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EXPLORING THE IMPACTS OF BUILT ENVIRONMENTS ON VEHICLE OWNERSHIP

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Abstract: Previous land use-transportation literature suggests that higher density, reduced segregation of land uses can reduce auto-dependency levels by making more services available within a short distance from housing location. Vehicle ownership has been considered as an independent choice modelled within travel demand systems, influenced by socio-economic characteristics of households. A few studies (Holtzclaw 1994; Cervero and Groham 1995; Hess and Ong 2003) attempt to incorporate the effects of urban physical attributes to improve the vehicle ownership models. In this paper, using Metropolitan Adelaide travel data, logit based models will be tested to explain vehicle ownership on the basis of household and urban features. The results provide evidence that some features of built environments including dwelling density and land use mix have varying degrees of influence on vehicle-ownership levels, thus they would be useful in addressing auto-dependency concerns in low density urban development through spatial planning.

Key Words: Vehicle Ownership, Built Environment, Adelaide, Spatial Planning, Logit Models.

1. INTRODUCTION

An important question to answer is whether there is a significant relationship between the number of vehicles owned by a household and the physical attributes of the urban area where the householder has chosen to live. This paper provides evidence that built environments play an important role in a householder's decision making regarding vehicle ownership. While several aspects of the connection between land use and transportation have already been investigated, it is still unclear how land uses patterns impact on the level of vehicle ownership. In fact, little systematic effort has been made to treat vehicle ownership within a broader framework of household choice regarding housing location, workplace, and travel patterns (Waddell 2001). The hypothesis is that areas with higher density and intensity have lower rates of vehicle ownership. Also a more pedestrian-friendly environment and better access to public transport reduces the level of vehicle ownership. In this study, metropolitan Adelaide, in South Australia is considered as a case study because it is an example of vehicle-dependency trends.

2. PREVIOUS WORKS

The impacts of some attributes of built environment including density, land use mix, and urban design on travel patterns have been often discussed. Some of the previous studies such

as Frank and Pivo (1994), Schimek (1996) and Cervero (2002) have broadly supported the hypothesized associations between higher density levels and lower automobile emissions; lower vehicle kilometers traveled (VKT), lower rates of vehicle ownership and higher rates of transit usage. Their proposals have briefly embraced reducing sprawl, mixing land uses, and increasing the pedestrian orientation of neighbourhoods. In fact, three specifications of built environments have been noted: density; diversity; and design (the pedestrian environment).

2.1 Urban Density

Several evidences from previous research can be found to show that areas with higher density are associated with less vehicle travel. Newman and Kenworthy (1989) showed that gasoline usage is directly correlated with density levels. For Australian cities, gasoline usage was 2.5 times that of European cities and five times as much as for Asian cities. According to ECMC (2001) report, a survey amongst various cities throughout the world in terms of the relationship between population density and the subsequent car ownership rate, Australia was found to have a relatively low urban density and a high car ownership rate. Holtzclaw (1991) with a study of California communities found that a doubling of residential density is associated with a decrease of 20% to 30% in VKT per capita. Holtzclaw suggested that residential density and access to public transportation were the two urban variables that could be used to explain household car use. Also, higher density was associated with lower car ownership. According to Hess and Ong (2003), the households located in high density areas own fewer cars than those in low density areas. The lower level of car ownership in higher density areas is probably the result of greater vehicle costs such as parking costs.

2.2 Diversity of Land Use

Diversity shows the spatial distribution of urban opportunities and services. Diversity in neighborhood level refers to the arrangement of different uses across several blocks or acres of land that they are not physically isolated from one another (EPA 2002). What was mostly found by previous empirical tests is that diversity within a neighborhood affects travel behavior in three distinct ways: higher mix use leads to lower average travel distance; more diversity is associated with greater modal share of walking / cycling thereby lower car use; a higher level of mixed use (especially work-housing places) tends to be associated with lower levels of vehicle ownership. For instance, Lynch (1986) explained that Canberra, Australia is a place in which shops are several kilometers or more from most homes and workers must travel 8 kilometers to workplaces. The open spaces are located in quite far distances; without proper access. Then he concluded that such dispersed distribution of activities results in wasted land and inevitable problems of traveling and social cohesion. On the other hand, increasing transportation accessibility through transportation-oriented development (TOD) has the potential to increase the share of trips made by transportation, in addition to influencing car ownership levels. Also, clustering different uses such as shopping, offices and retailing would help to encourage more trips done by walking and public transportation. Such development certainly could decline the level of car ownership and car use. Cervero (1996) found a significant amount of elasticity between built environments and commuting choices in 11 large U.S. Metropolitan areas. The neighborhoods with mixed land uses tended to reduce vehicle ownership rates and were associated with shorter commutes, controlling for socio-economic characteristics. The study of the Portland metropolitan region in US showed that land use mix variable (defined as the number of retail jobs in a transportation analysis zone) was statistically significant in predicting car ownership and modal choice (1000 Friends of

