A Tale of Two Aging Nations: How Do Urban Designs Impact Elderly Mobility in Automobile Versus Transit Societies?

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Sustainability strategies have called for dense and accessible designs to facilitate convenient access to destinations for all, especially transportation-disadvantaged populations such as older adults (65+). Yet, the lack of studies leaves the relationship between sustainable planning and elderly mobility needs unclear even though the aging population grows substantially. Using the 2017 National Household Travel Survey and the 2018 Tokyo Person Trip Survey, we examine how sustainable urban designs in automobile (U.S.) and transit (Tokyo) societies affect elderly mobility. Our multivariate analyses find that older people living in dense and transit-accessible environments in transit societies conduct more active/transit/social-activity tours but fewer automobile and shorter travel. For those in the U.S., having a driver's license and household vehicles show overwhelming explanatory power, which may be related to the country's automobile culture. Our findings suggest that dense and accessible designs could improve elderly's mobility with more sustainable travel and out-of-home activities, but the influences of the macro-regional culture should be deliberately considered.

Key Words : *Older Adults, Travel-Activity Behaviors, Built Environments, Sustainable Urban Planning, International Comparisons*

1. INTRODUCTION

Convenient access to transportation for all, with a particular focus on vulnerable populations, facilitates safe, inclusive, and sustainable cities. Urban and transportation policies, yet, often overlook the needs of older people even though aging populations are projected to grow substantially worldwide [1–4]. The United States (U.S.), for example, is projected to have the largest older population (aged 65 and older) by 2030 among the developed countries when all baby boomers pass age 65 [3]. A similar trend has been found in Japan, where situations are more difficult than the other developed countries. Low mortality and birth rates lead the country to become the most aging society in the world. The older adults accounted for 28% of Japan's population in 2019, the highest rate across the world, and the rate will rise to 40% in 2060 [3–5].

These considerable demographic changes in aging populations in the two countries pose significant challenges to travel demands, infrastructure needs, and traffic safety [5–10]. Moreover, it is critical for the older adults, suffering from physical decline, to stay connected to the society [11,12]. Comprehensive urban transportation planning with dense and accessible neighborhood designs that help improve mobility are crucial to encouraging older adults' physical and social activities, thereby enhancing their quality of life and supporting them to age in place [1,2,11–15]. The understanding of the effectiveness of urban designs on the mobility of older people, however, remain limited: some find that built environments play a significant role in older adults' mobility, but others reveal that the urban forms have little impacts [1,2,9,16–21]. Could these mixed results relate to the macro-regional designs and automobile-oriented culture that offset/retain the effectiveness of the built environments at the neighborhood level [22]?

To address this concern, we extend previous literature by investigating how compact designs in automobile and transit societies are associated with elderly mobility. To the best of our knowledge, this is the first study to comprehensively compare the travel and activity behaviors of people aged 65 and more in the U.S. and Japan, the two top fast-aging countries with completely different spatial paradigms. More specifically, the former is known for its extensive automobile-oriented culture with low density and suburban sprawl while the latter has well-developed transit networks featuring compact, walkable, accessible, and mixed-use development. The analysis of older people's travel and activity behaviors helps understand whether regional and local spatial characteristics matter to elderly mobility, travel burden, and out-of-home activity engagement. We hypothesize that denser and more accessible built environments in transit societies are associated with more mobile and active older adults, but the influences of compact designs in automobile societies on elderly mobility is modest.

We conduct the analysis for the older adults in the U.S. and Japan based on the 2017 National Household Travel Survey and the 2018 Tokyo Person Trip Survey to examine how urban size, population density, employment density, and access to rail stations influence the tour complexity and tour counts and activity duration by mode and by purpose among the older adults. Our multivariate regressions account for residential self-selection and control for socio-demographic characteristics and health conditions. We find that older people living in denser and more accessible environments in transit societies in Tokyo, Japan tend to conduct more active and transit tours but fewer automobile tours and shorter travel. Moreover, these older adults are more likely to be engaged in social, shopping, and recreational activities. Compared to their counterparts in the U.S., built environments have little impacts, but the possession of driver license and household vehicles show greater explanatory power, which could be related to the country's automobile-oriented culture. Our results suggest that dense and accessible neighborhood designs can enhance older people's mobility with more out-of-home activities, but the influences of the macro-regional contexts and automobile-oriented culture should be deliberately considered.

The remainder of the paper consists four sections. Section 2 provides a literature review on the travel and activity patterns of older adults, the differences in mobility among older adults with different characteristics, and the influence of the built environment on older adults' travel and activity behaviors. Section 3 describes the study data and the methodology. Section 4 reports the results of our analysis. Section 5 discusses the results, policy implications, and future research.

2. LITERATURE REVIEW

(1) Travel and activity patterns of older adults

As the world's population aged 65 and older grows substantially as the baby boomers reach their retirement age, the mobility of older people has received increased attention in challenging transportation planning, economic, public health, and social policies [1,2,8,9,12,19,23–28]. Since mobility is associated with the need for physical movement and participation in social activities in daily life, it is often used as a key indicator to assess the quality of life of older people [15,29,30].

Existing evidence provides insightful information on how older people (i.e., those aged 65 and older) move and act. Compared to their younger counterparts, older adults make fewer and shorter trips due to the changes in their travel needs, physical capacity, and economic conditions, and their ability to move decreases as they age [1,4,6,9,15,16,20,31,32]. Older people's travel preferences and choices are also worthy of attention. In the U.S., for example, the elderly population heavily relies on personal vehicle travel, just much as the younger cohorts [6,9,31]. Older adults in Denmark, Norway, and Sweden have similar patterns [33]. Results for the developing world, however, show the opposite [16,17].

Available evidence on how older people travel by other transportation alternatives remains unclear. For example, based on the 2001 National Household Travel Survey (NHTS), Collia et al. (2003) found that older Americans walk more than their younger counterparts [6]. Similar results are found in Chinese and Korean studies [16,17,32].. Kubota et al. (2022) found no significant differences in walking between age groups in Shizuoka, Japan [34]. Using the 2009 NHTS, Yang [Yong] et al. (2018) find that older people walk and cycle less [20].

The physical changes of aging may limit older adults' usage of public transportation [20,35], and thus they could be favorably inclined toward public transit modes with fewer transfers and shorter walking distance [4]. Yet, social context and policy reforms in China and Korea seem to encourage older adults to take more public transit trips than the younger cohorts [16,17,32].

Since most older adults are retired, their increased time availability allows their activities to shift away from work to shopping, meal, socializing, and recreation [4,6,16,17,20]. Health care visits are another notable

activity purpose with increased participation among the elderly population [4,6,9]. This could be because most older people have at least one chronic condition that needs to be managed [23].

(2) Differences among old adults

Although older adults, on average, travel less and engage in more nonwork activities than the younger adults, previous studies have suggested that older adults should not be identified as a homogeneous group, as their travel and activity behaviors vary considerably by socio-demographic and health characteristics [19,35,36]. For example, the age differences between older adults could be a significantly associated with their travel mode preference. Some empirical results show that younger older adults (e.g., aged 65-74) are more likely to use public transit than the oldest older adults (e.g., aged 75 and older) [31,35], but Kim and Ulfarsson (2004) found that older adults aged 80 and more had a slightly higher bus/para-transit trip frequency than the younger older adults based on the 2000 Puget Sound Transportation Panel data in Washington State [13]. While some studies in the U.S. and Japan have found that younger older adults (e.g., aged 65-74) tend to walk more than the oldest older adults (e.g., aged 75 and older) [20,31,35], Kim and Ulfarsson (2004) and X. Hu et al. (2013) showed that the oldest older adults could have a higher proportion of walking trips than the younger older population [13,17].

Gender is another key factor in explaining the heterogeneity in the travel and activity patterns among the elderly population. Compared to male older adults, female older adults make fewer trips, travel shorter distances, and walk and cycle less [6,9,17,20]. Indeed, the gender difference in the frequency of travel by older people is opposite to the gender difference in the number of trips by the younger counterparts, and this contrast could be possibly due to different levels of household responsibilities in different life stages [6,9,37,38]. Driver license and car ownership also have significant impacts on the travel and activity patterns of older people, as licensed and car-owning older adults travel more frequently and farther than their unlicensed and non-car-owning counterparts, especially in car-dependent societies [9,20]. Moreover, older adults with a sound economic and health status are likely to be linked a more mobile and active lifestyle, compared to their counterparts who are poor and have medical conditions [9,20].

The combined influences of socio-demographic and health status may help more fully explain the heterogeneous travel and activity patterns of older adults. A recent study by Mitra et al. (2021) used cluster analysis to categorize older adults into six groups by income, location, living status, and medical condition to provide further insight [19]. Based on the 2017 NHTS, the authors found that female elderly in the middle-aged elder group with the lowest household income, and in the oldest group with the most elders with at least one medical condition and the fewest licensed drivers, suffer from mobility difficulties after they cessation of driving [19].

(3) Influences of built environments on older people's travel and activity behaviors: Macro-regional background vs. Micro-local planning

As older people prefer to stay in the same neighborhoods where they have lived for most of their adult lives, even after retirement, existing research has indicated the importance of "aging in place" - helping the older population live safely, independently, and comfortably in their own homes and communities, regardless of age, income, or ability [9,11,12,28,36,39,40]. This further implies that the success of aging in place could depend in part on community supports that provide convenient, accessible, and safe built environments for the older adults to remain healthy, mobile, active, and engaged in their daily lives [9,11,12,28,36,40].

A body of literature has examined the influence of various built environment factors, including urban size, density, destination accessibility, and distance to transit, on mobility patterns [41]. However, their implications often overlook the mobility needs of older people, despite the substantial growth in the aging population [1,2]. The relative lack of research further leaves a puzzling relationship between the built environment and older people's travel and activity behaviors.

While compact urban designs with greater accessibility to amenities (e.g., leisure, shopping) and transits could be associated with shorter travel distances and more engagement in out-of-home activities for older adults [14,16,31], Kim (2003) found that population and employment densities did not appear to be significant older people's mobility patterns, after residential selection was taken into account [18]. Results based on the clustered groups in Mitra et al. (2021) showed that the built environment may only play a more important role in the mobility of low-income female elderly with family than in the mobility of other older cohorts [19]. Giuliano (2004) used the 1995 National Person Trip Survey (NPTS) to find that older adults who lived outside of a metropolitan statistical area (MSA) tended to travel shorter distances than older MSA residents [1], which is inconsistent with the previous findings [42].

The influence of the built environment on travel modes has also been studied. Some studies have

found that higher density, walkability, and proximity to destinations may reduce private vehicle trips and encourage older adults to walk more and take more public transit trips [13,16,20,21,35,43–45], while others have found that urban designs with denser populations, more connected streets, and more diverse land uses could be negatively associated with active travel for older adults [20,21].

Some of the inconsistencies observed in the previous literature could also be attributed to the social, cultural, and regional contexts behind the data studied [16,22]. For example, the preference for automobile travel and low-density living environments in an automobile-oriented society could lead older adults to continue using private vehicles, implying a limited role for the compact and accessible designs [9]. Moreover, the majority of these studies focused on car-dependent countries while the studies based on transit-oriented societies are relatively little [4,36,46]. A comprehensive comparison between countries with different settings could provide more insights into the influence of the built environments in the mobility needs of older adults.

3. DATA AND METHODS

(1) Travel survey and sample selection

This study investigates the differences in the daily travel and activity behaviors of the older adults (age 65+) in the U.S. and Tokyo, Japan, where the former is known for car-dependent, low-density living and the latter is characterized by extensive transit networks with dense and accessible environments. We analyzed the 2017 National Household Travel Survey (NHTS) and the 2018 Tokyo Person Trip Survey (PTS), conducted by the Federal Highway Administration (FHWA) in the U.S. and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan, respectively [47,48] Both of the surveys provided the latest data sources for analyzing individual travel patterns in the two countries when we began this research project.

