Does Urban Living Influence Baby Boomers' Travel Behavior?

Jae Seung Lee (Corresponding author)
School of Urban and Civil Engineering, Hongik University
K520, 94 Wausan-ro, Mapo-gu
Seoul, 121-791, Republic of Korea
Email: jaeseung74@gmail.com
Mobile: +82-10-7577-5085
Fax: +82-2-336-7416

P. Christopher Zegras
Massachusetts Institute of Technology
Department of Urban Studies and Planning
77 Massachusetts Avenue, Room 10-403
Cambridge MA 02139
Email: czegras@mit.edu
Phone: 617-452-2433
Fax: 617-258-8081

Eran Ben-Joseph
Massachusetts Institute of Technology
Department of Urban Studies and Planning
77 Massachusetts Avenue, Room 10-485
Cambridge, MA 02139
Email: ebj@mit.edu
Phone: 617-253-7305

Sungjin Park
Assistant Professor,
School of Urban and Civil Engineering, Hongik University
K521, 94 Wausan-ro, Mapo-gu
Seoul, 121-791, Republic of Korea
Email: sungjin.park1@gmail.com
Mobile: +82-10-4793-1969

Highlights

- Urban baby boomers are less automobile-dependent and more transit-oriented.
- Urban baby boomers make more recreational NMT, social, and utilitarian trips.
- We find small self-selection effects on automobile, NMT, and utilitarian trips.
- We find relatively large self-selection effects on public transportation use.
- Baby boomers’ preference for social activities is mismatched to their environments.

1. Introduction

The baby boomers, individuals born between 1946 and 1964, represent the current major wave of aging adults. As of 2010, more than 40 million individuals were aged 65 and over in the United States, representing 13 percent of the population. By 2030, all of the baby boomers will be aged over 65, pushing the United States' share of 65+ to 19 percent of the population, or more than 72 million persons (Vincent and Velkoff, 2010).

This demographic reality is related to a range of now well-documented public policy challenges. Among these, mobility looms importantly. Will the baby boomers follow previous generations of older adults, for whom the share of non-drivers increases rapidly after age 65? (U.S. DOT, 2011). If so, how would such a trend be reconciled with the boomers' current high automobile dependency, itself influenced by their apparently overwhelming preferences for non-urban living?

Table 1

Baby Boomers' Residential Location and Travel Mode Share: 2001 to 2009.[1]

	Urban		**Second City**		**Suburban**		**Town & Rural**	
	2001	**2009**	**2001**	**2009**	**2001**	**2009**	**2001**	**2009**
Share of All Boomers	14.3	17.1	16.1	17.1	25.8	24.3	43.8	41.4
Private Vehicle Share of All Trips	77.6	72.3	91.0	87.1	92.4	88.0	93.6	91.2
Walk Share of All Trips	14.9	18.0	7.5	9.8	5.7	9.7	5.1	7.2
Bike Share of All Trips	0.6	0.7	0.5	1.1	0.4	0.9	0.4	0.5
Transit Share of All Trips	6.1	7.3	0.6	1.4	1.1	0.9	0.3	0.4

Sources: U.S. DOT, 2005; 2011. *Notes*: For comparability, only trips <50 miles included; baby boomers were represented by individuals aged 37 to 55 in 2001 and 45 to 63 in 2009.

The past decade provided modest evidence that baby boomers became more urban and less automobile dependent (across residential settings) and walked for a greater share of all trips (again across residential settings). The 2009 mode shares in Table 1 show that urban boomers' walk mode share is more than double than those of non-urban boomers in second city, suburban, and town & rural. Also, urban boomers' transit mode share is at least seven times greater than their non-urban counterparts (Table 1). If this trend continues, baby boomers may decrease their automobile dependency as urban boomers use private motor vehicles considerably less than their non-urban counterparts. Nonetheless, massive relocation of non-urban boomers to urban areas

[1] The four categories (Urban, Second City, Suburban, and Town & Rural) reflect the classification of "Urban / Rural Indicator – Block Group" (U.S. DOT, 2011). The classification is based on population density (persons per square mile), which was converted into centiles (a scale from 0 to 99).
Urban: Downtown areas and surrounding neighborhoods. 94% of "Urban" block groups have a density centile score between 75 and 99.
Second City: Satellite cities surrounding major metropolitan areas. 96% of "Second City" block groups have a density centile score between 40 and 90.
Suburban: Areas surrounding urban areas. 99% of "Suburban" block groups have a density centile score between 40 and 90.
Town & Rural: Exurbs, farming communities, and various rural areas. 100% of "Rural" block groups have a density centile score between 0 and 20. 98% of "Town" block groups have a density centile score between 20 and 40.

remains to be seen. While suburban baby boomers may express concerns regarding their current neighborhoods becoming unsuitable for them as they age, they may also be unlikely to forego the privacy, amenity, and social networks suburbia provides (Zegras et al., 2008). Also, it is difficult to implement major environmental changes of non-urban areas – such as radical improvement of density, diversity, and transportation services – to satisfy the travel (and other) needs of their aging demographic.

The boomers' demographic geography and underlying preferences raise a series of inter-related questions for planners, designers, and others concerned with improving current residential settings and/or providing options that support healthy and active aging. How do boomers decide whether to live in "suburban/town" or "urban" environments? How do transportation and the role of the automobile factor into this decision? Does urban and suburban boomers' travel behavior differ and, if so, in what ways? Would an urban migration of baby boomers change their travel behavior? In this paper, we aim to answer some of these questions by comparing the travel behavior of urban and suburban baby boomers in Greater Boston.