Oregon, 1996). Also the report explained that the use public transportation for the journey to work contributed declining vehicle ownership rates, although density was not found to be significant. The report suggested that the number of retail jobs in a zone is significant determinant in explaining car ownership levels. When the number of retail jobs in a zone increases vehicle ownership per household decreases if household income and size are controlled. Kockelman (1997) analyzed of travel data in the San Francisco region and found that a doubling in accessibility results in a 7.5% decrease in the number of vehicles owned by a household, when controlling for other urban and household features.

2.3 The Pedestrian Environment

The pedestrian environment can also impact on vehicle ownership. According to the study of 1000 friends of Oregon (1996), pedestrian environments were found to be important in estimating the number of vehicles owned per household. Similarly, in a logit model presented for vehicle ownership for the Chicago area, the pedestrian environment and car work trip modal share were found to be statistically significant in forecasting vehicle ownership rates. Less than 40% of these households in urban areas have two or more vehicles while more than 90% in suburban areas have two or more vehicles (Eash 1996).

It can be concluded from these background studies that some features of the built environment can be significant factors in affecting vehicle ownership in some cases. On the other hand, the findings of such studies have remained ambiguous in terms of the amount and direction of the effect of urban factors for different study areas.

3. THE CONCEPTUAL MODEL

As previous studies (Holtzclaw et al. 2001; Hess and Ong 2003) show, the probability that a household owns a vehicle is a function of several factors including socio-economics and built environment elements. Therefore, the average vehicle number per household is primarily a function of neighborhood density, income, household size and the availability of public transport. A model for an examination of the probability of vehicle ownership can take the following form:

$$\text{Vehicle ownership} = f\,(SE, BE). \tag{1}$$

Such a model involves not only a determination of how land use pattern relates to the level of vehicle ownership, but how they relate to other factors of influence. In this formula, SE is a vector of socio-economics such as household size, household type, household income, and some local specifications such as dwelling structures and median income, at the zone level. For instance, increasing household size raises the probability of owning more vehicles because of the higher demand of workers or their children for vehicle use. In addition, increasing household income will increase the probability that households will own a greater number of vehicles.

The second group of important factors is indicated with the BE vector and includes specific physical characteristics such as density, land use mix and design features. For example, the density of an area is an important factor in car-ownership. Mixed use areas can also provide better access to different activities through walking proximity locations such as retailing, local shops and recreational facilities, thus reducing the need for vehicles.

4. STUDY DATA AND METHODOLOGY

A database was created using different datasets including the 1999 Metropolitan Adelaide Household Travel Survey (MAHTS99), 2001 Australian Journey to Work (JTW) data (taken from 2001 Census of Population and Housing), Transportation Area Zones (TAZ) used in JTW Survey and South Australian Digital Cadastral Data Base (DCDB). In the data base, each household was considered as data records, which totaled 5873 households for metropolitan Adelaide, South Australia. The analysis was done on household level because choosing a household as a unit of analysis helps to reduce the risk of aggregation bias. The study area covers whole metropolitan Adelaide zones which were used in JTW Survey 2001(Figure 1).

The 1999 Adelaide Household Travel Survey was conducted over two days. The respondent households (about 2% of Households) were randomly selected across the Adelaide metropolitan area. Interviews were then undertaken for the selected households in the survey. All the members of each household were asked to provide details of all their travel activities they made over two consecutive days, including where they went, at what time, and for what purpose, the forms of transport they used, as well as socio-demographic information.