The main survey of the 2017 NHTS was carried out between March 2016 and May 2017 with travel dates starting on April 19, 2016 and ending on April 25, 2017. Focusing on a stratified random sample of U.S. households, the survey assigned travel days for all seven days of the week, including holidays, and collected all unlinked trips made by household members age 5+ within a 24-hour period on the assigned travel date. The survey respondents needed to report the detailed information of each unlinked trip in terms of trip purpose, travel mode, time of day of travel, day of the week, and vehicle occupancy. Data user can relate these trip-level data to the household vehicle characteristics (e.g., make, model, and year) and individual/household socio-demographics (e.g., gender, age, medical condition, household income, neighborhood characteristics…etc.). The final dataset of the 2017 NHTS contains information on the 129,696 usable households.

The 2018 Tokyo PTS was conducted between September 2018 and November 2019. The Tokyo PTS data were collected directly from a simple random sample of households living in Greater Tokyo Area, including Tokyo Metropolis and the prefectures of Kanagawa, Saitama, Chiba, and Southern Ibaraki. The survey assigned travel days for Tuesday, Wednesday, and Thursday, excluding holidays or the days before and after a holiday. Unlike NHTS, Tokyo PTS collected tour-based travel data. Each tour, anchored at an origin and a destination with a specific activity purpose, consolidated more than one trip segment, including transfers. Figure 1 provides an example of a tour consist of three trip segments.

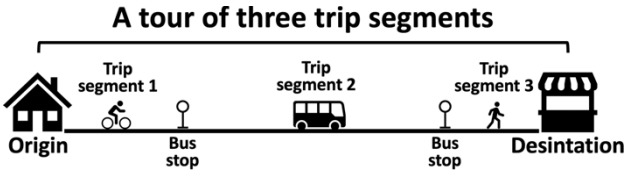


Fig. 1 Example of a tour composition.

In PTS, all tours made by household member age 5+ on the assigned travel date were recorded. The data obtained the details of each tour in terms of origin/destination type (e.g., home, school, park, supermarket, bank…etc.), tour purpose, travel time, time of day of travel, and the primary travel mode of each tour. The tour data can be related to each survey respondent's individual/household characteristics (e.g., gender, age, any difficult of going out, household income, number of household vehicles…etc.). The 2018 Tokyo PTS provides the travel information of 164,934 households in total.

Our analysis samples were extracted from the two surveys. We analyzed only the NHTS elderly whose assigned travel month was in September since the September temperatures across the country were similar to the temperatures from September to November in Tokyo. Focusing on the travel and activity behaviors of the older adults whose assigned travel days were Tuesday, Wednesday, and Thursday, we retained the survey respondents who were age 65 or older, started and ended their daily activities at home, and provided complete information regarding their travel logs (e.g., travel time, mode, activity time, purpose), gender, employment status, possession of driver's license, household income, household vehicle count, ages of other household members, and

physical condition. Based on these criteria, we obtained two types of samples for each survey, respectively. Type 1 older adults were those with or without any travel activities and Type 2 older adults conducted at least one travel activity on the assigned travel day. For 2017 NHTS, we obtained 2,959 Type 1 and 2,303 Type 2 older adults. For 2018 Tokyo PTS, 53,526 Type 1 and 28,478 Type 2 older people were retained.

One primary focus in this study is to examine the influence of built environmental factors. Yet, concerns have been raised regarding the endogeneity between built environments and unobserved residential preference in non-randomized observational studies [49,50]. Individuals could possibly self-select into a residential location given their preferred travel and activity patterns. For example, people who prefer active travel or using public transits are likely to reside in a more compact neighborhood facilitated by higher transit and destination accessibility. Neglecting the endogeneity problem could results in residential selection bias and the overestimated influences of built environments on older adults' travel and activity behaviors [49,50].

Our analysis employed propensity score matching (PSM) in order to control for the potential residential selection issue [51]. The PSM method attempts to resemble a quasi-randomized experiment that matches individual characteristics between the control and treatment groups. The first step of PSM uses a binary choice model to estimate the propensity score, namely the predicted probability, of an individual receiving the treatment based on a set of covariates. Each treated individual is then paired with an individual from the control group that has the closet propensity score to the treated individual [51]. Since the matched individuals from both groups have a more similar propensity score and more balanced characteristics, the comparison of the travel behaviors based on the PSM sample could yield unbiased treatment effects [49–51].

In this study, we defined the treatment using the rail transit accessibility of an individual's residential location. For the older adults of the 2017 NHTS data, the individuals living in a metropolitan statistical area (MSA) with heavy rail were assigned to the treatment group. For the older people of the 2018 Tokyo PTS data, we considered those who lived within 0.6-mile (i.e., 1km) of the nearest rail station to home were treated.

Using the MatchIt package in R [52], we first predicted the propensity score of receiving the treatment for each older adult based on a binary logit model, given a set of covariates, including gender, the possession of driver's license, employment, household income, household vehicle count, living status, and medical condition. The process next used the predicted propensity score to match a treatment older adult with a control older adult who lived in areas without any heavy rails or outside of 0.6-mile (i.e., 1km) of the nearest rail station to home. Treated and control older adults were matched when the difference between their propensity score was smaller than 0.01 [37,53]. The unmatched observations were removed from our analysis samples.

The matching methods yielded four PSM samples for the two surveys (Table 1). The characteristics of the treatment and control groups were balanced since the standardized mean differences between the matched pairs were less than 0.1 (results not shown), as suggested by previous research (Austin, 2011; Normand et al., 2001). For NHTS, the PSM samples contain 443 Types 1 (i.e., 369 treated and 74 control) and 345 Type 2 (i.e., 284 treated and 61 control) older adults. For Tokyo PTS, we obtained 34331 Types 1 (i.e., 31821 treated and 2510 control) and 19049 Type 2 (i.e., 17315 treated and 1734 control) older adults.

The PSM samples resembled the full sample across most of the socio-demographic characteristics but the possession of a valid driver's license and built environmental factors. This is because the PSM samples consist of more households living in the area with higher transit accessibility, which enables them to travel by non-automobile modes and is often associated with larger urban area sizes and population and employment densities (described in greater detail below). When comparing the summary statistics of our analysis samples, we also find that the older adults in the U.S. had a higher rate of possessing a driver's license and more household vehicles than their counterparts in Tokyo. Moreover, the U.S. older adults lived in a less populated and less denser environments compared to the Tokyo older adults.

(2) Travel and activity behavior indices

Since the 2017 NHTS and the 2018 Tokyo PTS used different survey formats to record the respondents' travel logs (i.e., unlinked trips vs. tour), we converted each NHTS older adult's unlinked trips to a tour-based format in order to make comparable travel and activity behavior outcomes. Using tour as the basic unit of analysis, rather than unlinked trips, could help us better understand the associations between complete travel activities, the role of the built environment, and the implied benefits of flexible travel modes for older adults [36].

In accordance with the Tokyo PTS definition, a tour was formed if the trip purpose of the last trip segment was not mode transfer (Figure 1). As one tour could consist of more than one trip segment and thus

presumably more than one travel mode, we characterized the principal travel mode of each tour using the order of priority defined by the Tokyo PTS: rail transit, bus, automobile, cycling, and walking. For instance, if an individual went from home to a rail station by automobile car and commuted from the station to her workplace by rail, the principal mode for this tour is rail transit.

Table 1 Summary statistics of the independent variables for the older adults

	Type 1 older adults				**Type 2 older adults**			
	NHTS		PTS		NHTS		PTS	
	Full	PSM	Full	PSM	Full	PSM	Full	PSM
Sample size	2959	443	53526	34331	2303	345	28478	19049
Treated	-	369	-	31821	-	284	-	17315
Control	-	74	-	2510	-	61	-	1734
Socio-demographics								
Age	73.53	73.83	74.11	74.34	73.21	73.20	72.70	72.92
Age 65-69 (1/0)	0.37	0.37	0.31	0.31	0.39	0.42	0.37	0.36
Age 70-74 (1/0)	0.26	0.23	0.27	0.26	0.27	0.22	0.29	0.29
Age 75-79 (1/0)	0.17	0.18	0.20	0.20	0.16	0.17	0.19	0.19
Age 80+ (1/0)	0.20	0.21	0.21	0.23	0.18	0.19	0.14	0.16
Male (1/0)	0.46	0.49	0.50	0.50	0.49	0.51	0.55	0.54
Valid driver's license (1/0)	0.89	0.83	0.56	0.52	0.93	0.91	0.65	0.60
Worker (1/0)	0.16	0.19	0.27	0.28	0.19	0.22	0.35	0.34
Household income level: low (1/0) *NHTS, less than USD 50,000* *PTS, less than JPY 2 million*	0.49	0.37	0.16	0.17	0.47	0.36	0.12	0.13
Household income level: middle (1/0) *NHTS, USD 50,000-125,000* *PTS, JPY 2-9.99 million*	0.41	0.41	0.78	0.76	0.42	0.42	0.81	0.79
Household income level: high (1/0) *NHTS, greater than USD 125,000* *PTS, greater than JPY 9.99 million*	0.10	0.21	0.07	0.08	0.11	0.22	0.07	0.08
Number of household vehicles	1.96	1.96	0.93	0.77	1.97	1.97	0.93	0.79
Living alone (1/0)	0.27	0.26	0.17	0.19	0.27	0.29	0.16	0.18
Living with only members age 65+ (1/0)	0.50	0.40	0.46	0.45	0.52	0.41	0.48	0.46
Living with at least one member < age 65 (1/0)	0.22	0.33	0.38	0.37	0.21	0.31	0.37	0.36
Health status								
Medical conditions or physical difficulties of going out? (1/0)	0.20	0.22	0.18	0.19	0.16	0.17	0.10	0.10
Built environments								
Urban area with 1 million+ people (1/0)	0.30	0.64	0.34	0.42	0.29	0.64	0.34	0.42
Population density (persons/mi^2)	3225.9	6137.9	27172.8	32779.7	3253.0	6064.9	28249.8	33217.7
Employment density (employees/mi^2)	1117.9	1938.4	9227.5	12421.8	1142.1	1947.8	9694.3	12664.2
MSA with heavy rail (NHTS only, 1/0)	0.13	0.83	NA	NA	0.13	0.82	NA	NA
Distance to the nearest rail station (PTS only, mi)	NA	NA	0.73	0.40	NA	NA	0.69	0.40

Note: As of year 2018, one U.S. dollar (USD) = 110.424 Japanese Yen (JPY) https://www.irs.gov/

In this study, we considered a set of travel and activity behavior indices to comprehensively analyze the older adults' travel behaviors, including the choice of making any tours, the number of tours by mode, the daily tour duration (minutes) by mode, the daily out-of-home activity duration (minutes) by destination purpose, and the choice of conducting any complex tour. More specifically, we analyzed three types of transportation modes by aggregating the principal modes, including active travel (i.e., walking and cycling), public transit (i.e., rail and bus), and automobile. This study also considered three nonwork activity purposes for analyzing older adults' out-of-home activity engagement, including shopping/meal/social, healthcare/medical visit, and other personal business (e.g., post office, recreational, religious…etc.). Lastly, a complex tour is defined as the tour with more than one trip segment. Our focus on these indices was to better understand the mobility and intensity of the older adults' travel and activity patterns.

(3) Built environmental factors

As existing research indicates, the combined effects of various built environment characteristics on travel behaviors could be remarkable [41]. We therefore focus our analysis on the influences of a set of built environments, including living in urban areas with more than 1 million people, population density (persons per square mile), employment density, and rail transit accessibility. In NHTS, the four variables are readily available at census tract or block group level of a respondent's home address. We particularly introduced the density measurements as continuous variables to our analysis using the midpoints of given categorical values in the NHTS. Moreover, we used whether one lives in an MSA with heavy rail to characterize the rail transit accessibility for NHTS older adults.

For PTS, we performed the geographic information system analysis to compute the built environmental variables of each older adult's home location based on the 2015 Population Census, the 2014 Economic Census, and the 2018 railroad data shapefiles in Japan [54–56]. More specifically, we considered an

older adult living in urban areas of more than 1 million people if she lived in one of the 23 special wards in Tokyo Metropolis or one of the designated cities of more than 1 million people [Note 1)].

