Region 2
UNIVERSITY TRANSPORTATION RESEARCH CENTER

Walking Frequency, Cars, Dogs, and the Built Environment

Prepared by
Bahareh Sehatzadeh, Ph.D
Robert B. Noland, Ph.D

Co-Author:
Marc D. Weiner, Ph.D

Alan M. Voorhees Transportation Center and Bloustein Center for Survey Research
Edward J. Bloustein School of Planning and Public Policy, Rutgers University

Edward J. Bloustein School of Planning and Public Policy
Rutgers University
New Brunswick, NJ 08901, USA
732-932-6812 x536
rnoland@rutgers.edu

RUTGERS
Center for Advanced Infrastructure and Transportation

July 13, 2011

Disclaimer

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2.Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Walking Frequency, Cars, Dogs, and the Built Environment		5. Report Date July 13, 2011 6. Performing Organization Code
7. Author(s) Bahareh Sehatzadeh, Robert B. Noland, Marc D. Weiner of Rutgers the State University of New Jersey		8. Performing Organization Report No.
9. Performing Organization Name and Address Center for Advanced Infrastructure and Transportation Edward J. Bloustein School of Planning and Public Policy Rutgers University New Brunswick, NJ 08901, USA		10. Work Unit No. 11. Contract or Grant No. 49111-20-20
12. Sponsoring Agency Name and Address New York Metropolitan Transportation Council 199 Water Street 22nd Floor New York, NY 10038		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

This report explains ways to reduce car usage in order to meet climate targets and how to analyze these effects. Much of the analysis has focused on differences between more compact areas that are more walkable versus more extensive car-dependent areas. Given our interest in physical activity (to combat obesity) we are interested in overall walking similar to studies such as (Berrigan, Troiano 2002) which also evaluated all walking trips jointly. Several studies have previously assessed the relationship between dog ownership and walking in the broader context of the effects of pet ownership on human health. In spite of the variations in methods and results these studies draw the same conclusion that dog owners are more physically active (primarily through walking their dog) than non-owners ((Bauman et al. 2001, Cutt et al. 2007, Cutt et al. 2008a, Brown, Rhodes 2006, Ham, Epping 2006, Oka, Shibata 2009, Owen et al. 2007, Serpell 1991, Sirard et al. 2011). It has generally been acknowledged that residential self-selection explains a part of the observed walking behavior in more walkable neighborhoods; that is, individuals who prefer to walk (or do not like to drive) will choose to live in more walkable neighborhoods.

Our results show that the level of household car ownership is important in the choice of whether individuals walk and that car ownership itself is partly determined by many of the walkability features that typically have an association with walking. The findings show that the most significant built environment variables are the ones related to network connectivity and these affect walking behavior both directly and indirectly through the influence on vehicle ownership. Most of the socio-economic factors are only associated with vehicle ownership (with the exception of age). These findings highlight the importance of policy that affects vehicle ownership decisions; more connected walkable networks seem to be a negative factor, but other variables that increase the cost and difficulty of vehicle ownership (such as how parking is provided) can be as promising as promoting pedestrian friendly environments.

17. Key Words Walking; two-stage least squares; built environment; car ownership	18. Distribution Statement		
19. Security Classif (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No of Pages 36	22. Price

Form DOT F 1700.7 (8-69)

Abstract

To explain walking propensity or frequency, empirical studies have generally used two sets of explanatory variables, namely, socio-demographic variables and built environment variables. They have generally shown that both socio-demographic characteristics and built environment characteristics are associated with walking propensity. We examine the traditional walk ability variables that encompass density, mix of uses, and network connectivity in New Jersey, using a statewide sample including an oversample of Jersey City. We estimate a two-stage least squares model using a conditional mixed process that combines an ordered probit model of walking frequency in the second stage based on a truncated regression of car ownership in the first stage. Our results show that built environment variables have some small effects, mainly associated with better network connectivity associated with increased walking frequency. One of our key findings is that built environment features also work indirectly via how they influence car ownership. In general, we find sufficient evidence that suggests fewer cars are owned in areas with more walk able built environment features. The other key variable that we control for is whether a household owns a dog. This also proved to be strongly associated with walking suggesting that dog ownership is a necessary control variable to understand the frequency of walking.

Keywords: walking; two-stage least squares; built environment; car ownership

Introduction

A large body of literature has examined factors associated with walking over the last two decades. This has been due primarily to concerns about increasing traffic congestion, environmental effects of increasing vehicle use, and more recently, with increasing rates of obesity in the population (Forsyth, Krizek & Rodríguez 2009). Empirical studies have shown that increased walking has an association with reduced obesity (Frank, Andresen & Schmid 2004, Frank et al. 2008). Concerns over climate change and finding ways to reduce car usage in order to meet climate targets are another reason for analyzing these effects (Yang et al. 2009). Much of the analysis has focused on differences between more compact areas that are more walkable versus more sprawling car-dependent areas (Ewing, Cervero 2010).

It has been generally held that neighborhoods with features that are amenable to walking generate significantly higher volumes of walking trips (Sallis et al. 2004). Many studies have defined a walkability index to explain walking propensity and have found a significant positive association with increased levels of walking. Walkability is usually measured by combining measures of net residential density, street connectivity, and land-use mix (Frank et al. 2005, Leslie et al. 2007, Saelens et al. 2003). One reason to create an index is that the individual components are often highly correlated (Cervero, Kockelman 1997), making decomposition of individual effects problematic. There is a large literature that has examined many of these factors. A review of the literature by (Saelens, Handy 2008) shows that walking for transportation is associated with density, distance to nonresidential destinations, and land use mix. Route/network connectivity, parks and open space, and personal safety are less significant. There is little or no evidence for relations between transportation walking and pedestrian infrastructure conditions, traffic-related issues, aesthetics, or accessibility of facilities for physical activity.

The same review article concluded that recreational walking has stronger associations with pedestrian infrastructure and aesthetics as well as personal safety and land use mix (compared to utilitarian walking). There is little or no evidence for associations between recreational walking and density, distance to nonresidential destinations, route/network connectivity, parks and open space, traffic, and accessibility to facilities for physical activity (Saelens, Handy 2008). Several studies have focused on walking for specific purposes such as work trips (Craig et al. 2002, Guo, Bhat & Copperman 2007), non-work trips (Greenwald, Boarnet 2001), and walking for recreation (Rutt, Coleman 2005). Although studies have shown differences in the correlates associated with utilitarian walking versus for recreation, our data precludes a separate analysis of these effects. Given our interest in physical activity (to combat obesity) we are interested in overall walking similar to studies such as (Berrigan, Troiano 2002) which also evaluated all walking trips jointly.

Several studies have previously assessed the relationship between dog ownership and walking in the broader context of the effects of pet ownership on human health. In spite of the variations in methods and results these studies draw the same conclusion that dog owners are more physically active (primarily through walking their dog) than non-owners ((Bauman et al. 2001, Cutt et al. 2007, Cutt et al. 2008a, Brown, Rhodes 2006, Ham, Epping 2006, Oka, Shibata 2009, Owen et al. 2007, Serpell 1991, Sirard et al. 2011). This association is mainly explained by the motivation and obligation to walk one's dog in addition to any other factors that support walking (Cutt et al. 2008b, Hoerster et al. 2010). While many features of the built environment that support walking in general would also support people walking with their dogs, accessibility of public open spaces and the quality of dog-accessible spaces are among the common built environment factors recognized to be conducive to dog ownership and dog walking (Cutt, Knuiman & Giles-Corti 2008, Coleman et al. 2008, Tilt 2010). Our study includes an indicator variable for dog ownership that is statistically significant in all our models of walking frequency.

It has generally been acknowledged that residential self-selection explains a part of the observed walking behavior in more walkable neighborhoods; that is, individuals who prefer to walk (or do not like to drive) will choose to live in more walkable neighborhoods. This can lead to bias in estimates of the effect of building more walkable neighborhoods. There are several ways to account for self-selection, including direct survey questions (Owen et al. 2007, Frank et al. 2007), simultaneous models (Pinjari et al. 2007), and structural equation modeling (Bagley, Mokhtarian 2002a, Bagley, Mokhtarian 2002b). Most estimates that attempt to control for self-selection still find an effect from built environment features on the choice of walking or frequency of walking (Pinjari et al. 2007, Cao 2010). Some evidence exists that there is less self-selection into car-dependent neighborhoods, compared to more urban neighborhoods (Schwanen, Mokhtarian 2005, Cao, Mokhtarian & Handy 2009).