The present study attempts to assess the role of urban living in influencing baby boomers' travel behavior. We focus on baby boomers aged 55 to 64, or the "pre-senior" or "pre-retiree" group (Frey, 2003). Hereafter, the term baby boomers in this study refers to this "leading-edge" cohort. Specifically, we examine two issues. First, relative to residence in suburban locations, do urban locations exert causal influences on baby boomers' travel patterns, including driving, transit use, and trip-making for different purposes? Second, to what degree does self-selection, in terms of travel behavior-related residential preferences, influence differences in observed baby boomers' travel behavior? To compare urban and suburban baby boomers' travel behavior, and control for potentially confounding socio-demographic and attitudinal characteristics, we use a propensity score matching approach to approximate "true" versus self-selection effects. Ultimately, we aim to offer a better understanding of baby boomers' travel behaviors in urban versus suburban settings and the role of residential locations in promoting active and healthy aging.

The next section reviews previous studies regarding the built environment, travel behavior, and residential self-selection, as well as aging baby boomers' travel patterns. The following section introduces the data, key variables, and propensity score matching modeling approach, followed by model results. The final section summarizes the results and discusses their implications.

2. Research Precedents and Approach

2.1. Older Adults' Travel Behavior

Researchers have long been interested in older adults' travel behavior (Wachs, 1979). Recently, Cvitkovich and Wister (2001) focus on the role of transportation in promoting the well-being of older adults. Schmöcker et al. (2005) investigate overall trip generation rates and travel distances of older adults. Despite intensive research activity on the built environment-travel behavior relationship more generally, relatively little of the research into the travel behavior of older adults has focused specifically on the role of the built environment. Bailey (2004) attempts to measure "elderly isolation," using the 2001 National Household Travel Survey (NHTS) data. She refers to people who stay at home on a given day, as related to the auto-dependency of older adults as influenced by urban form. In another study, using the 1999 Nationwide Personal Transportation Survey (NPTS), Rosenbloom and Waldorf (2001) include the effects of relative location (e.g., urban, suburban) on older adults' public transport and automobile choice.

Unfortunately, these studies use few controls in their analysis and the crude location measure used provides few insights into neighborhood design and possible influences. Using the 1995 NPTS, Giuliano (2004) attempts to detect the effects of metropolitan-scale and neighborhood-scale (defined at census tract level) on older adults' travel behavior. The neighborhood-scale variables are used to represent the built environment, including population density, employment density, a local services index, housing age as a proxy for land use dispersal, and share of homeowners as an income proxy. She finds few significant built environment effects on trip rates, except for a positive effect of local access. For trip distances (for non-work travel), she identifies significant effects of local access and density with differing effects detected between the "younger elderly" (65-74) and "older elderly" (75+).

2.2. The Built Environment and Travel Behavior

A rich research base, spanning several decades, now exists on the relationship between the physical form of the built environment and travel behavior. Ewing and Cervero (2010) offer a recent review, including a meta-analysis of more than 50 studies. Their analysis finds reasonably consistent, and relatively modest, correlations among characteristics such as density, land use mix, and street configurations on driving, public transportation use, and walking. As concerns over aging have increased, a growing number of studies have examined various dimensions of older adults' travel behavior and relationships with the built environment, as reviewed by Cao, Mokhtarian, and Handy (2010), Zegras et al. (2012), and Lee et al. (2013).

An important challenge to empirical work on the built environment-travel behavior relationships, however, is in inferring causality. A classical experimental design randomly assigns subjects to treatment and control groups, seeking to balance all relevant covariates, whether observed or unobserved, between the groups. This would enable one to infer that the difference between outcomes, post-treatment, is an unbiased estimate of treatment effect. Carrying out such an experiment in the built environment-behavioral realm is clearly a challenge, since rarely does a researcher have the chance to randomly assign subjects to different built environments. As such, much of the relevant research relies on observational studies using cross-sectional data of observed behaviors.

To understand the challenges in such observational studies, consider a basic example: do residents of more "walkable" places walk more because their neighborhoods cause them to walk more or do residents who walk more choose to live in more walkable places (but would walk more regardless)? This example reflects the challenge known generally as "self-selection," which technically arises from endogeneity (simultaneity and/or omitted variable bias), and can result in inconsistent and biased estimates of effects. Mokhtarian and Cao (2008) provide a technical review and outline analytical and research design solutions while Cao et al. (2009) review 38 empirical studies using different approaches to controlling for self-selection. They find that controlling for self-selection moderates the estimated effects of built environment on travel behavior. Ewing and Cervero (2010) include 19 studies attempting to control for self-selection in some way and find the opposite result to Cao et al. (2009): controlling for self-selection increases the magnitude of estimated effects. The former authors note this result could reflect differences in the samples and/or in the different ways that self-selection was operationalized in the two summary analyses.

2.3. Analytical Technique

Among the various self-selection controls, one option is matched sampling, whereby observed variables are used to adjust for differences in outcomes unrelated to the "treatment" (e.g., built environment) and producing selection bias. Propensity-score matching (PSM) is one such matching approach, particularly popular in evaluating social programs (Ravallion, 2008). Essentially, PSM attempts to control for the influence of confounding factors that may lead to self-selection in observational research by mimicking randomization among the observations. The approach has been somewhat recently introduced into built environment-travel behavior research. Boer et al. (2007) use the propensity score matching method and travel data from the 1995 US National Personal Transportation Survey (NPTS), to estimate the effects of six built environment measures on the odds of walking (making at least one walk trip), finding business diversity, intersection density and housing density (at the highest density levels) to be related to walking. Zegras et al. (2009) propose, but do not implement, the PSM approach as a method for estimating travel emissions reductions from a neighborhood development project in China. Cao (2010) uses a propensity score stratification approach to estimate the causal effect of "traditional" (treatment; defined as mostly pre-dating World War II) versus suburban (control) neighborhoods on residents' utilitarian and recreational walking frequencies. He finds evidence of self-selection for both trip types, with a stronger effect, intuitively, for utilitarian walking; he finds the neighborhood effects on walking behavior tend to be greater than self-selection effects. Cao et al. (2010) apply propensity score matching to assess the effects of residential location on residents' vehicle miles driven in the Raleigh (North Carolina) region. They estimate the effects on individual vehicle miles driven per day of living at various locations relative to the city center: urban, inner-ring, suburban, exurban. Similar to Cao (2010), Cao et al. (2010) find the location effects, generally to be larger than self-selection effects, with the location effects increasingly dominant with as the distance from city center increases.

