The Built Environment as a Determinant of Walking Behavior: Analyzing Non-Work Pedestrian Travel in Portland, Oregon

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Abstract: Much has been written about the connection between land use/urban form and transportation from the perspective of impacting automobile trip generation. This only addresses half the issue. The theoretical advances in land use/transportation relationships embodied in paradigms such as the jobs housing balance, Neo-Traditional Design (NTD) standards and Transit Oriented Development (TOD) rely very heavily on the generation of pedestrian traffic in order to realize their proposed benefits. The analysis presented here employs similar models and data sets used in Boarnet & Greenwald for the Portland, Oregon area, but applies them towards analysis of non-work walking travel. The results suggest that whatever effects land use has on affecting individual non-work walking trip generation, the impacts take place at the neighborhood level.

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I. INTRODUCTION

A great deal of time and effort has been expended in the popular planning literature investigating the connection between land use and transportation behavior. Most of this research has focused primarily on the linkages between land use and automotive travel, particularly with regards to commuting behavior (Cervero, 1989 (*1*); Cervero 1996 (*2*); Cervero & Wu, 1998(*3*)). Although this relationship is a large part of the theories guiding the current inquiries, it is only part of the story. The theoretical advances in land use/transportation relationships embodied in paradigms such as the jobs housing balance, Neo-Traditional Design (NTD) standards and Transit Oriented Development (TOD) rely very heavily on the generation of pedestrian traffic in order to realize their proposed benefits. In addition, recent evidence suggests work commutes and related activities make up a relatively small proportion of the total number of trips made and distance traveled (FHWA, 1995 (*4*)).

Taken together, these facts suggest a major component in testing the relationship between land use and transportation is measuring the degree to which land use characteristics influence pedestrian travel behavior for activities other than employment. Some notable initial efforts in this direction have taken place. Handy (1996) hypothesized walking trips may be substituted for or supplement automobile trips as neighborhood accessibility, defined as "the intensity of the possibility of interaction," increased with respect to changes in urban form (Handy, 1996 (*5*)). Though not directly addressing Handy, the recent work of Vernez-Moudon & Hess (2000) regarding regional clustering effects of residential and retail land uses in the Puget Sound area suggests that there may in fact be spill over utility beyond the local level in increasing pedestrian accessibility in relatively small neighborhoods (Vernez-Moudon & Hess, 2000 (*6*)). These perspectives are supported by Ewing, who, using travel diary data from the Palm Beach County, Florida area, has shown how differences in local employment and residential densities, mixture of retail and residential land uses, and conformity to NTD principles for street design (collectively considered as measures of local accessibility) reduce the total amount of driving time per household (Ewing, et. al., 1994 (*7*); Ewing, 1995 (*8*)). These findings have subsequently been incorporated into practical local and regional development guidelines (Ewing, 1996 (*9*)).

Though an impressive start, these works do not directly test the influence of land uses on the generation of pedestrian trips for non-work purposes. This work adds to the growing body of case study literature seeking to draw that connection, and do so in a way that provides unique methodological benefits. This analysis employs similar models and data sets used in Boarnet & Greenwald (*10*) for the Portland, Oregon area to examine non-work vehicle trip generation, but applies them towards analysis of non-work walking travel, using the same data sets from that research. The consistency in data sets provides two advantages. First, as this work uses the same data to answer a different key question regarding the linkage between land use and travel behavior, the results here can be used as a starting point for drawing comparison based conclusions about a single population. Second, stemming from this first advantage, to the extent that Portland is representative of other major metropolitan environments, this research speaks to the ability of strategies such as NTD and TOD to achieve their goals of travel mode substitution in different urban forms.

II. PREVIOUS RESEARCH

Because the research presented here focuses quite heavily on testing the impacts of neo-traditional design, it is appropriate to begin with a brief description of what NTD (and it's related concepts) is. The basics of these strategies are not all that complex; retail and employment centers are to be constructed within walking distance (approximately 15 minutes travel time) of high density multi-family or single family attached housing. Atash (*11*) notes that this is reminiscent of traditional town planning practices of the late 19th and early 20th century. Depending on the specific application of NTD employed (standard NTD, or more specifically transit related TOD), rectilinear street orientation in conjunction with the high population densities plays a major role in promoting travel by means other than personal automobile by facilitating path finding. This focus away from the automobile is reinforced by the use of narrow street right of ways in NTD neighborhoods. Developers who practice NTD strategies point to commercially successful projects as examples that their perspectives are valid (e.g., Kentlands, Maryland and Seaside, Florida for Duany & Plater-Zyberk, Portland, Oregon and Sacramento, California for Calthorpe).

Although the ability to sell one's product in the marketplace can be an indicator in a capitalist society of popular support for the underlying social constructs on which it is based, it is not proof that the theories work in the manner NTD proponents suggest. Crane (*12*) demonstrated that NTD strategies reduced time costs for all modes of travel, and as such these strategies could lead to an increase in automobile travel if the orientation of land usage in these communities did more to reduce impediments to vehicle usage than promote pedestrian behavior. Could NTD backfire?