We take another approach to these issues. Our analysis focuses on the frequency of walking in New Jersey, using a statewide sample including an oversample of Jersey City, which is in the most densely populated part of the state. While we examine the traditional walkability variables that encompass density, mix of uses, and network connectivity, we do this using a two-stage least squares model that examines how these factors affect car ownership followed by an ordered probit model of walking frequency. Previous work by (Bhat, Guo 2007) estimated a joint choice model of residential choice and car ownership and found that built environment variables affect car ownership. Theoretically, this is an appealing approach, as the built environment can affect the cost of car ownership, mainly through how the built environment affects the ease and convenience of driving, whether due to slower speeds in more walkable areas or more difficulty finding free or cheaply priced parking.

Our results show that the level of household car ownership is important in the choice of whether individuals walk and that car ownership itself is partly determined by many of the walkability features that typically have an association with walking. The findings show that the most significant built environment variables are the ones related to network connectivity and these affect walking behavior both directly and indirectly through the influence on vehicle ownership. Most of the socio-economic factors are only associated with vehicle ownership (with the exception of age). These findings highlight the importance of policy that affects vehicle ownership decisions; more connected walkable networks seem to be a negative factor, but other variables that increase the cost and difficulty of vehicle ownership (such as how parking is provided) can be as promising as promoting pedestrian friendly environments.

Theoretical Framework and Methodology

Our basic approach assumes that various built environment factors have an influence on the frequency of walking. As previous research has found, frequency or the propensity to walk increases due to proximity to a mix of uses (represented by land use features and density), decreased barriers to walking (as represented by a lack of network connectivity), and socio-economic factors associated with a household. These latter have been used as controls for residential self-selection, but do not completely control for this bias (Cao 2010). The other factors represent the generalized cost to walking; built environment features can both affect the amount of time a walk trip takes, but also the comfort, safety, and enjoyment of the walking environment. Built environment features can also affect the cost of car ownership through the ease and convenience of owning a car (or multiple cars). For example, land costs are higher in more urbanized areas and, all else equal, this would increase the cost of parking a car, although often individuals may not perceive this marginal cost (Shoup 1997). These areas also tend to have street networks that make driving less convenient and often traffic is more congested, both increase the generalized cost of car ownership.

If we initially ignore the costs of car ownership we can specify a simple reduced form model as follows:

$$W = \alpha + \beta \boldsymbol{E} + \gamma \boldsymbol{S} + \varepsilon$$

Where *W* represents the frequency of walking, which will be defined as an ordered categorical value, ***E*** represents a variety of different built environment factors, and ***S*** represents socio-demographic factors. A constant term is represented by α and parameters associated with the independent variables are β and γ, with an error term, *ε*, that is normally distributed with mean 0. Estimations of this mode will provide associations between the independent and dependent variable, and this has commonly been shown in the literature (Ewing, Cervero 2010).

In this framework the built environment variables represent a cost to walking, which can be high if these variables represent deterrents to walking (such as longer distances, physical barriers to walking, unsafe environments for walking, or unpleasant aesthetics). Barriers (such as large arterial roads) can increase the travel time, for example, by necessitating long walks to crosswalks that have long signal cycles. Car ownership is normally embodied within socio-demographic factors. We extend this framework by explicitly considering how deterrents to walking may affect car ownership and then how car ownership (as well as other factors) affects walking.[1] This leads to the following two-stage model:

$$C = k + \delta E + \omega S + \varphi$$

$$W = \alpha + \beta E + \gamma S + \delta C + \varepsilon$$

Car ownership is represented by *C*. Thus, we have a structural model in the second stage such that built environment and socio-demographic variables are essentially instruments for car ownership, leading to both a direct and indirect effect on walking. While this model says nothing about the propensity to drive (or use other modes), it is well known that increased car ownership tends to lead to more driving.

Our dependent variable is the frequency of walking, an ordered categorical variable, defined as five ordered categories, ranging from walking frequency of a few times a year or less to more than once a day. Thus, our basic modeling approach requires the use of an ordered probit model. This method assumes a normal distribution in the data and has the following general structure:

$$\mathrm{y}_{\mathrm{n}}^{*} = \mathbf{X}_{\mathrm{in}} \boldsymbol{\beta}_{\mathrm{in}} + \varepsilon_{\mathrm{n}}$$

where the dependent variable, y_n*, is a latent variable that measures the ordered frequency of walking in our model. As we have 5 ordered categories, this results in *m=4* in the equation below, or one less cut-point (or threshold value) than the number of categories.

$$y_i = \begin{cases} 1 \quad \text{if} \quad -\infty \le y_i^* \le \mu_1 \\ 2 \quad \text{if} \quad \mu_1 \le y_i^* \le \mu_2 \\ \quad\quad\quad \vdots \\ \quad\quad\quad \vdots \\ \mathrm{n} \quad \text{if} \quad \mu_m \le y_i^* \le \infty \end{cases}$$

---

[1] Car ownership may have differential impacts on walking for recreation. It can affect the type of recreational opportunities within easy access, thus increasing walking as a recreational activity; on the other hand, it may reduce walking for recreation if the need to walk for utilitarian transportation purposes is greater. Our data, unfortunately, does not allow us to analyze this effect.

The μ_m are unknown parameters to be estimated. The coefficients ($\hat{\boldsymbol{\beta}}$) and the cut points (μ_m) are estimated using maximum-likelihood estimation. No constant is estimated as it is absorbed into the cut points.

We then extend our modeling framework using a two-stage least squares regression approach. Our first stage regression, estimates car ownership by household using a truncated regression (left truncated at 0), while the second stage regression is an ordered probit model. We use a conditional mixed process which allows the mixing of different distributions in a sequential model. This results in a Limited Information Likelihood Maximization (LIML) model where the first stage of the model is a reduced form, with the final stage parameters being structural. We use the user written 'cmp' module in Stata, which is fully explained in (Roodman 2009). The primary benefit of this method is that we are estimating a structural model that instruments car ownership in our model.

Data Collection and Processing

Data was collected under the supervision of the Bloustein Survey Research Center at Rutgers University. The survey was administered by phone via random-digit dialing and was conducted in November 2009. Our goal was to elicit data on questions related to outdoor walking habits and behavior; trip purpose and characteristics; geographic capacity to reach key locations by walking; satisfaction with pedestrian-related neighborhood characteristics; safety and security concerns; home location and neighborhood built-environment characteristics; child pedestrian activity; and, environmental and demographic control variables.[2] Our analysis in this paper focuses on the frequency of all pedestrian trips.

The survey included a statewide cross-section of New Jersey and an oversample of Jersey City. The latter was designed to drill down on urban walking patterns, which are theoretically assumed to vary from non-urban walking patterns. We targeted and achieved 800 completed interviews for the statewide sample, and 400 completed interviews for Jersey City. The survey was administered in both English and

[2] A copy of our survey instrument is available on request from the authors.

Spanish; for the statewide sample, 773 interviews were conducted in English (97%) and 27 in Spanish (3%). For the Jersey City oversample, 366 interviews were conducted in English (91.5%), 34 in Spanish (8.5%). Thus, all told, 1,139 interviews were conducted in English (95%) and 61 in Spanish (5%).

Our response rates, based on the AAPOR3 method of calculating response rates,[2] were 20.9% for the statewide cross-section and 19.9% for our Jersey City oversample. We calculate the cooperation rate as "the proportion of all cases interviewed of all eligible units ever contacted" (The American Association for Public Opinion Research 2009). The AAPOR COOP3 cooperation rate is taken as the number of completed interviews (and screen-outs) divided by the sum of the number of complete and partial interviews and the number refusals and break offs (*i.e.*, the formula "defines those unable to do an interview as also incapable of cooperating" and are thus "excluded from the base"). From this we calculate the cooperation rates at 39.7% for our statewide cross-section and 38.3% for our Jersey City oversample. Our margins of sampling error were 3.4% for the statewide sample and 4.9% for our oversample of Jersey City, both calculated at 95% confidence for population proportions at or near the 50/50 margin.