Our work draws methodological inspiration from these recent PSM-based approaches, but examines specifically the suburban/urban differences associated with baby boomers travel behavior. We build from our own previous work, which focused on suburban and urban boomers, in separate analyses. In Zegras et al. (2012), we utilize structural equation modeling (SEM) to estimate the effect of neighborhood physical *and* social characteristics on baby boomers' recreational non-motorized transport (NMT) and social trips in suburban Boston. We find very modest, indirect, effects of the physical setting on trip-making, as well as evidence of self-selection into desired social settings (i.e., to satisfy social trip-making predilection), which, in turn, influence the likelihood being "active" (making at least one recreational NMT trip). In a subsequent analysis of urban baby boomers (Lee et al., 2013), we find, again using SEM, stronger evidence of physical characteristics affecting baby boomers' utilitarian and recreational walking. The models reveal little evidence of self-selection among urban boomers regarding the behaviors analyzed, but they do suggest that social norms and safety concerns do influence walking behavior. Overall, our previous findings suggest that, relative to suburban areas, urban areas' greater varieties in physical forms may influence boomers' travel behaviors. While we find little evidence of self-selection *within* the urban or suburban residents focusing primarily on NMT trips, we now combine the two datasets to examine diverse travel behaviors (i.e., automobile and public transportation commuting, NMT trips, social trips, and utilitarian trips) and possible self-selection *across* urban and suburban boomers to reveal the degree to which behavioral differences among boomers arise due to locational differences versus self-selection.

3. Methods

3.1. Study area

We examine differences between urban and suburban baby boomers' travel behaviors in the Boston metropolitan area (Fig. 1). The Boston-Cambridge-Quincy Metropolitan Statistical Area includes 546,219 "leading-edge" boomers in 2010, out of a total population of 4,552,402 (US Census Bureau, 2011).

Fig. 1. Urban and suburban study areas.

3.2. Neighborhood and Household/Individual Data

We base our analysis on two household mail-back surveys of suburban and urban baby boomers. Zegras et al. (2012) and Lee et al. (2013) provide details on the survey approaches and related data collection on neighborhood characteristics. The suburban and urban baby boomer surveys were carried out in 2008 and 2010, respectively. Our sampling approach maintains the range of the age cohort, in order to make the two surveys comparable. Therefore, this study refers to baby boomers aged 55 to 64 as of 2008 (suburban survey) and 2010 (urban survey).[2] For the first mail-

[2] The overall travel trend during 2008- 2010 was quite stable. Motor vehicle travel declined slightly from 2008 to 2010 by 0.25% (U.S. DOT, 2010). Per capita VMT during the period was also relatively stable: the 10-year rolling averages for change in U.S. per capita VMT were 0.1% in 2008 and -0.01% in 2010 (SSTI, 2011). The number of work trips per worker (350/year) has remained stable over the four decades from 1969 (McGuckin & Lynott, 2012). While the utilitarian trips increased during 2001-2009, the growth has leveled off (McGuckin & Lynott, 2012). Therefore, the influence of overall travel changes between 2008 and 2010 on the result may be trivial.

back survey of suburban baby boomers, we acquired mailing addresses from USAData, a commercial data vendor, requesting addresses for residents ages 55–64 from specific suburban neighborhoods; we mailed survey instruments to 7,000 randomly selected addresses from those acquired with a $5 cash incentive and achieved an effective response rate of 20 percent with 1422 effective household responses (Zegras et al. 2012). The second mail-back survey focused on urban baby boomers. Our sampling frame was mailing addresses purchased from USAData for residents 55 and over from urban neighborhoods in four cities from the Boston metropolitan area (Boston, Cambridge, Somerville, and Brookline). Without a cash incentive, we mailed survey instruments to 7,000 randomly selected addresses and achieved a lower effective response rate (10.6 percent with 745 effective household responses), relative to the suburban survey (Lee et al., 2013).

Table 2 shows that the urban neighborhoods in the sample tend to have greater street connectivity and access to recreational facilities, potential destinations, and transportation services. For example, the average intersection density of the urban neighborhoods is approximately twice as high as that of the suburban neighborhoods. Likewise, while 92 percent of the urban neighborhoods in the sample have nearby recreational facilities, including public open spaces and trails, only 35 percent of the suburban neighborhoods have such amenities. A large difference also exists in the percentages of neighborhoods with at least one potential destination within 400m: 99 percent in the urban study areas versus 45 percent in the suburban study areas. Finally, the urban neighborhoods tend to have greater access to rail transit: 79 percent of the urban neighborhoods have subway stations, while 22 percent of the suburban neighborhoods have commuter rail stations within 1km.

This comparison could be biased due to different data sources and different approaches to neighborhood definition in the two location types (see note to Table 2). For example, the urban destination data is from the ESRI Business Analyst Data, whereas the suburban destination data comes from Google Earth's "places of interest." Despite these potential sources of differences, however, it is safe to say that the urban neighborhoods in the sample tend to have greater street connectivity, more amenities, more nearby destinations, and greater access to public transportation than suburbs. These urban neighborhoods' physical characteristics are expected to encourage more active travel patterns, relative to the suburban neighborhoods.

Table 2

Comparison of Urban and Suburban Neighborhood Characteristics in Study Area.

