TRANSIT ACCESSIBILITY AS A DETERMINANT OF AUTOMOBILE OWNERSHIP

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Automobile ownership is generally accepted as the most important determinant of the number of trips made by residents of a traffic zone. For this reason, the way in which it is forecast can have a dominant influence on a regional travel forecast. Because most automobile ownership forecasts have been independent of the transportation alternatives being tested, a major portion of the regional travel demand was set prior to the distribution of travel and the allocation among modes. This paper analyzes the relation between transit accessibility and automobile ownership by eliminating variations in family size and income through a household analysis. The findings show that there is a significant correlation between automobile ownership and transit accessibility for almost every category of automobile ownership in an area by improving transit accessibility. Such a finding could have a major effect on estimates of regional travel demand in areas where major transit improvements are made. Furthermore, reductions in future regional automobile ownership levels that would accrue from a major transit improvement could be considered as a benefit of the transit improvement. These findings could tend to make transit investment slightly more favorable than when the only benefits considered are improved ridership for existing transit users and some diversion of trips from automobile to transit.

•RESEARCH into the demand for urban transportation has shown that automobile ownership is the variable that exhibits the closest association with reported trip generation rates (1). Moreover, when used as a variable to estimate the relative use of different travel modes, automobile ownership rates are much more important than other variables (2). Because of the major importance of automobile ownership in forecasting travel demand, the way in which automobile ownership rates are forecast can be the primary determinant of the amount of travel demand on a future network.

This research has investigated the relation between the transportation system and automobile ownership. Specifically, the effect of variations in transit accessibility on levels of automobile ownership has been analyzed.

PREVIOUS RESEARCH

In a review of previous research of methods of estimating automobile ownership, Deutschman found that the three variables most commonly used were family size, income, and residential density (3). The size of the family largely determines the amount of travel that would be made by that household in the absence of any financial constraints. The income of the family determines the extent to which travel demands can be satisfied through the ownership of one or more automobiles. Residential density determines the percentage of travel desires that can be satisfied by walking trips, which are not counted in the traditional travel survey. In very high-density areas, it is possible for a large percentage of people to walk to shops, schools, recreation, and even work. In low-density areas, only persons living adjacent to shopping centers generally walk to them. Residential density may be considered to be a location variable because it affects the number of opportunities that can be reached from a location in a given amount of time.

It is normally greatest near the central business district (CBD) and declines regularly with increasing distance from the center of the region.

From the perspective of the transportation systems planner, the use of only these independent variables in predicting car ownership, and eventually the number of trips, makes the resulting forecast independent of the transportation system. In testing transit alternatives, this means that the number of transit trips is largely predetermined regardless of the type of system tested. In an attempt to overcome this analysis difficulty, Ferrari and Shindler (2) found that automobile ownership rates varied with the relative level of service provided between the transit and highway systems. This relative transit accessibility is actually a location variable similar to residential density because it indicates the number of opportunities that can be reached from an origin in different time intervals. It tends to be highest in the core of the region and to decline with increasing distance from the CBD. This relation is caused by the centralized orientation of most transit systems. Because of this orientation, transit service tends to be best in the downtown area and progressively worse with increasing distance from the core.

Besides affecting automobile ownership, transit accessibility was shown to be related to those other factors that are accepted as determinants of automobile ownership—family size, income, and residential density. For this reason, some questions have been raised about whether transit accessibility can actually affect automobile ownership or whether it is simply correlated with other factors that are more causative in nature. For example, it has been suggested that transit accessibility is an effect rather than a cause of car ownership. If transit service were provided to a greater extent only in low-income or high-density residential areas, which were assumed to generate the patronage needed to support transit service, then the relation between car ownership and transit accessibility would be meaningless for affecting total transit demand. One of the problems with this type of analysis is that it deals with aggregates of car ownership, income, and family size for an area. However, recent work in trip generation analysis identifies a need for household analysis, in which the basic unit is not an average rate for a traffic zone but rather the average rate for an individual household. Such disaggregate analysis might solve some of the problems previously mentioned (4).

