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ACCESSIBILITY AND AUTO USE IN A MOTORIZED METROPOLIS

by

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Introduction

Studies in earlier stages of motorization looked into the ownership and use of automobiles as a function of population density and public transit service levels. The issue then was how to cope with the wave of motorization, and how much infrastructure would be needed. As motorization progressed, it has become increasingly evident that the traffic congestion "problem" cannot be solved by building more road infrastructure (e.g., Downs, 1992). Alternatives to infrastructure expansion, such as travel demand management (TDM) schemes, are being considered and implemented in many urban areas of North America, Europe and Japan. One common aim of these schemes is to reduce trips by single-occupant vehicles by inducing solo drivers to ride-share, take public transit, walk, ride a bicycle, or work at home.

One approach to achieve this objective is to make the use of automobiles more costly by means of congestion pricing, parking surcharges, or increased gasoline taxes, or to adopt a regulatory approaches such as odd-even license plate schemes or mandating a certain minimum vehicle occupancy for auto commuters as in Regulation XV. It is unlikely, however, that a consensus can be attained to implement such schemes (Downs, 1992; Kitamura et al., 1999). This has been eloquently revealed by the shift from congestion pricing in ISTEA to "value pricing" and "HOT lanes" in TEA-21. Congestion pricing as implied by economic theory, which increases the monetary cost of auto travel, did not receive political support, while HOT lanes, which offer to solo drivers a new option of paying for a better service and improve the traffic condition on mixed-use lanes, enjoy their popularity and a number of projects are being proposed nationwide (ITE, 1998). In fact an inspection of the congestion pricing projects under ISTEA and TEA-21 would reveal that there is no project that has been implemented in which the cost of solo driving is made higher. An exception, the proposed San Francisco Bay Area project, never materialized. There is thus a clear indication that a scheme that increases the cost of auto travel will not be tolerated.

If it is desired to induce solo drivers to take another means of travel, but the cost of driving cannot be increased, then the option that is left is to improve the quality of alternatives to solo driving by, say, improving public transit. Although this could be a very inefficient and costly proposition (Downs, 1992), it appears to be the cost that must be born by society. Theoretically it is possible that people live conveniently in transit-oriented “enclaves” with lower levels of auto ownership and use. If such enclaves can be created, then less auto-oriented urban development seems possible. More generally, it is often argued that auto ownership and use can be suppressed by improving public transit. Is this in fact the case?

Study after study has shown a negative association between residential density and auto ownership (e.g., Beesley and Kain, 1964). Since public transit service is generally positively associated with residential density, a negative association can be found between auto ownership and transit service (e.g., Fairhurst, 1975). Burns and Golob (1976) found accessibility terms highly significant in their utilitarian models of auto ownership that were estimated using a 1965 data set from the Detroit metropolitan area. These findings in the literature, however, are from earlier stages of motorization. It is not clear if the same association can be expected when it has become a norm to own as many automobiles as drivers in the household, and the automobile has established itself as the predominant means of travel in most urban areas. Can one reasonably expect that auto ownership and use can be appreciably reduced by improving public transit service levels?

Effects of automobile and transit accessibility on vehicle holding, vehicle type choice, and use, are examined in this study using data from the South Coast metropolitan area. Household-based models are developed for: the total number of vehicles available to the household, the number of vehicles per household member and that per driver in the household, the choice of vehicle type for the most recently acquired vehicle, and its use (in terms of annual mileage). In each model, indicators of accessibility by auto and that by transit are introduced, along with residential density and other indicators of residence area, and household attributes. The objective is to assess whether transit accessibility affects auto ownership, vehicle type choice, or use, in such an auto-dominated area as the South Coast region, through statistical analysis of survey data.

Data and Accessibility Indices

The data used in this study are from the first wave survey of a panel study whose aim was to provide revealed-preference (RP) and stated-preference (SP) data for the assessment of the demand for electric vehicles in California. The panel surveys took on the form of customized computer-aided telephone interviews with written survey instruments mailed to the respondents. Sample households were obtained by random digit dialing with area code used for geographical stratification. The first wave survey was conducted in 1993 and the resulting sample contains 4,747 households from most of the urbanized areas in California, excluding San Diego County. In this study, a sub-sample of 1,898 households from the South Coast metropolitan area is used (as the tables in the subsequent sections will show, the sample size varies from model to model as small numbers of households are excluded due to missing data). Of these 1,898 households, 19 (1.00%) had no vehicle available, 675 (35.6%) had one vehicle, 880 (46.4%) had two vehicles, 231 (12.17%) had three vehicles, and 93 (4.90%) had four or more vehicles available at the time of the survey.