	Urban Neighborhoods (n=933)	Suburban Neighborhoods (n=458)	Mean Difference
Average Intersection Density (True intersections / 100m of streets)	0.66	0.32	0.34**
Percentage of neighborhoods with Recreational Amenities within 400m	92	35	57**
Percentage of neighborhoods with Destinations within 400m.	99	45	54**
Percentage of neighborhoods with Rail within 1km	79	22	57**

Notes: * p<0.05, ** p<0.01, indicating significance levels of difference of means/proportions. The Suburban neighborhoods were identified visually, based on primary street characteristics surrounding each sampled household (households could share neighborhoods) (see Zegras et al., 2012); the "urban neighborhoods" were defined based on 400 meter walk buffers drawn according to walking paths along streets emanating from each household (each household had unique buffer) (see Lee et al., 2013).

The information collected through the survey includes: (1) socioeconomic and demographic characteristics, (2) weekly behavioral characteristics (trip frequency by travel modes, purposes, and social activities), and (3) travel and residential choice-related attitudes and preferences. The latter psychological factors are included to be used as controls for self-selection.

Examining differences in travel behavior between the urban and suburban boomers (Table 3), we can see that urban baby boomers tend to commute less frequently by car than their suburban counterparts, but commute more frequently by public transportation. Urban baby boomers also demonstrate higher levels of physical and social activity, making more NMT and social trips. They also more actively undertake utilitarian trips, such as going out for shopping, eating, banking, meeting a doctor, or doing an errand.

In terms of socioeconomics and demographics, our sampled urban boomers have a higher share of high-income households, whereas the suburban boomers have a greater proportion of mid-income and low-income households. The sampled urban households tend to be smaller in size, with fewer cars, higher employment levels, more years of residence, and better health, relative to the suburban households. The sampled suburban baby boomers are slightly older. The suburban baby boomers tend to prefer large homes, while urban baby boomers tend to prefer homes convenient to work, retail, and services.

Table 3

Descriptive Statistics by Neighborhood Type and Tests of Differences.

Variables		**Mean (SD) N=2792[a]**	**Group Mean (SD)**		
			Urban N=933	**Suburban N=1859**	**Mean Diff.**
Behavioral Variables (Last week, how many times did you:)					
Automobile Commuting	drive to work?	2.48 (2.72)	1.62 (2.54)	2.93 (2.70)	1.31*
Public Transit Commuting	go to work on public transportation?	0.57 (1.77)	1.31 (2.57)	0.18 (0.94)	1.14*
Recreational NMT Trip	walk or cycle for exercise in your neighborhood?	2.76 (3.12)	3.75 (3.94)	2.24 (2.42)	1.52*
Social Trip	visit your neighbors?	1.03 (1.63)	1.45 (2.02)	0.80 (1.32)	0.65*
Utilitarian Trip	go out for nonwork purpose (e.g., shopping, easting, errand, etc.)?	9.09 (6.25)	12.18 (7.28)	7.55 (4.99)	4.63*
Household Characteristics					

High-Income	High annual household income ($100k- more) (0. otherwise, 1. high income)	0.34	0.42	0.30	0.12*
Mid-Income	Medium annual household income ($50k- 99.9k) (0. otherwise, 1. medium income)	0.47	0.41	0.50	0.09*
Low-Income (base)	Low annual household income (less than 49.9k) (0. otherwise, 1. low income)	0.19	0.17	0.21	0.04*
Persons	Number of persons in a household	2.10 (0.95)	1.95 (1.01)	2.16 (0.91)	0.21*
Car	Cars in a household (0. No cars, 1. More than one cars)	1.79	1.15	2.14	0.99*
Bike	Bikes in a household (0. No bicycles, 1. More than one bicycles)	1.16	1.17	1.15	0.02
Residential Years	Years of living at a current address	15.81 (12.75)	17.27 (11.95)	15.10 (13.06)	2.17*
Personal Characteristics					
Employ	Employment status (0. unemployed, 1. employed)	0.65	0.68	0.64	0.04*
Healthy	Health status (0. unhealthy, 1. healthy)	0.88	0.94	0.85	0.09*
Male	Gender (0. female, 1. male)	0.45	0.41	0.47	0.06*
Age	Residents' age	60.78 (3.46)	60.00 (2.32)	61.19 (3.88)	1.19*
Residential Preferences					
Large Home	Level of Importance (1. Less important, 3. Neutral, 5. More important)	2.61 (1.28)	2.43 (1.24)	2.70 (1.29)	0.27*
Convenient to Work	Level of Importance (1. Less important, 3. Neutral, 5. More important)	2.93 (1.51)	4.01 (1.27)	2.34 (1.29)	1.67*
Convenient to Retail and Services	Level of Importance (1. Less important, 3. Neutral, 5. More important)	3.70 (1.16)	4.44 (0.72)	3.30 (1.15)	1.14*

Notes: * p<0.05, indicating significance levels of difference of means/proportions; - : indicates not applicable; [a]: N may differ by variables due to missing values.

3.3. Propensity Score Matching

As discussed above, our research design poses a challenge to inferring whether urban settings produce different travel behavior among baby boomers vis-à-vis their suburban counterparts. Our subjects, urban and suburban residents, were not randomly assigned to their neighborhoods, but rather deliberately select their locations. Therefore, the observed behavioral differences (in Table 3) may be due to relative locations (i.e., urban versus suburban) and/or they may arise from unobserved preferences among the subjects (i.e., residential preferences) and observable attributes such as household characteristics (i.e., household size, household income, residential years, and car ownership) and personal characteristics (i.e., age, employment status, health status, and gender).