APPLICATION OF HOUSEHOLD ANALYSIS

A major criticism of Ferrari and Shindler's work related to the use of average household characteristics for a traffic zone as the independent variables. Because both family size and income were correlated with transit accessibility, it was difficult to determine the exact relation between car ownership and transit accessibility with all other characteristics held constant. One way to control variations in household characteristics is to perform a household analysis in which the basic observation is an individual interview rather than a zonal average. This type of analysis has been recommended for studies of trip generation, primarily because it attempts to explain more of the basic variation in trip-making (5).

The latter type of analysis was used in this study. The basic data were developed from a home-interview survey conducted by the National Capital Region Transportation Planning Board (TPB) and Metropolitan Washington Council of Governments (COG) in 1968. The data were disaggregated by type of household, which made it possible to formulate for each type of household a simple linear regression.

$$Y_{is} = a + bX$$

where

Y_{is} = the number of automobiles owned by a household of a given income and size,
X = the transit accessibility available to that household, and
a, b = regression coefficients calculated by standard least squares techniques.

Household Categories

Disaggregation of households into individual categories for this analysis makes it possible to eliminate the effect of correlation between the independent variables. Furthermore, it permits a test of whether automobile ownership can be affected by transit accessibility for some types of households but not for others. For example, it could show that those households that would be most willing to exchange automobile ownership for transit accessibility might be small households (especially those with only one person) and very poor households. It would also seem logical that there would be less of a possibility to reduce car ownership through increased transit accessibility for larger, higher income families.

Because of the need to preserve as much of the original variation in the data as possible, grouping of types of households was kept to a minimum. Plotting the relation between car ownership and income for different sizes of households showed that, for any income group, a plateau seemed to be reached for car ownership in families with more than three persons. As shown in Figure 1, it seemed that larger households did not have higher automobile ownership rates. To maintain a larger sample size, all households with more than four persons were combined with the four-person category. Each of the original 10 income groups coded in the survey was used. Table 1 gives the number of samples in each category.

Transit Accessibility

It was mentioned previously that transit accessibility, like residential density, is a location variable. It reflects not only the spatial distribution of opportunities about a point but also the relative speed with which these opportunities may be reached by a given transportation system. Because the distribution of opportunities about a point is a result of development density and location, transportation accessibility is actually a density measure that also incorporates network speed. The measure of transit accessibility currently being used at COG for work travel is the percentage of jobs reached from an area in 45 min by transit (6). It was determined that, in 1968, the average worker could reach three-quarters of the regional employment in 45 min by the fastest mode (usually highway). Because this time boundary accounted for 9 out of every 10 work trips, it was felt to be a representative boundary for commuting travel.

FINDINGS

As given in Table 2, the calculated F-ratios between automobile ownership and transit accessibility were significant at the 99 percent level of confidence for all but three categories. These three categories were one-person households with annual incomes of $4,000 to $5,999; one-person households with annual incomes of $20,000 to $24,999; and households having four or more persons with annual incomes of more than $25,000.

Not only does this analysis show that there is generally a significant correlation between car ownership and transit accessibility to employment, but also it shows that the three exceptions do not follow a clear pattern. Except for the highest income households of four persons or more, transit accessibility to employment appears to have a significant impact on the number of cars owned. Moreover, as shown in Figures 2 through 5, the effect of transit accessibility on car ownership is approximately the same at all income levels for a given family size. Although increasing income results in a higher level of car ownership with a constant family size and accessibility for almost all of the regression equations, the slopes of the curves are very similar for different income categories within a particular household size. The exact equations are given in Table 3.

SUMMARY

This study has shown that there is a statistically significant relation between automobile ownership and transit accessibility, even when the other significant household characteristics of family size and income are held constant. It appears that a high level of accessibility to employment by transit may reduce the need to own cars. This

Figure 1. Relation between average car ownership and household income.