The study area, Metropolitan Adelaide is a highly car-dependent. According to the available Australian Bureau of Statistics (ABS) data, car trips had reached 79% of total week day trips in 1999. Passenger kilometres travelled by car increased by 150 million kilometres during 2000-01. Also only 4.9% of employed people in Adelaide chose walking or cycling for their journey to work in 1990 which gradually declined to 3 % by the 2002 census. The number of vehicles per 1000 persons has grown from 660 in 1997 to 700 in 2002, and remains still above the national average of car ownership within Australia (Government of South Australia 2003).

Figure 1 depicts overall image of metropolitan Adelaide and the geographical distribution of population (in person per hectare) and vehicle ownership (in vehicle per household) within metropolitan Adelaide. This figure shows imbalanced physical development of Adelaide. As shown, the outer suburbs - especially in the east side and north wing- with lower density are mostly populated by those have higher vehicle ownership levels. The average vehicle ownership for theses areas ranged between 1.8 and 2.7 vehicles per household. On the other hand, centrally located suburbs have higher density but lower level of vehicle ownership.

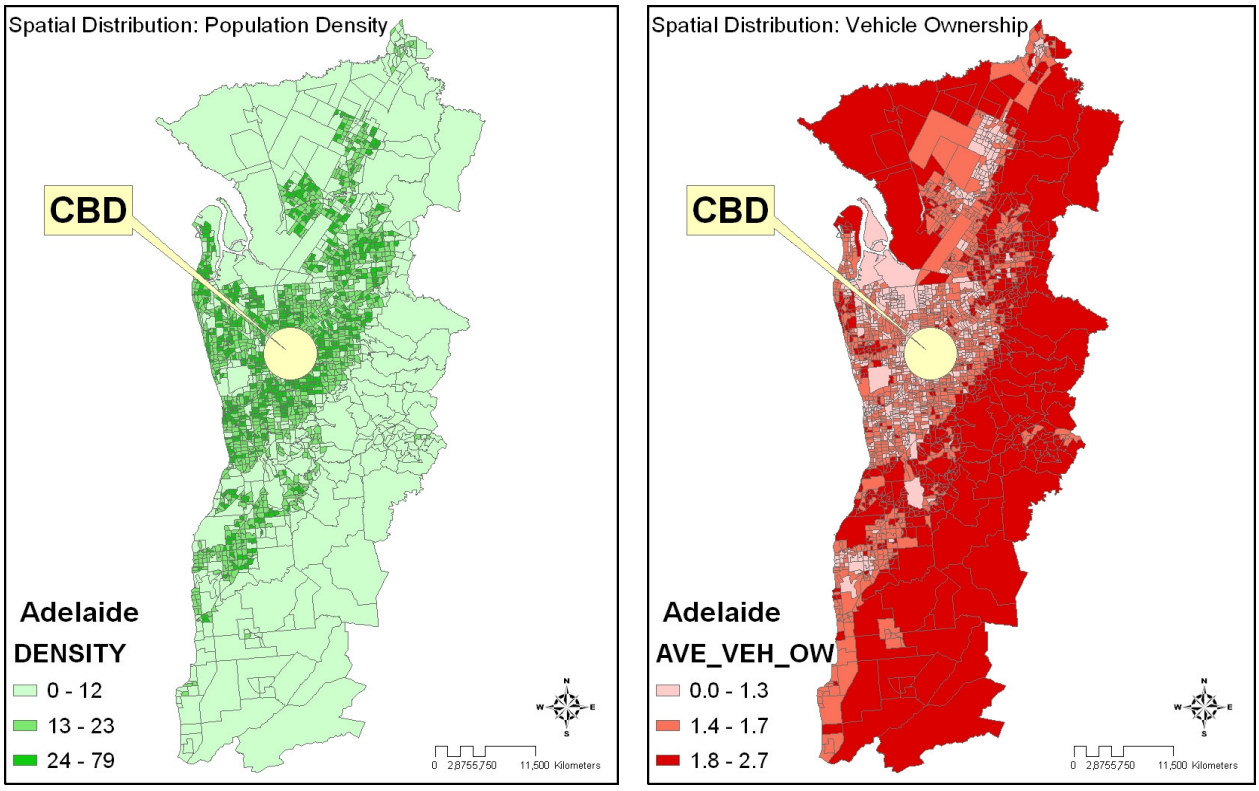


Figure 1 Metropolitan Adelaide: Spatial Distribution of Population Density (person per hectare) and Vehicle Ownership (vehicle per household) in Metropolitan Adelaide.