The accessibility indices used in this study are based on multinomial logit destination choice models developed using the results of the 1991 home interview travel survey conducted by the Southern California Association of Governments (SCAG) along with accompanying zone-based land use and network data (Kitamura et al., 1998). The so called log-sum index of the multinomial logit model is used as a measure of accessibility (Ben-Akiva and Lerman, 1979), namely,

$$I_i^m = \ln \sum_{\forall j \in C_i} \exp(V_{ij}^m)$$

where

I_i^m = the accessibility index for zone i and purpose m,
V_{ij}^m = the utility, for a traveler in zone i, of destination zone j for purpose m, and
C_i = the set of destination zones for a traveler in zone i.

The destination choice models of Kitamura et al. (1998) contains as their explanatory variables: time of day, activity duration at the destination zone, and selected demographic and socio-economic variables. The accessibility indices of this study are developed using the models for home-based trips with non-work purposes (shopping and recreational), for a trip starting time of 1:00 P.M., an activity duration of 30 minutes, assuming that a traveler is a male.

Public transit travel time data are not available for a number of zone pairs. With the interpretation that a pair of zones is not connected by public transit in case transit travel time is missing in the data file, the transit travel time is set at infinity for these zone pairs. The value of $\exp(V_{ij}^m)$ reduces to 0 in this case. Occasionally there are zones whose public transit accessibility index becomes negative infinity computationally or is undefined because the number of destination zones for which transit travel time is available is too small or transit travel time is not defined at all. This is indicated in the models of this study by a dummy variable, “Public transit accessibility undefined.”

Vehicle Holding Models

The number of vehicles available to the household is modeled as ordered-response probit models in this study. Two models are presented in Table 1, one without accessibility indices and other measures of residence zone characteristics (Model 1) and the other with these measures (Model 2).

Table 1. Ordered-Response Probit Models of Household Vehicle Holdings

Explanatory Variables	Model 1		Model 2	
	Coef.	t	Coef.	t
Constant	0.657	2.00	0.866	2.29
Household Attributes				
Household size	-0.125	-3.67	-0.131	-3.73
Number of licensed drivers	0.962	17.09	0.970	16.90
Number of workers	0.199	4.79	0.200	4.72
Number of members of 21 years old or older	0.181	3.35	0.202	3.65
Household of a male-female couple (D)	-0.154	-1.68	-0.165	-1.79
Single-person household (D)	-0.735	-6.38	-0.748	-6.40
Household annual income ≤ $30,000 (D)	-0.306	-4.09	-0.321	-4.23
Household annual income > $60,000 (D)	0.117	1.50	0.124	1.60
Owns home (D)	0.361	4.38	0.356	4.18
Single family housing (D)	0.264	3.35	0.233	2.80
Private parking space available (D)	0.188	2.22	0.178	2.02
Other parking space available (D)	0.647	2.23	0.629	2.10
Residence Zone Characteristics				
Accessibility Indices				
Auto ($\times 10^{-2}$)			0.232	0.80
Public transit ($\times 10^{-4}$)			0.968	0.23
Public transit accessibility undefined (D)*			0.113	0.71
Number of households per acre ($\times 10^{-2}$)			-0.135	-1.05
Retail employees per acre ($\times 10^{-1}$)			-0.328	-0.95
Thresholds	0.000	-	0.000	-
	3.076	29.84	3.113	29.12
	5.232	49.30	5.295	47.88
	6.425	54.57	6.516	52.46
L(C)**	-2104.8		-2104.8	
L(β)***	-1348.3		-1342.8	
N	1814		1814	

(D): A 0-1 dummy variable.
* No public transit travel time information is available for the zone.
** Log-likelihood value with the constant and threshold terms alone.
*** Log-likelihood value at convergence.
The dependent variable is the number of vehicles available to the household, represented by five categories: 0, 1, 2, 3, and 4 or more.