---

[2] This generally accepted method "estimates what proportion of cases of unknown eligibility are actually eligible." In formulaic terms, this appears as:

$$RR3 = \frac{I}{[(I+P)+(R+NC+O)+e(UH+UO)]}$$

$$e = \frac{(I+P+R+NC+O)}{[(I+P+R+NC+O)+NE]}$$

where *I*=complete interviews (and screen-outs); *P*=partial interviews; *R*=refusals and break-offs; *NC*=non-contacts; *O*=other; *e*=the estimated eligibility of unknowns; *UH*=unknown households; and *UO*=unknown other and *NE*=not eligibles (The American Association for Public Opinion Research 2009).

Figure 1: Spatial distribution of geo-coded respondents in statewide samp

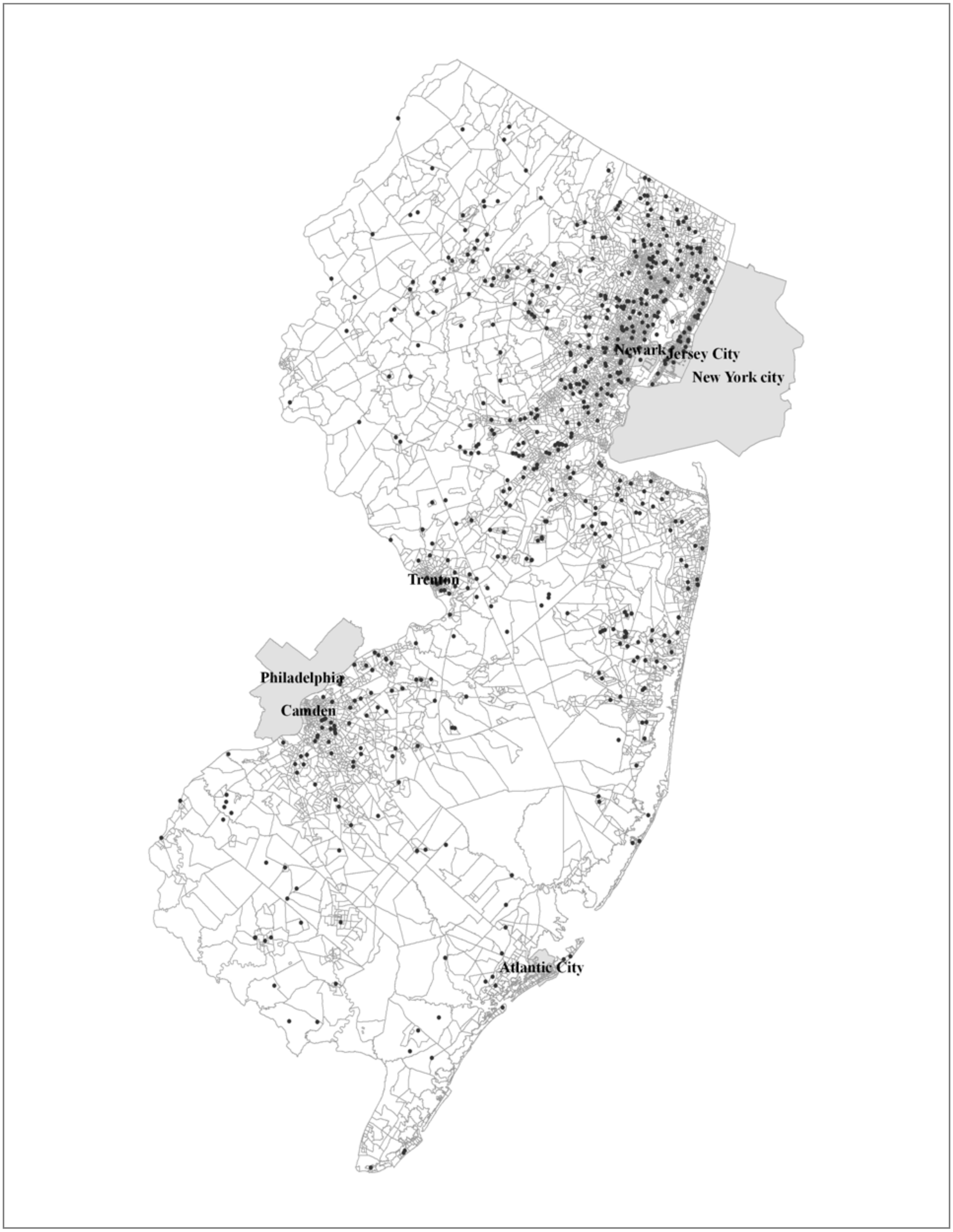

Figure 2: Spatial Distribution of geo-coded respondents in Jersey City sample

During analyses some observations were excluded due to lack of a valid address (nearest street intersection), which was used to geo-code supplementary data on respondents' location. Those respondents with physical limitations that completely restricted them from walking outdoors were also excluded from the analysis. Therefore our final sample size for the state of New Jersey was 603 and for Jersey City was 329 observations. While estimating the models these numbers were reduced to 466 and 251, excluding observations with missing values.

Our survey gathered information on the nearest intersection to respondents' home residence (and also to the location of their last walking trip). This was done to generally avoid the privacy concerns attendant to a home address probe, , as well as to minimize the likelihood of privacy-concern-related non-response.. Of our sample, 1030 respondents (86%) answered the intersection location question and we successfully geocoded all but five of these responses. While most were geo-coded at or near the intersection, for some respondents we used zip code centroids or municipality centroids as we could not locate the specific intersection information; this breakdown is detailed in Table 1. Using the geo-coded information on the residence of our sample we joined observations to various area-based data. This included demographic, land use and road network data. Our sample encompassed 655 of 6510 block groups in New Jersey and 305 of 578 five-digit zip code areas. We display the spatial distribution of both the statewide sample and the Jersey City sample for those successfully geo-coded in

Figure **1** and

Figure **2**, respectively. Note that in our Jersey City sample there is a small amount of spill-over into Hoboken and Union City to the north. This is expected given that the random-digit dialing sampling scheme is based on geographic area codes and prefixes, which do not completely correspond with municipal boundaries.

Table 1: Geo-coding of intersection location question

	Frequency	Percent
At Intersection	753	73.11
Near Intersection	105	10.19
Zip Code Centroids	160	15.53
Municipal Centroids	7	0.68
Unmatched Address	5	0.49
Total	1030	100.00

Our dependent variable in the analysis that follows is the frequency of walking. This was collected by asking survey respondents whether on average they "walk outdoors for five minutes or more," "a few times a year or less," "several times a month," "several times a week," "once a day," or "more than once a day." Thus, we have an ordinal response variable as our dependent variable to measure walking frequency. Table 2 displays the frequency of our dependent variable; about 10% of our sample walks relatively infrequently, while nearly 40% report walking more than once a day.

Table 2: Distribution of Frequency of Walking

Frequency of Walking	All Respondents		New Jersey		Jersey city	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
A few times a year or less	31	4.32	22	4.72	9	3.59
Several times a month	44	6.14	39	8.37	5	1.99
Several times a week	193	26.92	145	31.12	48	19.12
Once a day	165	23.01	108	23.18	57	22.71
More than once a day	284	39.61	152	32.62	132	52.59
Total	717	100.00	466	100.00	251	100.00

Measures of connectivity were based on road network data for intersections, different road classifications, and estimates of roads that function as barriers to pedestrians. Intersection densities were calculated by analyzing 2009 Census TIGER/Line files in GIS and calculating the number of intersections in each block group normalized by block group's area (per square mile). In addition to the total number of intersections, t-intersections, intersections (for those with four or more legs), and cul-de-sac density measures were also compiled. New Jersey Department of Transportation (NJDOT) 2008 roadway network files were analyzed in GIS to calculate road densities in block groups (miles per square mile) for each of the eight road types.[3] Roads that are barriers to pedestrians were identified based on the NJDOT Statewide Bicycle and Pedestrian Master Plan (New Jersey Department of Transportation 2005); this includes GIS files that identify the proportion of time that a road can be safely crossed by a pedestrian.[4] This information was used to categorize barriers and calculate distance from the nearest barrier road (feet) and barrier densities (miles per square mile) in block groups within 0.5, 1.0, and 1.5-mile radius circles around each respondent's residence location. Correlation and regression results were evaluated to identify the best proxies for connectivity; thus we only use the distance from roads crossable 20% of the time (or less) in the analysis.