5. MODELLING

Multinomial logistic regressions were applied to model the decision to own one, two, three or more vehicles as the dependent variable. It is assumed that vehicle ownership decisions are an expression of preferences, and vehicle ownership can be predicted if the utility function and all of the relevant factors are known. This method has been verified as a reasonable methodology (Meurs 1993; Bhat et al. 1993; Hocherman et al. 1983).

> *"As a general guideline, auto ownership modeling must be pursued using the unordered-response class of models (such as the multinomial logit model or the multinomial probit model)" (Bhat et al. 1998, page 74).*

A probabilistic prediction of choice is the statement of the probabilities that each of the available alternatives will be chosen. A model that relates these probabilities to the values of a set of explanatory variables is called a probabilistic choice model. The multinomial logit model is expressed as (Ben-Akiva and Lerman 1985):

$$P_{ik} = \frac{e^{z_{ik}}}{\sum_k e^{z_{ik}}} \tag{2}$$

where P_{ik} is the probability that the ith case falls in category k. z_{ik} is the value of the kth unobserved variable for the ith case.

For a dependent variable with k categories, consider the existence of k unobserved continuous variables $z_1, z_2, \ldots z_k$ each of which can be thought of as the "propensity toward"

a category. In the case of a vehicle ownership, z_k represents a household's propensity toward selecting the kth vehicle, with larger values of z_k corresponding to greater probabilities of choosing that vehicle (assuming all other Z's remain the same).

Mathematically, the relationship between the Z's and the probability of a particular outcome is described in this formula.

$$z_{ik} = b_{k0} + b_{k1}\, x_{i1} + \ldots + b_{kj}\, x_{ij} \tag{3}$$

where x_{ij} is the value of the jth predictor for the ith case. b_{kj} is the jth coefficient for the kth unobserved variable and j is the number of predictors.

z_k is also assumed to be linearly related to the predictors. Since z_k is unobserved, the predictors must be related to the probability of interest by substituting for z_k.

As it stands, if a constant is added to each Z, then the outcome probability is unchanged. This is the problem of non-identifiably. To solve this problem, z_k is (arbitrarily) set to 0. The kth category is called the reference category, because all parameters in the model are interpreted in reference to it. Owning no car is chosen as reference category here. The coefficients are estimated through an iterative maximum likelihood method. Logit coefficients are used for interpreting. Logits are the natural log of the odds. They are used in the logistic regression equation to estimate (predict) the log odds that the dependent equals its highest/last value.

Explanatory variables were selected from the available datasets to represent each of the factors outlined in the conceptual model. They were based on the hypothesized relationship between the characteristics of built environments and vehicle ownership. The variables considered in analysis are listed in Table 1. The vehicle ownership models in this study use the household as the decision-making unit. It is structured more behaviorally compared to aggregate vehicle ownership models (which model vehicle ownership at the zonal, regional, or national level).

Table 1 Variable Description.

Variable	Description
Dwelling Density	Number of dwellings per developed area (person per hectare)
Employment Density	employee per developed area (person per hectare)
Land Use Mix (LUM)	mean entropy for land use categories within a zone (CCD) LUM for each zone, computed as: $\{\sum_k [\sum_j P_{jk} Ln(p_{jk})]/Ln(j)\}/k$, where: P_{jk} = proportion of land use category j within a zone; j = number of land use categories; and k = number of actively developed hectares in zone. The mean LUM ranges between 0(where in all land uses area of a single type) and 1(where in developed area is evenly distributed among all land use categories) this index suitably indicates the diversity of an urban area (Cervero and Kockleman 1997) Dummy variable For LUM > 0.50 [LUM=1]; for LUM < 0.50 [LUM=0]
Pedestrian Environment Factor (PEF)	PEF is an indicator for the character of local streets and is based on LUTRAQ Report, vol. 5.(1000Friends of Oregon 1996) Dummy variable for pedestrian friendly neighborhoods [PEF=1]
Public Transport; Level of Service(LOS)	Level of service (LOS) ranked from A to F based on the percentage of transit-supportive area covered for each zone. Covered area is the area within 0.4km of local bus route, where pedestrian connections to transit area available from the surrounding area. LOS defines as follow (Kittelson & Associates, Inc (1999): A=90-100 ; B=80-89.9; C=70-79.9; D=60-69.9; E=50-59.9; F<50.
Home Structure	Dummy variable for separate house [Home Structure = 1] for semi-detached, row or terrace house, townhouse and flat, unit or apartments [Home Structure = 0]
Household Type	Dummy variable for householders as Family living with children or adults or householders as single adult living with children or adults [Household Type =1]; for others [Household Type =0]
Neighbourhood Income	Mean income at the zone level
Number of members in household	Mean household size (no. of members)
Household Income	Mean income(weekly) of the head of householder For income less than 160$: Household Income = 1.00 For income between 160$ and 499$: Household Income = 2.00 For income between 500$ and 1499$: Household Income = 3.00 For income equal or more than 1500$: Household Income = 4.00
Vehicle Ownership	Discrete values for number of available vehicles per household For owning no vehicle : No of Vehicle =0 For owning one vehicle: No of Vehicle =1 For owning two vehicles: No of Vehicle =2 For owning three or more vehicles: No of Vehicle =3