Coefficient estimates for the three accessibility measures of Model 2 are all insignificant at any reasonable level of confidence. The two density measures ("Number of households per acre" and "Retail employees per acre") have negative coefficient estimates, which confirm the finding in the literature that vehicle ownership is inversely associated with density. These coefficient estimates too are, however, insignificant. These five variables as a group have a chi-square statistic of 10.94 with 5 degrees of freedom, indicating that they are not significant as a group at a 10% level. It may be concluded from the model estimation results here that the number of vehicles available to the household is not statistically associated with accessibility or density measures.

The coefficient estimates and t-statistics indicate that the number of drivers is by far the most significant single determinant of the number of vehicles available to the household. The coefficient estimates of “Number of workers” and “Number of members of 21 years old or older” are also positive and significant. These are compensated for by the negative coefficient of “Household size”; a household member has a negative effect on the number of vehicles if he is not a driver, a worker, or at least 21 years old. The negative coefficient of “Single-person household” implies the presence of a non-linear effect of household size. The coefficients of the two income variables exhibit, as expected, a positive association between income and the number of vehicles available to the household. Also as expected, home owners and households residing in single-family housing units tend to have more vehicles available. Finally, two indicators of parking availability, “Private parking space available” and “Other parking space available,” both have positive and significant coefficient estimates. It seems as though it is the availability of parking space, but not density, that affects the number of vehicles a household has available.

Number of Vehicles per Household Member and per Driver

The measures of residence zone characteristics are more strongly associated with the number of vehicles per household member or per driver than with the number of vehicles available to the household. Tobit models are estimated, treating the number of vehicles per household member or per driver as a non-negative real variable, using similar sets of explanatory variables as in the models of the number of vehicles. The results presented in Table 2 show that the two density measures, “Number of households per acre” and “Inhabitants per acre,” are significant (at a 5% level) in the model for the number of vehicles per household member, and the former is also significant in the model for the number of vehicles per driver. The coefficient estimates for “Number of households per acre” are positive and those for “Inhabitants per acre” are negative in both models. The coefficient estimates of these two collinear variables may be interpreted as follows; the number of vehicles per household member or per driver tends to be larger in more densely developed residential area, more so if the average household size is smaller. This is in addition to the tendency that households with children tend to have fewer vehicles per member, indicated by the coefficient estimates of the household demographic variables in the model for the number of vehicles per member.

“Public transit accessibility undefined” has a positive coefficient estimate that is significant at a 10% level in the model for vehicles per household member. If we accept the interpretation noted earlier that transit travel time is not defined for a pair of zones that are not connected by public transit, and therefore a transit accessibility index is undefined for a zone that is not served by public transit, then this result constitutes evidence that households in areas where public transit is unavailable tend to have more vehicles per member. The transit accessibility index itself, however, is not significant at all. The auto accessibility index has positive coefficient estimates in both models, which can be theoretically supported. They, however, are not significant.

Table 2. Tobit Models of Vehicles per Household Member and per Driver

Explanatory Variables	Vehicles/Member Coef.	Vehicles/Member t	Vehicles/Driver Coef.	Vehicles/Driver t
Constant	0.528	6.03	0.902	9.04
Household Attributes				
Household size			-0.031	-2.84
Number of workers	0.037	3.23	0.014	1.16
Number of members of 21 years old or older			-0.042	-2.42
Number of children of 5 years old or younger	-0.143	-9.64		
Number of children between 6 and 15 years old	-0.149	-11.83		
Number of members of 16 years or older	-0.053	-3.07		
Household of a male-female couple (D)	0.170	7.29	-0.032	-1.17
Single-person household (D)	0.412	13.04	0.083	2.25
Household annual income ≤ $30,000 (D)	-0.035	-1.82	-0.043	-1.97
Household annual income > $60,000 (D)	0.066	3.44	0.030	1.36
Owns home (D)	0.049	2.45	0.054	2.36
Single family home (D)	0.064	3.26	0.071	3.20
Private parking space available (D)	0.048	2.30	0.038	1.59
Other parking space available (D)	0.100	1.55	0.137	1.86
Residence Zone Characteristics				
Accessibility Indices				
Auto ($\times 10^{-3}$)	1.070	1.40	0.381	0.44
Public transit ($\times 10^{-3}$)	-0.034	-0.35	0.003	0.02
Public transit accessibility undefined (D)	0.069	1.75	0.046	1.02
Number of households per acre	0.148	2.76	0.013	2.07
Retail employees per acre ($\times 10^{-1}$)	-0.871	-0.99	-0.144	-1.42
Inhabitants per acre ($\times 10^{-2}$)	-0.539	-2.73	-0.328	-1.45
Variance of the Error Term	0.314	59.71	0.360	59.87
L(C)	-934.8		-782.2	
L(β)	-486.0		-737.6	
N	1803		1814	