Another built environment attribute typically associated with walking is proximity. To measure proximity several variables were considered here including land use mix entropy, residential, and retail densities. We used 2002 land use data from the New Jersey Department of Environmental Protection to calculate a measure of entropy, representing the mix of land uses of different types. Land use was classified into five categories including residential, commercial, industrial, recreational and other and the following formula was used,

$$-\frac{\sum_k (p_k \ \ln \ p_k)}{\ln \ N},$$

where k is the category of land use; p is the proportion of the land area within a block group devoted to a specific land use, and N is the number of land use categories (Cervero 1988).

Table 3: Summary Statistics

Variables	All Respondents		New Jersey		Jersey city		Data Source
	Percent or Mean	Standard Deviation	Percent or Mean	Standard Deviation	Percent or Mean	Standard Deviation	
Number of household cars	1.665272	1.125917	2.004292	1.063562	1.035857	.9564043	Survey
Walkability index	2.502092	1.120683	2.493562	1.119217	2.505976	1.122036	Derived

[3] Road categories in New Jersey include interstates, toll authority roads, US highways, state highways, two levels of county highways (500 and 600 route designations), local roads, and ramps and jughandles.
[4] The NJDOT Statewide Bicycle and Pedestrian Master Plan (New Jersey Department of Transportation 2005) identified all roads that are barriers to pedestrians by calculating the proportion of time each road segment can be safely crossed by a pedestrian taking into account the width of the road, traffic volume and speed. This information was used to categorize barriers into those that can be safely crossed more than 80% of the time, 61-80%, 41-60%, 21-40%, and 20% or less.

Distance from roads safely crossable 20% of times or less	5864.434	9004.049	7844.662	10600.1	2187.996	1523.092	NJDOT
Local road density	12.83867	8.146412	11.78265	8.120754	14.79926	7.840142	NJDOT
T-intersection density	137.6665	91.32096	130.9483	90.0723	150.1393	92.48693	TIGER/Line
Cross-intersection density (includes more than 4-way intersections)	127.2096	122.8233	85.77088	92.86174	204.1436	134.2475	TIGER/Line
Land use mix entropy	.4787688	.1931161	.4847792	.198231	.4676102	.1831053	NJDEP
Population density	14049.74	17820.93	6037.898	8660.974	28924.31	20694.3	Census
Retail employee density	307.4977	979.3183	199.6755	594.1785	507.6773	1424.143	InfoUSA
Being female	51.19%	--	51.29%	--	51.00 %	--	Survey
Age	50.93584	15.59415	52.7382	15.30971	47.58964	15.59496	Survey
Age squared	2837.298	1646.92	3015.202	1658.246	2507.008	1576.402	Survey
Being employed or going to school	66.39 %	--	63.73%	--	71.31 %	--	Survey
Number of children under 18	.7698745	1.143984	.7875536	1.163946	.7370518	1.107511	Survey
Having dogs in the household	28.87%	--	36.27%	--	15.14%	--	Survey
Annual household income less than $100,000	66.81%	--	62.02%	--	75.70%	--	Survey
Having less than a 4-year college degree	47.70%	--	47.64%	--	47.81%	--	Survey
Non-Hispanic Black	16.46%	--	9.01%	--	30.28%	--	Survey
Hispanic	14.64%	--	10.73%	--	21.91 %	--	Survey
Asian or Native American	9.62%	--	6.22%	--	15.94%	--	Survey
Living in multi-family home, apartment, or condominium	38.35%	--	18.67%	--	74.90%	--	Survey
Living in Jersey City	35.01%	--	--	--	--	--	Survey
Ramp density	.3718897	1.244235	.4101426	1.442719	.3008703	.7446834	NJDOT
Cul-de-sac density	11.55596	14.35097	13.60146	13.08931	7.758334	15.77623	TIGER/Line
Living in a neighborhood with mostly free-standing single family homes	61.48%	--	79.31%	--	28.40%	--	Survey

This measure of proximity was complemented with residential and retail densities by block groups. Residential density was based on 2000 population density per square mile from the Census Bureau and retail density was extracted from information provided by Infogroup (InfoUSA) for New Jersey employers in 2005.

For the purpose of comparing the findings with those of previous studies, a walkability index was also developed combining four of the above mentioned variables: land use mix entropy, intersection density (includes cross-intersections and more than 4-way intersections), population density, and retail employee density. First the normalized distribution of each variable (z-score) was calculated and then the four z-scores were summed up to develop the walkability index. This index is further classified into quartiles resulting in a walkability index that varies from 1 to 4, with 4 representing the most pedestrian friendly block groups in the sample.

Demographic and socio-economic data were collected during the survey. This included information on respondents' gender, age, race, education, employment status, household income, residence type, home ownership, number of children under 18, number of cars in the household, and the number of dogs owned.

Our summary statistics, displayed in Table 3, indicate that we have captured the diversity of respondents whose socio-economic characteristics are consistent with New Jersey's overall population. Of 717 respondents, 51% were female and 49% male. The majority of this population, 59%, was White (not Hispanic) while Black (not Hispanic), White Hispanic, and Asian persons respectively constituted 16%, 12% and 9% of the respondents. The share of White persons was higher (74%) for the statewide sample whereas Jersey City had almost the same share of White and Black (non-Hispanic) persons (32% and 30%). The average age of respondents was 51, almost half of whom (48%) have less than a four-year college degree. A total of 64% of the respondents were employed (part-time or full-time) and considering the relatively high average age, the next biggest share belonged to retirees at 20%. Regarding households' annual income, persons from households with less than \$50,000 and \$50,000-\$100,000 each accounted for 33% of the sample. There was a considerable difference between the Jersey City oversample and the statewide sample; in Jersey City persons from households with less than \$50,000 and \$50,000-\$100,000 respectively made up 46% and 30% of the sample while in the statewide sample these shares were 27% and 35%. The survey also collected information on the number of registered vehicles in each household. The results showed 6% of households in the statewide sample and 30% in Jersey City did not own any car while the numbers are 25% and 45% for having one car and 44% and 19% for having two. Dog ownership is another variable considerably different for New Jersey as a whole versus Jersey City, the number of households owning dogs was 21% lower in Jersey City in comparison to the state (15% versus 36%).

Modeling Results

Our initial estimates are of the reduced form model of walking frequency. We include socio-demographic variables and collapse the built environment into the walkability index described previously. This avoids issues of multi-collinearity between the various components of the index, but also does not allow us to examine individual components of walkability. We estimate this model primarily to provide a comparison to similar models in the literature (Frank et al. 2005, Leslie et al. 2007, Saelens et al. 2003).

Table 4 displays results for three estimates using three different samples: all respondents, the New Jersey statewide sample, and the Jersey City oversample. The walkability index is the only measure of built environment characteristics and we find the coefficient is not statistically significant in any of the estimated models. However, the dummy variable for Jersey City, is positively associated with frequency of walking in our model with all respondents. This is likely capturing some of the built environment characteristics of a more urbanized area. In our Jersey City sample, the walkability index may not be statistically significant due to a lack of variation in the index. The mean and standard deviation for the New Jersey sample and the Jersey City sample are surprisingly similar (see Table 3). Alternatively, the index itself may not be a good enough measure to capture the relevant components of the built environment, at least for our dataset.

Among the socio-demographic characteristics the estimates for age (in the statewide sample), residence type, number of cars owned in the household, and dog ownership are statistically significant. Living in a multi-family home, apartment, or condominium is positively associated with the frequency of walking at the 99% level for all the respondents and those included in the New Jersey sample. While this is typically assumed to be a socio-demographic variable, it is in some sense also a measure of the built environment. We also find that the number of cars owned is significant in our model with all respondents at the 90% level. Our most robust variable, however, is whether or not the household owns a dog, which is strongly associated with the frequency of walking.

This result has various possible implications. It may be that some people walk more because they own a dog (something about which many dogs will be quite insistent) or possibly that those who enjoy walking have a dog. This could also represent self-selection in that people who are looking for ways to commit themselves to walk more may acquire a dog. Certainly if one owns a dog in an urbanized area where one may not have a yard, it will be an incentive to walk; on the other hand, some dog owners may only obtain dogs when they have sufficient yard space so that they do not need to walk. In any case, this is an intriguing, although not surprising, result; and it holds up in all our models, which we turn to next. The coefficient size on the dog ownership variable is less in Jersey City compared to the statewide sample, suggesting that individuals with dogs walk more despite the built environment. The Jersey City model, however, also does not fit well as shown by the likelihood ratio test, which is not statistically significant, suggesting that we cannot distinguish coefficient values as being different from zero.