The initial research in the area of land use/transportation connection suggests that land use characteristics do little to influence individual non-work automobile travel behavior. Boarnet & Crane (*13*) and Boarnet & Sarmiento (*14*) both found that where land use influences travel behavior, the effect is indirect through influencing the non-monetary costs of travel (i.e. time in transit). This is consistent with NTD theory. However, these works also demonstrated that whatever relationship is present is not robust (and possibly highly endogenous with residential choice), as the statistical significance of land use measures changes between models employed. Though these findings are based on the Los Angeles County/Orange County/San Diego County metropolitan region, Boarnet & Greenwald (*10*) verified these results using similar models on the Portland, Oregon region. Yet these works speak only to the impact of land use characteristics on automotive behavior. Without a comparative discussion of impacts on pedestrian behavior, this body of literature is incomplete. It is to this task we now turn.

III. THE MODELS

Following Crane (*12*), we represent demand for non-work walking trips as

$$N = f(p,y;\mathbf{S}) \quad (1)$$

where N = the number of non-work walking trips taken by an individual

p = the time cost (or price) of a non-work walking trip

y = individual income

S = a vector of sociodemographic shift (or taste) variables, which will be defined later.

In general, travel cost (p in Equation 1) includes both money and time cost. However, our sample is limited to individuals who are faced with similar money costs. Since all travel diary respondents are from the greater Portland area, we assume that there are no important variations in fuel cost across persons in our sample. Note that this assumption is reasonable, since the greatest variation in fuel costs occurs across rather than within urban areas. Hence the model is simplified to consider only the time cost of travel.

The time cost of travel varies across individuals depending on their respective values of time. Differences in individual time value are captured by income and other sociodemographic characteristics. Following Kitamura, et. al. (*15*), income squared (y^2) is included in the empirical model. Of the studies reviewed earlier, only Kitamura (*15*) gives any attention to the need to control for how the value of time spent driving will change as income levels change. This quadratic representation is intended to capture both the extent to which non-work trip-making is a normal good and the extent to which time spent driving is more valuable (and thus more costly) for persons with higher income.

Given the inclusion of prices (here, time cost) and income in the non-work car trip generation model -- standard practice in any application of the theory of consumer demand -- the tricky question involves how land use might enter into a specification like Equation 1. Following Boarnet and Crane (*13*), we test two specifications.

Model 1: Price Variation that is Completely Determined by Observable Land Use Characteristics

Perhaps the differences in time costs of non-work trips can be completely explained by differences in land use patterns. In other words, land use might affect non-work automobile trip frequencies by directly affecting the price, e.g. time cost, of travel. This is shown below.

$$p = f(\mathbf{L}) \qquad (2)$$

where **L** is a vector of land use or urban design characteristics. Substituting Equation 2 into Equation 1 gives

$$N = f(\mathbf{L}, y; \mathbf{S}) \qquad (3)$$

The model in Equation 3 is a reduced form which reflects the assumption that differences in the time cost of travel are due to differences in land use and urban design at different locations. Yet if land use and design are measured incompletely, which is plausible given the difficulty of operationalizing and measuring the characteristics associated with, e.g., the New Urbanism, there might be differences in the time cost of travel even after the land use variables are introduced into a trip generation regression. Crepeau (*16*) addresses this point directly, saying the literature examining land use and transportation has up to this point been constrained by the use of proxy variables for land use such as population and retail densities at different levels of geography (e.g., zip code, census tract, or transportation analysis zone). According to Crepeau, though these variables are readily available and relatively easy to incorporate and interpret in existing models, they do not get to the heart of incorporating land use characteristics into travel behavior. This suggests the next model.

Model 2: Include both Price Variables and Land Use Variables in the Trip Generation Regression

Both the price variable, p, and the land use variables, L, can be used in a regression equation, as shown below.

$$N_a = f(p, y,; \mathbf{L}, \mathbf{S}) \qquad (4)$$

The time-cost variable p can be broken down into two components, trip distances and trip speeds. These variables can be more easily linked to policy, since urban designs have been proposed with the explicit intent of, for example, changing automobile trip speeds (e.g. traffic calming) or changing trip distances (e.g. mixed land uses or more direct, grid-oriented, street patterns). The result of representing p by trip distances and trip speeds is shown below.

$$N = f(m, t, y; \mathbf{L}, \mathbf{S}) \qquad (5)$$

where m = non-work trip distance

t = non-work trip speed.

Following Crane and Crepeau (*17*), we use the median of non-work trip distances (m) and non-work trip speeds (t) for each travel diary respondent.

IV. DATA

The Portland Travel Diary for 1994 is a two day travel diary collected for individuals in the three county area surrounding Portland Oregon. Information was collected on standard socio-demographic data, trip speeds and distances, and nature of related activities. Table 1 provides a list of variables used in the regressions presented here.