We calculated the population density and the employment density in the CHŌ where an older adult's home was located. In Japan, a CHŌ represents the subdivision of a municipality and is the smallest geographic census unit [57)]. The average population per CHŌ in our study area was about 1600 people, which falls within the range of the block group defined by the U.S. Census Bureau and thus could correspond to a census block group in the U.S. [57,58)]. In this context, we chose CHŌ as the basic geographic unit for the built environment measurements for the PTS older adults in Greater Tokyo in order to more directly compare the effects of the density variables between the two countries.

The transit accessibility variable for the PTS older adults was measured by the distance to from home to the nearest rail transit station, rather than by the presence of any heavy rail in the MSA (i.e., the definition of the transit accessibility for the NHTS older adults), given the coverage of the dense and extensive urban rail network in Greater Tokyo. That is to say, nearly 85 percent of the wards, cities, and towns in the metropolitan area had at least one rail station (preliminary results not shown), according to MLIT's 2015 railroad station data. Using a binary indicator to describe the presence of heavy rail for the PTS samples might not be very informative. Therefore, we measured the transit accessibility using the distance to the nearest rail station instead.

(4) Analytical approach

In this research, we carried out two stages of analysis. First, we examined the decision to conduct any tours for Type 1 older adults using bivariate analyses, binary logistic regressions, and hurdle negative binomial (HNB) models to assess the influences of socio-demographics, health status, and built environments. The bivariate analyses adopted the one-way analysis of variance (ANOVA) and the two-sample t-test to compare the within-country and the between-country differences in the older adults' travel behavior, respectively. Binary logistic models were performed to estimate the factors associated with the probability that an older adult chose to take at least one tour on the assigned travel day. The model takes the following form:

$$P_i = \Pr\left(D_i = 1 \mid S_i\right) = \Lambda\left(S_i'\gamma\right)$$

, where P_i is the probability of older adult i to conduct at least one tour on the assigned travel day; D_i is i's decision of conduction at least one tour; $\Lambda(\cdot)$ is the cumulative density function of logistic distribution; S_i is a row vector of older adult i's socio-demographics, medical/physical condition, and built environmental variables; γ is a column vectors of coefficients.

We used HNB regressions to estimate the tour count of Type 1 older adults instead of regular negative binomial (NB) models since HNB can capture the zero and nonzero values resulting from distinct regimes [59–62)]. The concept of the hurdle model concept was introduced by Cragg (1971) and further developed by Mullahy (1986) [62,63)]. For count data, the zero and nonzero outcomes could arise from a different data generating process [60)]. For instance, an individual first decides whether or not to conduct a tour. If the individual chooses to conduct (i.e., hurdle crossed), she separately decides the intensity of her tour counts [60)]. The basic HNB model structure, f_{HNB}, consists of two components as shown below:

$$f_{HNB}\left(Z_i = z_i\right) = \begin{cases} q_i = \Pr\left(Z_i = 0 \mid s_i\right) = \Lambda\left(S_i'\gamma\right) & \text{if } z_i = 0 \\ \left(1 - q_i\right) f_{count}\left(z_i \mid X_i\right) \big/ f_{count}\left(z_i = 0 \mid X_i\right) & \text{if } z_i > 0 \end{cases} \quad (2)$$

, where Z_i is older adult i's observed tour count; q_i is the first model component that predicts older adult i's probability of not conducting any tours; the second component is the count data model fcount(·), which takes the negative binomial (NB) form; x_i is a row vector of i's socio-demographic, health status, and built environment characteristics. Recent research on the number of walking trip generation also applied the same method [64)].

To understand the factors associated with older adults' out-of-home travel and activity behaviors, our second stage of analysis examined Type 2 older people's tour count by mode, daily travel time by mode, daily out-of-home activity time by purpose, and decision to take any complex tour. For the number of tours by mode, we used the methods similar to Equation (2). For the travel time and out-of-home activity time, we used the following Tobit model as these dependent variables were left-censored:

$$Y_i = \begin{cases} Y_i^* = f_{tobit}\left(X_i\right) & \text{if } Y_i^* > 0 \\ 0 & \text{if } Y_i^* \le 0 \end{cases} \quad (3)$$

, where Y_i is the dependent variable of interest for older adult i; $f_{tobit}(\cdot)$ is the a linear function.

For the decision to make any complex tour, we applied the binary logistic choice model described in Equation (1).

4. RESULTS

(1) Factors influencing the choice to conduct any

tour for Type 1 older adults

a) Bivariate analysis

Our first-stage analysis examines whether Type 1 older adults chose to conduct a tour, how many tours they took, and what factors influenced their choices, including age, gender, valid driver's license, household vehicles, health status, and built environments. In Table 2, the overall results show that 78% of the Type 1 older adults in the NHTS sample and 53% of the Tokyo PTS Type 1 older adults made at least one tour. On average, these NHTS older adults made 3.55 tours per day while their Tokyo PTS counterparts made 1.48 tours per day. The differences in the tour decisions between the two samples were found to be statistically significant.

The bivariate results based on the two samples show that Type 1 older adults who were younger (e.g., age 65-69), or male, or with a valid driver's license, or without any health problems were more likely to conduct tours than their counterparts in other subgroups. Results of one-way ANOVA confirmed the significant differences across these socio-demographic groups. Built environmental factors consistently appeared to influence the Tokyo PTS Type 1 older adults' tour decisions but not NHTS Type 1 older adults. For the Tokyo PTS sample, the tendency of conducting at least one tour and the average tour number were the largest for the Type 1 older adults living in areas with highly populated, dense, compact, and transit-accessible designs. These tour indicators decreased as urban size, population density, employment density, and transit accessibility become smaller.

b) Multivariate analysis

To disentangle factors associated with the tour decisions among Type 1 older adults, we used binary logistic choice to examine the relative influences of socio-demographic, health status, and built environmental factors on the probability of conducting any tours in the PSM samples, respectively. The likelihood ratio (LR) test and the McFadden's pseudo R^2 suggest that the models fit the data well (Table 3).

For Type 1 older adults in both samples, being male, valid driver's license, living alone, and health status were statistically significant in the decision to conduct any tours. The odds for the male older adults in the NHTS and the PTS samples were 64% and 10% higher , respectively, than for their female counterparts. Possessing a valid driver's license increased the odds of making at least one tour by more than 400% for NHTS Type 1 older adults and by 36% higher for Tokyo PTS Type 1 older adults, compared to their counterparts without a valid driver's license. The odds for NHTS and Tokyo PTS Type 1 older adults living alone were 126% and 28% higher, respectively, than those living with at least one household member under age 65. The odds of taking any tours decreased by 50% and 61% for NHTS and Tokyo PTS Type 1 older adults with any health problem, respectively.

Among the Tokyo PTS Type 1 older adults, those who were aged 65-69, 70-74, and 75-79 were more likely to conduct any tours than their counterparts who were aged 80+, for whom the odds were increased by 62%, 45%, and 28%, respectively. In addition, these older adults who were employed, or had a higher household income, or lived with only members age 65+ were associated with higher odds of conducting at least tours. Each addition household vehicle, however, decreased the odds by 12%. The built environments were also found to be significant to the decision of conducting any tours for the PTS Type 1 older adults. Living in urban areas with 1 million+ people reduced the odds by 5%. The odds increased by 0.3% with a one thousand unit increase in population density, but decreased by 13% with a one-mile increase in the distance from home to the nearest rail transit station.

HNB regressions were then used to assess the relative importance of covariates on the number of daily tours taken by Type 1 older adults. We performed LR test and calculated Akaike's information criterion (AIC) to compare and choose between HNB and NB models [61,65,66]. Result of the AIC statistics are in favor of HNB models (Table 4, results for NB models are not shown). The LR test against the null model and McFadden's pseudo R^2 for the HNB estimations also suggest that the models had good fit to the data.

The first part of the HNB model estimated whether the zero tour hurdle was crossed (Table 4). An estimated coefficient with a positive sign indicates that a variable increased the odds of conducting at least one tour (i.e., hurdle crossed). Overall, the influences of the socio-demographic, health, and built environmental factors on the odds of conducting any tours are consistent with what has been described in Table 3. The second part of the HNB model estimated the number of tours taken. The results for the NHTS sample show that the expected number of tours per day for Type 1 older adults living with only members age 65+ was 1.23 times ($\exp^{0.21}$) higher than for those living with at least one household member younger than 65 year-older ceteris paribus. Interestingly, having a driver's license was not significant for tour number even though the variable overwhelmingly increased the odds of zero hurdle crossed.

For the Tokyo PTS Type 1 older adults, the expected number of tours for those aged 79 or younger was 1.05-1.06 times ($\exp^{0.05}$-$\exp^{0.06}$) higher than those aged 80 or older. Having a valid driver's license, a higher household income, living alone, and living with household members aged 65 or older were associated with higher number of tours for Type 1 older adults in Tokyo. In contrast, being employed and having any health issues were associated with less tours. Although living farther from a rail transit

station could significantly reduce the odds of crossing the zero hurdle, the variable was insignificant for tour number.

Table 2 Bivariate analysis of factors associated with the tour decision of Type 1 older adults.

	Sample size		**Proportion of conducting at least one tour**			**Number of tours**		
	NHTS	PTS	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.
Overall	2959	52526	0.78	0.53	-0.25$^{\xi}$	3.55	1.48	-2.07$^{\xi}$
Age								
65-69	1098	16807	**0.81**	**0.63**	-0.18$^{\xi}$	**3.81**	**1.76**	-2.05$^{\xi}$
70-74	774	14462	**0.79**	**0.57**	-0.22$^{\xi}$	**3.78**	**1.63**	-2.15$^{\xi}$
75-79	497	10793	**0.75**	**0.51**	-0.24$^{\xi}$	**3.37**	**1.44**	-1.94$^{\xi}$
80+	590	11464	**0.72**	**0.36**	-0.36$^{\xi}$	**2.91**	**0.93**	-1.98$^{\xi}$
Gender								
Men	1372	26874	**0.82**	**0.58**	-0.24$^{\xi}$	**3.78**	**1.64**	-2.15$^{\xi}$
Women	1587	26652	**0.74**	**0.48**	-0.26$^{\xi}$	**3.35**	**1.33**	-2.02$^{\xi}$
Valid driver license								
Yes	2635	30153	**0.81**	**0.61**	-0.20$^{\xi}$	**3.78**	**1.75**	-2.03$^{\xi}$
No	324	23373	**0.51**	**0.43**	-0.08$^{\xi}$	**1.69**	**1.14**	-0.55$^{\xi}$
Household vehicles								
Zero	115	18139	**0.68**	**0.48**	-0.19$^{\xi}$	**2.10**	**1.30**	-0.79$^{\xi}$
One	919	25508	**0.77**	**0.57**	-0.20$^{\xi}$	**3.60**	**1.63**	-1.97$^{\xi}$
Two or more	1925	9879	**0.79**	**0.51**	-0.28$^{\xi}$	**3.61**	**1.42**	-2.19$^{\xi}$
Health status (any medical conditions or physical difficulties of going out?)								
Yes	601	9715	**0.60**	**0.28**	-0.32$^{\xi}$	**2.43**	**0.69**	-1.74$^{\xi}$
No	2358	43811	**0.82**	**0.59**	-0.24$^{\xi}$	**3.84**	**1.66**	-2.18$^{\xi}$
Urban area with 1 million+ people								
Yes	873	17955	0.77	**0.55**	-0.23$^{\xi}$	3.43	**1.51**	-1.92$^{\xi}$
No	2086	35571	0.78	**0.53**	-0.25$^{\xi}$	3.60	**1.47**	-2.13$^{\xi}$
Population density (persons/mi^2)								
Level 1	504	89	0.76	**0.38**	-0.38$^{\xi}$	**3.26**	**1.06**	-2.20$^{\xi}$
Level 2	527	859	0.74	**0.36**	-0.38$^{\xi}$	**3.38**	**0.99**	-2.40$^{\xi}$
Level 3	251	1254	0.77	**0.39**	-0.38$^{\xi}$	**3.73**	**1.10**	-2.63$^{\xi}$
Level 4	396	1877	0.80	**0.44**	-0.37$^{\xi}$	**3.65**	**1.23**	-2.42$^{\xi}$
Level 5	544	2163	0.81	**0.46**	-0.35$^{\xi}$	**4.04**	**1.31**	-2.72$^{\xi}$
Level 6	601	4683	0.78	**0.50**	-0.29$^{\xi}$	**3.41**	**1.38**	-2.03$^{\xi}$
Level 7	103	16476	0.78	**0.55**	-0.23$^{\xi}$	**3.49**	**1.53**	-1.96$^{\xi}$
Level 8	33	26117	0.76	**0.56**	-0.20$^{\xi}$	**2.82**	**1.54**	-1.28$^{\xi}$
Employment density (employees/mi^2)								
Level 1	627	983	0.75	**0.42**	-0.33$^{\xi}$	3.38	**1.19**	-2.19$^{\xi}$
Level 2	211	3570	0.76	**0.46**	-0.30$^{\xi}$	3.39	**1.30**	-2.09$^{\xi}$
Level 3	312	3471	0.78	**0.49**	-0.29$^{\xi}$	3.52	**1.38**	-2.14$^{\xi}$
Level 4	325	6905	0.76	**0.52**	-0.24$^{\xi}$	3.47	**1.46**	-2.01$^{\xi}$
Level 5	383	12112	0.78	**0.54**	-0.24$^{\xi}$	3.66	**1.51**	-2.15$^{\xi}$
Level 6	519	15086	0.81	**0.54**	-0.27$^{\xi}$	3.92	**1.51**	-2.41$^{\xi}$
Level 7	430	7736	0.79	**0.55**	-0.24$^{\xi}$	3.46	**1.52**	-1.94$^{\xi}$
Level 8	152	3619	0.81	**0.58**	-0.23$^{\xi}$	3.43	**1.62**	-1.80$^{\xi}$
Living in MSA with heavy rail (NHTS) or within 0.6-mile (1km) of a rail station (PTS)								
Yes	378	14741	0.77	**0.54**	-0.23$^{\xi}$	3.28	**1.52**	-1.76$^{\xi}$
No	2581	38785	0.78	**0.51**	-0.27$^{\xi}$	3.59	**1.42**	-2.17$^{\xi}$

