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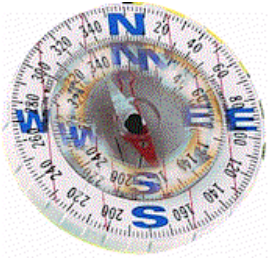
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**Publication Date**

2001-07-01



## ***The Ralph and Goldy Lewis Center for Regional Policy Studies at UCLA***

*...established to promote the study, understanding and solution of regional policy issues, with special reference to Southern California, including problems of the environment, urban design, housing, community and neighborhood dynamics, transportation and economic development...*

### **Working Paper Series**

## ***Traditional Neighborhoods and Auto Ownership***

By: Daniel Baldwin Hess and Paul M. Ong

**Working Paper #37 in the series**

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*July 2001*

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## ABSTRACT

Many cities have traditional neighborhoods, or established, inner-city districts comprised of diverse housing, mixed-land uses, pedestrian connectivity and convenient transit access. This study quantifies the likely effects of land use patterns on auto ownership for such neighborhoods. Using Portland, Oregon, we test a model that explains auto ownership based on household, neighborhood, and urban design characteristics. The index of mixed-land use is statistically significant, *ceteris paribus*. We find compelling evidence of the impact of mixed-land use on auto ownership: as land use mix changes from diverse to homogeneous, the probability of owning an auto decreases by 31 percentage points. The findings imply that traditional neighborhoods are more conducive to alternatives to private vehicle use, such as walking and public transit, and to higher motor vehicle costs.

4,500 words + 3 tables + 5 figures

**Key words** : traditional neighborhoods, transportation planning, travel behavior, auto ownership, modeling

## Acknowledgements

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The authors would like to acknowledge sponsorship from the Research Mentor Fellowship program of the Graduate Division of the University of California, Los Angeles and the Lewis Center for Regional Policy Studies of the University of California, Los Angeles. Special thanks to Randall Crane, Doug Houston, Anastasia Loukaitou-Sideris, Lisa Schweitzer, and Brian Taylor for providing helpful comments and to Kyung-Hwa Kim of Portland Metro for providing data.

## INTRODUCTION

How do land use patterns affect the number of autos that a household owns? Conventional wisdom holds that a household's income largely determines their decision to own an auto. But does the urban form surrounding the household — including the pedestrian environment, the mix of land uses, and the proximity to transit and light rail — influence auto ownership decisions?

If these factors have an impact, then they should be most noticeable in traditional neighborhoods, or those urban districts developed in the pre-auto era, with commerce, industry, and residences packed together more tightly than is common today (Muller 1995, Schaeffer and Sclar 1980). Compared to suburbs, traditional neighborhoods usually have a more inviting pedestrian environment, gridded streets, convenient transit access, and places to walk to, like neighborhood stores and services. In fact, traditional neighborhoods currently possess the same characteristics that proponents of the “new urbanism” have argued can address an array of modern urban problems by mixing land uses to reduce the spatial separation of activities, lessen the dominance of the auto, and add architectural and urban design features that encourage face-to-face interaction. An important component of traditional neighborhoods is the clustering of activities — diverse mixes of residential and commercial land uses are located in closer proximity than is found in undifferentiated low-density development. One potential benefit is a reduction in vehicular traffic as a direct result of the provision of higher than typical levels of transit service within the developed areas. And with shorter distances, people have the option of replacing auto trips with walking and bicycling in addition to riding transit.

A variety of studies and analytical approaches have been used to address the question of how urban form influences travel patterns. (See Susan Handy (1996) and Randall Crane (1999) for reviews of the research.) Findings about how built form affects people's travel behavior are often contradictory, but some common trends are emerging. Reid Ewing *et al.* (1994) find that households in the sprawling suburbs of Palm Beach County log two-thirds more vehicle hours per person than comparable households in more compact, traditional neighborhoods; “density, mixed use, and a central location all appear to depress vehicular travel” (Ewing *et al.* 1994 p. 60). Peter Newman and Jeffrey Kenworthy (1989a) find that the most self-contained places (with the least amount of cross-region commuting) are the densest urban centers like Manhattan, Chicago, and San Francisco, where the lowest transportation-fuel consumption rates per capita are found; they conclude that compact cities reduce auto use. Peter Gordon and Harry Richardson (1997), on the other hand, doubt that compact cities are an alternative to sprawl development and contend that commute reduction is a practical benefit of metropolitan decentralization.

While it is reasonable to assume that land use affects auto ownership, little empirical research has been conducted. A few studies suggest that land use patterns may impact auto

ownership and use (Holtzclaw 1994, Greenwald and Boarnet 2000, 1000 Friends of Oregon 1996).<sup>i</sup> And while many researchers have claimed that compact development lessens the dominance of the auto, Randall Crane (1999) has suggested that it is possible that denser places may *increase* rather than reduce auto use, because shorter origin-destination distances reduce the average cost per trip. Cheaper travel means more vehicle trips, and this may lead to a rise in vehicle miles of travel (VMT).

Most existing transportation studies, however, take auto ownership as a given rather than a mediating factor between land use and travel; consequently, the analyses miss some of the impact of land use as manifested in differences in auto ownership. Without accounting for this effect, the misspecification of the causal relations can lead to findings that underestimate the effect of land use. In this study we examine the missing link — auto ownership. Auto ownership is a vital component of travel demand due to its key role in transportation and land use planning: the possession of private vehicles influences the number of trips a household chooses to make and the travel modes that household members choose to make those trips.<sup>ii</sup> In this sense, auto ownership is one of the principal explanatory factors of trip frequency and mode choice for work and non-work activity destinations (see Gärling *et al.* 1998, Mogridge 1989, Stopher and Lee-Gosselin 1997).

Our work extends the literature by including land use patterns as well as urban design factors (like land use mix, street width and pedestrian connectivity) as they relate to auto ownership decisions. The expectation is that increases in land use intensity and integration reduce auto ownership. Likewise, greater pedestrian connectivity and proximity to transit decrease the need to own autos by making alternatives to driving more attractive.

This study is organized as follows. We first discuss both the conceptual and empirical models used to explore auto ownership patterns. We next introduce our case study and the data, followed by descriptions of the variables thought to influence auto ownership patterns. Finally, we discuss the model results and present key findings and conclusions.