Urban residents' preferences likely systematically differ from those of suburban residents. For instance, urban-living baby boomers' preferences for living conveniently to work and retail is statistically significantly higher than those of their suburban counterparts (Table 3). This result suggests that the observed higher utilitarian trip rates, for example, among sampled urban baby boomers may be a function of the fact that those boomers with higher access needs to non-work activities (e.g., shopping, eating out) choose to live in urban areas, which provide such activities nearby. Propensity score matching (PSM) has been widely utilized in the social program evaluation to control for such self-selection problems by mimicking a randomized experiment (Cao et al., 2009). PSM estimates the causal effect of the built environment on travel behavior by eliminating the imbalance in the observed characteristics that may influence individuals in urban and suburban neighborhoods. However, PSM does not require the evaluation of multicollinearity, statistical significance, and a normality assumption, unlike statistical control models or sample selection models (Cao, 2010) To control for self-selection possibilities among our sampled households, we apply PSM as a means for (1) matching observations, by identifying almost "identical" persons in the control group (i.e., suburban boomers) for each person in the treatment group (i.e., urban boomers) and then (2) computing the difference in outcomes (travel behavior) between the matched observations (Caliendo & Kopeinig, 2008). The mean outcome difference between the matched control and treatment groups is the average treatment effect (ATE) or "true" effect of living in urban areas, relative to the suburbs, on travel behavior. The self-selection effect (SSE) can be estimated by computing the difference between the actual observed influence and the ATE.

Propensity score matching relies on two basic assumptions: (1) conditional independence and (2) common support (Heinrich et al., 2010). The conditional independence assumption implies that controlling for a set of X variables, which are not affected by treatment and are observable to the researcher, makes potential outcomes independent of the treatment status; that is, treatment assignment is equivalent to random assignment. This assumption makes it possible to reduce selection bias, by taking into account systematic differences between treatment and control groups. The common support assumption means that each subject has a positive probability of being assigned to both the treatment and control groups, and there are individuals in both groups with the same characteristics (covariates), within the range that treatment effects are being measured. This second condition ensures sufficient overlap between the treatment and control groups, in terms of characteristics, to find an adequate number of matched individuals (i.e., common support).

Matched sampling still faces the problem of dimensionality: the difficulty of finding the same or similar individuals, matching on all relevant covariates. Rosenbaum and Rubin (1983) suggest matching individuals based on the propensity score – the probability of participating in a treatment given observed characteristics. PSM avoids the problem of dimensionality by matching on a single variable (the propensity score) instead of on the entire set of relevant covariates. Rosenbaum and Rubin (1983) show that if it is valid to match units based on multiple covariates, it is equivalently valid to match on the propensity score. In practice, any discrete choice model, including logit and probit models, can be used to estimate the propensity score (Caliendo & Kopeinig, 2008).

4. Estimation and Results

4.1. Propensity Score Matching Estimation

We implemented PSM in Stata 11, which is a data analysis and statistical software providing the "psmatch2" module for propensity score matching (Leuven & Sianesi, 2003). A binary logit model estimates the probability of living in urban (treatment), compared to in suburban (control) areas. Typically, the propensity score is the probability of selection into treatment given observed characteristics. However, our particular sampling approach that combines two samples from two populations (urban and suburban baby boomers) with unknown population weights can result in biased estimation results. For consistent propensity score estimation, matching was conducted on the odds ratio of the propensity score, which spreads out the density of very low and very high propensity scores and therefore allows for consistent bandwidth (Heckman & Todd, 2009). The logit model included household characteristics, personal characteristics, and residential preferences as independent variables. Variables determined by residents' location choices, such as neighborhoods' physical characteristics, were excluded, since their inclusion would violate the conditional independence assumption. The model also included interaction and quadratic terms to achieve the balance of independent variables' values between treatment and control groups after matching. Table 4 shows the logit model result. Since the logit model is a prediction model to extract the propensity score, variable significance and potential multicollinearity are not a concern.

Table 4
Binary Logit Model for the Choice of Urban Neighborhoods.

	Coeff.	**(S.E.)**
Household Characteristics		
High-Income	0.92*	(0.21)
Mid-Income	0.48*	(0.20)
Persons	-0.21	(0.61)
Persons x Car	0.10	(0.61)
Car	-4.30	(0.96)
Bike	-1.25	(0.64)
Bike x Convenient to Retail and Services	0.32*	(0.16)
Residential Years	0.03*	(0.01)
Personal Characteristics		
Employ	-0.92*	(0.16)
Healthy	1.19*	(0.26)
Male	0.02	(0.13)
Age	-0.05*	(0.02)
Residential Preferences		

Large Home	-0.12*	(0.05)
Convenient to Work	0.08	(0.24)
Convenient to Work^2	0.13*	(0.04)
Convenient to Retail and Services	0.86	(0.51)
Convenient to Retail and Services^2	-0.01	(0.07)
Constance	0.77	(1.91)
N	2101	
Log-Likelihood at Zero	-1412.61	
Log-Likelihood at Convergence	-757.67	
Pseudo R-square	0.46	

Note: * p<0.05

We used a "caliper matching" algorithm to match an observation from the treatment group (urban boomers) to one from the control group (suburban boomers), searching for observations with propensity scores within 0.01 of each other. This caliper range is commonly used in similar empirical studies (Cao et al., 2010).[3] Urban baby boomers with propensity scores outside of the suburban baby boomers' propensity score range were excluded to satisfy the common support assumption.

Table 5 compares independent variables between urban and suburban neighborhoods before and after matching in order to test the robustness of matching results. Before the propensity matching adjustment, variables, except for bike ownership and employment status, were statistically significantly different between the treatment and control groups. After matching, none of the variables were significantly different between the two groups at the 0.05 alpha levels. Therefore, PSM successfully balanced the two groups on these variables.

Table 5

Comparison of Independent Variables between Treatment (Urban) and Control (Suburban) Groups Before and After Matching.