Note: We used two-sample t-test to examine the differences in the same subgroup between the two samples. Significance at 5% level is indicated by $^{\xi}$. Numbers in bold indicate that the results of one-way ANOVA across different subgroups within the same sample are statistically significant at the 5%.

Table 3 Binary logistic choice analysis of factors associated with tour decision (PSM sample of Type 1 older adults).

	NHTS		PTS	
	Coef. sig.	OR	Coef. sig.	OR
Intercept	-0.11	0.89	-0.79***	0.45
Socio-demographics				
Age 65-69 (1/0)	0.09	1.09	0.48***	1.62
Age 70-74 (1/0)	-0.47	0.62	0.37***	1.45
Age 75-79 (1/0)	-0.50	0.61	0.25***	1.28
Male (1/0)	0.48*	1.62	0.09***	1.10
Valid driver's license (1/0)	1.64***	5.15	0.31***	1.36
Worker (1/0)	0.66	1.94	0.46***	1.58
Household income level: middle (1/0)	0.32	1.38	0.57***	1.78
Household income level: high (1/0)	0.39	1.48	0.61***	1.85
Number of household vehicles	-0.11	0.90	-0.13***	0.88
Living alone (1/0)	0.81**	2.26	0.23***	1.26
Living with only members age 65+ (1/0)	0.21	1.24	0.07*	1.05
Health status				
Medical conditions (NHTS) or physical difficulties of going out (PTS)? (1/0)	-0.70**	0.50	-0.87***	0.42
Built environments				
Urban area with 1 million+ people (1/0)	-0.09	0.91	-0.05*	0.95
Population density (persons/mi^2)	1.1.e-05	1.00	3.31e-06**	1.00
Employment density (employees/mi^2)	9.2.e-05	1.00	1.33e-07	1.00
MSA with heavy rail (NHTS only, 1/0)	-0.43	0.65		
Distance to the nearest rail station (PTS only, mi)			-0.14***	0.87
Sample size	443		34331	
Log likelihood	-202.69		-21963.15	
P-value of LR test	3.37e-09		< 2.2e-16	
McFadden's pseudo R^2	0.1520		0.0730	

Note: OR=odds ratio. MSA=metropolitan statistical areas. LR=loglikelihood ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

Table 4 Hurdle negative binomial (HNB) analysis of factors associated with tour count (PSM sample of Type 1 older adults)

	NHTS			PTS		
	Count model	Zero hurdle logit model		Count model	Zero hurdle logit model	
	Coef. sig.	Coef. sig.	OR	Coef. sig.	Coef. sig.	OR
Intercept	1.28***	0.12	1.13	0.79***	-0.68***	0.51
Socio-demographics						
Age 65-69 (1/0)	0.14	0.13	1.13	0.05***	0.49***	1.63
Age 70-74 (1/0)	-0.02	-0.44	0.64	0.06***	0.38***	1.46
Age 75-79 (1/0)	0.04	-0.45	0.64	0.06***	0.25***	1.29
Male (1/0)	-0.08	0.49*	1.64	0.00	0.10***	1.10
Valid driver's license (1/0)	0.07	1.53***	4.62	0.08***	0.30***	1.36
Worker (1/0)	0.02	0.64	1.90	-0.12***	0.46***	1.59
Household income level: middle (1/0)	0.11	0.28	1.32	0.08***	0.58***	1.78
Household income level: high (1/0)	0.09	0.36	1.43	0.10***	0.62***	1.87
Number of household vehicles	-0.03	-0.14	0.87	0.02***	-0.15***	0.86
Living alone (1/0)	0.13	0.79**	2.21	0.11***	0.23***	1.25
Living with only members age 65+ (1/0)	0.21***	0.15	1.16	0.05***	0.05*	1.05
Health status						
Medical conditions (NHTS) or physical difficulties of going out (PTS)? (1/0)	0.02	-0.69**	0.50	-0.14***	-0.87***	0.42
Built environments						
Urban area with 1 million people (1/0)	-0.08			-0.01		
MSA with heavy rail (NHTS only, 1/0)	-0.04	-0.27	0.76			
Distance to the nearest rail station (PTS only, mi)				-0.02	-0.17***	0.84
Ln(theta)	3.23***			12.99*		
Sample size	443			34331		
Log likelihood	-922.11			-51314.26		
AIC	1904.23			106688.50		
P-value of LR test						
— against negative binomial model	< 2.2e-16			< 2.2e-16		
— against null model	< 2.2e-16			< 2.2e-16		
McFadden's pseudo R^2	0.0460			0.0354		

Note: OR=odds ratio. MSA=metropolitan statistical areas. Ln(theta) is the log value of the inverse dispersion parameter. AIC=Akaike's Information Criterion. LR=likelihood ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

Table 5 Bivariate analysis of factors associated with tour engagement for Type 2 older adults.

	Sample size		**Number of tours**			**Number of unlinked trip segments**		
	NHTS	PTS	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.
Overall	2303	28478	4.56	2.79	-1.77ξ	4.59	4.23	-0.36ξ
Age								
65-69	892	10585	**4.69**	**2.80**	-1.89ξ	**4.72**	**4.33**	-0.39ξ
70-74	614	8276	**4.76**	**2.85**	-1.92ξ	**4.79**	**4.25**	-0.54ξ
75-79	372	5526	**4.51**	**2.81**	-1.70ξ	**4.53**	**4.18**	-0.35ξ
80+	425	4091	**4.04**	**2.61**	-1.43ξ	**4.05**	**3.98**	-0.07
Gender								
Men	1130	15644	4.60	**2.82**	-1.78ξ	4.62	**4.32**	-0.31ξ
Women	1173	12834	4.53	**2.75**	-1.78ξ	4.55	**4.12**	-0.43ξ
Valid driver license								
Yes	2137	18445	**4.66**	**2.86**	-1.80ξ	**4.68**	**4.16**	-0.53ξ
No	166	10033	**3.30**	**2.65**	-0.65ξ	**3.32**	**4.36**	1.04ξ
Household vehicles								
Zero	78	8778	**3.09**	**2.69**	-0.40ξ	**3.14**	**4.87**	1.73ξ
One	710	14661	**4.66**	**2.84**	-1.82ξ	**4.69**	**4.15**	-0.54ξ
Two or more	1515	5039	**4.59**	**2.79**	-1.80ξ	**4.61**	**3.33**	-1.28ξ
Health status (any medical conditions or physical difficulties of going out?)								
Yes	359	2732	**4.07**	**2.46**	-1.60ξ	**4.08**	**3.50**	-0.58ξ
No	1944	25746	**4.65**	**2.82**	-1.83ξ	**4.68**	**4.31**	-0.37ξ
Urban area with 1 million+ people								
Yes	676	9802	4.43	**2.76**	-1.66ξ	4.46	**4.78**	0.32ξ
No	1627	18676	4.62	**2.80**	-1.82ξ	4.64	**3.94**	-0.70ξ
Population density (persons/mi^2)								
Level 1	383	34	**4.29**	2.76	-1.53ξ	**4.30**	**3.62**	-0.68
Level 2	390	305	**4.57**	2.78	-1.79ξ	**4.59**	**3.05**	-1.54ξ
Level 3	194	487	**4.82**	2.83	-2.00ξ	**4.88**	**3.16**	-1.71ξ
Level 4	318	822	**4.55**	2.80	-1.74ξ	**4.56**	**3.16**	-1.40ξ
Level 5	442	1000	**4.97**	2.84	-2.13ξ	**4.99**	**3.38**	-1.61ξ
Level 6	471	2320	**4.35**	2.78	-1.57ξ	**4.39**	**3.61**	-0.78ξ
Level 7	80	8987	**4.49**	2.80	-1.68ξ	**4.54**	**4.12**	-0.42
Level 8	25	14522	**3.72**	2.77	-0.95ξ	**3.80**	**4.58**	0.78
Employment density (employees/mi^2)								
Level 1	471	414	4.50	2.83	-1.67ξ	4.53	**3.36**	-1.16ξ
Level 2	161	1637	4.44	2.84	-1.60ξ	4.45	**3.43**	-1.03ξ
Level 3	244	1714	4.50	2.79	-1.71ξ	4.51	**3.80**	-0.71ξ
Level 4	247	3603	4.56	2.80	-1.77ξ	4.57	**3.98**	-0.60ξ
Level 5	299	6591	4.69	2.78	-1.91ξ	4.72	**4.22**	-0.50ξ
Level 6	420	8177	4.85	2.78	-2.06ξ	4.86	**4.35**	-0.51ξ
Level 7	338	4232	4.40	2.77	-1.63ξ	4.45	**4.50**	0.05
Level 8	123	2085	4.24	2.82	-1.42ξ	4.28	**4.83**	0.54ξ
Living in MSA with heavy rail (NHTS) or within 0.6-mile (1km) of a rail station (PTS)								
Yes	291	8183	**4.26**	2.80	-1.47ξ	**4.31**	**4.38**	0.07
No	2012	20295	**4.60**	2.77	-1.83ξ	**4.63**	**3.99**	-0.64ξ

Note: We used two-sample t-test to examine the differences in the same subgroup between the two samples. Significance at 5% level is indicated by ξ. Numbers in bold indicate that the results of one-way ANOVA across different subgroups within the same sample are statistically significant at the 5%.

(2) Factors influencing tour engagement by principal mode for Type 2 older adults

a) Bivariate analysis

The second-stage of analysis assessed how socio-demographics, health status, and built environmental factors were associated with the daily travel behavior for Type 2 older adults, focusing on active travel, public transit, and automobile modes. In Table 5, the bivariate results show that the NHTS Type 2 older adults on average made 4.56 tours per day, which was 1.77 tours more than their PTS counterparts (significantly different at 5% level). However, the difference in the number of unlinked trips between the two samples was only 0.36 (significantly different at 5% level). This indicates that the PTS Type 2 older adults were more likely than their NHTS counterparts to have complex trips, linking multiple trip segments and making mode changes within a trip.