(***Insert Table 1 Here***)

The exogenous socio-demographic variables used here are identical to those used in Boarnet and Greenwald. The land use variables are also the same, with the following exception. Boarnet and Greenwald used a derivative of the Pedestrian Environment Factor (PEF) score to incorporate urban form into the discussion of non-work automobile trip generation. The score is a composite generated on four criteria: ease of street crossing, sidewalk continuity, street connectivity (grid vs. cul-de-sac) and topography. In that work, each category was scored on a scale from one to four (four being the best ranking), so each transportation analysis zone had a maximum possible score of 16 and a minimum of four. The higher the score, the greater the degree to which the zone accommodates non-automobile based travel.

The PEF score used in Boarnet and Greenwald were modifications of the original pedestrian factors developed by the 1,000 Friends of Oregon, created specifically for the purpose of measuring the degree to which specific transportation analysis zones facilitated pedestrian travel (*18*). These changes were made to incorporate the PEF score into Emme2 traffic modeling as part of the Portland Metro regional planning process. However, since this process focused on automobile usage as opposed to pedestrian travel, we chose to use the original PEF scores developed by the 1,000 Friends of Oregon. These scores measure the same attributes, but have a slightly different scoring scale, ranging from a maximum of 12 to a minimum of four.

The PCTGRID variable was created using GIS software by buffering within one quarter mile of the home location of each individual respondent, then summing the land area of all street sections within that buffer that were of a quadrilateral nature. That sum was then divided by the area of the quarter mile radius circle to get a proportion of the buffer area covered by a grid street pattern. This leads to a measure of street patterns that is similar to the one used in Boarnet and Sarmiento (*14*). The incorporation of the PCTGRID and pedestrian based PEF variables are direct attempts to address the points raised by Crepeau (*16*).

V. RESULTS

The analysis presented here is conducted at two similar levels of geography for the local level. Census block groups and transportation analysis zones were chosen due to their similarity in geographic scale for the region under investigation. Visual comparison of maps for the Portland Metro region suggest that transportation analysis zones are contiguous with individual census block groups or combinations of adjacent block groups. In addition, this finer level of geographic detail allows for more localized observations, making these findings more in line with the scale of geography intended by neo-traditionalist proponents and New Urbanists.

Table 2 shows the results of an ordered probit regression for non-work walking trip frequencies.

(***Insert Table 2 Here***)

The independent variables in the first column of Table 2 are socio-demographic characteristics of the individual traveler or their family; this regression provides a framework against which to measure the effects of land use on influencing individual travel decision making. The results in column 1 confirm behavior patterns one would expect to see with regards to walking trip generation. Age reduces the likelihood of walking trips, as does the number of cars per driver in the household, though both of these results evaporate as land use characteristics are incorporated into the models. Households with more children consistently make more walking trips, while households with greater numbers of employed persons tend to make fewer non-work walking trips. One possible explanation for the latter effect is that some non-work activities are tied to the work commute, which is less likely to be completed exclusively on foot.

Columns 2 and 3 of Table 2 demonstrate what effect land use variables have on local walking behavior. Column 2 indicates that in the presence of land use considerations, the only variable that significantly predicts non-work walking behavior is the number of children per household. This is most likely an artifact of the specific regression, due to the loss of degrees of freedom associated with the PCTGRID variable. When this variable is removed in the Column 3 model, the statistical significance of children in the household is maintained and the importance of the number of employed persons per household returns. Additionally, the importance of traveling on workdays and census block group population density is revealed; fewer non-work walking trips are expected on weekdays, and population density positively affects the likelihood of non-work travel being completed by walking trips. This last point speaks directly to the New Urbanist contention that density affects walking behavior, a contention bolstered by the fact that as trip cost variables (median walking distance and speeds for individuals) are added in Column 4, block group density becomes an even stronger predictor of walking behavior.

Ideally, one would expect all land use variables to be significantly related to non-work walking behavior. However, correlations between the land use is high enough to question whether or not including all urban form variables in the same model will mask the effects each is contributing to the behavioral pattern under examination (correlations for block group population density compared with retail density and PEF scores were r=.4363 and r=.5026, respectively). Table 3 shows a joint significance test for the set of local land use measures, per the strategy used by Boarnet & Sarmiento (*14*).

(Insert Table 3 Here)

The differences in log-likelihood results between the unrestricted model (i.e., including the full set of land use variables, less the PCTGRID variable for reasons already mentioned) and the restricted model (the basic model without any land use characteristics) is sufficiently large to imply that the land use variables as a set are significant in determining probabilities of non-work walking travel. Table 4 further supports this point by running the base model with each land use characteristic included separately. In each case the land use variables are significant and of the expected sign with regards to the New Urbanist paradigms.