A descriptive statistics including frequency, median, mean, variance and range of the numeric variables are summarized in Table 2.

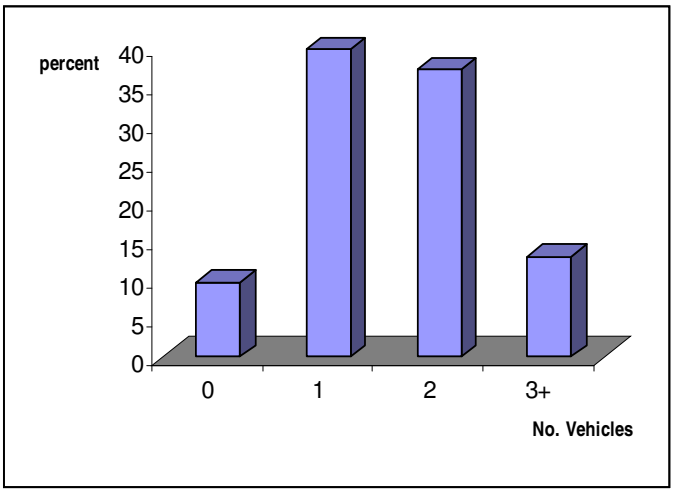
Table 2 Descriptive Statistics for Numeric Variables.

	Dwelling Density (person per ha)	Employment Density (jobs per ha)	No of Members	Neighborhood Income $AUS
N	5848	5848	5848	5848
Mean	6.954	5.226	2.48	717.96
Median	7.210		2.00	700.00
Std. Deviation	3.532	8.642	1.301	142.28
Variance	12.473	74.683	1.693	20244.24
Minimum	.02	.08	0	424.00
Maximum	19.41	247.96	8	1132.00

(Source: ABS 2001)

Figure 2 shows the vehicle ownership for the householders. Only less than 10% of Adelaide's households have no vehicles. About 40% of households have one vehicle, whereas 37% of the

householders have two vehicles. And 13% have three or more vehicles.



(Source: ABS 2001)

Figure 2 Number of Vehicles per Household, Metropolitan Adelaide.

The variables were included in modeling if they showed a significant association with the dependent variable in the preliminary analysis. The following logit models as summarized in Table 3 indicate that the probability of a household owning a vehicle is affected by different factors. They also determine the magnitude and direction of the effect of the factors predicting ownership of a vehicle.

6. RESULTS

From the pseudo R-Square value, we see that the model fits the data properly, explaining about 45 percent of the variation of the dependent variable. In all three models, the most important statistical determinants of the probability of vehicle ownership are household income, household size, and residence in a separated home, the presence of children (household type), dwelling density, and mixed-land uses. The analysis also showed that some of the urban variables including employment density, pedestrian environment factor (PEF), and level of service for public transport were insignificant in explaining the level of vehicle ownership, although the direction of association can be achieved from a primary correlation analysis (which is not detailed here).