For both samples, the Type 2 older adults who were older (e.g., age 80+), did not have a driver's license, and had health problems tended to make fewer tours and fewer trip segments on a daily basis. Having zero household vehicles was associated with fewer daily tours more within-tour mode transfers. The NHTS Type 2 older adults living in the areas with high population density and with heavy rail were segments than those living in areas with low density or without access to heavy rai found to conduct few tours and fewer unlinked trip. For the PTS Type 2 older adults, being female was associated with smaller numbers of tours and unlinked trip segments. Living in urban areas with 1 million+ people was associated with less tours but more unlinked trip segments. Those who lived in areas with higher population density, higher employment density, and within 1km of the nearest rail station had a greater number of unlinked trip segments than those living in less dense and less transit-accessible areas. Results of one-way ANOVA suggests significant differences across subgroups described above. More detailed bivariate results were obtained when we analyzed the travel behaviors for the Type 2 older adults in terms of tour number and daily travel time by mode. As shown in Table 6, the NHTS Type 2 older adults made 0.39, 0.04, and 4.12 tours by active travel, public transit, and automobile modes, respectively, indicating that the predominant travel mode was by automobile. Their PTS counterparts, by contrast, made 1.04, 0.62, and 1.13 active travel, public transit, and automobile tours, respectively.

Table 6 Bivariate analysis of factors associated with tour engagement by principal mode for Type 2 older adults.

	Number of nonmotorized tours			**Number of public transit tours**			**Number of automobile tours**		
	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.
Overall	0.39	1.04	0.65ξ	0.04	0.62	0.57ξ	4.12	1.13	-2.99ξ
Age									
65-69	0.43	**0.92**	0.49ξ	0.06	**0.67**	0.61ξ	**4.20**	**1.21**	-2.98ξ
70-74	0.35	**1.07**	0.72ξ	0.04	**0.60**	0.56ξ	**4.37**	**1.17**	-3.19ξ
75-79	0.40	**1.18**	0.78ξ	0.04	**0.58**	0.54ξ	**4.06**	**1.05**	-3.01ξ
80+	0.35	**1.11**	0.75ξ	0.02	**0.57**	0.54ξ	**3.63**	**0.93**	-2.70ξ
Gender									
Men	0.42	**0.91**	0.48ξ	0.05	**0.64**	0.59ξ	4.11	**1.27**	-2.84ξ
Women	0.36	**1.20**	0.84ξ	0.04	**0.59**	0.55ξ	4.12	**0.96**	-3.16ξ
Valid driver license									
Yes	**0.37**	**0.82**	0.46ξ	**0.02**	**0.55**	0.53ξ	**4.26**	**1.49**	-2.77ξ
No	**0.66**	**1.43**	0.77ξ	**0.28**	**0.74**	0.46ξ	**2.30**	**0.47**	-1.83ξ
Household vehicles									
Zero	1.14	**1.51**	0.37ξ	**0.49**	**0.96**	0.49ξ	**1.44**	**0.22**	-1.22ξ
One	0.47	**0.94**	0.47ξ	**0.04**	**0.55**	0.04ξ	**4.14**	**1.35**	-2.79ξ
Two or more	0.31	**0.50**	0.19ξ	**0.02**	**0.21**	0.02ξ	**4.24**	**2.07**	-2.17ξ
Health status (any medical conditions or physical difficulties of going out?)									
Yes	0.30	**0.90**	0.60ξ	0.06	**0.41**	0.35ξ	**3.69**	1.13	-2.55ξ
No	0.41	**1.05**	0.65ξ	0.04	**0.64**	0.60ξ	**4.19**	1.13	-3.07ξ
Urban area with 1 million+ people									
Yes	**0.48**	**1.24**	0.76ξ	**0.10**	**0.88**	0.78ξ	**3.83**	**0.64**	-3.19ξ
No	**0.35**	**0.93**	0.58ξ	**0.02**	**0.48**	0.46ξ	**4.24**	**1.39**	-2.85ξ
Population density (persons/mi^2)									
Level 1	**0.24**	**0.29**	0.06	**0.03**	**0.32**	0.30ξ	**4.01**	**2.15**	-1.86ξ
Level 2	**0.27**	**0.22**	-0.05	**0.02**	**0.10**	0.08ξ	**4.27**	**2.46**	-1.81ξ
Level 3	**0.52**	**0.23**	-0.29ξ	**0.03**	**0.11**	0.08ξ	**4.27**	**2.48**	-1.79ξ
Level 4	**0.45**	**0.35**	-0.10	**0.02**	**0.15**	0.13ξ	**4.04**	**2.30**	-1.74ξ
Level 5	**0.38**	**0.53**	0.14ξ	**0.01**	**0.21**	0.20ξ	**4.56**	**2.10**	-2.47ξ
Level 6	**0.39**	**0.70**	0.31	**0.04**	**0.34**	0.29ξ	**3.91**	**1.74**	-2.17ξ
Level 7	**0.74**	**0.94**	0.20	**0.23**	**0.55**	0.32ξ	**3.53**	**1.31**	-2.21ξ
Level 8	**1.80**	**1.28**	-0.52	**0.96**	**0.79**	-0.17	**0.92**	**0.71**	-0.21
Employment density (employees/mi^2)									
Level 1	**0.27**	**0.36**	0.09	**0.02**	**0.20**	0.18ξ	**4.19**	**2.27**	-1.92ξ
Level 2	**0.25**	**0.45**	0.19ξ	**0.02**	**0.24**	0.21ξ	**4.14**	**2.15**	-1.99ξ
Level 3	**0.35**	**0.66**	0.31ξ	**0.01**	**0.40**	0.39ξ	**4.14**	**1.72**	-2.41ξ
Level 4	**0.43**	**0.81**	0.38ξ	**0.01**	**0.49**	0.48ξ	**4.12**	**1.50**	-2.62ξ
Level 5	**0.37**	**0.96**	0.59ξ	**0.03**	**0.60**	0.57ξ	**4.25**	**1.21**	-3.04ξ
Level 6	**0.38**	**1.13**	0.76ξ	**0.02**	**0.67**	0.65ξ	**4.45**	**0.98**	-3.47ξ
Level 7	**0.48**	**1.39**	0.91ξ	**0.04**	**0.77**	0.72ξ	**3.88**	**0.62**	-3.26ξ
Level 8	**0.90**	**1.51**	0.61ξ	**0.38**	**0.92**	0.54ξ	**2.94**	**0.38**	-2.56ξ
Living in MSA with heavy rail (NHTS) or within 0.6-mile (1km) of a rail station (PTS)									
Yes	**0.60**	**1.20**	0.60ξ	**0.17**	**0.71**	0.53ξ	**3.46**	**0.89**	-2.58ξ
No	**0.36**	**0.79**	0.43ξ	**0.02**	**0.48**	0.45ξ	**4.21**	**1.51**	-2.70ξ

Note: We used two-sample t-test to examine the differences in the same subgroup between the two samples. Significance at 5% level is indicated by ξ. Numbers in bold indicate that the results of one-way ANOVA across different subgroups within the same sample are statistically significant at the 5%.

The youngest older cohorts (age 65-69) made the least number of active travel tours (PTS only) but higher numbers of tours by public transit (PTS only) and by automobile. Not having a driver's license and living in the areas with greater urban size, denser population, higher employment density, and more accessible rail transit were associated with more active travel and public transit tours but fewer automobile tours. A higher number of household vehicles could be associated with less active travel (PTS only) and public transit tours but greater number of tours by automobile.

For the PTS sample, being female was associated more active travel and public transit tours but fewer automobile tours. Having health problems was associated with fewer active travel and public transit tours for the PTS Type 2 older adults and less automobile tours for the NHTS counterparts. The one-way ANOVA tests found significant differences among the subgroups described above.

Table 7 summarizes the results of the bivariate analysis for daily travel time by mode. The NHTS Type 2 older adults spent much more time traveling by automobile than by active travel and public transit, whereas their PTS counterparts showed the opposite trend. Being male was associated with more time traveling by public transit (PTS only) and by automobile. The Type 2 older adults who did not have a driver's license, had fewer household vehicles, and lived in areas with higher population and employment densities tended to spend more time traveling by active travel and public transit tours but less time traveling by automobile. These older adults with any health problems spent less time traveling.

Table 7 Bivariate analysis of factors associated with daily travel time by principal mode for Type 2 older adults.

	Daily travel time (min) of nonmotorized tours			**Daily travel time (min) of public transit tours**			**Daily travel time (min) of automobile tours**		
	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.
Overall	7.76	18.59	10.83ξ	3.00	36.48ξ	33.48ξ	74.59	28.51	-46.08ξ
Age									
65-69	8.16	**16.12**	7.96ξ	3.99	**42.31**	38.32ξ	75.93	**32.32**	-43.61ξ
70-74	7.76	**19.22**	11.46ξ	2.16	**35.40**	33.24ξ	78.82	**29.81**	-49.01ξ
75-79	8.23	**21.62**	13.39ξ	4.52	**31.96**	27.45ξ	72.26	**25.00**	-47.26ξ
80+	6.49	**19.61**	13.11ξ	0.82	**29.71**	28.89ξ	67.69	**20.77**	-46.92ξ
Gender									
Men	8.71	17.83	9.12ξ	3.21	**41.03**	37.82ξ	**77.87**	**33.99**	-43.89ξ
Women	6.84	19.50	12.67ξ	2.80	**30.94**	28.14ξ	**71.42**	**21.83**	-49.59ξ
Valid driver license									
Yes	**7.02**	**15.07**	8.05ξ	**1.97**	**35.18**	33.21ξ	**76.57**	**38.02**	-38.56ξ
No	**17.22**	**25.05**	7.82ξ	**16.33**	**38.89**	22.56ξ	**49.04**	**11.03**	-38.01ξ
Household vehicles									
Zero	**32.82**	**26.59**	-6.23	**23.94**	**51.65**	27.71ξ	**28.77**	**5.41**	-23.36ξ
One	**8.67**	**17.20**	8.53ξ	**2.86**	**34.53**	31.67ξ	**70.71**	**34.39**	-36.32ξ
Two or more	**6.04**	**8.67**	2.63ξ	**1.99**	**15.75**	13.76ξ	**78.77**	**51.66**	-27.11ξ
Health status (any medical conditions or physical difficulties of going out?)									
Yes	7.77	**16.04**	8.26ξ	4.16	**22.13**	17.96ξ	**66.52**	**25.49**	-41.03ξ
No	7.75	**18.86**	11.10ξ	2.79	**38.01**	35.22ξ	**76.08**	**28.83**	-47.25ξ
Urban area with 1 million+ people									
Yes	9.56	**21.43**	11.87ξ	**6.85**	**46.22**	39.37ξ	72.12	**17.96**	-54.16ξ
No	7.01	**17.10**	10.09ξ	**1.40**	**31.38**	29.97ξ	75.61	**34.05**	-41.56ξ
Population density (persons/mi^2)									
Level 1	**4.62**	**12.21**	7.59	**1.03**	**34.32**	33.29ξ	**79.53**	**71.85**	-7.68
Level 2	**4.00**	**3.36**	-0.64	**2.60**	**9.55**	6.95ξ	**83.97**	**60.31**	-23.66ξ
Level 3	**7.90**	**4.87**	-3.02	**2.63**	**9.81**	7.18ξ	**75.58**	**58.19**	-17.39ξ
Level 4	**8.38**	**5.92**	-2.46	**0.74**	**10.63**	9.89ξ	**73.99**	**54.32**	-19.68ξ
Level 5	**7.00**	**8.37**	1.38	**0.64**	**16.39**	15.75ξ	**75.64**	**46.96**	-28.68ξ
Level 6	**11.06**	**13.78**	2.72	**5.10**	**22.36**	17.26ξ	**66.30**	**41.00**	-25.30ξ
Level 7	**16.90**	**17.06**	0.16	**9.54**	**35.25**	25.71ξ	**57.90**	**32.70**	-25.20ξ
Level 8	**27.36**	**22.52**	-4.84	**52.56**	**43.82**	-8.74	**43.32**	**19.43**	-23.89ξ
Employment density (employees/mi^2)									
Level 1	**4.82**	**8.75**	3.93ξ	**0.92**	**18.06**	17.13ξ	**82.12**	**54.03**	-28.09ξ
Level 2	**3.80**	**8.61**	4.82ξ	**2.64**	**17.55**	14.91ξ	**84.25**	**50.44**	-33.81ξ
Level 3	**5.30**	**12.21**	6.91ξ	**1.41**	**28.15**	26.74ξ	**77.55**	**40.15**	-37.40ξ
Level 4	**7.57**	**15.13**	7.55ξ	**0.99**	**31.80**	30.81ξ	**71.06**	**36.78**	-34.29ξ
Level 5	**7.09**	**17.81**	10.72ξ	**2.36**	**37.71**	35.35ξ	**79.14**	**30.48**	-48.66ξ
Level 6	**7.55**	**20.31**	12.76ξ	**1.07**	**39.54**	38.47ξ	**72.80**	**25.88**	-46.92ξ
Level 7	**12.78**	**24.02**	11.24ξ	**5.36**	**40.99**	35.63ξ	**65.20**	**16.17**	-49.03ξ
Level 8	**17.96**	**24.28**	6.32ξ	**20.34**	**44.92**	24.57ξ	**55.16**	**11.61**	-43.56ξ
Living in MSA with heavy rail (NHTS) or within 0.6-mile (1km) of a rail station (PTS)									
Yes	**10.97**	**20.90**	9.93ξ	**12.38**	**39.64**	27.26ξ	68.20	**23.12**	-45.07ξ
No	**7.29**	**14.96**	7.67ξ	**1.65**	**31.53**	29.89ξ	75.51	**36.96**	-38.56ξ

Note: We used two-sample t-test to examine the differences in the same subgroup between the two samples. Significance at 5% level is indicated by ξ. Numbers in bold indicate that the results of one-way ANOVA across different subgroups within the same sample are statistically significant at the 5%.