	Unmatched Mean [a]			**Matched Mean**		
	Treatment	**Control**	**Diff. [b]**	**Treatment**	**Control**	**Diff. [c]**
<u>Household Characteristics</u>						
High-Income	0.44	0.35	0.09*	0.44	0.46	0.02
Mid-Income	0.41	0.43	0.03	0.41	0.39	0.02
Persons	1.96	2.14	0.19*	2.06	2.12	0.06
Persons x Car	1.71	2.14	0.43*	2.04	2.11	0.07
Car	0.82	1.00	0.18*	0.98	0.98	0.00
Bike	0.56	0.58	0.02	0.57	0.53	0.04
Bike x Convenient to Retail and Services	2.49	1.89	0.60*	2.44	2.30	0.14

[3] In appendix, Table A. 1 shows the sensitivity analysis result. Most commonly used caliper lengths in empirical studies are 0.01 and 0.02 (Cao et al., 2010). Therefore, caliper lengths of 0.1, 0.15, and 0.2 are tested. In general, the results are relatively stable across the caliper lengths. Although the changes of Social Trip's ATEs are relatively large, the Social Trip's ratios of ATE to the observed influence remain greater than 1.

Residential Years	17.11	15.03	2.08*	16.36	15.3	1.06
Personal Characteristics						
Employ	0.69	0.67	0.02	0.69	0.68	0.01
Healthy	0.95	0.85	0.10*	0.93	0.93	0.00
Male	0.42	0.49	0.07*	0.42	0.40	0.02
Age	59.95	60.91	0.96*	60.15	60.32	0.16
Residential Preferences						
Large Home	2.43	2.66	0.22*	2.45	2.37	0.09
Convenient to Work	4.02	2.28	1.74*	3.56	3.54	0.02
Convenient to Work^2	17.75	6.88	10.87*	14.57	14.47	0.10
Convenient to Retail and Services	4.44	3.26	1.17*	4.25	4.29	0.05
Convenient to Retail and Services^2	20.22	11.97	8.25*	18.72	19.17	0.45

Notes: * p<0.05, indicating significance levels of bootstrapping p-values; (a): Values are different from the descriptive statistics (Table 3) because of missing values; some unmatched means differ from descriptive statistics due to missing items in the sample. (b): Treatment means - control means before matching; (c): Treatment means - control means after matching.

Through PSM, we can infer statistically significant "true" travel behavior effects for baby boomers living in urban neighborhoods. Table 6 shows the observed influence, the difference in behaviors observed before matching, as well as the estimated ATE and SSE, for the five travel behaviors analyzed. The estimated ATE of living in urban neighborhoods (the third column in Table 5) on automobile commuting is -1.33, indicating that, after controlling for self-selection, urban baby boomers tend to make 1.33 fewer trips per week, on average, than suburban baby boomers. Likewise, after controlling for self-selection, urban baby boomers tend to make 0.66 more public transit trips per week, on average, than suburban baby boomers. Residence in urban neighborhoods also induces higher levels of recreational NMT trips (1.34 more trips per week), social trips (0.77 more trips per week), and utilitarian trips (4.53 more trips per week) for urban versus suburban baby boomers. The latter effect may partly reflect increased trip-chaining and/or consolidated larger-scale (e.g., once per week grocery shopping) for suburban baby boomers.

Our results indicate relatively weak self-selection effects (SSE). The ratio of ATE to the observed influence (last column in Table 6) indicates the share of "true" behavioral effect of residing in urban areas. This ratio suggests that virtually all of the differences in automobile commuting, recreational NMT trip-making, and utilitarian trip-making are due to baby boomers residing in urban areas instead of suburban areas (i.e., the urban area effect on boomers travel behavior). Interestingly, the ratio for social trip-making is greater than 1, indicating overall mismatch between baby boomers' preference for social activities and their environments (Cao, 2010). This result implies that the suburbs suppress baby boomers' social trip-making relative to what we would expect them to make, and therefore, that the treatment (an urban boomer) would generate even more social trips than the observed difference. This result appears consistent with our previous analysis of the suburban boomers which found self-selection to social settings, based on social trip-making preferences (Zegras et al, 2012); in other words, limited to suburban locations, socially inclined individuals choose social neighborhoods, but urban living options would increase social trip-making even more than expected. Finally, we find relatively strong self-selection effects for public transit commuting; 57 percent of the observed influence can be attributable to living in urban neighborhoods, while the remainder is apparently due to innate preferences for transit. This finding implies a possible “transit-oriented” market segment among the Boston’s boomers, an important share of whom make location choices to satisfy their transit preferences.

Table 6
The Effects of Urban Residential Location on Travel Behavior.

	Observed Influence	ATE	SSE	ATE / Observed Influence
Automobile Commuting	-1.35*	-1.33*	-0.02	0.99
Public Transit Commuting	1.16*	0.66*	0.50	0.57
Recreational NMT Trip	1.44*	1.34*	0.10	0.93
Social Trip	0.70*	0.77*	-0.07	1.10
Utilitarian Trip	4.57*	4.53*	0.04	0.99

Notes: * $p<0.05$; ATE = Average Treatment Effect (Treatment mean – control mean); SSE = Self-Selection Effect.

4.2. Limitations

This analysis has several limitations. Our analysis is based on two different samples, carried out at different times, with somewhat different methods, which might be problematic. While the instruments were similar, they were not identical. In particular, we used different measures of residential preferences in the two instruments and thus were constrained to include only a few such measures in our PSM approach. If other unobserved preferences induced residential self-selection, our results may be biased. The survey responses themselves may be biased, in unknown ways; that is, we do not know the representativeness of the sample vis-à-vis the population. For example, we identified that our urban sample is biased toward higher income households, comparing our sample and Massachusetts Travel Survey (Lee et al., 2013).

Empirically focusing on the Boston metropolitan area, the external validity of this analysis is limited to North American cities similar to Boston. Parallel studies in other metropolitan areas in the United States and international contexts can enhance local understanding of older adults’ behavior, as well as improve the generalizability of this study. Also, our samples are pre-senior, leading-edge boomers who are active and healthy, relative to the senior group. Therefore, the generalization of the results into the senior group should be done with caution.