## THE MODEL

When making auto ownership decisions, we expect that all households, regardless of

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<sup>i</sup>The link between land use patterns and urban travel has been examined by Robert Cervero and R. Gorham (1995), Randall Crane and Richard Crepeau (1998), and Susan Handy (1993, 1996). The findings of these studies were inconclusive. Nevertheless, the Institute of Transportation Engineers (1997) has suggested that neotraditional neighborhoods designs might lead to substantially lower trip generation rates. Reid Ewing (1997) criticizes the Urban Land Institute and the National Association of Home Builders for promoting mixed land use and clustered development (strategies that enhance the value of nearby residential properties and offer economies in site development) despite the fact that research has not sufficiently demonstrated the travel behavior consequences.

<sup>ii</sup>See Boarnet and Crane (2001) for a discussion of how income often proves to be a better predictor of travel behavior across neighborhoods than urban form considerations.

income, consider their own mobility needs, purchasing power, availability of alternative modes, and various characteristics of the urban environment. Thus, the model developed here examines the probability of auto ownership and takes the following form<sup>iii</sup>:

$$\text{Auto Ownership}_i = f [ H_i, N_i, L_i ]$$

$H_i$  is a vector of the household characteristics (such as household size, household income, presence of a white householder, dwelling type) thought to influence auto ownership. The existing literature tells us that increasing income raises the amount that households spend on transportation, and this is reflected both in auto ownership and activity-travel decisions. In fact, household income is perhaps the strongest indicator of a household's ability to obtain, maintain, and operate autos.<sup>iv</sup> We also know that increasing household size increases the probability that households will own a greater number of autos; additional adult household members are likely to increase the number of workers in the household, which is correlated with auto ownership, and the presence of children in a household also increases the likelihood of auto ownership.<sup>v</sup> We include the race of the householder because differences in loan access and insurance premiums may affect the ability of people in various racial groups to own autos (Ong 2001, Raphael and Stoll 2000). For household members living in dwellings other than single family homes, parking may be less available and more costly via higher land costs.<sup>vi</sup> In addition, neighborhoods where single-family homes predominate may accommodate auto travel more easily than non-motorized travel.

$N_i$  is a vector of neighborhood characteristics (median income, household density and racial composition at the census tract level). Household density is likely to be negatively associated with auto ownership — in the densest areas, there will be greater opportunity for walking and riding transit, and the cost of parking autos increases.<sup>vii</sup> We include the median

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<sup>iii</sup>Our conceptual model is consistent with previous empirical research, notably Holtzclaw *et al.* (2001) who found that average auto ownership in Chicago, Los Angeles, and San Francisco is primarily a function of neighborhood residential density, average per capita income, average family size, and the availability of public transit.

<sup>iv</sup>However, research has shown that lower-income households convert income into autos at a higher rate than medium- and high-income households (Gardenhire and Sermons YEAR).

<sup>v</sup>le Clercq and de Vries (2000) demonstrate that the more tasks households must carry out (work, shopping, care of children, etc.), the less public transit is used.

<sup>vi</sup>We do not have appropriate information in the data set to include auto ownership costs, but we believe auto ownership costs are partly correlated with land use mix. Household density helps approximate the cost and convenience of parking at home. In very dense parts of an urban area, parking supply at the residence may affect the choice of auto ownership. Some residents may have no dedicated parking space available, for example, and may compete for nearby curb parking. Others may have one space that is provided with their apartment or condominium but have no off-street parking for a second auto. Still others may have to pay to rent parking spaces.

<sup>vii</sup> While there has been little empirical research on the relationship between residential density and auto ownership, there has been research on the relationship between residential density and mode choice, beginning with Pushkarev and Zupan (1977), Smith (1984), and Newman and Kenworthy (1989).

income of the census tract to address the contention that some insurance and financial institutions under-serve low income and minority communities.

$L_i$  is a vector of the urban design characteristics. Households located in dense, mixed-land use areas may be able to access many activities by walking or bicycling to nearby locations, thus reducing the need for autos. Households in areas well-served by transit similarly may be able to access many destinations and services using transit.<sup>viii</sup>

An ordered logit regression is used to model the decision to own zero, one, two, or three or more autos as the dependent variable.<sup>ix</sup> The individual falls in category 0 if  $u < \beta^l x$ , in category 1 if  $\beta^l x < u < \beta^l x + c_1$ , in category 2 if  $\beta^l x + c_1 < u < \beta^l x + c_1 + c_2$  and in category 3 if  $u < \beta^l x + c_1 + c_2$ . We estimate the probabilities as follows:

$$\begin{aligned} P_0 &= F(\beta^l x) \\ P_1 &= F(\beta^l x + c_1) - F(\beta^l x) \\ P_2 &= F(\beta^l x + c_1 + c_2) - F(\beta^l x + c_1) \\ P_3 &= 1 - F(\beta^l x + c_1 + c_2) \end{aligned}$$

For  $F$  we use the logistic normal distribution,  $\beta$  is a vector of estimated coefficients,  $x$  is a vector of independent variables, and  $c_1$  and  $c_2$  are estimated constants (Maddala 1991).

## THE DATA

We use Portland, Oregon as a case study to examine the link between land use mix/urban design and auto ownership. (See Figure 1.) The City of Portland displays a contiguous core area of five to seven square miles of built environment with mixed land uses conducive to pedestrian activity. The oldest settled areas of the city were developed as “streetcar suburbs,” supported by a large network of horse-drawn and eventually electrified trolley service (Warner 1962). Today,

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<sup>viii</sup>We use a quarter-mile to light rail line because this distance is often defined as the maximum walking distance for access to transit (Untermann 1984). Boarnet and Crane (1998, p. 208) point out that this is the distance most commonly associated with the residential component of TOD, and they cite several studies of rail-based housing development. Transit accessibility, proximity to residential locations, and distance to nearest stop act as a measure of choice and range, respectively, for non-auto travel resources. We expect that as access to these resources increases, their use would also increase (due to convenience), and auto ownership would decrease. Households with no autos available will be captive to transit, ride-sharing with non-household members, or non-motorized means of transportation.

<sup>ix</sup>We assume that auto ownership decisions are an expression of preferences, and that auto ownership can be predicted if the utility function and all of the relevant variables are known. 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 (Horowitz 1995). See M. Ben-Akiva and S.R. Lerman (1985) and G.W. Harvey (1994) for examples of the use of logit models in transportation research.