Living in urban areas with 1 million+ people was associated with longer active travel (PTS only) and public transit travel time, but shorter automobile travel time (PTS only). Compared to those living in areas with less transit accessibility, the older adults living in rail transit-accessible areas had longer active travel and public transit travel time, but less time traveling by automobile (PTS only). For the PTS sample, those who were aged 65-69 spent the least time traveling by active travel modes but the most time traveling by public transit and by automobile.

b) Multivariate analysis

Since our bivariate analysis found that the PTS Type 2 older adults were likely to made a complex tour by consolidating several trip segments within a tour, we first used binary logistic regressions to estimate the relative influences of the factors associated with their decision of any complex tours. Based on the LR tests and the McFadden's pseudo R^2, the model only fitted the PTS data well (Table 8).

Table 8 Binary logistic choice analysis of factors associated with complex tour (PSM sample of Type 2 older adults).

	NHTS		PTS	
	Coef. sig.	OR	Coef. sig.	OR
Intercept	-40.56	2.43E-18	-1.01***	0.37
Socio-demographics				
Age 65-69 (1/0)	0.32	1.37	0.13**	1.13
Age 70-74 (1/0)	-1.51	0.22	0.07	1.07
Age 75-79 (1/0)	0.52	1.69	0.05	1.05
Male (1/0)	0.61	1.84	0.15***	1.16
Valid driver's license (1/0)	16.84	2.1e+07	-0.16***	0.86
Worker (1/0)	-0.27	0.76	0.86***	2.36
Household income level: middle (1/0)	18.42	1.0e+08	0.36***	1.43
Household income level: high (1/0)	19.21	2.2e+08	0.69***	1.99
Number of household vehicles	-0.24	0.79	-0.72***	0.49
Living alone (1/0)	1.46	4.32	0.23***	1.26
Living with only members age 65+ (1/0)	1.51	4.53	-0.02	0.98
Health status				
Medical conditions (NHTS) or physical difficulties of going out (PTS)? (1/0)	-17.85	0.00	-0.48***	0.62
Built environments				
Urban area with 1 million people (1/0)	1.28	3.60	0.35***	1.41
Population density (persons/mi^2)	0.00	1.00	3.50e-06***	1.00
Employment density (employees/mi^2)	0.00	1.00	-1.42e-06**	1.00
MSA with heavy rail (NHTS only, 1/0)	-1.07	0.34		
Distance to the nearest rail station (PTS only, mi)			-0.18**	0.84
Sample size	345		19049	
Log likelihood	-26.63		-11197.65	
P-value of LR test	0.12		< 2.2e-16	
McFadden's pseudo R^2	0.2996		0.091	

Note: OR=odds ratio. MSA=metropolitan statistical areas. LR=loglikelihood ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

The PTS Type 2 older adults aged 65-69 were 13% likely to conduct any complex tours than those aged 80+. Being male, a worker, and living alone increase the odds of conducting any complex tours by 16%, 136%, and 26%, respectively. Having a higher household income increased the odds by 43-99%. In contrast, having a driver's license, one additional household vehicle, and any health problems reduced the odds of making any complex tours by 14%, 51%, and 38% respectively.

Built environment variables remained significant influences. Living in urban areas with 1 million+ people and a 1000-unit increase in population density was associated with 41% and 0.4% of increase in the odds of making any complex tours. A 1000-unit increase in employment density and a one-mile increase in the distance to the nearest rail transit station reduced the odds by 0.14% and 16%, respectively.

Our HNB and Tobit regressions further unraveled the intertwined relationships among the factors influencing the tour number and daily travel time by mode for the Type 2 older adults. Table 9 shows the results for the tour counts by active travel modes and public transit and by automobile for the two samples. The AIC values (lower than the values of NB models, not shown), the LR tests against a NB model and a null model, and the McFadden's pseudo R^2 suggest that the models fit the data well.

In the first part of HNB model that estimated the likelihood of crossing the zero tour hurdle for active travel modes and public transit, having a driver's license and a higher household income increased the odds of making any active travel and public transit tours (i.e., hurdle crossed) for the Type 2 older adults in both samples. The odds, however, were decreased for those who had a driver's license or one additional vehicle. The NHTS Type 2 older aged 75-79 were more likely to conduct any active travel and public transit tours than those aged 80+. However, their PTS counterparts in all younger cohorts were less likely to make these tours compared to those aged 80+.

For the PTS Type 2 older adults, living with only members age 65+ and having some health problems were associated with a lower likelihood of taking any active travel and public transit tours. A one-mile increase in the distance from home to the nearest rail station decrease the odds of making any active travel and public transit tours by 40%.

Results based on the second part of the HNB model show that each additional household vehicle reduced the number of active travel and public transit tours for both samples. The PTS Type 2 older adults who were in the younger cohorts, had a higher household income, lived alone, and lived in urban areas with 1 million+ people had around 1.1 times ($\exp^{0.05}$~ $\exp^{0.11}$) higher of expected active travel and public transit tour counts than those aged 80+ when the hurdle of having any active travel and public transit tours was crossed. On the other hand, being a worker and having any health problems were associated with lower numbers of active and public transit tours.

Table 9 Hurdle negative binomial (HNB) analysis of factors associated with tour count by mode (PSM sample of Type 2 older adults).

	Nonmotorized and public transit						**Automobile**					
	NHTS			PTS			NHTS			PTS		
	Count model	Zero hurdle logit model		Count model	Zero hurdle logit model		Count model	Zero hurdle logit model		Count model	Zero hurdle logit model	
	Coef. sig.	Coef. sig.	OR	Coef. sig.	Coef. sig.	OR	Coef. sig.	Coef. sig.	OR	Coef. sig.	Coef. sig.	OR
Intercept	0.28	0.76	2.14	0.83***	3.91***	50.14	0.99***	-0.63	0.53	0.50***	-3.53***	0.03
Socio-demographics												
Age 65-69 (1/0)	0.34	0.63	1.88	0.05**	-0.47***	0.63	0.00	-0.58	0.56	0.07**	0.29*	1.34
Age 70-74 (1/0)	0.36	0.56	1.74	0.06***	-0.26**	0.77	-0.19*	-0.35	0.70	0.05	0.18*	1.20
Age 75-79 (1/0)	0.00	0.78*	2.17	0.05**	-0.30***	0.74	-0.02	-0.76	0.47	0.03	0.23***	1.26
Male (1/0)	0.21	-0.05	0.95	0.00	0.00	1.00	-0.09	-0.07	0.93	0.01	-0.02***	0.98
Valid driver's license (1/0)	-0.16	-1.91***	0.15	0.01	-1.19***	0.31	0.42**	2.29***	9.91	0.23***	1.19***	3.28
Worker (1/0)	0.23	-0.28	0.76	-0.11***	0.05	1.05	0.07	0.25	1.28	-0.04*	-0.20***	0.82
Household income level: middle (1/0)	-0.20	0.09	1.10	0.04**	0.31***	1.36	0.22***	0.07	1.07	0.05*	-0.08	0.92
Household income level: high (1/0)	0.11	0.73*	2.08	0.11***	0.69***	2.00	0.18*	-1.38**	0.25	0.04	-0.48***	0.62
Number of household vehicles	-0.45***	-0.49***	0.61	-0.06***	-1.25***	0.29	-0.04	1.09***	2.98	0.05***	1.36***	3.91
Living alone (1/0)	0.32	0.32	1.38	0.08***	-0.04	0.96	0.01	0.24	1.28	0.01	0.27***	1.31
Living with only members age 65+ (1/0)	0.37	0.35	1.41	0.00	-0.19***	0.83	0.14*	0.14	1.14	0.05**	0.30***	1.35
Health issues												
Medical conditions (NHTS) or physical difficulties of going out (PTS)? (1/0)	-0.06	-0.36	0.70	-0.13***	-1.49***	0.22	0.09	-0.04	0.96	-0.01	1.31***	3.70
Built environments												
Urban area with 1 million+ people (1/0)	0.21			0.04***			-0.08			-0.09***		
MSA with heavy rail (NHTS only, 1/0)	0.49	0.10	1.10				-0.04	-0.45	0.64			
Distance to the nearest rail station (PTS only, mi)				-0.05*	-0.51***	0.60				0.02	0.48***	1.61
Ln(theta)	3.38***			13.01			4.32**			17.23		
Sample size	345			19049			345			19049		
Log likelihood	-323.65			-29698.55			-702.30			-20108.95		
AIC	707.30			59457.1			1464.609			40277.89		
P-value of LR test												
— against negative binomial model	9.49e-16			< 2.2e-16			2.34e-7			< 2.2e-16		
— against null model	1.40e-12			< 2.2e-16			< 2.2e-16			< 2.2e-16		
McFadden's pseudo R^2	0.1173			0.0723			0.0658			0.1175		

Note: OR=odds ratio. MSA=metropolitan statistical areas. Ln(theta) is the log value of the inverse dispersion parameter. AIC=Akaike's Information Criterion. LR=likelihood ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

The HNB estimations for the automobile tours show that the odds of making any automobile tours (i.e., zero hurdle crossed) could be overwhelmingly increased for both samples when the Type 2 older adults had a driver's license (NHTS: 891%, PTS: 228%) and an additional vehicle (NHTS: 198%, PTS: 291%). Having a high income, however, reduced the odds of crossing the hurdle for both samples.

Moreover, for the PTS Type 2 older adults, being in the younger cohorts, living alone or with only members age 65+ were more likely to take any automobile tours. Noticeably, having any health problems increased the odds of take any automobile tours by 270%. Yet, being a worker decreased the odds of crossing the zero automobile tour hurdle. A one-mile increase in the distance between home and the nearest rail station was associated with a 61% increase in the odds of having any automobile tours.

The second part of the HNB regressions for the automobile tour count showed that the NHTS Type 2 older adults aged 70-74 had a lower number of automobile tours than those aged 80+, but their PTS counterparts aged 65-69 had more automobile tours than those aged 80+ as the zero hurdle was crossed. Having a driver's license was associated with 1.5 ($\exp^{0.42}$) and 1.3 ($\exp^{0.15}$) times higher of the automobile tours for the NHTS and PTS Type 2 older people, respectively. For both samples, having a higher income increased the number of automobile tours. For the PTS sample, being employed and living in urban areas with 1 million+ population decreased the number pf automobile tour counts by 4% and 9%, respectively.