In addition, we crudely distinguish the “treatment” (urban) and “control” (suburban) (see Figure 1); suburban areas with urban qualities, such as suburban centers, may be inaccurately characterized and there is a large variation in the regional accessibility (relative location), particularly among the suburban boomers. Furthermore, our PSM only suggests the causal influence of living in urban neighborhoods, without identifying the specific environmental factors that contribute to behavioral changes. Hence, we cannot conclude which physical characteristics (e.g., density, mixed uses, street design, etc.) specifically influence boomers’ travel behavior. Finally, PSM will still not remove all selection bias (e.g., Cao, 2010), even though we have a number of preferences included from our instrument.

4.3. Implications

Despite the limitations, our results have some interesting potential implications, at minimum indicating promising areas for additional research. Analytically, in terms of the self-selection effects estimated, we uncover noticeably smaller effects than previous findings for the population at large. Cao's (2010) estimation of ATE on walking ranges from approximately 47 to 62 percent, while our estimated proportion of ATE on recreational NMT trips is 93 percent. However, the relatively large self-selection effect (43 percent of observed influence) suggests potential transit-oriented housing and transportation market segments for boomers, despite baby boomers' predominant automobile-oriented mode share.

More generally, our results must be viewed in light of the likely continued non-urban residential locations of aging older adults in the USA. Some boomers may move to urban settings as they age, which our findings suggest will reduce automobile use and increase transit, walking and social trip-making, with likely positive individual and societal benefits. But a broad urban migration of the US's older adults seems unlikely; most indicate a preference to "age in place" (Keenan, 2010; Lipman et al., 2012), reflecting an attachment to their current homes or neighborhoods, their desire to live in familiar environments, and a lack of affordable, convenient, and attractive alternative housing options. At the same time, making the suburbs more "urban," in an attempt to generate some of the travel behavior effects estimated here also seems unlikely in the short to medium term. This is because promoting desired behavioral outcomes requires quite large environmental changes: for example, radical improvement of density and diversity in suburbs may result in behavioral changes by baby boomers. Also, achieving urban-level density or diversity, as well as transportation service, in suburban areas is highly unlikely, given current zoning systems, real estate business structures, and baby boomers' preferences.

We find the relative convenience of proximity to desired destinations associated with urban living influences trip-making; such convenience is also apparently highly valued by older adults (65+) (Keenan, 2010). Resolving this disconnect seems to be a policy imperative, especially in the face of driving cessation prospects and its negative psychological effects (e.g., D'Ambrosio et al., 2007). Relatively "easy" suburban retrofits, such as improved walking facilities could help (e.g., Skufca, 2008). Our own previous suburban-focused research (Zegras et al., 2012) indicates that social networks can also increase walking activity, and even has a greater effect than physical settings in suburbia. This finding introduces the challenge of planning communities that foster social, not just physical, settings for aging adults. Therefore, provision of diverse social services and programs to create social environments can be an effective way to encourage baby boomers' active and healthy travel behavior, as well as social interactions discouraged by suburban living.

5. Conclusion

We find that baby boomers (aged 55 to 64) in the Boston urban area tend to be less automobile-dependent and use public transit more frequently than baby boomers living in Boston's suburbs. Urban baby boomers also make more recreational NMT, social, and utilitarian trips. Most of these differences seem to be primarily a result of the urban setting, not the particular preferences of boomers living in urban settings. Using propensity score matching, we find very small self-selection effects on automobile commuting, recreational NMT, and utilitarian trips: one to seven percent of observed influence. The negative self-selection on social trips indicates that baby boomers' preference for social activities tends to be mismatched to their environment. Suburban boomers want more social opportunities than their settings enable. For public transport, we find a relatively large self-selection effect, 43 percent of observed influence, suggesting a transit-oriented boomer market segment exists.

Shortcomings in our data collection approach, including unknown biases among the survey respondents, suggest our findings should be viewed as preliminary and only suggestive. Even accepting the general indications of the study, the results may ultimately raise more planning and policy questions. For example: even if urban living produces more sustainable travel behavior for baby boomers, what could attract suburban boomers to city living when many may prefer to age in place? What are the conditions by which suburban neighborhoods can be transformed to create more sustainable travel behavior? What could encourage suburban baby boomers' sustainable travel behavior without their relocation to urban locations or major transformation of suburban built environments?

Acknowledgments

This research was supported by grants from the New England University Transportation Center. We thank Sara Brown for research and editorial assistance and Erin Kenney for NHTS data analysis.

References

Bailey, L. 2004. Aging Americans: Stranded Without Option. Surface Transportation Policy Project.

Boer, R., Zheng, Y., Overton, A., Ridgeway, G. K., Cohen, D. A. 2007. Neighborhood Design and Walking Trips in Ten U.S. Metropolitan Areas. *American Journal of Preventive Medicine 32*(4), 298-304.

Caliendo, M., Kopeinig, S. 2008. Some Practical Guidance for the Implementation of Propensity Score Matching. *Journal of Economic Surveys 22*(1), 31-72.

Cao, X., Mokhtarian, P., Handy, S. 2009. Examining the Impacts of Residential Self-selection on Travel Behaviour: a Focus on Empirical Findings. *Transport Reviews* 29(3), 359–395.

Cao, X. 2010. Exploring Causal Effects of Neighborhood Type on Walking Behavior Using Stratification on the Propensity Score. *Environment and Planning A* 42(2) 487-504.

Cao, X., Mokhtarian, P., Handy, S. 2010. Neighborhood Design and the Accessibility of the Elderly: An Empirical Analysis in Northern California. *International Journal of Sustainable Transportation* 4(6), 347-371.

Cao, X., Xu, Z., Fan, Y. 2010. Exploring the Connections among Residential Location, Self-Selection, and Driving: Propensity Score Matching with Multiple Treatments. *Transportation Research Part A* 44(10), 797-805.

Cvitkovich, Y., Wister, A. 2001. The Importance of Transportation and Prioritization of Environmental Needs to Sustain Well-Being Among Older Adults. *Environment and Behavior* 33(6), 809-829.