(Insert Table 4 Here)

The results from Tables 2 through 4 beg the question of whether or not these observations are indicative of an effect beyond the local scale. Does land use affect walking behavior at the regional level? Although most neo-traditional design advocates tend to restrict their observations and recommendations to the local level, the work of Vernez-Moudon & Hess (*6*) suggests a regional aspect of NTD impacts on walking behavior should be explored. Additionally, if the work presented here is to be compared to previous research on land use impacts on automobile trip generation (Boarnet & Crane (*13*); Boarnet & Sarmiento (*14*); Boarnet & Greenwald (*10*)), similar models must be employed in order to get the full picture. Tables 5 and 6 speak to this issue by employing the same models for population and retail density that were used in Tables 2 and 3 for the ZIP code level of analysis.

(Insert Tables 5 and 6 Here)

Direct measures of urban form are not employed in these latest tables because there are no methodological equivalents of pedestrian environmental factor or percentage of urban street grid orientation at the regional level known to the authors at this time. The results in Table 5 suggest regional densities are not as important in determining individual walking behavior, as indicated by the insignificance of the population and retail density variables. Additionally, individual trip costs become insignificant when analyzed in the context of regional variables, lending further support to the idea that land use impacts on pedestrian travel have highly localized impacts, and results in Table 6 argue that regional densities are not significantly useful as a set of predictors.

The results in Tables 5 and 6 should not be taken as the final word on regional impacts of New Urbanist practices. Though the standardized scores for population density in ZIP codes are strictly insignificant at the traditional five percent level, they are sufficiently close to the critical values to imply that these results are artifacts of this particular data set; magnitude and sign are still preserved. In addition, without similar urban form measures at the regional level any comparisons between the results in Tables 2 and 5 are unwarranted.

VI. FEEDBACK BETWEEN RESIDENTIAL LOCATION CHOICE AND TRAVEL BEHAVIOR

Up to this point we have made the assumption that travel behavior is the exogenous component of land use/transportation relationships; urban form dictates travel behavior. However, a plausible alternative explanation does exist. Perhaps individuals who prefer to travel by pedestrian modes select into residential locations where the urban environment facilitates this type of behavior. The observed relationship between land use and transportation would not in this situation be indicative of support for New Urbanist practices as a method for altering travel behavior.

To demonstrate the problem formally, we expand the model represented by Equation 3 in Section III. Assume the number of non-work walking trips is approximately continuous, such that the number of such trips is given by

$$N = a_0 + a_1'\mathbf{L} + a_2y + a_3y^2 + a_4'\mathbf{S} + u \qquad (9)$$

where u = the regression error term.

If persons choose residential locations (and thus land use patterns near their residence) based on unobserved preferences which are correlated with attitudes about walking (or any other mode of transportation), the variables in the **L** vector can be correlated with **u**, the error term in Equation 9. Under those circumstances, the least squares parameter estimates for the above equation will be biased and inconsistent. As in other situations where independent variables are correlated with the regression error term, a solution is to use instrumental variables.

Choice of instruments in this situation requires careful consideration. The instrumental variables selected must be highly correlated with urban form yet not significantly correlated with

u. The residential location of an individual is a function of individual and location characteristics, shown below.

$$ResLoc_i = f(\mathbf{C}_i, \mathbf{A}_i) \qquad (10)$$

where $ResLoc_i$ denotes the residence location for person "i"

$\mathbf{C}_i$ = individual sociodemographic characteristics

$\mathbf{A}_i$ = characteristics of residential locations, including location-specific amenities such as school quality, the demographic composition of the surrounding neighborhood, and the age of the housing stock in the surrounding neighborhood.

The variables in Equation 10, because they explain residential location choice, are potential instruments for the **L** variables in Equation 9. Of the variables in Equation 10, the individual characteristics in **C** are likely to be the same as the demographic variables in **S**, leaving only the non-transportation neighborhood amenities in **A** as allowable instruments. We select six non-transportation neighborhood amenities as instruments, listed below.

PCIncTrc - Per capita income in the area (Census Block Group only)

PctCollege – Percentage of population living in geographic area with at least a college education.

PctBlk - Percentage of population identified as African American from the 1990 Census living in the geographic area

PctHsp - Percentage of population identified as Hispanic from the 1990 Census living in the geographic area

PctNFrm - Percentage of housing units in the geographic area classified as rural and not classified as farms

PctUrb - Percentage of housing units in the geographic area classified as urban dwelling units.

All instruments are taken from the 1990 U.S. Census (*19*). The ethnicity based instruments are reminiscent of Boarnet and Crane, Boarnet and Sarmiento and Boarnet and Greenwald (*13, 14, 10*). The education and income instruments are selected to get at previously unexamined aspects of the **C** matrix that might impinge on location choice. Individuals might choose residential location on aspects of similarity other than ethnicity, and income and educational attainment are strong indicators of socioeconomic class. The housing stock instruments selected for density and urban form variables were chosen because they come closer to measuring the realized physical characteristics of the surrounding environment than the housing stock age instruments used by the Boarnet and Crane, Boarnet and Sarmiento and Boarnet and Greenwald inquiries (*13, 14, 10*).

Tables 7 and 8 show how successful was the use of instrumental variables analysis for location choice.