Results of our Tobit regressions for analyzing the daily travel time by mode for the Type 2 older adults are shown in Table 10. The LR test against the null and the McFadden's pseudo R^2 indicate that that the models fit to the data well. For both samples, being in a younger cohort was associated with more time spent traveling by active travel modes and public transit, but less time spent by automobile, respectively. By contrast, having a driver's license and an additional household vehicle reduced the active travel and public transit travel time, but increased the automobile travel time. Higher household income was associated with more active travel and public transit travel time, but less automobile travel time, particularly for the PTS Type 2 older adults. Being a worker with more time traveling by active travel modes and public transit for the PTS Type older adults and by automobile for the NHTS counterparts.

For the PTS Type 2 older people, living with only members aged 65+ was associated with about 3 fewer

minutes of active travel and public transit travel time, but 12 more minutes of automobile travel time. Having a health problem significantly reduced about 38 minutes of the time traveling by active travel and public transit modes but increased 56 minutes of the time traveling by automobile for the PTS Type 2 older adults.

Moreover, for the PTS Type 2 older people living in urban areas with a 1 million+ population was significantly associated with an increase of nearly 10 minutes in active travel and public transit travel time, but a decrease of 26 minutes in automobile travel time. A one-mile increase in the distance between home and the nearest rail station could reduce 8 minutes of the time traveling by active travel modes and public transit, but increase nearly 5 minutes of the time traveling by automobile.

Table 10 Tobit analysis of factors associated with daily travel time by mode (PSM sample of Type 2 older adults).

	Nonmotorized and public transit		**Automobile**	
	NHTS	PTS	NHTS	PTS
	Coef. sig.	Coef. sig.	Coef. sig.	Coef. sig.
Intercept	-5.87	50.91***	-36.43	-119.27***
Socio-demographics				
Age 65-69 (1/0)	88.41**	18.10***	-11.92	-11.61**
Age 70-74 (1/0)	61.00	12.26***	-24.75*	-7.25***
Age 75-79 (1/0)	85.88**	9.26***	-34.50**	-6.89**
Male (1/0)	-6.63	13.08***	10.22	3.64*
Valid driver's license (1/0)	-148.71***	-18.78***	83.88***	64.11***
Worker (1/0)	-15.31	17.20***	30.23***	-0.62
Household income level: middle (1/0)	17.38	12.45***	3.54	-1.50
Household income level: high (1/0)	58.76*	26.31***	-6.70	-13.91***
Number of household vehicles	-46.58***	-38.88***	7.89*	46.19***
Living alone (1/0)	-1.54	2.72	15.33	4.72
Living with only members age 65+ (1/0)	33.16	-2.89*	14.00	12.21***
Health issues				
Medical conditions (NHTS) or physical difficulties of going out (PTS)? (1/0)	-2.21	-37.48***	1.27	55.67***
Built environments				
Urban area with 1 million people (1/0)	48.15	9.60***	-6.26	-25.91***
MSA with heavy rail (NHTS only, 1/0)	-11.40		6.15	
Distance to the nearest rail station (PTS only, mi)		-8.38***		4.61*
Sample size	345	19409	345	19409
Log likelihood	-725.42	-84404.03	-1751.26	-45787.95
P-value of LR test	5.06e-06	< 2.2e-16	1.81e-08	< 2.2e-16
McFadden's pseudo R^2	0.0336	0.0170	0.0181	0.0435

Note: MSA=metropolitan statistical areas. Ln(theta) is the log value of the inverse dispersion parameter. AIC=Akaike's Information Criterion. LR=likelihood ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

(3) Factors influencing out-of-home activity engagement by purpose for Type 2 older adults

a) Bivariate analysis

In the second stage of this study, we further analyzed how socio-demographics, health status, and the built environments accounted for the out-of-home activity engagement by purpose for the Type 2 older adults. The overall bivariate results shown in Table 11 indicate that the NHTS older adults spent 68.54 minutes on shopping/meal/social activity while their PTS counterparts spent about half as much time (38.11 minutes) on the same activity. The NHTS and the PTS Type 2 older adults spent an average of 13.89 and 18.85 minutes, respectively, on healthcare/medical visit activities. For other personal activities, the NHTS and PTS Type 2 older people spent nearly 55 minutes per day.

The amount of time spent on healthcare/medical visits increased with age, especially for the PTS Type 2 older adults (significant differences among subgroups). However, there is no monotonic increase (or decrease) with age in the amount of time spent on the other two activities. Compared to the older male adults, the older female adults in both samples spent more time on shopping/meal/social and other personal business activities. For those with a driver's license, they spent less time on shopping/meal/social activity (PTS only) and healthcare/medical visit but more time on other personal activities.

The Type 2 older adults without any household vehicles spent the most time on shopping/meal/social activity (PTS only) and healthcare/medical visit but a similar pattern was not found for the other personal activities. For those with some health problems, they spend much more time on healthcare/medical visits but less time on shopping/meal/social (PTS only) and other personal activities.

For the built environment variables, the PTS Type 2 older adults who lived in urban areas with 1 million+ people spent more time on other personal activities. For the older adults from the same sample, those living within 0.8-mile (1km) of a rail station spent more time on shopping/meal/social activities, compared to those living outside of 0.8-mile of a rail station. a consistent, monotonic increase/decrease in out-of-home activity time along with population and employment density was not revealed, although the one-way ANOVA results indicate significant differences among some subgroups.

b) Multivariate analysis

Our Tobit analysis disentangled the relative importance of the factors associated with the out-of-home activity time by purpose for the Type 2 older

adults. Note that we also analyzed the factors influencing the combined amount of time on shopping/meal/social and other personal activities. As shown in Table 12, the results of the LR test and the McFadden pseudo R^2 suggest that the shopping/meal/social model only had a moderate fit to the NHTS sample but the remaining fit the data well.

Table 11 Bivariate analysis of factors associated with out-of-home activity time for Type 2 older adults.

	Out-of-home shopping/meal/social activity time (min)			**Out-of-home healthcare/medical visit activity time (min)**			**Out-of-home other personal activity time (min)**		
	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.	NHTS	PTS	Diff.sig.
Overall	68.54	38.11	-30.43ξ	13.89	18.85	4.97ξ	54.98	51.79	-3.19
Age									
65-69	65.29	**34.13**	-31.16ξ	11.86	**8.91**	-2.94ξ	56.53	**45.47**	-11.06ξ
70-74	69.30	**39.52**	-29.78ξ	14.04	**13.08**	-0.96	58.22	**58.05**	-0.18
75-79	75.22	**43.12**	-32.09ξ	14.05	**20.38**	6.33	49.93	**60.43**	10.50
80+	68.45	**38.82**	-29.63ξ	17.78	**54.19**	36.41ξ	51.47	**43.84**	-7.63
Gender									
Men	**63.48**	**32.06**	-31.42ξ	**11.73**	**14.88**	3.15	55.94	52.28	-3.66
Women	**73.43**	**45.50**	-27.93ξ	**15.96**	**23.70**	7.73ξ	54.06	51.21	-2.86
Valid driver license									
Yes	69.04	**35.41**	-33.62ξ	**13.00**	**10.99**	-2.01ξ	**57.11**	**55.84**	-1.27
No	62.21	**43.08**	-19.13ξ	**25.27**	**33.31**	8.05	**27.55**	**44.35**	16.81ξ
Household vehicles									
Zero	62.29	**42.15**	-20.15ξ	**30.10**	**25.29**	-4.82	35.64	**45.06**	9.42
One	72.17	**38.29**	-33.88ξ	**14.36**	**15.33**	0.97	53.83	**55.88**	2.05
Two or more	67.17	**30.59**	-36.58ξ	**12.83**	**17.91**	5.08ξ	56.51	**51.64**	-4.87
Health status (any medical conditions or physical difficulties of going out?)									
Yes	67.37	**31.93**	-35.44ξ	**25.14**	**92.45**	67.31ξ	**37.05**	**25.68**	-11.37ξ
No	68.76	**38.77**	-29.99ξ	**11.81**	**11.04**	-0.76	**58.29**	**54.57**	-3.73
Urban area with 1 million+ people									
Yes	69.48	39.19	-30.29ξ	12.33	18.72	6.39ξ	57.59	**50.11**	-7.48
No	68.16	37.55	-30.61ξ	14.53	18.92	4.39ξ	53.90	**52.68**	-1.22
Population density (persons/mi^2)									
Level 1	64.41	**25.41**	-39.00ξ	**15.49**	**17.35**	1.86	**50.43**	76.03	25.60
Level 2	66.08	**18.00**	-48.09ξ	**17.61**	**25.24**	7.63	**56.15**	53.98	-2.17
Level 3	74.28	**29.06**	-45.22ξ	**16.93**	**25.29**	8.36	**58.83**	50.12	-8.71
Level 4	69.10	**32.84**	-36.26ξ	**10.14**	**24.86**	14.72ξ	**56.87**	47.09	-9.79
Level 5	68.60	**30.17**	-38.44ξ	**15.58**	**16.98**	1.40	**60.18**	53.25	-6.93
Level 6	68.38	**37.04**	-31.35ξ	**10.08**	**20.59**	10.51ξ	**50.07**	50.92	0.85
Level 7	90.98	**38.14**	-52.83ξ	**6.54**	**17.99**	11.45	**50.23**	54.86	4.64
Level 8	48.92	**39.87**	-9.05	**20.80**	**18.55**	-2.25	**68.20**	50.16	-18.04
Employment density (employers/mi^2)									
Level 1	67.82	**24.64**	-43.18ξ	15.51	21.36	5.85	49.48	**50.21**	0.74
Level 2	72.81	**34.44**	-38.37ξ	10.20	20.26	10.06	54.99	**52.14**	-2.84
Level 3	58.55	**37.18**	-21.38ξ	18.93	18.48	-0.45	54.04	**50.04**	-4.00
Level 4	65.53	**36.66**	-28.87ξ	17.03	18.71	1.68	70.74	**54.91**	-15.84ξ
Level 5	67.61	**37.42**	-30.19ξ	11.33	18.67	7.34	53.56	**54.83**	1.27
Level 6	71.92	**38.69**	-33.22ξ	12.71	18.92	6.22	55.73	**51.19**	-4.54
Level 7	67.34	**40.09**	-27.25ξ	12.49	19.82	7.33ξ	52.62	**48.39**	-4.23
Level 8	85.67	**42.54**	-43.14ξ	10.28	16.25	5.97	53.65	**47.96**	-5.69
Living in MSA with heavy rail (NHTS) or within 0.6-mile (1km) of a rail station (PTS)									
Yes	60.83	**39.42**	-21.41ξ	10.52	18.96	8.44ξ	62.16	52.01	-12.28ξ
No	69.66	**36.07**	-33.59ξ	14.37	18.69	4.31ξ	53.94	51.45	-1.38

Note: We used two-sample t-test to examine the differences in the same subgroup between the two samples. Significance at 5% level is indicated by ξ. Numbers in bold indicate that the results of one-way ANOVA across different subgroups within the same sample are statistically significant at the 5%.

Table 12 Tobit analysis of factors associated with out-of-home activity time (PSM sample of Type 2 older adults).