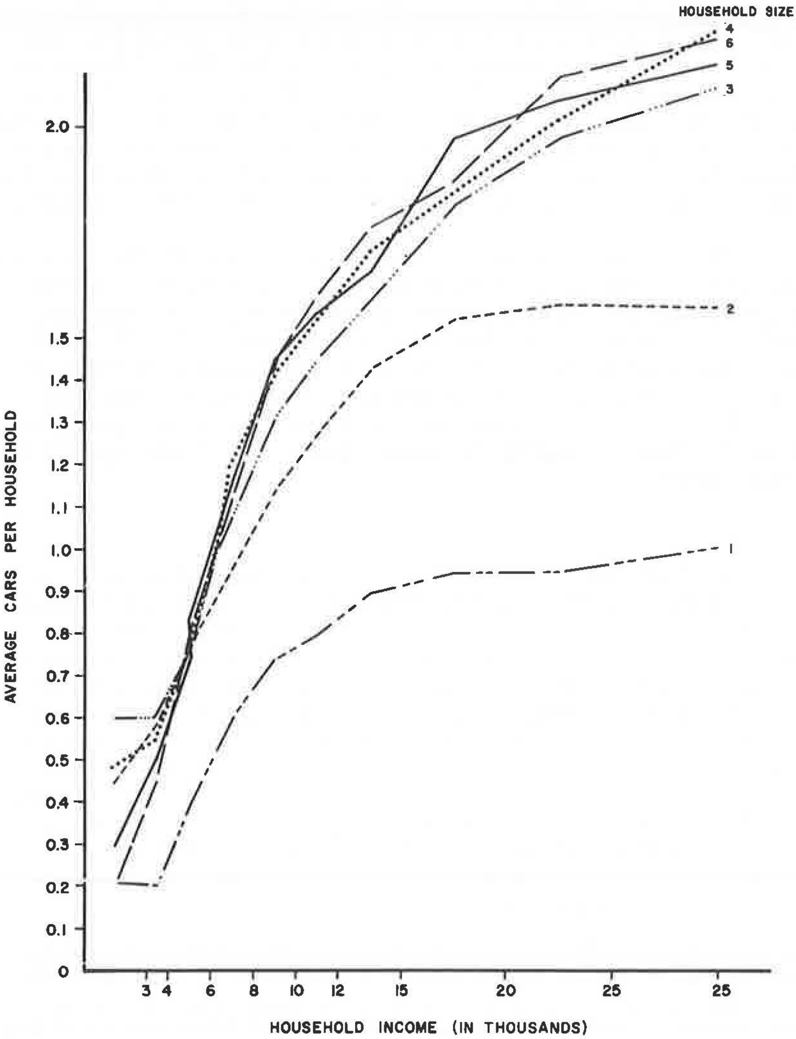


Table 1. Distribution of samples by household characteristics.

1968 Annual Household Income (thousands of dollars)	Number of Persons in Households				
	1	2	3	≥4	Total
0 to 3	1,871	300	110	126	2,407
3 to 4	593	393	107	127	1,220
4 to 6	784	939	318	410	2,451
6 to 8	882	1,437	567	788	3,674
8 to 10	536	1,505	730	1,130	3,901
10 to 12	360	1,397	723	1,307	3,787
12 to 15	228	1,266	722	1,425	3,641
15 to 20	129	921	602	1,356	3,008
20 to 25	38	378	306	683	1,405
>25	36	312	217	486	1,051
Total	5,457	8,848	4,402	7,838	26,545

Table 2. Calculated F-ratio for regression equations.

1968 Annual Household Income (thousands of dollars)	Number of Persons in Household: 1	2	3	≥4
0 to 3	32.13	75.67	19.37	26.56
3 to 4	58.45	62.02	21.22	43.94
4 to 6	5.04[a]	184.34	80.24	92.55
6 to 8	139.58	273.33	95.35	200.00
8 to 10	90.12	303.71	108.40	178.92
10 to 12	72.34	194.74	71.31	159.48
12 to 15	38.14	226.74	61.25	121.08
15 to 20	15.52	120.12	51.04	176.98
20 to 25	6.86[a]	25.07	22.04	31.42
>25	9.12	55.61	16.91	1.75[a]

[a]F-ratio is not statistically significant at the 99 percent level of confidence.

Figure 2. Relation between car ownership and transit accessibility to employment (one-person household).