Table 4: Ordered Probit Model of Walking Frequency with Walkability Index

Variables	All Respondents		New Jersey		Jersey city	
Frequency of Walking	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Number of household cars	-0.083*	0.045	-0.054	0.054	-0.121	0.083
Walkability index	0.040	0.044	-0.028	0.050	0.037	0.068
Being female	-0.042	0.084	0.029	0.102	-0.148	0.153
Age	0.018	0.017	0.029	0.021	0.001	0.030
Age squared	-0.0003	0.0002	-0.0004*	0.0002	-0.00008	0.0003
Being employed or going to school	-0.129	0.105	-0.153	0.129	-0.090	0.183
Number of children under 18	-0.037	0.040	0.001	0.050	-0.080	0.072
Having dogs in the household	0.477***	0.100	0.504***	0.114	0.399*	0.219
Annual household income less than $100,000	-0.065	0.101	0.008	0.118	-0.164	0.204
Having less than a 4-year college degree	-0.026	0.093	-0.034	0.110	0.039	0.180
Non-Hispanic Black	0.061	0.132	0.219	0.191	-0.095	0.212
Hispanic	-0.055	0.133	0.035	0.179	-0.250	0.216
Asian or Native American	0.070	0.154	0.146	0.217	-0.073	0.236
Living in multi-family home, apartment, or condominium	0.332***	0.112	0.452***	0.152	0.172	0.176
Living in Jersey City	0.257**	0.120	-	-	-	-
Cut 1	-1.519	.467	-1.293	.613	-2.262	.810
Cut 2	-1.032	.465	-.708	.611	-2.041	.805
Cut 3	-.032	.463	.318	.612	-1.093	.794

Variables	All Respondents		New Jersey		Jersey city	
Frequency of Walking	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Cut 4	.595	.464	.944	.612	-.451	.793
Number of observations		717		466		251
LR chi2	LR chi2(15)	81.03	LR chi2(14)	42.74	LR chi2(14)	14.89
Prob > chi2		0.0000		0.0001		0.3858
Pseudo R2		0.0414		0.0323		0.0250
Log likelihood		-938.36907		-640.01445		-290.82073

One question is whether dog ownership is somehow associated with the type of housing a household occupies as well as the walkability of the neighborhood. One might expect that households are more likely to own a dog if they are more able to walk their dog; alternatively, they may prefer to have a home with larger yard space and do not walk their dog as frequently. We examine the determinants of dog ownership in a bit more detail by estimating a binary logit model of dog ownership in Table 5. Results show that the likelihood of owning a dog is less for those in multi-family housing, less in Jersey City, and less for higher income households. We also examined whether owning or renting a home affects dog ownership and found that those living in rental units were less likely to own a dog, as shown in model 2 of **Table 5**. This variable was highly correlated with our income variable which was less significant in this model. While there is a some effect of being less likely to own a dog associated with greater land use mix entropy, most of the other significant variables are demographic and generally meet our expectations. Our basic conclusion from this is that dog ownership is influenced more by the type of housing a household lives in than by the immediate features that make a neighborhood walkable with land use entropy having a negative impact (other walkability features were tested and were not statistically significant).

Table 5: Binary logit model of dog ownership

Variables	Model 1		Model 2	
Dog Ownership	Coef.	Std. Err.	Coef.	Std. Err.
Annual household income less than $100,000	-0.357*	0.202	-0.330	0.205
Living in multi-family home, apartment, or condominium	-0.743***	0.239		
Owning a home			0.705**	0.240
Living in Jersey City	-0.623**	0.250	-0.816***	0.228
Land use mix entropy	-0.895*	0.465	-0.936**	0.463
Age	0.055	0.0388	0.061*	0.039
Age squared	-.000679*	0.000382	-0.00075**	0.000381

Being employed or going to school	0.511**	0.231	0.490**	0.232
Having less than a 4-year college degree	0.522***	0.200	0.556**	0.200
Non-Hispanic Black	-0.623**	0.306	-0.559*	0.307
Hispanic	-0.220	0.277	-0.138	0.279
Asian or Native American	-1.038***	0.396	-1.002**	0.397
Cons	-1.161	0.999	-1.939*	1.000
Number of observations	717		715	
LR chi2 (11)	99.21		97.10	
Prob > chi2	0.0000		0.0000	
Pseudo R2	0.1151		0.1131	
Log likelihood	-381.302		-380.773	

One way to improve our model fit is to include the actual built environment variables instead of combining them into a walkability index and evaluate effects individually. We examined the variance inflation factor for a model with individual components of walkability and found that multi-collinearity does not seem to be an issue, as the VIF did not exceed 3, eliminating one of the rationales for creating an index.[5] Table 6 displays a reduced form estimate of this model.

The components of the walkability index modeled separately include intersection density (for those with four or more legs), land use mix entropy, population density, and retail employee density. Three additional variables are also included to capture other characteristics of the built environment including distance from barrier roads (those that are safely crossable 20% of the time or less), local road density and T-intersection density in block groups. Most results are similar to the previous model, however, we do find that both the density of T-intersections and intersection with four or more legs are statistically significant in our model with all respondents. The former is negative, as expected, since T-intersections likely have less connectivity; full intersections with four or more legs are positive and represent an increase in connectivity being associated with increased walking frequency. The T-intersection variable is also significant (at the 90% level) in the Jersey City model, although the overall model fit remains insignificant. We do not pick up any associations with the built environment components for our statewide sample. Living in multi-family home, apartment, or condominium is positively associated with walking (significant at the 99% level) in the statewide model and the model

[5] The one exception being our age variables which are expected to be correlated.

with all respondents. We also find that respondents' age-squared is significantly associated with walking frequency, so this relationship is non-linear with age; as respondents get older they are more likely to walk but the trend reverses when they pass the age of 38.

Given the relative lack of statistical significance we examined the correlation patterns in the data. The number of cars owned by households was highly correlated with walking frequency, as was road density, intersection density, population density, dog ownership, residence type, and living in Jersey City. What this analysis also revealed was that car ownership was correlated with most of the other independent variables in our model at a 90% level of significance.

Table 6: Ordered Probit Model of Frequency of Walking with Components of Walkability

Variables	All Respondents		New Jersey		Jersey city	
Frequency of Walking	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Number of household cars	-0.078*	0.045	-0.048	0.055	-0.126	0.084
Distance from roads safely crossable 20% of times or less	-0.000004	0.000005	-0.000003	0.000005	-0.00002	0.00005
Local road density	-0.002	0.009	-0.005	0.011	0.008	0.016
T-intersection density	-0.001**	0.0006	-0.0007	0.0008	-0.002*	0.001
Intersection density (4 or more legs)	0.001***	0.0006	0.001	0.0009	0.001	0.0008
Land use mix entropy	-0.083	0.236	-0.149	0.284	0.049	0.478
Population density	-0.000003	0.000004	-0.000002	0.000009	-0.000005	0.000006
Retail employee density	0.00002	0.00005	0.00009	0.00009	-0.00002	0.00005
Being female	-0.041	0.085	0.018	0.103	-0.117	0.155
Age	0.021	0.017	0.028	0.021	0.006	0.030
Age squared	-0.0003*	0.0002	-0.0003*	0.0002	-0.0001	0.0003
Being employed or going to school	-0.148	0.105	-0.162	0.130	-0.132	0.189
Number of children under 18	-0.030	0.041	-0.004	0.051	-0.068	0.073
Having dogs in the household	0.483***	0.100	0.503***	0.115	0.426*	0.223
Annual household income less than $100,000	-0.050	0.102	0.015	0.118	-0.175	0.211
Having less than a 4-year college degree	-0.027	0.093	-0.034	0.111	0.011	0.184
Non-Hispanic Black	0.102	0.134	0.188	0.194	-0.040	0.216
Hispanic	-0.036	0.134	0.023	0.181	-0.221	0.219
Asian or Native American	0.074	0.155	0.078	0.220	-0.0007	0.244
Living in multi-family home, apartment, or condominium	0.344***	0.113	0.403***	0.157	0.227	0.178
Living in Jersey City	0.208	0.138	-	-	-	-
Cut 1	-1.624	.482	1	.635	-2.291	.855
Cut 2	-1.133	.479	-.843	.633	-2.061	.849
Cut 3	-.124	.478	.188	.633	-1.094	.839
Cut 4	.509	.478	.817	.633	-.443	.838
Number of observations		717		466		251

Variables	All Respondents		New Jersey		Jersey city	
Frequency of Walking	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
LR chi2	LR chi2(21)	93.32	LR chi2(20)	46.15	LR chi2(20)	22.16
Prob > chi2		0.0000		0.0008		0.3319
Pseudo R2		0.0477		0.0349		0.0371
Log likelihood		-932.22452		-638.3069		-287.18535

These observations suggested that the behavioral process that affects walking frequency may not be directly influenced by the built environment, but indirectly by how these factors affect car ownership. In other words, it is not the walkability of neighborhoods that leads residents to walk, but the cost of alternative options, in this case the cost of car ownership as represented by the increased difficulty of owning a car in a walkable area. One additional issue is that once a car is owned, even in a walkable area, it is more likely to be driven, reducing the frequency of walking.