Multnomah County has a dense central core [the Portland central business district (CBD)]<sup>x</sup> surrounded by a mix of suburban areas and outlying semirural areas. The central business district was revitalized in the 1970s with pedestrian and transit-oriented enhancements, including parallel transit malls, wide sidewalks, street plantings and benches, transit systems, and light rail that operates on surface streets was added later. Outside the city, however, there are only a few districts that possess an attractive pedestrian environment, primarily because they were developed in an era when automobiles did not dominate (1000 Friends of Oregon 1996). Auto ownership is slightly lower in Portland than in other U.S. urban areas: Multnomah County averages 1.5 vehicles per household (the lowest in the state), while Oregon averages 1.8 vehicles per household and the United States averages 1.7 vehicles per household.<sup>xi</sup>

This study uses data from the *Oregon and Southwestern Washington 1994 Activity and Travel Behavior Survey* which includes a detailed travel diary (Cambridge Systematics 1992).<sup>xii</sup> The synthesis of travel, activity participation, and land use information makes this data set unique compared to travel surveys in other U.S. metropolitan areas and the Nationwide Personal Transportation Survey (NPTS). By combining the travel survey with detailed land use and environmental data, Portland Metro made one of the first attempts to incorporate information on urban form and non-motorized travel choices into the process of forecasting regional travel.

The household activity survey collected information about individuals, households, and vehicles, and the activity diary recorded what each member in a household did (activity choice), where (location choice), for how long (activity duration), and with whom (activity participation).<sup>xiii</sup> For each activity that required travel, the survey collected detailed information about the trip. Activity/travel data were collected for every household member, regardless of age. Households were geocoded and located within transportation analysis zones (TAZs) in Portland Metro's 1,260-TAZ system.

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<sup>x</sup>For this study, Portland, Oregon's CBD is the area bounded by I-5 and I-405; this corresponds to TAZs 1 through 16.

<sup>xi</sup>1990 U.S. Census Summary Tape File 3A, available at <http://homer.ssd.census.gov/cdrom/lookup/972331852>.

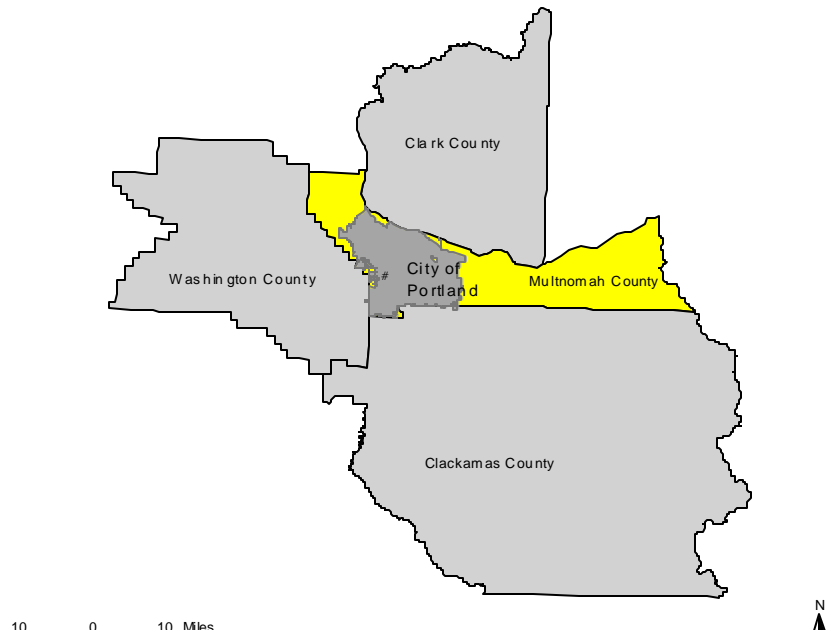
<sup>xii</sup>Households were recruited by telephone; person, vehicle, and household information were collected by survey staff at this time. Recruited households were then sent a packet of information. Two days before their assigned travel days, households were sent a reminder. During the survey days, household members used activity recording sheets. After the survey days, survey staff collected activity information from respondents using CATI (computer-assisted telephone interviewing); 20,161 households were contacted and 4,451 household ultimately completed surveys. The survey data consists of 9,471 persons reporting 122,348 activities and 67,981 valid trips (Cambridge Systematics 1992).

<sup>xiii</sup>Data were collected at the person, household, trip, and vehicle level; these data files can be joined together using a unique sample number. The sample number has x,y coordinates and can be located within a census tract or TAZ. In this way, several independent variables collected at different levels of analysis (zone based vs. household vs. individual) can be joined together.



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Figure 1  
Portland, Oregon Metropolitan Area



One primary objective of Portland’s household activity survey was to collect data that could be used to study a variety of transportation-related behavior. The relationship between the built environment and transportation behavior was of particular interest to Portland Metro, the MPO (metropolitan planning organization) for the five-county metropolitan area. The survey was designed to capture enough observations of less common transportation choices to be able to understand the underlying factors. For these reasons, the sample universe in the metropolitan area was stratified by geographic “market areas” and enriched to include different numbers of transit and park-and-ride users. The survey involved a random sample of households that was selected after geographic stratification within the survey perimeter. In particular, three geographic strata demarcate areas suitable for travel on foot and on light rail: (1) urban areas with good pedestrian environments and transit, (2) urban areas with poor pedestrian environments, and (3) areas within the light rail corridor. Each household within the household activity survey is assigned a stratum.<sup>xiv</sup> Households in areas defined under the coding scheme developed by Portland Metro as having good pedestrian and transit access were oversampled. However, to perform research that is representative of the entire Portland metropolitan area, a weighting system was developed to apply to the sampled households. The geographic weighting system is used in all statistical analyses in this study.<sup>xv</sup>

The dependent variable and explanatory variables are listed and described in Table 1.<sup>xvi</sup> Table 2 lists the variable means for the data set.

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<sup>xiv</sup> Multnomah County is subdivided into five strata: urban, good pedestrian environment factor (PEF), land use mix, and transit (stratum 1); urban, bad PEF and transit (stratum 2); urban, good PEF and transit (stratum 3); light rail corridor (stratum 4); remainder of County (stratum 5). Respondents from other counties and park-and-ride users coming from outside the area with assigned strata 6 through 10. Source: NuStats International, Inc. Technical Memorandum, *Sample Productivity Plan*.