D'Ambrosio, L., Coughlin, J., Mohyde, M., Gilbert, J., Reimer, B. 2007. Family Matter: Older Drivers and the Driving Decision. *Transportation Research Record* 2009, 23-39.

Ewing R., Cervero, R. 2010. Travel and the Built Environment. *Journal of American Planning Association* 76(3), 265-294.

Frey, W. H. 2003. *Boomers and Seniors in the Suburbs: Aging Patterns in Census 2000*. The Brookings Institution, Washington, D.C.

Giuliano, G. 2004. Land Use and Travel Patterns Among the Elderly Transportation. In *An Aging Society: A Decade of Experience*, Technical Papers and Reports from a Conference, Bethesda, Maryland, 192-210.

Heckman, J. J., Todd, P. E. 2009. A Note on Adapting Propensity Score Matching and Selection Models to Choice Based Samples. *Econometrics Journal* 12(s1), S230-S234.

Heinrich, C., Maffioli, A., Vázquez G. 2010. A Primer for Applying Propensity-Score Matching. Inter-American Development Bank, Washington, D.C.

Keenan, T. A. 2010. Home and Community Preferences of the 45+ Population. American Association of Retired Persons, Washington, D.C.

Lee, J. S., Zegras, P. C., Ben-Joseph, E. 2013. Safely Active Mobility for Urban Baby Boomers: the Role of Neighborhood Design. *Accident Analysis and Prevention* 61, 153-166.

Leuven, E., Sianesi, B. 2003. psmatch2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. <http://ideas.repec.org/c/boc/bocode/s432001.html>.

Lipman, B., Lubell, J., Salomon, E. 2012. Housing an Aging Population: Are We Prepared? Center for Housing Policy, Washington, D.C.

McGuckin, N., Lynott, J. 2012. Impact of Baby Boomers on U.S. Travel, 1969 to 2009. AARP Public Policy Institute.

Mokhtarian, P., Cao, X. 2008. Examining the Impacts of Residential Self-selection on Travel Behavior: a Focus on Methodologies. *Transportation Research B* 42(3), 204–228.

Ravallion, M. 2008. Evaluating Anti-Poverty Programs. In Schultz T., Strauss, J., (Eds), *Handbook of Development Economics*, Vol. 4. North-Holland, Amsterdam, pp. 3787–3846.

Rosenbaum, P., Rubin, D. 1983. The Central Role of the Propensity Score in Observational Studies for Causal Effects. *Biometrika* 70, 41-50.

Rosenbloom, S., Waldorf, B. 2001. Older Travelers: Does Place or Race Make a Difference? E-circular E-C026 Transportation Research Board, Washington, D.C.

Schmöcker, J. D., Quddus, M. A. Noland, R. B., Bell, M. G. H. 2005. Estimating Trip Generation of Elderly and Disabled People: Analysis of London Data. *Transportation Research Record: Journal of the Transportation Research Board* 1924, 9-18.

Skufca, L. 2008. Is the Cost of Gas Causing Americans to Use Alternative Transportation? American Association of Retired Persons, Washington, D.C.

State Smart Transportation Initiative (SSTI). 2011. VMT per capita declines in 2000s. <http://www.ssti.us/2011/03/vmt-per-capita-declines-in-2000s/>

U.S. Census Bureau. 2011. 2010 Census of Population and Housing.

U.S. Department of Transportation (DOT). 2005. 2001 National Household Travel Survey. Version 4.0. Federal Highway Administration.

U.S. Department of Transportation (DOT). 2010. Public Road Mileage - VMT - Lane Miles 1920–2010. Federal Highway Administration. <http://www.fhwa.dot.gov/policyinformation/statistics/2010/vmt421.cfm>

U.S. Department of Transportation (DOT). 2011. 2009 National Household Travel Survey. Version 2.1. Federal Highway Administration.

Vincent, G. K., Velkoff, V. A. 2010. *The Next Four Decades: The Older Population in the United States: 2010 to 2050.* U.S. Department of Commerce, U.S. Census Bureau.

Wachs, M. 1979. *Transportation for the Elderly: Changing Lifestyles, Changing Needs*. University of California Press, Berkeley, CA.

Zegras, P. C., Ben-Joseph, E., Hebbert, F., Coughlin, J. 2008. "Everyday life without a car would be impossible." A Comparative Study of Baby Boomers' Travel Behavior and Residential Preferences in Age-Restricted and Typical Suburban Neighborhoods. The Transportation Research Board 87th Annual Meeting, Washington, D.C.

Zegras, P. C., Lee, J. S., Ben-Joseph, E. 2012. By Community or Design? Age-Restricted Neighborhoods, Physical Design and Baby Boomers' Local Travel Behavior in Suburban Boston, USA. *Urban Studies* 49(10), 2169-2198.

Zegras, C., Chen, Y., Grütter, J. 2009. Behaviorally-Based Transportation Greenhouse Gas Mitigation under the Clean Development Mechanism: The Case of Transport-Efficient Development in Nanchang, China. *Transportation Research Record* 2114, 38-46.

Appendix

Table A. 1

The Sensitivity Analysis of the Effects of Urban Residential Location on Travel Behavior (Caliper Length: 0.01, 0.015, and 0.02).

	Caliper: 0.01		**Caliper: 0.015**		**Caliper: 0.02**	
	ATE	**ATE / Observed Influence**	**ATE**	**ATE / Observed Influence**	**ATE**	**ATE / Observed Influence**
Automobile Commuting	-1.33	0.99	-1.31	0.97	-1.29	0.96
Public Transit Commuting	0.66	0.57	0.69	0.59	0.66	0.57
Recreational NMT Trip	1.34	0.93	1.36	0.94	1.33	0.92
Social Trip	0.77	1.10	0.72	1.03	0.71	1.01
Utilitarian Trip	4.53	0.99	4.51	0.99	4.40	0.96

ATE = Average Treatment Effect (Treatment mean – control mean)