For areas with higher employment density, the level of vehicle ownership was lower than for those areas with lower employment density. One reason could be having better access to workplaces in such areas. In regard to metropolitan Adelaide, the employment density is high only in the CBD area and a few local business centers. Higher levels of service (coverage) of public bus resulted in lower rates of vehicle ownership. In other words, the people living in areas with better coverage and frequency of public transport were less likely to own and use private vehicles. The LOS in fact, is not the major factor for poor transit patronage levels in Adelaide, since the LOS (transit coverage) in all districts is highly satisfactory (Sekhar et al. 2002). Also, there is a negative relationship between the design quality of an area and owing a vehicle. The suburbs with less pedestrian friendly streets are associated with higher levels of vehicle ownership. Normally the residents of well designed areas prefer to use

walking/cycling to go to work.

Table 3: Parameter Estimates.

No of Vehicles	Variables	B	Std. Error	Sig.	95% Confidence Interval for Exp(B)	
1	Intercept1	-5.790	2.103	.006		
	Dwelling density	-.044	.017	.008	.926	.988
	Number of members	1.068	.102	.000	2.384	3.549
	Average income at zone level (Natural Logarithm)	1.055	.264	.000	1.712	4.821
	LUM =1	-.185	.115	.007	.561	.908
	Home Structure =1	.620	.105	.000	1.438	1.661
	Household Type =1	.655	.207	.002	1.285	2.886
	[Household Income =1	-1.948	1.041	.061	.019	1.096
	Household Income=2	-1.534	1.036	.139	.028	1.643
	Household Income= 3	.098	1.069	.576	.224	14.776
2	Intercept2	-11.331	2.324	.000		
	Dwelling density	-.041	.019	.027	.925	.995
	Number of members	2.154	.109	.000	6.966	10.661
	Average income at zone level (Natural Logarithm)	1.565	.300	.000	2.657	8.604
	LUM =1	-.218	.132	.009	.960	1.612
	Home Structure =1	1.419	.129	.000	2.188	2.311
	Household Type =1	1.704	.221	.000	3.562	8.481
	Household Income =1	-3.831	1.044	.000	.003	.168
	Household Income =2	-3.049	1.035	.003	.006	.360
	Household Income = 3	.045	1.067	.067	.129	8.469
3+	Intercept3	-17.440	2.693	.000		
	Dwelling density	-.066	.022	.003	.897	.978
	Number of members	2.838	.116	.000	13.624	21.429
	Average income at zone level (Natural Logarithm)	1.897	.356	.000	3.319	13.401
	LUM =1	-.379	.161	.019	.064	1.004
	Home Structure =1	1.565	.184	.000	2.146	2.300
	Household Type =1	3.265	.246	.000	16.159	42.394
	Household Income =1	-4.452	1.076	.000	.001	.096
	Household Income =2	-3.195	1.050	.002	.005	.321
	Household Income = 3	.136	1.081	.009	.105	7.269

No of Vehicle = 0 is the comparison choice.

Model Summary:
Chi-Square (30) = 3092.276
Number of cases = 5873
-2 Log Likelihood = 9183.768
Pseudo R-Square = 0.45

The logit based models showed those two urban form variables: dwelling density and land use mix were significant in the models. The results indicate that as the dwelling density increases, the likelihood of owning more vehicles for households, decreases. Households in denser areas tend to have fewer cars presumably due to higher auto level of service (because of congestion

problems, parking limitations, etc) associated with denser areas (Bhat and Koppelman 1993) and more availability of other modal choices i.e. walking; cycling or public transport. The findings are consistent with previous empirical research, notably Holtzclaw et al.(2001) and Hess and Ong (2003) who found that average auto ownership in Chicago, Los Angeles, and San Francisco is affected by neighborhood residential density in addition to socio-economics. The same result was found for land use mix (LUM), where an increased amount of LUM decreases the likelihood of households owning more vehicles. The householders in mixed areas own fewer vehicles than those in homogenous areas. Without a diverse and compact land use, it is more difficult for people to express their choice to: *not* own vehicles. Both of these results, while still needs more investigation, tend to lend some support to popular planning movements such as *New Urbanism* and *Smart Growth*, which suggest that auto-dependency is increased by segregated uses and low density. These findings support the contention that suburban development of metropolitan Adelaide induces higher use of private vehicles. For example, two newly designed outer suburbs: Golden Grove and Para Hills have moderately higher car uses whereas the density and diversity of them are lower than the median features of metropolitan Adelaide (Soltani & Allan 2004). One can argue since denser areas are usually associated with better public transport services as well as accommodating different social groups which all together make a denser area feasible for non-automobile travel activities thus decreasing car ownership level (Kitamura et al. 1997). Density, in fact does act as a proxy for several unmeasured-or immeasurable- attributes thus represents their ambiguous associations with travel behavior (Brunton & Brindle 1999). A certain types of urban form, in fact attract certain types of people which would show their effects in such relationship. This claim needs to be more investigated.

