduction of unnecessary travel, possibly in the area of personal use of trucks and other energy-intensive vehicles. Finally, a long-term commitment is needed to the development of coordinated statewide transportation land use planning as the ultimate mechanism for reducing the consumption of transportation energy.

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