To further investigate this relationship we estimate the two-stage least squares model where our first stage is a car ownership model and the second stage is our walking frequency model. As discussed previously we estimate this model using the Conditional Mixed Process (cmp) estimator in Stata, that allows a sequential estimate that mixes an ordered probit (for walking frequency) with a truncated regression (for car ownership, as this variable is left-truncated at zero). The estimations for all three samples are presented in Table 7.

Unlike previous estimations the two-stage conditional mixed process passes the goodness of fit test for all samples. Road density and population density are also statistically significant in the first stage of the model which is the equation for the number of cars households own. Demographic and socio-economic characteristics prove to be more influential as income, education and race also become significant in the car ownership equation.

Examining all estimated coefficients (statistically significant or not) reveals various interesting points. The number of cars in a household is negatively associated with walking not only for all the respondents but for all three samples with much greater coefficients at the 99% level. We thus find that as car ownership increases, the frequency of walking decreases. From a policy perspective, this suggests that one way to increase walking is to reduce the number of cars that a household owns. While long run changes to increase land use density and mix is one option, in the short run policies aimed at increasing the cost of parking, providing car-sharing options, and encouraging alternate modes of travel can all reduce the incentive and need for a household to own more than one car.

Our built environment variables now show mixed results. Distance from barriers (defined as roads that can be safely crossed 20% of times or less) was expected to show a positive association with walking implying that the closer one is located to a barrier the less often one walks. Although this variable did not show any significance in any of the estimations, surprisingly, the coefficient's sign was negative. Local road density does not have a significant effect on walking although it shows a positive association with the number of household cars in Jersey City and the model with all our respondents. This is a bit surprising as increased road density is generally associated with increased walking. T-intersection density, as predicted by the literature, has a negative association with walking in Jersey City as well as in the overall sample. T-intersections may lead to poor connectivity, and represent non-grid street patterns and dead-ends (Cervero, Duncan 2003). However, in our data this may not be the case; we replaced our T-intersection density variable with cul-de-sac density in block groups. The latter variable was not statistically significant in our model. Thus, we suspect that T-intersection density may proxy as a barrier to walking, rather than a lack of connectivity. Other intersections (four or more-way intersections) have a positive association with frequency of walking in the overall sample and a negative association with number of cars at higher levels of significance both for all the respondents and Jersey City residents. Intuitively this is what we expect, as more intersections leads to increased connectivity; and might likewise make owning a car more difficult as these areas tend to be more walkable. Interestingly, and despite its importance in the literature, population density is only significant in Jersey City (negative coefficient in the car equation); it is, however, likely being captured by other built environment variables. Other built environment factors including land use mix entropy and retail employee density are not statistically significant.

The first stage model of car ownership seems to suggest components of the built environment that make it less likely to own a car, as well as some that are positively associated with car ownership (road density). Other studies have previously focused on broader aspects of the built environment as opposed to its components and found mixed results on the relationship between the built environment and car ownership. In general, households living in single-family housing, located in suburban areas and farther away from employment sites, tend to own more vehicles than households living in denser neighborhoods or closer to the central business district ((Bagley, Mokhtarian 2002b, Cervero 1996, Chu 2002, Sermons, Seredich 2001). A study by (Holtzclaw et al. 2002) found that in case studies of Chicago, Los Angeles, and San Francisco automobile ownership was significantly correlated with neighborhood residential density, after accounting for average per capita income, average family size, and availability of public transit. A study in Portland, Oregon found a very significant association between households' socio-demographic variables and automobile ownership while among built environment variables they only found land use mix (measured as a dichotomous variable) to be influential (Baldwin Hess, Ong 2002). Using negative binomial regression models in Chapel Hill, North Carolina, (Shay, Khattak 2005) found that automobile ownership is not significantly different in neo-traditional and conventional neighborhoods. However auto use measured through trip generation, travel time and travel distance is associated with urban design features (Shay, Khattak 2005). Furthermore (Cao, Mokhtarian & Handy 2007) applied ordered probit models to investigate the causal link from the built environment to auto ownership in both cross-sectional and quasi-panel contexts in Northern California. They found that individuals' attitudes regarding residential neighborhood and travel are more strongly associated with their auto ownership decision than is the built environment. Their quasi-panel results indicated that some built environment elements such as outdoor spaciousness and mixed land use are causes of auto ownership (remaining even after attitudes were allowed to enter the model), but their effects are marginal (Cao, Mokhtarian & Handy 2007).

The socio-demographic variables in our first stage car ownership model have a mix of results. Employment status and number of children are not significant at the 90% level. Women are less likely to own cars in Jersey City, but not in our statewide sample or for our full model. All other socio-demographic variables with the exception of age and dog ownership are significant in the first stage equation of cars owned and not in the final stage of the model for frequency of walking. Dog ownership as mentioned before has a very significant effect on walking frequency, at the 99% level in New Jersey and for all the respondents and 90% level in Jersey City. It is also significant in the first stage equation. Having an annual income of less than $100,000 is negatively associated with the number of household cars in the New Jersey sample and the full sample, whereas having less than a four-year college degree has a positive association.[6] Race and ethnic background is another influential factor in the number of cars households own. Results are relative to non-Hispanic White and thus non-Hispanic Black has a similar effect on car ownership while Hispanic has a negative association with the number of cars in New Jersey and for all the respondents. In Jersey City only the last category of race and ethnic background, Asian or Native American, shows some significance in the first stage equation. These variables show no effect on walking frequency.

Finally, living in a multi-family home, apartment, or condominium is negatively associated with car ownership (perhaps because of the unavailability of free parking facilities). This was still the case when we replaced the respondents' residence type with their neighborhoods' dominant residence type (based on US Census data). One can conclude that there are other built environment characteristics, besides those mentioned in the literature and included in our models, which affect car ownership and walking behavior. Here parts of these characteristics are captured by residence type and parts by the negative association between living in Jersey City and the number of cars. If we exclude this dummy variable from the model and let the other built environment variables explain the differences in car ownership, population density has a negative and statistically significant association with number of cars. Thus, this is another urbanization variable that increases the cost (or reduces the desirability) of owning a car.

Table 7: Two-stage Least Squares Model of Frequency of Walking

Variables	All Respondents		New Jersey		Jersey city	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Frequency of Walking						
Number of household cars	-0.303***	0.088	-0.295***	0.112	-0.366***	0.133

[6] We further tested whether our education result was due to collinearity with income, but found that alternatively excluding each variable did not change this result.