<sup>xv</sup> The household activity survey includes sample weights; these weights ensure that the estimation is based on calibration data that reflect actual distributions in the population rather than the shares present in the 4,451-household sample. For the auto ownership model, population-share weights were computed as the data-expansion weight previously assigned to each household (for the purposes of expanding the sample to represent the populations) times the factor (1,132/119,771). The factor normalizes the resulting weight so that the sum of the weights remains 1,132 while the weighted distributions from the sample match the characteristics of all the households in Multnomah County and their auto ownership patterns.

<sup>xvi</sup> Current examples of market-segmented auto ownership rate models are provided by Panos Prevedourous and Joseph Schofer (1992) and James Ryan and Gregory Han (1999). Don Pickrell and Paul Schimek (1999) use the 1969, 1977, 1983, 1990, and 1995 Nationwide Personal Transportation Survey (NPTS) to reveal important insights into the changing patterns of household auto ownership and use, as well as the underlying behavior that produces it. The two major trends revealed by the succession of surveys are the trend toward nearly ubiquitous ownership of at least one vehicle among U.S. households, and the rapidly increasing number of households owning multiple vehicles. For other examples of auto ownership models, see S.R. Lerman (1976); for discussions of auto dependence see José Gómez-Ibáñez (1991), Peter Newman (1996); for studies concerning the interaction of auto ownership and travel and activity participation, see Thomas Golob *et al.* (1995), Thomas Golob (1990), Thomas Golob and L. van Wissen (1989); for studies of households with no autos, see Charles Lave and Richard Crepeau (1994), Richard Crepeau and Charles Lave (1996), U.S. Department of Transportation (1994). Other studies of urban form and travel behavior have dealt with auto ownership peripherally; Peter Newman and Jeffrey Kenworthy (1989a, 1989b) use gross aggregate data to show that high-density residential developments result in less dependence on the auto and higher rates of commuting to work by walking or public transportation. Yet contradictory evidence does exist in the literature — other studies (Holtzclaw 1990, 1994) find lower rates of auto ownership in low density areas.

## Table 1: Explanatory Variables

### DEPENDENT VARIABLE

Auto Ownership

Continuous variable equal to 0, 1, 2, 3 if there are 0, 1, 2, or 3 or more autos available in the household.

(Source: 1994/95 Portland, OR Household Activity Survey.)

### INDEPENDENT VARIABLES

#### Household Variables

Household Income

Annual household income, bracketed into fourteen classifications.

1	\$ 0 - \$ 4,999	8	\$ 35,000 - \$ 39,999
2	\$ 5,000 - \$ 9,999	9	\$ 40,000 - \$ 44,999
3	\$ 10,000 - \$ 14,999	10	\$ 45,000 - \$ 49,999
4	\$ 15,000 - \$ 19,999	11	\$ 50,000 - \$ 54,999
5	\$ 20,000 - \$ 24,999	12	\$ 55,000 - \$ 59,999
6	\$ 25,000 - \$ 29,999	13	\$ 60,000 or more
7	\$ 30,000 - \$ 34,999	14	don't know/refused

Source: 1994/95 Portland, Ore. Household Activity Survey.

Household Size

Number of persons in household.

Source: 1994/95 Portland, Ore. Household Activity Survey.

Single Family Home

Dwelling type. Dummy variable equal to 1 for single family home and equal to 0 for other types of dwellings (apartment or condominium.)

Source: 1994/95 Portland, Ore. Household Activity Survey.

White Householder

Race of head of household. Dummy variable equal to 1 if the head of household is Caucasian and 0 for all other races (black/African American, Hispanic/Mexican American, Asian/Pacific Islander, Native American, or other.)

Source: 1994/95 Portland, Ore. Household Activity Survey.

Male Householder

Sex of head of household. Dummy variable equal to 1 if the head of household is male and 0 for female.

Source: 1994/95 Portland, Ore. Household Activity Survey.

Non-senior Householder

Age of head of household. Dummy variable equal to 1 if the head of household is 65 years of age or less and 0 if the head of householder is greater than 65 years of age.\*

Source: 1994/95 Portland, Ore. Household Activity Survey.

#### Local Demographic Variables (by Census Tract)

Median Income

Median income of households in census tract.

Source: 1996 American Community Survey.

Household Density

Number of households in census tract divided by land area (in acres).

Source: 1996 American Community Survey.

% White

Percent of population that is Caucasian.

Source: 1996 American Community Survey.

#### Local Urban Design Variables

Land Use Mix

Dummy variable equal to 1 for diverse land use mix and equal to 0 otherwise.

Source: Portland Metro Regional Land Information System.

Pedestrian Environment Factor

Dummy variable equal to 1 for good pedestrian environment factor and equal to 0 otherwise.

Source: Portland Metro Regional Land Information System

Transit Accessibility

Dummy variable equal to 1 for good transit accessibility and equal to 0 otherwise.

Source: Portland Metro Regional Land Information System.

Light Rail Corridor

Dummy variable equal to 1 if the household is located within 1/4 miles of light rail and 0 otherwise. Source: Portland Metro Regional Land Information System.

\* Note: Elderly is defined as age 65 years or older. This is the most commonly used definition in the literature on mobility of elderly persons (*Effects of Age on the Driving Habits of the Elderly* 1994).

**Table 2: Mean of Variables for Auto Ownership Regression**

	All households in sample	Autos per household			
		Zero	One	Two	Three or more
Auto Ownership	1.281	0.000	1.000	2.000	3.000
Household Income	7.931	4.374	7.756	10.002	10.550
HH Size	1.922	1.134	1.605	2.508	2.954
Single Family Home	0.574	0.041	0.580	0.810	0.960
White Householder	0.942	0.877	0.956	0.975	0.952
Male Householder	0.378	0.220	0.404	0.445	0.473
Non-senior Householder	0.774	0.772	0.692	0.819	0.877
Median Income (Census Tract)	31,115.00	15,898.00	32,982.00	37,775.00	40,445.00
HH Density (Census Tract)	0.092	0.127	0.100	0.066	0.058
% White (Census Tract)	0.866	0.820	0.877	0.884	0.887
Land-Use Mix	0.295	0.733	0.221	0.130	0.046
Pedestrian Environment Factor	0.464	0.830	0.434	0.312	0.258
Transit Accessibility	0.556	0.851	0.524	0.449	0.411
Light Rail Corridor	0.149	0.045	0.198	0.194	0.146
Sample size	1,132	300	330	394	108

Our sample includes respondents in Multnomah County with complete data for the explanatory variables, a total of 1,132 observations, whose geographic distribution is shown in Figure 2. Among this sample, 300 households (27 percent) own zero autos, 330 households (29 percent) own one auto, 394 households (35 percent) own two autos, and 108 (9 percent) own three or more autos.<sup>xvii</sup> The geographic distribution of households by auto ownership category is shown in Figure 3. Note that households with zero autos are clustered in the City of Portland show less county-wide dispersion than households at other auto ownership levels. The geographic distribution of households by household income is shown in Figure 4.