The dependent variable is truncated at 0.

Vehicle Type Choice

The accessibility measures are significant in the vehicle type choice model shown in Table 3. The coefficient estimates of “Public transit accessibility undefined,” along with those of “Inhabitants per acre,” indicate that four-door sedans tend not to be chosen in areas where public transit is not available, and both four-door sedans and two-door coupes tend not to be chosen in low density areas. Vans and station-wagons and sports cars also appear to be preferred in more urbanized areas. Sports utility vehicles, on the other hand, seem to be preferred more where accessibility is low, either by auto or public transit. The spatial distribution of vehicle type preferences that emerges from the results is that sports utility vehicles and also pick-up trucks tend to be preferred in the fringe of the metropolitan area, while four-door sedans, vans and station-wagons tend to be

Table 3. Multinomial Logit Model of Vehicle Type Choice

Explanatory Variables	4-door Sedan		2-door Coupe		Van/Wagon		Sports Car		Sports Utility		Pick-up Truck	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Constant	1.108	2.09	1.265	2.50	-1.115	-1.99	-0.639	-1.09	-0.377	-0.83		
Vehicle Attributes												
Same vehicle type (D)	2.023	8.04	2.038	7.87					-1.206	-1.92		
Attributes of Primary User												
Age ($\times 10^{-1}$)	0.398	6.89	0.218	7.87	0.465	6.21						
Male (D)	-2.140	-8.35	-1.586	-6.16	-2.001	-7.00	-1.469	-4.12	-1.368	-4.40		
College education (D)	0.332	2.78										
Employed full-time (D)											0.870	3.19
Commuter (D)											-0.714	-2.85
Commute distance ($\times 10^{-2}$)	0.670	2.79										
Participated in acquisition decision (D)	-0.516	-2.28										
Household Attributes												
Household size					0.640	9.29						
Number of workers			0.252	2.55			0.740	2.60				
Number of members of 16 years or older	0.329	3.39					-0.840	-2.92				
Household annual income ≤ \$30,000 (D)			0.502	3.48								
Household annual income > \$60,000 (D)									0.463	1.98	-0.591	-2.54
Single family housing (D)			-0.498	-3.67								
Group housing (D)											-0.836	-2.67
Number of vehicles	-0.826	-6.30	-0.645	-5.13	-0.752	-5.01						
Residence Zone Characteristics												
Accessibility Indices												
Auto ($\times 10^{-1}$)	-0.124	-1.61	-0.094	-1.30			-0.273	-2.74	-0.133	-1.39		
Public transit ($\times 10^{-2}$)									-0.206	-2.38		
Public transit accessibility undefined (D)	-0.512	-2.24			-0.451	-1.59						
Number of households per acre							0.100	2.88				
Retail employees per acre					0.152	2.10						
Inhabitants per acre ($\times 10^{-1}$)	0.289	3.07	0.319	3.41								
$L(0) = -2578.3$, $L(C) = -2210.5$, $L(\beta) = -1935.7$, $N = 1439$												

preferred in areas with public transit access, and sports cars in high density areas.

As can be seen from the coefficient estimates of “Same vehicle type,” four-door sedans and two-door coupes tend to be replaced by the same type of vehicle, while sports utility vehicles tend to be replaced by vehicles of other types. The attributes of the primary user are significantly associated with vehicle type. In particular, male primary users tend to prefer pick-up trucks, and younger users tend to prefer sports cars, utility vehicles and pick-up trucks. Primary users with college education and long-distance commuters tend to prefer four-door sedans, and primary users who commute tend not prefer pick-up trucks.