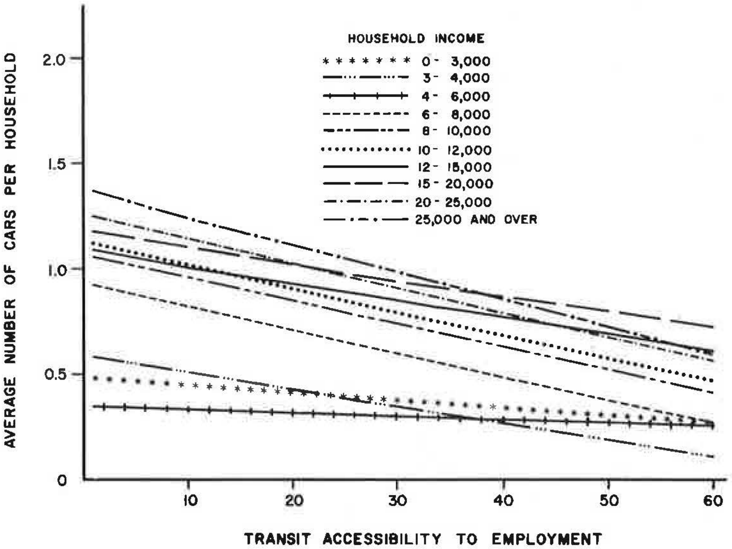


Figure 3. Relation between car ownership and transit accessibility to employment (two-person household).

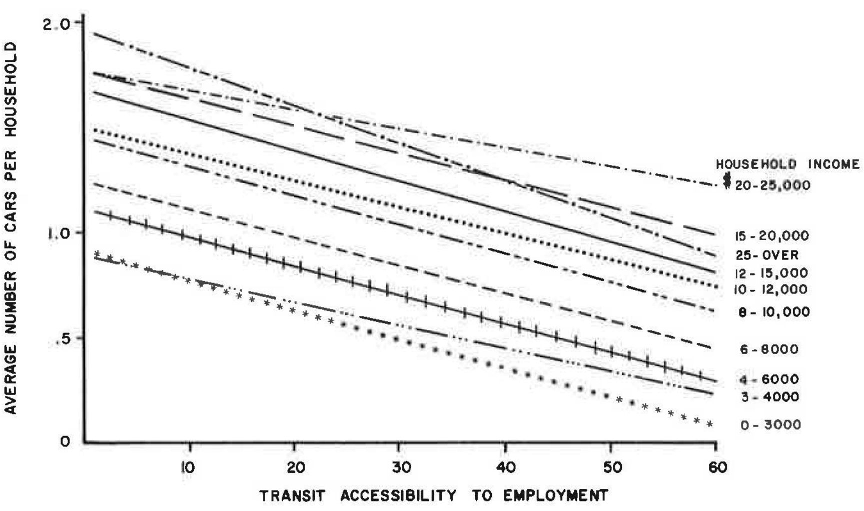


Table 3. Summary of car ownership regression equations.