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<sup>xvii</sup>The auto ownership model in this study uses the household as the decision-making unit. It is structured more behaviorally compared to aggregate auto ownership models (which model auto ownership at the zonal, regional, or national level). We believe disaggregate models are better able to capture the causal relationship between auto ownership determinants and auto ownership levels.

Figure 2  
Distribution of Sample in Multnomah County

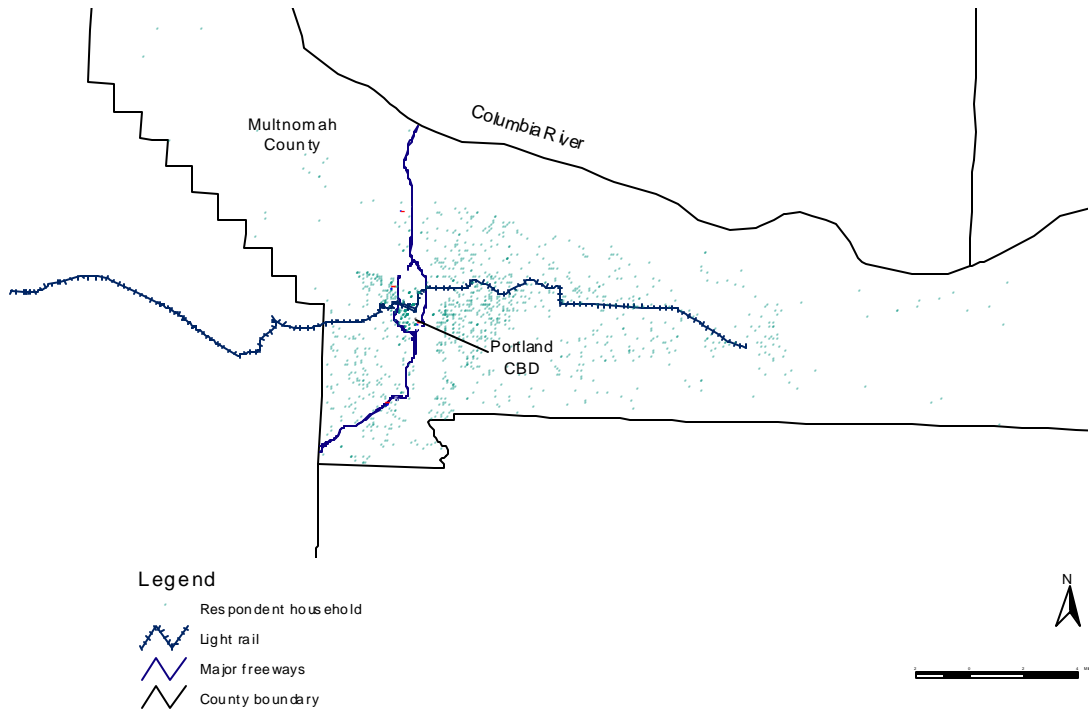
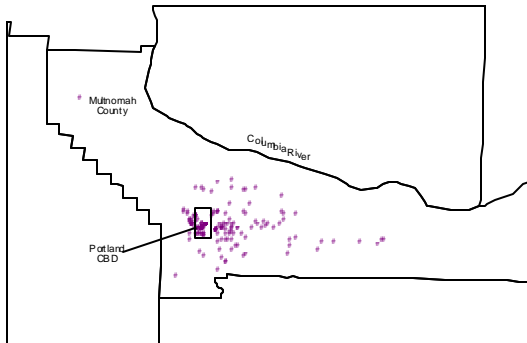
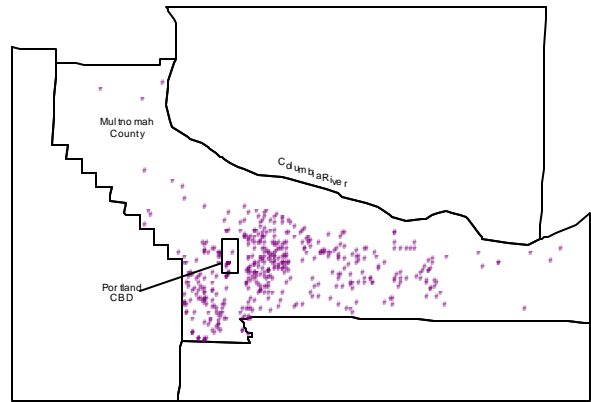