Vans and station-wagons are preferred by larger households, and households with a large number of vehicles tend not to newly acquire four-door sedans, two-door coupes and vans or station-wagons. With respect to household income, pick-up trucks and two-door coupes tend to be preferred by households with lower incomes, while sports utility vehicles tend to be preferred by higher income households. These and other relations shown by the estimation results are intuitively agreeable and quantifies the relationships between primary user and household attributes and vehicle type choice.

Vehicle Use

Ordinary least squares models of vehicle use are estimated for the vehicle which was last acquired in each sample household. Selectivity bias correction is applied to account for potential correlations between the error terms of the model of vehicle type choice presented in Table 3 and the model of vehicle use. The method proposed by Hay (1980) and Dubin and McFadden (1984) and applied in Mannering (1986) is used. Estimation results are presented in Table 4. Model 1 in Table 4 contains no correction term, Model 2 contains a single correction term with the assumption that the same correlation coefficient applies regardless the vehicle type between the error terms of the two models, and Model 3 assumes that the correlation coefficient varies by vehicle type. As can be seen, the correction terms are at best only marginally significant and the goodness-of-fit statistics indicate that the model’s fit is not improved by the inclusion of the correction terms. In the rest of the discussion here, it is therefore assumed that the selectivity bias is negligible and the results given by Model 1 will be discussed.

Many of the variables representing vehicle attributes, attributes of the vehicle user, and those of the household are highly significant. The measures of residence zone characteristics, on the other hand, are at best only marginally significant. The auto accessibility index has a negative coefficient estimate, implying that residents of areas with higher auto accessibility tend to use their vehicles less, presumably because opportunities are available within short distances. With a t-statistic of -1.58, the coefficient is not significant at a 10% level. Neither the public transit accessibility index nor “Public transit accessibility undefined” is significant at any appropriate level of confidence. Overall, the estimation results suggest that vehicle use is determined primarily by the attributes of the vehicle, its users, and the owner household. In particular, public transit accessibility is not associated with vehicle use.

The inclusion of a vehicle type variable, “Van/wagon,” in the vehicle use model, nevertheless, suggests that accessibility indirectly affects vehicle use through vehicle type choice. The relation implied by the estimation results, however, is that a van or station-wagon tends to be used more,

Table 4. Ordinary Least Square Models of Vehicle Use

Explanatory Variables	Model 1 Coef.	t	Model 2 Coef.	t	Model 3 Coef.	T
Constant	9.301	46.18	9.381	44.82	9.434	43.46
Vehicle Attributes						
Van/wagon (D)	0.166	2.49	0.187	2.73	0.261	1.14
Household owns the vehicle (D)	0.142	2.02	0.144	2.05	0.140	1.97
Acquired brand new (D)	-0.165	-3.76	-0.163	-3.71	-0.160	-3.63
Attributes of Primary User						
Age ($\times 10^{-2}$)	-0.572	-3.43	-0.601	-3.58	-0.613	-3.64
Need a car for work (D)	0.115	2.23	0.115	2.22	0.111	2.14
Commute distance ($\times 10^{-2}$)	0.614	6.78	0.616	6.81	0.616	6.78
Participated in acquisition decision (D)	0.225	2.56	0.233	2.65	0.236	2.67
Attributes of Secondary User						
There is another user(s) other than primary user (D)	-0.335	-2.75	-0.361	-2.93	-0.384	-3.08
Male (D)	0.202	2.79	0.216	2.95	0.228	3.10
Commute distance ($\times 10^{-2}$)	0.311	2.20	0.328	2.31	0.333	2.33
Household Attributes						
Number of licensed drivers	0.151	3.21	0.147	3.12	0.144	3.04
Number of vehicles available	-0.095	-2.31	-0.091	-2.20	-0.089	-2.12
Single-parent households	-0.240	-1.95	-0.235	-1.91	-0.241	-1.95
Households with three or more adults (D)	-0.289	-4.15	-0.290	-4.18	-0.296	-4.25
Number of years at present address ($\times 10^{-1}$)	-0.383	-2.20	-0.387	-2.22	-0.393	-2.25
Household annual income < $15,000 (D)	-0.248	-2.89	-0.252	-2.94	-0.252	-2.93
Residence Zone Characteristics						
Accessibility Indices						
Auto ($\times 10^{-2}$)	-0.354	-1.58	-0.361	-1.61	-0.374	-1.67
Public transit ($\times 10^{-3}$)	0.154	0.55	0.155	0.55	0.162	0.57
Public transit accessibility undefined (D)	-0.011	-0.10	-0.012	-0.11	-0.015	-0.13
Retail employees per acre ($\times 10^{-2}$)	0.709	0.30	0.797	0.34	0.868	0.37
Inhabitants per acre ($\times 10^{-2}$)	-0.332	-1.04	-0.358	-1.12	-0.368	-1.15
Selectivity correction term						
λ			0.221	1.39		
λ_1					0.325	1.11
λ_2					0.483	1.72
λ_3					0.496	1.03
λ_4					0.200	0.92
λ_5					0.140	0.68
λ_6					0.396	1.74
R^2	0.152		0.153		0.155	
Adjusted R^2	0.138		0.138		0.137	
F	10.76		10.37		8.56	
N	1286		1286		1286	