The socio-economic factors such as the number of members of household, home structure, household type, householders' income, and median income at zonal level were significant in explaining the number of vehicles owned by a householder. Households with more members are more prove to own vehicles. For all three models increasing household size increases the likelihood that households will own more vehicles. Additional household members are likely to increase the number of workers in the household, which is correlated with vehicle ownership. One may argue that the increase in household size may imply greater essentials such as food, clothing and housing, thus reduces the amount of financial resources for expenditures on cars (Lerman and Ben-Akiva 1975). But in this study, the result can be attributed to higher demand because of more mobility needs. Also the presence of children in a household increases the probability of vehicle ownership for householders. This effect reflects the positive impact of children due to higher mobility requirements (Hocherman et al. 1983). Households residing in separated houses tend to have more vehicles. One reason could be that for the householders living in separate houses, parking might be more available than for other people living in other dwelling structures, thus increasing the likelihood of vehicle ownership. Finally, household income has the expected sign. Households with higher incomes tend to have more vehicles. This effect is significant in two models describing decision making for having two and three or more vehicles, although the higher income level does not significantly affect decision about the first vehicle. However, the study showed that higher-income households convert income into vehicles at a higher rate than low-and medium-income households. Also it seems that areas with higher median zonal income induce higher rates of vehicle ownership. In the case of metropolitan Adelaide, these areas are located on the east side (Figure 1).

In conclusion, this paper developed and implemented an empirical model that incorporates

built environment features into the vehicle ownership model. The result provides evidence that built environment factors are important determinants of decision making on vehicle ownership. Some features of built environment factors such as density and land use diversity have varying degrees of influence on vehicle-ownership levels. However previous research has less paid attention to these factors as exogenous to vehicle ownership analysis. The results of this analysis support the hypothesis that while physical urban attributes are important, they are not the sole factor that impacts on a householder's decision to own a vehicle. This finding provides useful information that significantly advances knowledge on the studies of transportation – land use interaction.

7. POLICY IMPLICATIONS

This study shows that urban form is a significant contributing factor in a householders' decision to own a vehicle. It is important for planners to determine what role each factor has in a decision-making process. Therefore, the outcomes can be helpful for planners because they suggest how elements of built environments can be also used to address essential concerns about auto-dependency. While there has been little empirical research on the relationship between built environments and vehicle ownership especially on the content of Australian cities, this study can be considered as a primary step towards the comprehensive study in this area. The findings also emphasis the importance of built environment features that are qualitative yet absent from the relevant literature suggesting that urban form should be given more attention in transport policy making. This study can inform the developmental process by providing insight into the impact of land use patterns decision on making a community. The new communities build in Metropolitan Adelaide should be accessible and accommodating to multiple modes and users of transportation.

An important direction for further work is to examine the specification of these models in more detail. The effects of built environments on vehicle ownership depend on several un-observed factors. Also the potential correlation between the urban-based regressors and un-observed heterogeneity must be controlled. This can be a subject of more detailed analysis. In addition, research may need to go much further in developing forecasts that consider the indirect casual relationship between the built environment and vehicle-ownership. This is a discipline that is little developed and in much need of more research.

REFERENCE

Australian Bureau of Statistics (ABS) (2001) Census of Population and Housing: Journey to Work datasheets, Australia.

1000 Friends of Oregon (1996) Analysis of Alternatives, LUTRAQ Report, vol. 5, prepared by Cambridge Systematic Inc., and Parsons Brinckerhoff Quad Douglas, Portland, Oregon.

Ben-Akiva M., and Lerman S. (1985) Discrete Choice Analysis: Theory and Application to Travel Demand, MIT press, Cambridge.

Bhat CR. and Koppelman., M. (1993) An endogenous switching simultaneous equation system of employment, income, and car ownership, **Transportation Research A, vol. 27A, no. 6**, pp. 447-459.