Variables	All Respondents		New Jersey		Jersey city	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Distance from roads safely crossable 20% of times or less	-0.00001	0.00001	-0.000005	0.00001	-0.00001	0.00005
Local road density	0.001	0.009	-0.003	0.011	0.015	0.016
T-intersection density	-0.001**	0.001	-0.001	0.001	-0.002*	0.001
Intersection density (4 or more legs)	0.001**	0.001	0.001	0.001	0.001	0.001
Land use mix entropy	-0.140	0.237	-0.183	0.284	-0.092	0.483
Population density	-0.000004	0.000004	0.000001	0.00001	-0.00001	0.00001
Retail employee density	0.00002	0.00005	0.0001	0.0001	-0.00001	0.0001
Being female	-0.070	0.085	-0.002	0.104	-0.201	0.154
Age	0.027	0.017	0.030*	0.021	0.010	0.031
Age squared	-0.0003**	0.0002	-0.0004	0.0002	-0.0001	0.0003
Being employed or going to school	-0.122	0.105	-0.144	0.129	-0.065	0.189
Having dogs in the household	0.526***	0.101	0.558***	0.119	0.401*	0.223
Having less than a 4-year college degree	-0.023	0.090	-0.003	0.108	-0.081	0.173
Non-Hispanic Black	0.047	0.135	0.125	0.199	-0.086	0.213
Hispanic	-0.107	0.136	-0.083	0.187	-0.236	0.220
Asian or Native American	0.096	0.155	0.085	0.220	0.052	0.246
Living in Jersey City	0.200	0.143	-	-	-	-
First stage model: Number of household cars						
Distance from roads safely crossable 20% of times or less	-0.00001	0.000005	-0.00001	0.000005	-0.00002	0.00005
Local road density	0.018**	0.009	0.013	0.011	0.035**	0.015
T-intersection density	-0.001	0.001	-0.001*	0.001	-0.000004	0.001
Intersection density (4 or more legs)	-0.002***	0.001	-0.0005	0.001	-0.002**	0.001
Land use mix entropy	-0.144	0.230	-0.007	0.266	-0.400	0.476
Population density	-0.000004	0.000004	0.00001	0.00001	-0.00001*	0.00001
Retail employee density	-0.0001	0.0001	-0.0001	0.0001	0.00001	0.0001
Being female	-0.098	0.081	-0.055	0.094	-0.255*	0.152
Age	0.040**	0.017	0.036*	0.020	0.039	0.036
Age squared	-0.0004***	0.0002	-0.0004**	0.0002	-0.0004	0.0004
Being employed or going to school	0.002	0.103	-0.073	0.121	0.226	0.182
Number of children under 18	0.043	0.038	0.007	0.045	0.105	0.070
Having dogs in the household	0.236***	0.088	0.316***	0.100	-0.202	0.191
Annual household income less than $100,000	-0.421***	0.091	-0.476***	0.102	-0.236	0.186
Having less than a 4-year college degree	0.248***	0.089	0.224**	0.101	0.178	0.175
Non-Hispanic Black	-0.061	0.136	-0.231	0.189	0.092	0.212
Hispanic	-0.276**	0.134	-0.350**	0.169	-0.137	0.214
Asian or Native American	0.177	0.147	0.006	0.198	0.398*	0.218
Living in multi-family home, apartment, or condominium	-0.394***	0.108	-0.507***	0.148	-0.177	0.155
Living in Jersey City	-0.269*	0.138	-	-	-	-
cons	1.589***	0.468	1.814***	0.563	0.911	0.928
lnsig_2	-0.091	0.035	-0.086	0.039	-0.196	0.075
atanhrho_12	0.262	0.102	0.262	0.124	0.367	0.178

Variables	All Respondents		New Jersey		Jersey city	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
cut_1_1	-1.952	0.465	-1.949	0.602	-2.438	0.820
cut_1_2	-1.480	0.463	-1.383	0.602	-2.225	0.813
cut_1_3	-0.506	0.465	-0.387	0.608	-1.309	0.800
cut_1_4	0.107	0.467	0.220	0.611	-0.679	0.798
sig_2	0.913	0.032	0.918	0.036	0.822	0.062
rho_12	0.256	0.095	0.256	0.115	0.352	0.156
Number of observations		717		466		251
LR chi2	LR chi2(38)	257.45	LR chi2(36)	139.29	LR chi2(36)	59.50
Prob > chi2		0.0000		0.0000		0.0082
Log likelihood		-1686.0273		-1195.5156		-471.16068

Conclusions

This analysis has examined the issue of walking from a new perspective. Our original intent was to examine some of the walkability features typically examined in the literature using data from New Jersey combined with an oversample of Jersey City. New Jersey is most urbanized state in the United States, yet it also is highly suburbanized with many design features that make it difficult to walk, often in highly populated areas. Thus, New Jersey provides substantial variation that offers a rich set of data for analysis.

Our key findings are really related to two variables not normally examined as indicators of walkability. One is car ownership, for which we manage to construct a structural two-stage least squares model that shows how various walkability features affect car ownership. While not all these variables have the expected association with car ownership, in general, we find sufficient evidence that suggests that fewer cars are owned in areas with more walkable built environment features. Put simply, those features that make it easier to walk, probably make it more difficult to own a car, or less desirable to do so. Thus, we see policies aimed at curbing car ownership as one means of increasing the frequency of walking. The other key variable that we control for is whether a household owns a dog. This is also strongly associated with walking; and yet dog ownership is less in urbanized areas such as Jersey City and those respondents who live in multi-family housing. This suggests that dog ownership is a necessary control variable to understand the frequency of walking.

Our built environment variables have some small effects, mainly associated with better network connectivity associated with increased walking frequency. However, built environment features also work indirectly via how they influence car ownership, which is one of our key findings. From a policy perspective this implies that if it is desired to increase walking (for health or environmental reasons), then improving the built environment can have some small but positive effect; larger effects can probably be found by policies that make owning a car less desirable or more costly (parking policies are one potent mechanism that could potentially be used). Therefore, as much research has found when it comes to reducing car usage, the carrot of promoting other modes will have a small benefit, but probably not as great as the stick of increasing the cost of car usage (or ownership).

ACKNOWLEDGMENTS

This research was supported by the region 2 University Transportation Research Center and by the New Jersey Pedestrian / Bicycle Resource Center, funded by the New Jersey Department of Transportation. All errors and omissions are the responsibility of the authors. Research assistance was provided by Ranjit Walia, Jennifer Rovito, Matthew Kabak, Nicholas Klein, and Patrick Brennan. We thank Devajyoti Deka for valuable discussions during the course of this research.

References

Bagley, M.N. & Mokhtarian, P.L. 2002a, "The impact of residential neighborhood type on travel behavior: A structural equations modeling approach", *The Annals of Regional Science,* vol. 36, no. 2, pp. 279-297.

Bagley, M.N. & Mokhtarian, P.L. 2002b, "The impact of residential neighborhood type on travel behavior: A structural equations modeling approach", *The Annals of Regional Science,* vol. 36, no. 2, pp. 279-297.

Baldwin Hess, D. & Ong, P.M. 2002, "Traditional neighborhoods and automobile ownership", *Transportation Research Record: Journal of the Transportation Research Board,* vol. 1805, no. -1, pp. 35-44.

Bauman, A.E., Russell, S.J., Furber, S.E. & Dobson, A.J. 2001, "The epidemiology of dog walking: an unmet need for human and canine health", *Medical journal of Australia,* vol. 175, no. 11/12, pp. 632-634.

Berrigan, D. & Troiano, R.P. 2002, "The association between urban form and physical activity in US adults", *American Journal of Preventive Medicine,* vol. 23, no. 2, pp. 74-79.

Bhat, C.R. & Guo, J.Y. 2007, "A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels", *Transportation Research Part B: Methodological,* vol. 41, no. 5, pp. 506-526.

Brown, S.G. & Rhodes, R.E. 2006, "Relationships among dog ownership and leisure-time walking in Western Canadian adults", *American Journal of Preventive Medicine,* vol. 30, no. 2, pp. 131-136.

Cao, X., Mokhtarian, P.L. & Handy, S.L. 2009, "Examining the impacts of residential self-selection on travel behaviour: a focus on empirical findings", *Transport Reviews,* vol. 29, no. 3, pp. 359-395.

Cao, X., Mokhtarian, P.L. & Handy, S.L. 2007, "Cross-sectional and quasi-panel explorations of the connection between the built environment and auto ownership", .

Cao, X.J. 2010, "Exploring causal effects of neighborhood type on walking behavior using stratification on the propensity score", *Environment and Planning A,* vol. 42, no. 2, pp. 487-504.

Cervero, R. 1996, "Mixed land-uses and commuting: evidence from the American Housing Survey", *Transportation Research Part A: Policy and Practice,* vol. 30, no. 5, pp. 361-377.

Cervero, R. 1988, *Land-Use Mixing and Suburban Mobility*.

Cervero, R. & Duncan, M. 2003, "Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay Area", *American Journal of Public Health,* vol. 93, no. 9, pp. 1478.

Cervero, R. & Kockelman, K. 1997, "Travel demand and the 3Ds: density, diversity, and design", *Transportation Research Part D: Transport and Environment,* vol. 2, no. 3, pp. 199-219.

Chu, Y.L. 2002, "Automobile ownership analysis using ordered probit models", *Transportation Research Record: Journal of the Transportation Research Board,* vol. 1805, no. -1, pp. 60-67.