Figure 3  
Distribution of Households by Auto Ownership

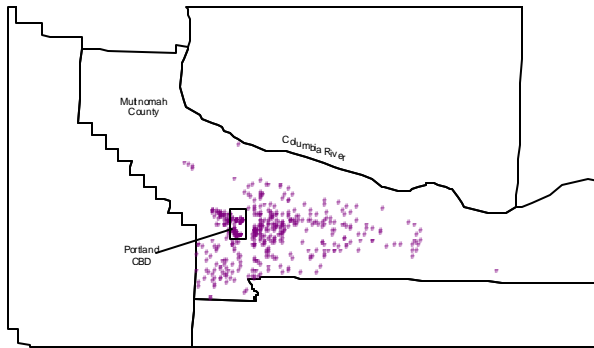
Households with Zero Autos



Households with Two Autos



Households with One Auto

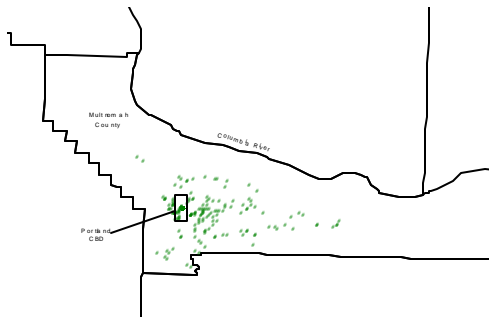


Households with Three or More Autos

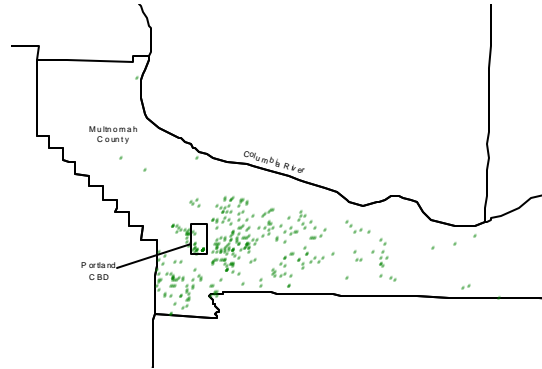


Figure 4  
Distribution of Households by Household Income

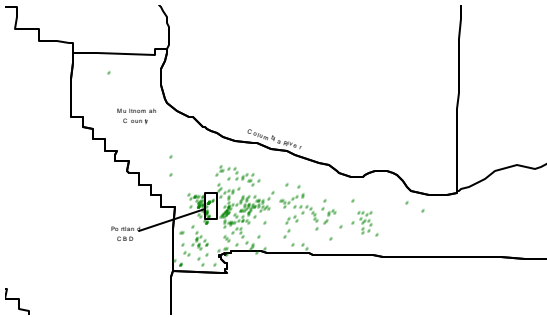
Household Income \$ 0 - \$ 15,000



Household Income \$ 30,000 - \$ 50,000



Household Income \$ 15,000 - \$ 30,000



Household Income \$ 50,000 or more

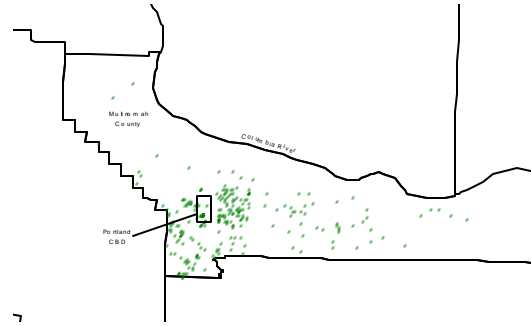
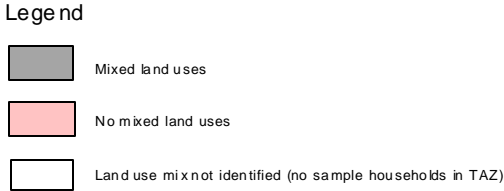
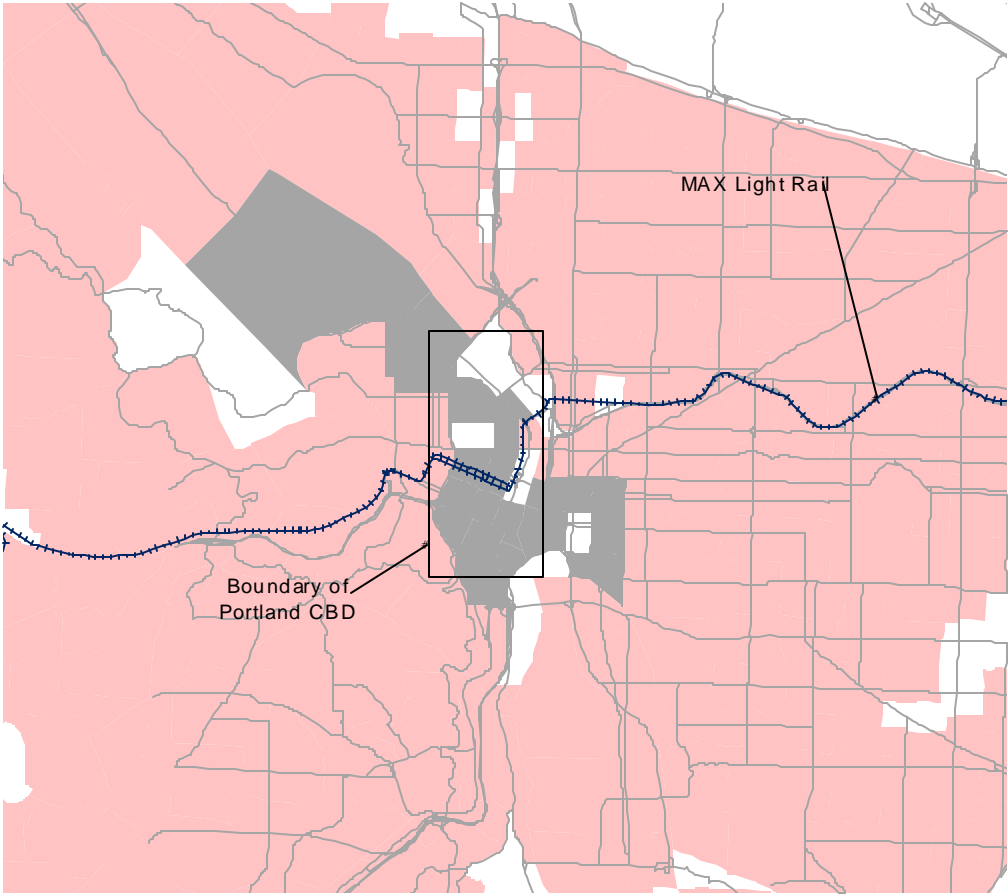


Figure 5  
Identification of Land Use Mix by TAZ





We create four new dichotomous variables to denote different aspects of urban design<sup>xviii</sup>:

### **Land use mix**

The land use mix index was determined by Portland Metro based on the ratio of the total employment to the total number of households in each TAZ, and only the top 10 percent of TAZs are given a rating of “good” land use mix. Figure 5 shows the land use mix designation of the Portland CBD and environs. The districts with mixed-land uses are dominated by Portland’s fine stock of old, neighborhood-scale multi-family housing built in the early 1900s along the streetcar lines and just north of downtown. In addition to the diverse housing stock, these neighborhoods (such as Hawthorne, Belmont, Northwest 23<sup>rd</sup> Avenue) have shops and services within walking distance of housing and transit, and gridded streets with sidewalks and pedestrian amenities (Harmon 1998).