and tends not be chosen when public transit is not available. In other words, a van or station-wagon, which tends to be used more, tends to be chosen when public transit is available. No evidence is thus offered which indicates public transit availability would suppress vehicle use.

Discussion

The results of statistical analyses have offered evidence that households tend to have more vehicles per member in areas where no public transit service is available. Other than this, however, indicators of transit accessibility have exhibited no significant effects on vehicle holding and use. Accessibility does affect vehicle type choice; preferences to different types of vehicles seem to have a certain spatial distribution. The vehicle use models estimated in this study indicate that vans and station-wagons tend to be used more. Transit accessibility which affects vehicle type choice, may therefore indirectly affect vehicle use. An inspection of the estimation results, however, offered no evidence that the availability of public transit reduces vehicle use; vans and station-wagons, which are more heavily used, tend to be preferred in areas where public transit service is available. The study results also indicate that the auto accessibility index is only marginally significant in the vehicle use models, and is negatively associated with vehicle use.

The statistical results in general support the conjecture that transit accessibility does not matter any more when it comes to household vehicle holding and use. The results lend no support to the notion that vehicle ownership and use can be reduced by improving public transit service levels. Yet there are at least three reasons why this conclusion may not be generalized, or may even be spurious. The first reason is that the accessibility measures used in this study are deficient, especially those for public transit for which level-of-service variables seem to be less well developed. Secondly, the results may be due to the idiosyncrasy of the South Coast metropolitan region where public transit plays only diminutive roles. Yet, many metropolitan areas in the United States are as automobile dominated as the South Coast region. For example, the distribution of travel modes for passenger transportation in the Sacramento region is surprisingly close to that in the Los Angeles region. And lastly, the inferences made in this study are all based on statistical associations found in cross-sectional data, but not on causal relationships identified by observing changes in longitudinal data.

With these caveats, it may be pointed out that the study results reinforce the finding of a previous study (Kitamura et al., 1999) which is based on a simple and theoretical bi-modal model of transportation. That study offers results supporting the Downs-Thomson paradox (see Mogridge, 1997): An increase in road capacity in a transportation system comprising both the automobile and public transit, will prompt some of the public transit users to switch to the auto, which reduces the public transit service level because the lost patronage raises the transit operating cost per passenger. The new auto users, at the same time, aggravate the congestion on road. When new equilibrium is reached after the addition of road capacity, the service level is reduced for both the automobile and public transit. Kitamura et al. (1999) further show that, once the transportation system becomes uni-modal as public transit patronage diminishes, the paradox no longer applies and increases in road capacity naturally improve the service level. In an automobile dominated metropolitan area like the South Coast region, it may be more appropriate to assume that the regional transportation system is virtually uni-modal. This present study offers a piece of empirical evidence that in such a metropolitan area improving public transit accessibility may not yield any appreciable consequences in terms of automobile ownership and use. It may be the case that the South Coast region has gone beyond the point of no return and increasing road capacity is the only viable option for the region. Long-term consequences of this policy, however, are yet to be seen.

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