Income (thousands of dollars)	Number of Persons in Household	Regression Equation[a]	r	s_y	$s^2_{y \cdot x}$
0 to 3	1	Y = 0.4835 - 0.3621 x	-0.13	0.57	0.32
	2	0.9155 - 1.4155 x	-0.45	0.59	0.28
	3	1.2202 - 1.9705 x	-0.39	0.87	0.64
	≥ 4	1.0234 - 1.8983 x	-0.42	0.74	0.44
3 to 4	1	Y = 0.5727 - 0.7619 x	-0.30	0.48	0.21
	2	0.8775 - 1.0898 x	-0.37	0.60	0.31
	3	1.0461 - 1.5119 x	-0.41	0.73	0.45
	≥ 4	1.1950 - 2.0075 x	-0.51	0.69	0.35
4 to 6	1	Y = 0.3512 - 0.1581 x	-0.08	0.48	0.23
	2	1.1163 - 1.378 x	-0.41	0.65	0.36
	3	1.2547 - 1.7369 x	-0.45	0.78	0.49
	≥ 4	1.2465 - 1.7048	-0.43	0.77	0.48
6 to 8	1	Y = 0.9189 - 1.0924 x	-0.37	0.55	0.27
	2	1.2572 - 1.363 x	-0.40	0.65	0.36
	3	1.3507 - 1.4926 x	-0.38	0.70	0.42
	≥ 4	1.5059 - 1.8386 x	-0.45	0.76	0.46
8 to 10	1	Y = 1.0758 - 1.1074 x	-0.38	0.54	0.24
	2	1.4552 - 1.4696 x	-0.41	0.68	0.39
	3	1.5276 - 1.4741 x	-0.36	0.70	0.43
	≥ 4	1.681 - 1.6601 x	-0.37	0.74	0.48
10 to 12	1	Y = 1.1282 - 1.1184 x	-0.41	0.50	0.21
	2	1.4973 - 1.2614 x	-0.35	0.66	0.38
	3	1.6601 - 1.3139 x	-0.30	0.74	0.50
	≥ 4	1.7705 - 1.5363 x	-0.33	0.75	0.51
12 to 15	1	Y = 1.108 - 0.8452 x	-0.38	0.41	0.14
	2	1.6801 - 1.4404 x	-0.39	0.65	0.36
	3	1.7991 - 1.1838 x	-0.28	0.72	0.48
	≥ 4	1.8834 - 1.3035 x	-0.28	0.74	0.50
15 to 20	1	Y = 1.1858 - 0.8889 x	-0.33	0.48	0.21
	2	1.7611 - 1.3001 x	-0.34	0.65	0.38
	3	1.9945 - 1.2122 x	-0.28	0.75	0.52
	≥ 4	2.1207 - 1.6754 x	-0.34	0.76	0.51
20 to 25	1	Y = 1.2577 - 1.1307 x	-0.40	0.53	0.24
	2	1.7546 - 0.8933 x	-0.25	0.62	0.36
	3	2.1536 - 1.1953 x	-0.26	0.76	0.54
	≥ 4	2.2535 - 1.1827 x	-0.21	0.81	0.63
>25	1	Y = 1.372 - 1.2995 x	-0.46	0.51	0.20
	2	1.9547 - 1.7736 x	-0.39	0.74	0.46
	3	2.324 - 1.3818 x	-0.27	0.82	0.62
	≥ 4	2.3994 - 0.4185 x	-0.06	0.95	0.90

[a] Y = average cars per household, and x = ratio of regional employment reached in 45 min by transit.

Figure 4. Relation between car ownership and transit accessibility to employment (three-person household).

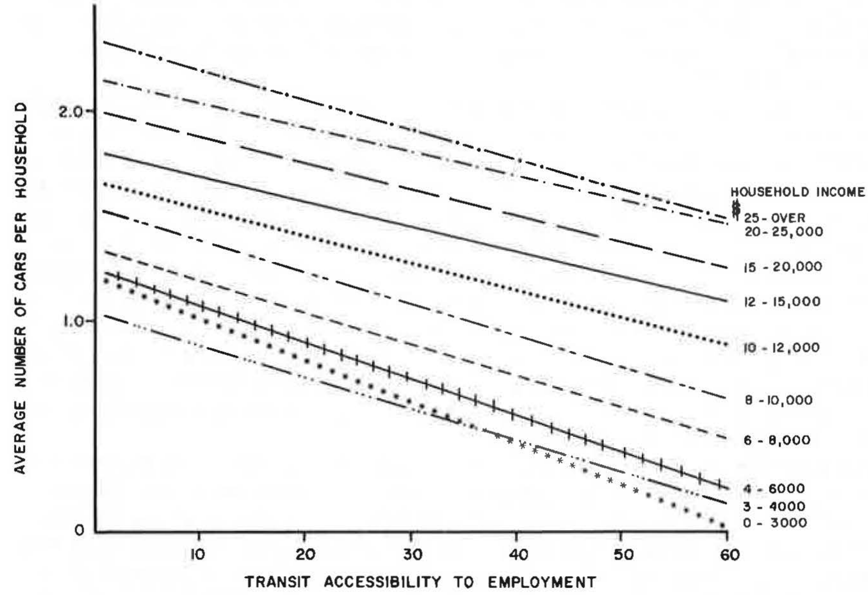
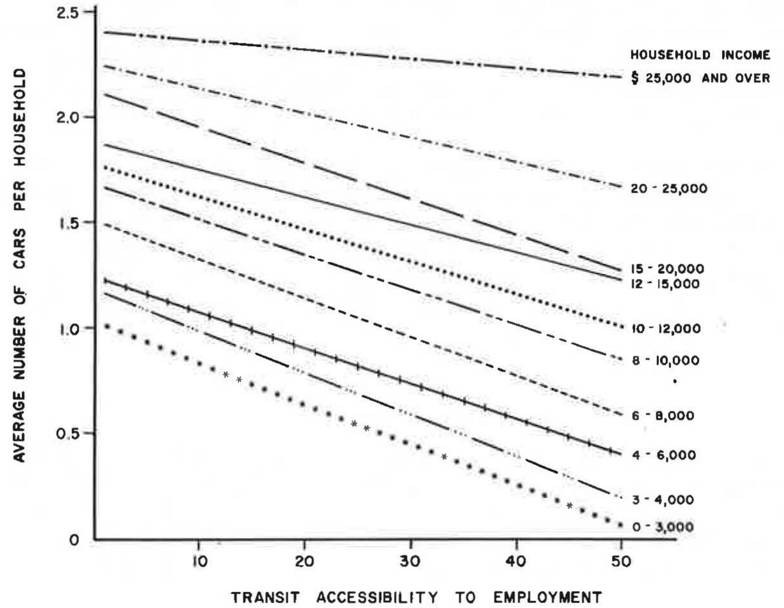