(Insert Table 7 Here)

For Table 7, the instrument set was valid for all land use variables except retail density, as indicated by the overidentification tests conducted on each IV model (note; the null hypothesis for overidentification tests is that the instrument set is valid). Of the three remaining valid instrumental regressions, two continue to support the conclusion that New Urbanist practices promote walking behavior for non-work travel, when considered individually. Block group population density and PEF score are both significant individually in both the ordinary least squares and the instrumental variable regressions. The PctGrid variable, though significant in the ordinary least squares model, becomes insignificant when instrumented. The socio-demographic and trip cost variables in each case exhibit the trends seen in Table 2, where only trip distances were a significant predictor for probabilities of non-work walking behavior.

Table 8 continues to support the conclusion that densities play a smaller role in generating non-work walking behavior at the regional level.

(Insert Table 8 Here)

The instrument set employed in the Table 8 regressions is slightly different in that it does not include a per capita income measure. Including this instrument would have made both instrumental regressions at the ZIP code level invalid. Again we find that regional population and retail densities are statistically insignificant in promotion of individual walking behavior for non-work trips.

VII. CONCLUSIONS

In this paper, we have analyzed the impacts of land use on decisions for non-work walking travel. Several lessons are apparent from this investigation. First, to the extent that densities do impact walking decision making, this effect is highly localized. This stands in stark contrast to previous findings regarding non-work automobile travel, where regional land use traits are more important (Boarnet & Sarmiento, Boarnet & Greenwald (*14, 10*)).

Second, though the elements of New Urbanist practices appear to have some merit, at least in the generation of walking behavior, the relative contribution of the elements is anything but clear. This is most likely due to correlation between the urban form variables and the density measures employed here, though the joint significance test in Table 3 and the individual contributions demonstrated in Table 4 suggest that each of these factors alone, or together in subsets, has the potential to influence walking behavior for non-work activities.

Third, with regards to trip costs, the most important determinant of walking behavior appears to be trip distances; shorter distances increase the likelihood of individual walking trips for non-work activities. New Urbanist and TOD practitioners are thus quite correct to focus on this aspect of urban design if they wish to promote pedestrian behavior as an alternative to personal vehicle use.

Finally, without the ability to test the importance of regional urban form variables any discussions about the ability of New Urbanist practices to generate benefits beyond the local level are unfounded. The use of direct measurements of urban form are a necessary precursor to testing land use/transportation practices, and the geographic scale of analysis can only legitimately proceed as far as these measurements have or can be developed. We now have reason to believe that neighborhood level urban form can influence walking behavior; this is of course useful to local planners whose job it is to optimize the operation of their specific jurisdictions. Whether or not that influence extends beyond one's immediate surroundings, and thus can be used by regional analysts, remains to be seen.

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Table 1: Variable Names and Definitions

Dependent Variable

NWTRIPS	Number of non-work walking trips per person over two day travel diary period

Socio-Demographic Variables

AGE	Age of individual respondent
CARSPRDR	Number of cars per licensed driver in household
GENDER	Gender of individual (1=Female, 0=Male)
INCOME	Household income
INCOMESQ	Household income squared
KIDS	Number of children under the age of 16 per household
NUMEMPLY	Number of employed workers per household
RACE	Ethnicity of individual respondent (1 = white, 0 = non-white)

Neighborhood Level Land Use Variables

PCTGRID	Percentage of area in 1/4 mile buffer zone covered by grid format
PEFSCORE	Pedestrian Environment Factor score for zone of home location
POPDENBG	Population density per square mile in 1990 census block group
RET94DEN	Density of retail employment within 1 mile of home location in 1994

Regional Land Use Variables

ZPPOPDEN	Population density per square mile for ZIP code in 1990
ZIPRETDN	Density of Retail jobs per square mile in ZIP code in 1992

Trip Cost Variables

MDWLKDST	Median trip distance per individual
MDWLKSPD	Median trip speed per individual
WORKDAY	Variable for whether or not diary covered at least one work day (1 = Yes, 0 = No)

Instrumental Variables

PCINCBG	Per capita income in census block group in 1990
PCTBLKBG	Percent of Black persons living in census block group in 1990
PCTBLKZP	Percent of Black persons living in ZIP code in 1990
PCTCLGBG	Percent of persons in census block group with at least an undergraduate degree in 1990
PCTCLGZP	Percent of persons in ZIP code with at least an undergraduate degree in 1990
PCTHSPBG	Percent of Hispanic persons living in census tract in 1990
PCTHSPZP	Percent of Hispanic persons living in ZIP code in 1990
PCTNUHBG	Percent of housing units in block group classified as located in rural environment but not classified as farms in 1990
PCTNUHZP	Percent of housing units in ZIP code classified as located in rural environment but not classified as farms in 1990
PCTUHBG	Percent of housing units in block group classified as located in urbanized environment in 1990
PCTUHZP	Percent of housing units in ZIP code classified as located in urbanized environment in 1990

Table 2: Ordered Probit Models for Non-Work Walking Trips - Census Block Group Level