Coleman, K.J., Rosenberg, D.E., Conway, T.L., Sallis, J.F., Saelens, B.E., Frank, L.D. & Cain, K. 2008, "Physical activity, weight status, and neighborhood characteristics of dog walkers", *Preventive medicine,* vol. 47, no. 3, pp. 309-312.

Craig, C.L., Brownson, R.C., Cragg, S.E. & Dunn, A.L. 2002, "Exploring the effect of the environment on physical activity:: A study examining walking to work", *American Journal of Preventive Medicine,* vol. 23, no. 2, pp. 36-43.

Cutt, H., Giles-Corti, B., Knuiman, M. & Burke, V. 2007, "Dog ownership, health and physical activity: a critical review of the literature", *Health & place,* vol. 13, no. 1, pp. 261-272.

Cutt, H., Giles-Corti, B., Knuiman, M., Timperio, A. & Bull, F. 2008a, "Understanding dog owners' increased levels of physical activity: Results from RESIDE", *American Journal of Public Health,* vol. 98, no. 1, pp. 66.

Cutt, H.E., Giles-Corti, B., Wood, L.J., Knuiman, M.W. & Burke, V. 2008b, "Barriers and Motivators for Owners Walking Their Dog: Results from Qualitative Research", *Health Promotion Journal of Australia: Official Journal of Australian Association of Health Promotion Professionals,* vol. 19, no. 2, pp. 118.

Cutt, H.E., Knuiman, M.W. & Giles-Corti, B. 2008, "Does getting a dog increase recreational walking?", *International Journal of Behavioral Nutrition and Physical Activity,* vol. 5, no. 1, pp. 1-10.

Ewing, R. & Cervero, R. 2010, "Travel and the built environment", *Journal of the American Planning Association,* vol. 76, no. 3.

Forsyth, A., Krizek, K.J. & Rodríguez, D.A. 2009, "Non-motorized travel research and contemporary planning initiatives", *Progress in Planning,* vol. 71, no. 4, pp. 170-183.

Frank, L.D., Andresen, M.A. & Schmid, T.L. 2004, "Obesity relationships with community design, physical activity, and time spent in cars", *American Journal of Preventive Medicine,* vol. 27, no. 2, pp. 87-96.

Frank, L.D., Kerr, J., Sallis, J.F., Miles, R. & Chapman, J. 2008, "A hierarchy of sociodemographic and environmental correlates of walking and obesity", *Preventive medicine,* vol. 47, no. 2, pp. 172-178.

Frank, L.D., Saelens, B.E., Powell, K.E. & Chapman, J.E. 2007, "Stepping towards causation: Do built environments or neighborhood and travel preferences explain physical activity, driving, and obesity?", *Social science & medicine,* vol. 65, no. 9, pp. 1898-1914.

Frank, L.D., Schmid, T.L., Sallis, J.F., Chapman, J. & Saelens, B.E. 2005, "Linking objectively measured physical activity with objectively measured urban form:: Findings from SMARTRAQ", *American Journal of Preventive Medicine,* vol. 28, no. 2, pp. 117-125.

Greenwald, M.J. & Boarnet, M.G. 2001, "Built environment as determinant of walking behavior: analyzing nonwork pedestrian travel in Portland, Oregon", *Transportation Research Record: Journal of the Transportation Research Board,* vol. 1780, no. -1, pp. 33-41.

Guo, J., Bhat, C. & Copperman, R. 2007, "Effect of the Built Environment on Motorized and Nonmotorized Trip Making: Substitutive, Complementary, or Synergistic?", *Transportation Research Record: Journal of the Transportation Research Board,* vol. 2010, no. -1, pp. 1-11.

Ham, S.A. & Epping, J. 2006, "Dog walking and physical activity in the United States.", *Preventing chronic disease,* vol. 3, no. 2, pp. A47.

Hoerster, K.D., Mayer, J.A., Sallis, J.F., Pizzi, N., Talley, S., Pichon, L.C. & Butler, D.A. 2010, "Dog walking: Its association with physical activity guideline adherence and its correlates", *Preventive medicine,* .

Holtzclaw, J., Clear, R., Dittmar, H., Goldstein, D. & Haas, P. 2002, "Location efficiency: Neighborhood and socio-economic characteristics determine auto ownership and use-studies in Chicago, Los Angeles and San Francisco", *Transportation Planning and Technology,* vol. 25, no. 1, pp. 1-27.

Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A. & Hugo, G. 2007, "Walkability of local communities: Using geographic information systems to objectively assess relevant environmental attributes", *Health & place,* vol. 13, no. 1, pp. 111-122.

New Jersey Department of Transportation 2005, *Final Report, NJ Statewide Bicycle & Pedestrian Master plan, Phase 2*.

Oka, K. & Shibata, A. 2009, "Dog ownership and health-related physical activity among Japanese adults.", *Journal of physical activity & health,* vol. 6, no. 4, pp. 412.

Owen, N., Cerin, E., Leslie, E., DuToit, L., Coffee, N., Frank, L.D., Bauman, A.E., Hugo, G., Saelens, B.E. & Sallis, J.F. 2007, "Neighborhood walkability and the walking behavior of Australian adults", *American Journal of Preventive Medicine,* vol. 33, no. 5, pp. 387-395.

Pinjari, A.R., Pendyala, R.M., Bhat, C.R. & Waddell, P.A. 2007, "Modeling residential sorting effects to understand the impact of the built environment on commute mode choice", *Transportation,* vol. 34, no. 5, pp. 557-573.

Roodman, D. 2009, *Estimating fully observed recursive mixed-process models with cmp*, Center for Global Development.

Rutt, C.D. & Coleman, K.J. 2005, "The Impact of the Built Environment on Walking as a Leisure-Time Activity Along the US/Mexico Border", *Journal of Physical Activity and Health,* vol. 3, pp. 257-271.

Saelens, B.E. & Handy, S.L. 2008, "Built environment correlates of walking: a review", *Medicine and science in sports and exercise,* vol. 40, no. 7 Suppl, pp. S550.

Saelens, B.E., Sallis, J.F., Black, J.B. & Chen, D. 2003, "Neighborhood-Based Differences in Physical Activity: an Environment Scale Evaluation", *American Journal of Public Health,* vol. 93, no. 9, pp. 1552-1558.

Sallis, J.F., Frank, L.D., Saelens, B.E. & Kraft, M.K. 2004, "Active transportation and physical activity: opportunities for collaboration on transportation and public health research", *Transportation Research-Part A Policy and Practice,* vol. 38, no. 4, pp. 249-268.

Schwanen, T. & Mokhtarian, P.L. 2005, "What affects commute mode choice: neighborhood physical structure or preferences toward neighborhoods?", *Journal of Transport Geography,* vol. 13, no. 1, pp. 83-99.

Sermons, M.W. & Seredich, N. 2001, "Assessing traveler responsiveness to land and location based accessibility and mobility solutions", *Transportation Research Part D: Transport and Environment,* vol. 6, no. 6, pp. 417-428.

Serpell, J. 1991, "Beneficial effects of pet ownership on some aspects of human health and behaviour.", *Journal of the Royal Society of Medicine,* vol. 84, no. 12, pp. 717.

Shay, E. & Khattak, A.J. 2005, "Automobile ownership and use in neotraditional and conventional neighborhoods", *Transportation Research Record: Journal of the Transportation Research Board,* vol. 1902, no. -1, pp. 18-25.

Shoup, D.C. 1997, "The high cost of free parking", *Journal of Planning Education and Research,* vol. 17, no. 1, pp. 3.

Sirard, J.R., Patnode, C.D., Hearst, M.O. & Laska, M.N. 2011, "Dog Ownership and Adolescent Physical Activity", *American Journal of Preventive Medicine,* vol. 40, no. 3, pp. 334-337.

The American Association for Public Opinion Research 2009, *Standard Definitions: Final Dispositions of Case Codes and Outcome Rates for Surveys,* 6th edn, AAPOR, Lenaxa, Kansas.

Tilt, J.H. 2010, "Walking trips to parks: Exploring demographic, environmental factors, and preferences for adults with children in the household", *Preventive medicine,* vol. 50, pp. S69-S73.

Yang, C., McCollum, D., McCarthy, R. & Leighty, W. 2009, "Meeting an 80% reduction in greenhouse gas emissions from transportation by 2050: A case study in California", *Transportation Research Part D: Transport and Environment,* vol. 14, no. 3, pp. 147-156.