Figure 5. Relation between car ownership and transit accessibility to employment (household of four or more persons).



effect might be to eliminate the need for a second car in two-car families or perhaps to make it possible for some households to exist without any car. In both cases, the family is simply trading off its expenditure for automobile travel for a public expenditure for transit services. In fact, in some cases this may not even be a complete shift of travel from automobile to transit, but simply an awareness that the transit system is there if it were ever needed.

This analysis has dealt entirely with employment-related transit accessibility. This does not mean, however, that those households having a lower level of car ownership because of high transit accessibility to jobs are not also able to use the transit system for other purposes. Although the measurement of accessibility for nonwork purposes is much more complex than that for work purposes, it is likely that this type of accessibility may also affect automobile ownership. In fact, those areas with the highest level of transit accessibility for work trips also have the highest level of accessibility for nonwork travel. The most important effect of transit accessibility may be to eliminate the need for an extra car to go to work. However, a high level of accessibility to nonwork destinations may make it possible for some of the other trips that would have been made in the car to be completed by transit. Innovative transit services such as dial-a-ride may be able to generate sufficient accessibility to nonwork destinations to reduce the need for multiple-car ownership.

Although this analysis deals with a single point in time, it is possible to assess the effect of policy changes over time. For a given point in time, a significant relation has been determined between automobile ownership of different households and transit accessibility to employment of those households. It is not unreasonable to suggest that, for a given household or group of households, a vastly improved transit accessibility may reduce the number of automobiles owned. In fact, a survey of riders on a special commuter bus service in Reston, Virginia, showed that many riders had already reduced the number of cars owned by their families as a result of the service (7).

This analysis has given further support to the theory that provision of good transit service can affect the automobile ownership rate in an area. The magnitude of this effect was shown in an evaluation of a proposal for a new town in the Washington area that included a special transit system. Given the forecast of resident income and family size characteristics, it was found that the level of automobile ownership would be 26 percent below that that would be expected in a similar suburban community with average transit service. A comparable reduction in automobile trip generation could also be expected.

Reductions in automobile travel constitute a public sector benefit, especially if they result in a reduction in highway construction or operation costs. However, the benefits of reducing automobile ownership can be much more significant to the individual. Because the cost to own and operate an automobile can average more than $1,300 per year (8), provision of transit services that eliminate the need for a second car could be a measurable benefit to multicar households. If such benefits are included in the evaluation of proposed transit improvements, it may be possible to justify a higher level of transit service than that that currently exists in many suburban areas.

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