	Socio Demographics		Socio Demographics and Land Use (PctGrid Included)		Socio Demographics and Land Use (PctGrid Excluded)		Socio Demographics, Land Use and Trip Costs	
Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
gender	-0.064482	-0.976	-0.125703	-1.394	-0.062192	-0.933	-0.062273	-0.932
age	**-0.005159**	**-2.47**	-0.002748	-0.964	-0.003833	-1.815	-0.003851	-1.82
race	-0.03977	-0.271	0.0338668	0.177	-0.082298	-0.554	-0.100161	-0.672
income	-1.28E-05	-1.834	-1.39E-05	-1.408	-1.02E-05	-1.461	-9.38E-06	-1.336
incomesq	8.39E-11	1.392	8.50E-11	1.006	6.47E-11	1.066	5.70E-11	0.937
kids	**0.089725**	**2.631**	**0.1070024**	**2.149**	**0.1443604**	**4.074**	**0.1391419**	**3.917**
workday	-0.221035	-1.656	-0.185839	-0.92	**-0.289129**	**-2.154**	**-0.297134**	**-2.207**
carsprdr	**-0.178713**	**-2.313**	-0.042041	-0.346	-0.096116	-1.22	-0.099895	-1.265
numemply	**-0.174813**	**-2.988**	-0.14181	-1.934	**-0.147597**	**-2.49**	**-0.151022**	**-2.546**
popdenbg			0.0000206	1.409	**0.0000282**	**2.985**	**0.0000291**	**3.061**
ret94den			0.0000304	0.386	0.0001021	1.815	0.0000999	1.773
pctgrid			0.008555	0.399	----------	----------	----------	----------
pefscore			0.4756505	1.562	0.0160342	1.079	0.0168821	1.128
mdwlkdst							**-0.047444**	**-2.229**
mdwlkspd							0.0040484	1.653
N		1091		608		1084		1084
Log (L)		-1545.9175		-822.86836		-1520.4641		-1517.7944

Note: Coefficients in bold are significant at the five percent level or greater.

Table 3: Test for Joint Significance of Land Use Explanatory Variables - Census Block Group Level

	Restricted Model		Unrestricted Model	
Variable	Coefficient	Z	Coefficient	Z
gender	-0.063458	-0.958	-0.062192	-0.933
age	**-0.005236**	**-2.503**	-0.003833	-1.815
race	-0.047851	-0.323	-0.082298	-0.554
income	-0.000013	-1.857	-1.02E-05	-1.461
incomesq	8.71E-11	1.441	6.47E-11	1.066
kids	**0.0920167**	**2.693**	**0.1443604**	**4.074**
workday	-0.218985	-1.641	**-0.289129**	**-2.154**
carsprdr	**-0.169044**	**-2.175**	-0.096116	-1.22
numemply	**-0.178345**	**-3.041**	**-0.147597**	**-2.49**
popdenbg			**0.0000282**	**2.985**
ret94den			0.0001021	1.815
pef2			0.0160342	1.079
log(L)		-1539.2985		-1520.4641

N = 1084

X^2 observed = 2*(log[Unrestricted Model] - log[Restricted Model]) 37.6688
X^2 critical (dF=4) 9.49

Table 4: Significance of Land Use Variables Run Individually - Census Block Group Level

	Population Density		Retail Densit		Percentage Grid Area		PEF Score	
Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z	Coefficient	Z
gender	-0.07173	-1.082	-0.044909	-0.677	-0.119029	-1.329	-0.073579	-1.109
age	-0.00408	-1.938	**-0.004136**	**-1.967**	-0.003177	-1.121	**-0.004778**	**-2.276**
race	-0.066128	-0.445	-0.06934	-0.472	0.0673819	0.353	-0.069678	-0.47
income	-1.06E-05	-1.515	-1.06E-05	-1.522	-0.000016	-1.649	-0.000012	-1.72
incomesq	6.70E-11	1.108	6.55E-11	1.083	1.05E-10	1.255	7.95E-11	1.314
kids	**0.1303174**	**3.735**	**0.131388**	**3.732**	0.088548	1.829	**0.1099993**	**3.188**
workday	**-0.271757**	**-2.029**	**-0.27039**	**-2.019**	-0.178149	-0.882	-0.256076	-1.911
carsprdr	-0.116371	-1.489	-0.129605	-1.661	-0.05885	-0.489	-0.136628	-1.748
numemply	**-0.157738**	**-2.681**	**-0.140397**	**-2.379**	**-0.155673**	**-2.139**	**-0.173771**	**-2.959**
pop90_sq	**0.0000417**	**5.776**						
ret94den			**0.0002235**	**4.831**				
pctgrid					**0.6452183**	**2.212**		
pef2							**0.0500604**	**3.876**
N		1089		1091		608		1084
Log(L)		-1533.2152		-1534.3041		-825.07784		-1531.7701