Bhat, CR and Pulugurta. V. (1998) A Comparison of Two Alternative Behavioral Choice Mechanisms for. Household Auto Ownership Decisions. **Transportation Research. , Vol. 32B, No.1**, 1998, pp. 61-75.

Brunton P. and Brindle, R. (1999) 'the relationship between urban form and travel behavior', **ARRB Research Report, ARR No. 335**, Australia.

Cervero, R., and Gorham R., (1995) Commuting in Transit Versus Automobile Neighborhoods, **Journal of American Planning Association, No. 61**, 210-225.

Cevero, R and Kockelman, K., (1997) 'Travel demand and the 3D's: density, diversity, and design', **Transportation Research D, vol** 2, no. **3**, pp. 199–219.

Cervero, R., (2002) Built environments and mode choice: toward a normative framework, **Transportation Research Part D, Vol.7,** 265-284.

Cevero, R., (1996) Mixed land-uses and commuting: evidence from the American housing survey, **Transportation Research A, Vol. 30, No. 5**, 361–377.

Eash, R., (1996) Incorporating Urban Design Variables in Metropolitan Planning Organization: Travel Demand Models, Williamsburg, VA, conference on Urban Design, Telecommuting, and Travel behaviour, October.

EPA (2002), Urban Sprawl and Public Health, Public Health Reports, May-June 2002, Vol. 117.

ECMC/OECD (2001), Conference Report, Transport and Economic Development, Round Table 119.

Frank, L., and Pivo G. (1994) the impacts of mixed use and density on the utilization of three modes of travel: the single occupant vehicle, transit, and walking, **Transportation Research Record, No. 1466**, 44-52.

Government of South Australia (1999) Metropolitan Adelaide Household Travel Survey, Transport SA, March.

Hess, D., and Ong P. (2003) Traditional neighbourhoods and automobile ownership, **Transportation Research Record, No. 1805**, 5-43.

Hocherman, I., Prashker J.N. and Ben-Akiva M. (1983) Estimation and Use of Dynamic Transaction Models of Automobile Ownership, **Transportation Research Record, no. 944**, pp. 134-141.

Holtzclaw, J., (1990) Explaining urban density and transit impacts on auto use, Presented by the Natural Resources Defense Council for California Home Energy Efficiency Rating Systems, June.

Holtzclaw, J., (1994) Residential Patterns and Transit, Auto Dependence, and Costs, Resources Defense Council, San Francisco.

Kitamura, R et al (1997) 'A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay area', University of California at Davis, report prepared for the California Air Resources Board.

Kittelson and Association, (1999) Transit Capacity and Quality of Service Manual, A report prepared for Transit Cooperative Research Program, National Research Council.

Kockelman, K.M., (1997) Travel behaviour as a function of accessibility, land-use mixing, and land-use balance: evidence from the San Francisco bay area, **Transportation Research Record, No. 1607**, 116–125.

Lerman, S. and M. Ben-Akiva (1975), "A Behavioral Analysis of Automobile.

Ownership and Modes of Travel," report prepared for the US Department. of Transportation.

Lynch K., (1984) **Good City Form**, MIT Press, Cambridge, Mass.

Meurs , R., (1993) A panel data switching regression model of mobility and car ownership, **Transport Research A, vol. 27A, no. 6**, pp. 461-476.

Newman, P., and Kenworthy J., (1989) Gasoline consumption and cities: a comparison of U.S. cities with a global survey, **Journal of the American Planning Association, Vol. 55, No. 1**, 24-37.

Schimek, P., (1996) Household motor vehicle ownership and use: how much does residential density matter?, **Transportation Research Record, No. 1552**, 120-125.

Sekhar Somenahalli V.C., Yue W.L., Taylor M.A.P., and Coffee N. (2002), Analysis of regional imbalance of quality of bus service within a city, in **Proceedings of European Transport Conference** 2002, 9-11 September, 2002 (on CD ROM), Homerton college, Cambridge.

Soltani, A., and Allan A. (2004) Urban Form Impacts on Travelling Choices: A Study of Four Suburbs in Metropolitan Adelaide, **Proceedings 27th Australasian Transport Research Forum**, Adelaide, September.

Waddell, P., (2001) Towards a Behavioral Integration of Land Use and Transportation Modeling. In D. Hensher, (Ed.), **The Leading Edge in Travel Behavior Research,** Pergammon.