### **Pedestrian environment factor**

The pedestrian environment factor (PEF) developed by Portland Metro is a constructed measure of the pedestrian environment describing the topography, sidewalk continuity, local street pattern, and ease of crossing streets within each TAZ.<sup>xix</sup> The PEF concept was first developed and applied in the Portland metropolitan region in the landmark Land Use Transportation and Air Quality (LUTRAQ) study (Cambridge Systematics 1992). The approach helps take development patterns and characteristics into account in the transportation planning process. This helps fill a gap in data, since the decennial census and the Public Use Microsample (PUMS) data do not have information on neighborhood characteristics (such as land use density or accessibility measures) at a fine geographic scale. LUTRAQ was the first effort to bridge the land use-transportation link by bringing

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<sup>xviii</sup>These dummy variables do not sum to one since there is an additional geographically stratified group (remainder of Multnomah County) that has been purposely omitted from the analysis.

<sup>xix</sup>Four main categories are used to measure the “walkability” of different areas: (1) ease in street crossing; (2) sidewalk availability; (3) development patterns; and (4) topography. Each of these four categories was subjectively ranked and a summed index was calculated for each transportation analysis zone. As used by Portland Metro in its regional travel demand model in the auto ownership, pre-mode choice and mode choice models for home-based-work and home-based-other trip purposes, model estimation proved the subjectively indexed value to be statistically significant.

Pedestrian access is defined as a mixture of the ease of street crossings, sidewalk continuity, topography and whether a neighborhood street network is primarily *cul-de-sac* or more open. Each category is subjectively ranked on a scale from one to four (four being the best ranking), so each zone has a maximum possible summed index of 16 and a minimum of four. The higher the score, the more the zone accommodates non-auto travel. The study found that, as expected, residents in neighborhoods with higher density, proximity to employment, grid street pattern, sidewalk continuity, and ease of street crossing tend to make more pedestrian and transit trips, whereas residents of more distant, lower density suburban areas with auto-oriented land use patterns show extensive reliance on autos (1000 Friends of Oregon 1996). As expected, high PEF areas are grouped together near the downtown area (Greenwald 2000).

environmental characteristics directly into the modeling process.

### **Transit accessibility**

This variable is a subjective measure of bus transit access. Households near multiple bus lines and/or bus lines with frequent service are identified as having “good” transit accessibility, while households not near bus lines or bus lines with infrequent service are considered to have “poor” transit accessibility. The measures were developed by Portland Metro using a geographic overlay linking households with detailed bus route information.

### **Proximity to light rail**

All homes within a quarter mile of light rail are considered to have convenient light rail access. Like the transit accessibility variable, this measure was also developed by Portland Metro using a geographic overlay.

## **THE RESULTS**

The regression results are shown in Table 3.<sup>xx</sup>

From the pseudo  $r^2$  values, we see that both models fit the data well, explaining about 40 percent of the variation of the dependent variable. In both models, the most important statistical determinants of the probability of auto ownership are household income, household size, residence in a single family home, the presence of a male householder, and mixed-land uses. The estimated parameters have the expected signs. In model 1, several neighborhood characteristics — pedestrian environment factor, transit accessibility, and light rail corridor — are statistically insignificant. This indicates that the most important urban design feature is mixed-land use. On the other hand, individual components of urban design by themselves do not have a statistically significant impact.

We can use model 2, the more parsimonious model, to estimate the effect of the statistically significant factors on auto ownership.<sup>xxi</sup> For each additional person in the household, the probability of owning zero autos decreases by about 10 percentage points. For each \$5,000 increase in annual household income, the probability of owning zero autos decreases by about 6 percentage points.

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<sup>xx</sup> We also performed a probit ordered regression on the dataset. We found that the coefficient values and probabilities were comparable to the logit ordered regression. We report the logit results here because performing simulations using the results is simpler.

<sup>xxi</sup> Behavior probability predictions are made using the following formula:  $\hat{p}/\hat{\Delta}x = c * p * (1 - p)$  where  $c$  is the coefficient,  $p$  is the grand mean for the outcome of the dependent variable for that sample,  $\hat{\Delta}p$  is the change in probability, and  $\hat{\Delta}x$  is the change in the independent variable being measured.

**Table 3: Estimated Ordered Logit Model of Auto Ownership**

Dependent variable: Number of autos per household

	Model 1		Model 2	
	Coefficient	prob	Coefficient	prob
Intercept 1	2.3242***	0.0015	2.3826***	0.0005
Intercept 2	5.1874***	<0.0001	5.2436***	<0.0001
Intercept 3	8.5854***	<0.0001	8.6396***	<0.0001
Household Income	-0.3140***	<0.0001	-0.3124***	<0.0001
HH Size	-0.5247***	<0.0001	-0.5315***	<0.0001
Single Family Home	-1.2069***	<0.0001	-1.2195***	<0.0001
White Householder	-0.7079**	0.0141	-0.7212**	0.0123
Male Householder	-1.1021***	<0.0001	-1.0875***	<0.0001
Non-senior Householder	0.0582	0.7294	0.0598	0.7219
Median Income (Census Tract)	-0.0128**	0.0354	-0.0099*	0.0733
HH Density (Census Tract)	-0.5850	0.1522	-0.5453	0.1796
% White (Census Tract)	0.2229	0.7803	0.0353	0.9623
Land Use Mix	1.5715***	<0.0001	1.6141***	<0.0001
Pedestrian Environment Factor	-0.2000	0.4742		
Transit Accessibility	0.1852	0.4674		
Light Rail Corridor	-0.1688	0.3576		
	n = 1,132		n = 1,132	
	df = 13		df = 10	
	X <sup>2</sup> = 1191		X <sup>2</sup> = 1189	
	pseudo r <sup>2</sup> = 0.392		pseudo r <sup>2</sup> = 0.392	
	p = <0.0001		p = <0.0001	

Key: \* p < 0.10, statistically significant at the 10% level  
 \*\* p < 0.05, statistically significant at the 5% level  
 \*\*\* p < 0.01, statistically significant at the 1% level