Table 5: Ordered Probit Models for Non-Work Walking Trips - Zip Code Level

	Socio Demographics		Socio Demographics & Land Use		Socio Demographics, Land Use and Trip Costs	
Variable	Coefficient	Z	Coefficient	Z	Coefficient	Z
gender	-0.064482	-0.976	-0.061138	-0.921	-0.065262	-0.982
age	**-0.005159**	**-2.47**	**-0.005019**	**-2.38**	**-0.005069**	**-2.399**
race	-0.03977	-0.271	-0.015501	-0.105	-0.022851	-0.155
income	-1.28E-05	-1.834	-0.000012	-1.716	-1.17E-05	-1.677
incomesq	8.39E-11	1.392	7.52E-11	1.241	7.29E-11	1.203
kids	**0.089725**	**2.631**	**0.0968196**	**2.785**	**0.0943681**	**2.711**
workday	-0.221035	-1.656	-0.234615	-1.756	-0.246758	-1.843
carsprdr	**-0.178713**	**-2.313**	**-0.154368**	**-1.975**	**-0.154674**	**-1.978**
numemply	**-0.174813**	**-2.988**	**-0.182507**	**-3.031**	**-0.185416**	**-3.077**
zppopden			0.0000258	1.945	0.0000258	1.934
zipretdn			0.000023	0.65	0.0000241	0.683
mdwlkdst					-0.037481	-1.86
mdwlkspd					0.0018124	1.674
N		1091		1083		1083
Log (L)		-1545.9175		-1531.8802		-1529.9204

Note: Coefficients in bold are significant at the five percent level or greater.

Table 6: Test for Joint Significance of Land Use Explanatory Variables - Zip Code Level

	Restricted Model		Unrestricted Model	
Variable	Coefficient	Z	Coefficient	Z
gender	-0.062245	-0.939	-0.061138	-0.921
age	**-0.00547**	**-2.605**	**-0.005019**	**-2.38**
race	-0.034471	-0.235	-0.015501	-0.105
income	-1.23E-05	-1.757	-0.000012	-1.716
incomesq	7.81E-11	1.292	7.52E-11	1.241
kids	**0.0842882**	**2.463**	**0.0968196**	**2.785**
workday	-0.221765	-1.661	-0.234615	-1.756
carsprdr	**-0.180696**	**-2.337**	**-0.154368**	**-1.975**
numemply	**-0.184674**	**-3.087**	**-0.182507**	**-3.031**
zppopden			0.0000258	1.945
zipretdn			0.000023	0.65
log(L)		-1534.8546		-1531.8802

N = 1083

X^2 observed = 2*(log[Unrestricted Model] - log[Restricted Model])	5.9488
X^2 critical (dF=4)	9.49

Table 7: Comparison of OLS and Instrumental Variable Regressions for Non-Work Walking Trips: Census Tract Level

	Block Group Density (OLS)		Block Group Density (IV)		PCT Grid (OLS)		PCT Grid (IV)	
nwtrips	Coefficient	T	Coefficient	T	Coefficient	T	Coefficient	T
gender	-0.051274	-0.608	-0.119559	-1.122	-0.111582	-1.016	-0.138369	-1.003
age	-0.003334	-1.254	0.0002769	0.08	-0.004307	-1.253	-0.00309	-0.671
race	-0.084117	-0.446	-0.145282	-0.621	-0.055707	-0.235	-0.008676	-0.028
income	-1.19E-05	-1.329	-1.44E-05	-1.248	-1.66E-05	-1.382	-1.62E-05	-1.044
incomesq	7.41E-11	0.959	9.24E-11	0.936	1.02E-10	0.994	8.61E-11	0.654
kids	**0.1715581**	**3.837**	**0.2699982**	**4.948**	0.0840812	1.418	0.1296092	1.54
workday	**-0.355839**	**-2.049**	**-0.561769**	**-2.776**	-0.238862	-0.951	-0.356252	-1.203
carsprdr	-0.181064	-1.832	**-0.290294**	**-2.072**	-0.083497	-0.567	-0.182351	-1.03
numemply	**-0.207611**	**-2.805**	-0.150316	-1.63	**-0.202986**	**-2.291**	-0.061939	-0.574
mdwlkdst	**-0.05909**	**-2.37**	-0.040686	-1.21	-0.042837	-1.33	-0.049822	-1.355
mdwlkspd	0.0020722	1.477	0.0023985	0.615	0.0005392	0.142	0.0012336	0.24
constant	**3.042184**	**9.344**	**3.098447**	**6.737**	**3.181426**	**7.043**	**3.050788**	**5.243**
popdenbg	**0.0000569**	**6.122**	**0.0000596**	**2.292**				
pctgrid					**0.9931173**	**2.774**	1.436442	1.071
N		1089		618		608		388
F-Test		8.31		5.22		2.66		1.44
Prob > F		0		0.0000		0.0018		0.1433
R^2		0.0848		0.115		0.0509		0.0572
Adj. R^2		0.0746		0.0975		0.0317		0.027
OverIdentification Test								
X^2 Critical				11.100				11.100
X^2 Observed				10.5678				8.0316

Note: Coefficients in bold are significant at the five percent level or greater.

Table 7 (Cont.): Comparison of OLS and Instrumental Variable Regressions for Non-Work Walking Trips: Census Tract Level

	PEF Score (OLS)		PEF Score (IV)		Employment Density (OLS)		Employment Density (IV)	
nwtrips	Coefficient	T	Coefficient	T	Coefficient	T	Coefficient	T
gender	-0.051381	-0.6	-0.102569	-0.972	-0.015627	-0.185	-0.069576	-0.649
age	-0.00433	-1.611	0.0000901	0.026	-0.003405	-1.276	0.0014164	0.393
race	-0.092054	-0.481	-0.169975	-0.727	-0.100313	-0.534	-0.233245	-0.96
income	-1.39E-05	-1.532	-1.26E-05	-1.089	-1.18E-05	-1.314	-1.25E-05	-1.065
incomesq	9.02E-11	1.15	7.70E-11	0.779	7.10E-11	0.914	8.13E-11	0.813
kids	**0.1439387**	**3.197**	**0.2646515**	**4.906**	**0.1762717**	**3.887**	**0.2986162**	**4.975**
workday	-0.329744	-1.872	**-0.572548**	**-2.833**	**-0.353847**	**-2.028**	**-0.581488**	**-2.828**
carsprdr	**-0.222403**	**-2.208**	**-0.307395**	**-2.232**	**-0.195718**	**-1.974**	-0.276852	-1.913
numemply	**-0.232003**	**-3.098**	-0.150554	-1.639	**-0.186387**	**-2.498**	-0.124328	-1.308
mdwlkdst	**-0.052537**	**-1.97**	-0.036642	-1.097	**-0.051407**	**-2.057**	-0.032392	-0.959
mdwlkspd	0.0024324	0.76	0.0023088	0.596	0.0017196	1.223	0.0018906	0.483
constant	**3.054213**	**8.589**	**2.806559**	**5.333**	**3.192477**	**9.887**	**2.971126**	**5.732**
PEF Score	**0.0606048**	**3.649**	**0.0792254**	**2.38**				
ret94den					**0.0003146**	**5.248**	**0.0007719**	**2.013**
N		1084		618		1091		618
F-Test		6.1		5.29		7.43		5.04
Prob > F		0		0		0		0
R^2		0.064		0.1208		0.0764		0.0985
Adj. R^2		0.0535		0.1034		0.0661		0.0806

OverIdentification Test		
X^2 Critical	11.100	11.100
X^2 Observed	10.7532	17.0568

Note: Coefficients shown in bold are significant at the five percent level or greater.

Table 8: Comparison of OLS and Instrumental Variable Regressions for Non-Work Walking Trips: ZIP Code Level

	CT Density (OLS)		CT Density (IV)		Employment Density (OLS)		Employment Density (IV)	
nwtrips	Coefficient	T	Coefficient	T	Coefficient	T	Coefficient	T
gender	-0.041276	-0.48	-0.042105	-0.489	-0.036977	-0.429	-0.034602	-0.4
age	-0.004736	-1.746	-0.004309	-1.562	-0.004985	-1.842	-0.004837	-1.762
race	-0.035652	-0.187	-0.021618	-0.113	-0.045089	-0.237	-0.041041	-0.215
income	-1.46E-05	-1.602	-1.42E-05	-1.547	-1.52E-05	-1.667	-1.53E-05	-1.673
incomesq	9.22E-11	1.171	8.81E-11	1.114	9.73E-11	1.235	9.77E-11	1.24
kids	**0.1259343**	**2.788**	**0.1341774**	**2.907**	**0.1258455**	**2.767**	**0.1320344**	**2.686**
workday	-0.298951	-1.693	-0.306106	-1.73	-0.299645	-1.695	-0.305555	-1.72
carsprdr	**-0.243857**	**-2.424**	**-0.222246**	**-2.145**	**-0.256717**	**-2.564**	**-0.249316**	**-2.43**
numemply	**-0.24277**	**-3.163**	**-0.244346**	**-3.179**	**-0.232437**	**-3.014**	**-0.226412**	**-2.857**
mdwlkdst	**-0.051084**	**-2.015**	**-0.050155**	**-1.974**	**-0.052168**	**-2.057**	**-0.052221**	**-2.058**
mdwlkspd	0.0016176	1.133	0.0017231	1.202	0.00154	1.079	0.0015658	1.095
constant	**3.500163**	**10.574**	**3.342037**	**8.887**	**3.611686**	**11.3**	**3.569702**	**10.385**
zppopden	0.0000276	1.718	0.000053	1.617				
zipretdn					0.0000526	1.221	0.0000893	0.753
N		1083		1083		1083		1083
F-Test		5.26		4.71		5.13		4.54
Prob > F		0		0		0		0
R^2		0.0557		0.0535		0.0544		0.0538
Adj. R^2		0.0451		0.0429		0.0438		0.0432
OverIdentification Test								
X^2 Critical				9.49				9.49
X^2 Observed				3.8988				3.4656

Note: Coefficients in bold are significant at the five percent level or greater.