Non-white householders are 13 percentage points less likely to own an auto than white householders. Households in neighborhoods with mixed-land uses are 31 percentage points more likely to be carless than households in heterogeneous neighborhoods. Clearly, this last finding provides compelling evidence of the impact of mixed land uses on auto ownership.<sup>xxii</sup>

One difficulty with this type of study is that auto ownership can influence the household location choice. Previous travel behavior research has addressed the possibility that there may be an endogenous relationship between observed travel behavior and land use characteristics influencing individual travelers' decisions. For this study we interpret this general argument to mean that households with higher rates of auto ownership may in fact have a preference for auto travel, and as such select environments which support the preferred level of auto ownership and preferred commuter mode choice. But the question remains: do certain groups of people locate their households in high density, mixed-use neighborhoods because they do not own autos or because they do not *want* to own autos? The underlying theory is that households predetermine their travel tendencies, mode choice, and auto ownership rate when they choose a residential location. To investigate this, Krizek (2000) tracked specific households through several waves of the Puget Sound transportation panel survey and determined that when household relocated from a non high-density, non mixed-use neighborhood to a high-density, mixed-use neighborhood, they reduced both vehicle miles traveled (VMT) and person miles traveled (PMT). Better access also resulted in a decrease in travel distance and a decrease in number of trips per tour but an increase in total number of tours. These findings support our contention that certain groups of people may locate their households in high-density, mixed-use environments because of the possibility of owning zero autos.

Urban areas have a different, and self-selected, population mix than suburban and rural areas (Levinson 1999). Thus, those who enjoy the benefits of urban activity will take advantage of it, while those who prefer space and quiet sort themselves into lower density suburbs. Riyuchi Kitamura *et al.* (2000) and Marlon Boarnet and Sharon Sarmiento (1998) argue that the self-selection phenomenon questions the degree to which urban form features, by themselves, can influence the travel behavior of residents who do not already have a preference for non-auto travel. The policy implication here is that some individuals may have an unexpressed desire to own no or fewer autos which they are able to act upon when they relocate to high-density, mixed-use environments.

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<sup>xxii</sup> We note that a limitation of the model/data set is that the existence of households possessing zero autos may be a downtown phenomenon. This is further complicated by the notion that areas with land use mix overlap the downtown area. To investigate this potential effect, we re-specified Model #1 with an additional variable called DOWNTOWN (equal to 1 if the household TAZ is within the CBD and 0 otherwise). When we specified this model the land use mix variable remained significant but the DOWNTOWN variable was not significant. This convinced us to rule out the notion that land use variables are proxies for downtown location.

## CONCLUSION

The findings of this study are consistent with our core hypothesis concerning the relationship between traditional neighborhoods and auto ownership. Households located in dense, mixed-land use areas may be able to access many activities by walking or biking to nearby locations, and thus they exhibit a lesser need for autos. Households in areas well-served by transit similarly may be able to access many destinations and services using transit. Consequently, it is important for any auto ownership specification to recognize differences in the built environment.

In the empirical models, the most important statistical determinants of auto ownership probability are household income, household size, residence in a single family home, the presence of a male householder, and mixed-land uses. The estimation results show that households in high density areas own fewer autos than those in low density areas. The lower auto ownership rate is not the result of the association between income and density, since our model controls for the influence of household income on residential density. Lower auto ownership in higher density areas is likely the result of greater attractiveness of alternatives (walking, public transit) and greater motor vehicle costs. This is an important finding when we consider that a key public policy goal is to reduce auto dependence.<sup>xxiii</sup>

Although our findings are robust, there is nonetheless some ambiguity in the interpretation. If the relationship between land use and urban form is considered to be a simple causal relationship, then the findings indicate that mixed-land use has an effect on auto ownership that is independent of other factors, observed and unobserved. The relationship between land use and auto ownership, however, may be more complex when we consider the individual choices and preferences of a heterogeneous population. The existence of a wide variety of urban environments can enable people who are less disposed to rely on auto travel to select a neighborhood where they can comfortably live without owning autos, but unfortunately we do not have any measures of such preferences. The consequence is that the estimated effect of land use captures both the sorting of people by preference and the ability of mixed-land use to enable people to pursue their preferences. This interpretation, however, does not diminish the importance of mixed-land use. Without the diverse and compact land use afforded by traditional neighborhoods it is more difficult for people to express their choice to *not* own autos.<sup>xxiv</sup>

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<sup>xxiii</sup> Some researchers and policymakers claim that high auto ownership levels thwart public policy efforts aimed at increasing transit trips, since the market share of public transit falls very rapidly as soon as a household owns one auto (Bonnel 1999).

<sup>xxiv</sup> Given the choice between low-density suburban living and high-density urban living, Gordon and Richardson (1997) argue that Americans overwhelmingly choose the former. However, the suburbs rank low in residential preference surveys, well below small town, village, and rural settings. Visual preference surveys conducted by Anton Nelessen (1994) reveal that sprawling low-density single-family home neighborhoods are less attractive to people than pedestrian-oriented villages; Reid Ewing (1997, p. 111) concludes that “people are especially taken with the idea of neighborhoods clustered around a town or village center.” Nevertheless, Gordon and Richardson (1997, p. 99) speak of the “expressed preferences of the majority of Americans for suburban lifestyles and the supposed

Our results support the contention that certain physical features of traditional neighborhoods lend themselves to households without autos. Because parts of Portland were built prior to the auto, certain neighborhoods — downtown, Lloyd Center, NE 42<sup>nd</sup> Ave. — possess these traditional features. Living units over commercial businesses, houses with front stoops and porches, good public transit, and abundant sidewalks and social spaces are ingredients for community-oriented neighborhoods that are unfriendly to autos and safe for children. However, we question whether it is possible to replicate traditional neighborhoods throughout a region. Economic and social forces have led to highly dispersed and highly segregated land development and undifferentiated “low density” development unrelieved by open land. Residences are separated from businesses and suburbs are separated from workplaces. The trend in the last 40 years in U.S. metropolitan areas has been toward greater urban decentralization and separation of activities, disassociated from nearby urban fabric and lacking transit and mixed uses. This combination has led to the need for greater reliance on autos for everyday life. “New urbanism” can potentially reverse some of this trend if “new urbanism” is able to replicate the desirable features of older, traditional neighborhoods. Whether this will occur, however, remains to be seen.

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sanctity of consumer sovereignty.” See also Salomon 1983.

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