	Shopping/meal/social		**Healthcare/medical visit**		**Shopping/meal/social & other personal business**	
	NHTS	PTS	NHTS	PTS	NHTS	PTS
	Coef. sig.	Coef. sig.	Coef. sig.	Coef. sig.	Coef. sig.	Coef. sig.
Intercept	6.26	5.56	-29.47	-149.52***	65.23*	54.82***
Socio-demographics						
Age 65-69 (1/0)	-1.19	10.90***	-21.44	-94.00***	23.75	12.31***
Age 70-74 (1/0)	-19.85	12.09***	-49.53**	-75.10***	9.33	21.36***
Age 75-79 (1/0)	6.81	7.56**	-12.86	-50.00***	-2.63	20.29***
Male (1/0)	-2.04	-26.60***	-24.35	-6.85	0.08	-17.15***
Valid driver's license (1/0)	23.53	1.42	-52.31**	-20.90***	35.12	17.44***
Worker (1/0)	-42.52***	-82.23***	-4.03	-86.56***	-104.87***	-143.50***
Household income level: middle (1/0)	20.92	12.82***	22.86	-20.22**	40.33**	22.63***
Household income level: high (1/0)	24.05	23.51***	16.30	-36.28***	27.58	34.20***
Number of household vehicles	0.83	-4.71***	5.75	8.57**	-8.58	3.90**
Living alone (1/0)	27.07*	19.80***	25.32	1.07	42.42*	36.38***
Living with only members age 65+ (1/0)	22.80*	2.93	26.61	-6.16	31.41*	18.94***
Health issues						
Medical conditions (NHTS) or physical difficulties of going out (PTS)? (1/0)	3.75	-32.16***	15.90	201.51***	-25.37	-72.89***
Built environments						
Urban area with 1 million people (1/0)	10.39	1.13	-50.36***	0.93	7.09	5.44**
MSA with heavy rail (NHTS only, 1/0)	-11.71		9.34		-7.92	
Distance to the nearest rail station (PTS only, mi)		-7.15**		-6.83		-3.65
Sample size	345	19049	345	19049	345	19049
Log likelihood	-1561.88	-60857.29	-478.72	-23168.49	-1923.06	-87180.70
P-value of LR test	6.90e-02	< 2.2e-16	5.59e-03	< 2.2e-16	6.30e-05	< 2.2e-16
McFadden's pseudo R^2	0.0071	0.0146	0.0313	0.0445	0.0113	0.0211

Note: MSA=metropolitan statistical areas. AIC=Akaike's Information Criterion. LR=likelihood ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

For the shopping/meal/social activities, being a worker was associated with 43 minutes less for the NHTS Type 2 older people and 82 min less for their PTS counterparts. Living alone was associated with 27 and 20 minutes more of shopping/meal/social activities for the NHTS and the PTS Type 2 older adults, respectively. For the NHTS Type 2 elderly living with only members aged 65+, they spent 23 minutes more shopping/meal/social activities than those living with members under age 65.

For the PTS Type 2 older adults in the younger cohorts, they spent about 7-12 minutes more of shopping/meal/social activity time than those aged 80+. Being male and having some health problems were associated with 27-32 minutes less shopping/meal/social activity time. Each additional household vehicle reduced the shopping/meal/social activity time of the PTS Type 2 older adults by about 5 minutes. The built environments were found to be insignificant for the time spent on shopping/meal/social activities among the NHTS Type 2 older adults. However, for their PTS counterparts, a one-mile increase in the distance between home and the nearest station was associated with a 7-minute reduction in the time spent on shopping/meal/social activities.

For the healthcare/medical visit activities, the younger Type 2 older adults in both samples spent less time than those aged 80+. In particular, a monotonic, decreasing trend with age was found for the PTS sample. Having a driver's license was associated with 52 minutes less and 21 minutes less of the healthcare/medical visit activity time for the NHTS and the PTS Type 2 older adults, respectively. For the NHTS Type 2 older people, living in urban areas with 1 million+ people was associated with a 50-minute reduction in the time spent on the healthcare/medical visit activities.

For the PTS Type 2 older adults, being a worker and having a higher household income were associated with less time spent on the healthcare/medical visit activities, but each additional household vehicle was associated with about a 9-minute of increase in the time spent on the healthcare/medical visit activities. In addition, the PTS Type 2 older adults with some health problems spent nearly 202 minutes more on the healthcare/medical visit activities than those without any health problems.

For the estimations on the combined activity time of shopping/meal/social and other personal business for both samples, being a worker spent more than 100 minutes less of activity time, but having a higher household income, living alone, and living with only members aged 65+ were associated more activity time, ranging between 19-40 minutes. For the PTS Type 2 older adults who were under aged 80 and possessed a driver's license spent 12-20 minutes more of activity time. For the same sample, being a male and having some health problems were associated with 17 and 73 minutes less of the combined activity time, respectively. Living in urban areas with 1 million+ people reduced the combined activity time by 5 minutes.

Table 13 Sensitivity analysis for the PTS Type 1 older adults with different PSM treatments.

	Baseline: Within 0.6-mile (1km)	**Sensitiviity test: Within 0.3-mile (500m)**
Sample size	34331	17026
Treated	31821	14710
Control	2510	2316
	Coef. sig.	Coef. sig.
Binary logistic choice for conducting any tours		
Urban area with 1 million+ people (1/0)	-0.05* (OR: 0.95)	-0.04 (OR: 0.96)
Population density (people/mi^2)	3.31e-06*** (OR: 1.00)	1.97e-06** (OR: 1.00)
Employment density (employees/mi^2)	1.33e-07 (OR: 1.00)	1.91e-07 (OR: 1.00)
Distance to the nearest rail station (mile)	-0.14** (OR: 0.87)	-0.14** (OR: 0.87)
HNB for tour count: zero hurdle model		
Distance to the nearest rail station (mile)	-0.17*** (OR: 0.84)	-0.15*** (OR: 0.86)
HNB for tour count: count model		
Urban area with 1 million people (1/0)	-0.01	0.01
Distance to the nearest rail station (mile)	-0.02	-0.01

Note: OR=odds ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

(4) Sensitivity analysis for the PTS older adults with different treatments

a) Bivariate analysis

In the sections above, the built environment variables were found to play a significant role in the daily travel behavior and activity engagement, particularly for the PTS older adults. To check to the robustness of our findings, we conducted model estimations with different subsamples obtained through PSM of an alternative treatment (i.e., living within 0.3-mile/500m of the nearest rail station). Tables 13 and 14 summarize the baseline and alternative results of the built environments for the PTS Types 1 and 2 older adults, respectively.

The overall comparisons show that our main findings from the baseline estimation are robust. Built environments remain significant influences even when we narrowed the treatment criteria. Yet, two notable exceptions need to be detailed. First, for the PTS Type 1 older adults, the baseline results for the binary choice of conducting any tour show that living in urban areas with 1 million+ people was significant at 10%, but the variable became insignificant for the alternative PSM sample (Table 13). Second, for the PTS Type 2 older adults, the baseline HNB estima-

tion for active travel and public transit tour count indicates that distance to the nearest rail station was significant at 10% in the count model part, but the factor was not significant for the alternative PSM sample (Table 14).

Table 14 Sensitivity analysis for the PTS Type 2 older adults with different PSM treatments.

	Baseline: Within 0.6-mile (1km)	**Sensitivity test: Within 0.3-mile (500m)**
Sample size	19049	9802
Treated	17315	8152
Control	1734	1650
	Coef. sig.	Coef. sig.
Binary logistic choice for conducting any complex tours		
Urban area with 1 million+ people (1/0)	0.35*** (OR: 1.41)	0.31*** (OR: 1.36)
Population density (people/mi^2)	3.50e-06*** (OR: 1.00)	3.11e-06*** (OR: 1.00)
Employment density (employees/mi^2)	-1.42e-06** (OR: 1.00)	-9.33e-07 (OR: 1.00)
Distance to the nearest rail station (mile)	-0.18*** (OR: 0.84)	-0.23** (OR: 0.79)
HNB for tour count by nonmotorized modes and public transit: zero hurdle model		
Distance to the nearest rail station (mile)	-0.51*** (OR: 0.60)	-0.39*** (OR: 0.68)
HNB for tour count by nonmotorized modes and public transit: count model		
Urban area with 1 million+ people (1/0)	0.04***	0.05***
Distance to the nearest rail station (mile)	-0.05*	-0.05
HNB for tour count by automobile: zero hurdle model		
Distance to the nearest rail station (mile)	0.48*** (OR: 1.61)	0.38*** (OR: 1.47)
HNB for tour count by automobile: count model		
Urban area with 1 million+ people (1/0)	-0.09***	-0.10***
Distance to the nearest rail station (mile)	0.02	0.02
Tobit for daily travel time (min) by nonmotorized modes and public transit		
Urban area with 1 million+ people (1/0)	9.60***	9.65***
Distance to the nearest rail station (mile)	-8.38***	-8.27***
Tobit for daily travel time (min) by automobile		
Urban area with 1 million+ people (1/0)	-25.91***	-29.44***
Distance to the nearest rail station (mile)	4.61	1.93
Tobit for out-of-home activity time (min) for shopping/meal/social		
Urban area with 1 million+ people (1/0)	1.13	-1.03
Distance to the nearest rail station (mile)	-7.15***	-9.20***
Tobit for out-of-home activity time (min) for healthcare/medical visit		
Urban area with 1 million+ people (1/0)	0.93	-2.93
Distance to the nearest rail station (mile)	6.83	-4.26
Tobit for out-of-home activity time (min) for shopping/meal/social and other personal business		
Urban area with 1 million+ people (1/0)	5.44**	5.99*
Distance to the nearest rail station (mile)	-3.65	-6.22

Note: OR=odds ratio. Significance: *p<0.1, **p<0.05, ***p<0.01.

5. DISCUSSIONS

This comparative research empirically examines the 2017 NHTS and the 2018 Tokyo PTS in order to identify the factors that influence the travel behavior and out-of-home activity engagement of older adults in the U.S. and in Tokyo, Japan, where the former is known for car-dependent, low-density living and the latter is characterized by extensive transit networks with dense and accessible environments. To address the potential residential selection bias due to preferrable travel mode in our analysis, we implemented the PSM technique that allowed us to more directly examine the influence of built environments on the mobility patterns of older adults. Our results support compact design strategies by showing that the Tokyo older adults living in the areas with a larger urban size and more accessible transit were more likely to make at least any tour, conduct complex, active travel, and public transit tours, reduce automobile travel, and engage in shopping/meal/social and other personal activities.

For the Tokyo older adults who made at least one tour (i.e., PTS Type 2), our HNB and Tobit regressions indicate that living in urban areas with 1 million+ people was associated with a 41% increase in the odds of making a complex tour consolidating more than one trip segment, a 4% increase in the expected tour count for active travel and public transit modes, a 9% decrease in the expected automobile tour number, a 10-minunte increase in travel time by active travel and public transit, a 26-minute reduction in automobile travel time, a 5-minute increase in the activity time for shopping/meal/social and other personal business. For the same older adults, these multivariate regressions find that a one-mile increase in the distance between home and the nearest rail transit station was associated with a 16% decrease in the odds of making a complex tour, a 40% reduction in the odds of making any active travel and public transit tour, a 61% increase in the odds of crossing the zero automobile tour hurdle, an 8-minute in active

travel and public transit travel time, a 5-minute increase in automobile travel time, and a 7-minute decrease in shopping/meal/social activity time.

Nevertheless, our multivariate results show that built environment factors were not significant for the travel behavior and activity engagement of the NHTS older adults, with the exception of activity time spent on healthcare/medical visits. The Tobit analysis indicates that living in urban areas with 1 million+ people was associated with a 50-minute reduction in healthcare/medical visit activity time. One possible explanation is that the access to healthcare and medical services may be more convenient in large cities than in suburban or rural areas [68–70]. Older urban residents could therefore could possibly spend less time on healthcare and medical services than their suburban counterparts [71].

Our results are in part consistent with our hypothesis and previous literature, which suggests that more compact, urbanized, and transit-accessible designs could provide convenient and valuable access to nearby amenities that support older adults' physical activity, reduce vehicle travel, and encourage them stay socially connected [2,16,17,20,21,31,43]. These built environment features could help older adults move and act more independently and comfortably, and thus achieving the goal of "aging in place" [11,12,30,36,39,40].

Yet, these findings are specific to the context of the older adults living in a transit-oriented society with high density development where public transit and active travel are the primary modes of transportation. The limited influence of urban design on the mobility of older people in an automobile-oriented, low-density living environment found in this study are in line with Cervero and Gorham (1995), who have indicated that the built environments at the neighborhood level will have little effect on travel habits given the high level of automobile dependence in a region [22]. This suggests that policy makers should cautiously evaluate the effectiveness of compact development in supporting older people to age in place in different macro-regional contexts.

For the older adults in both surveys, driver's license and car accessibility played a more dominating role in older adults' mobility compared to other socio-demographic variables. Consistent with previous research, having a driver's license and more household vehicles increased the chance of travel, particularly the tour traveling by automobile, and decreased the likelihood and travel time of active travel and public transit tour [9,13,20]. These factors had a greater explanatory power in explaining travel behavior for the NHTS older adults than for the Tokyo PTS older adults. This suggests, first, that the driving and car accessibility could be much more important for older adults living in an automobile-dependent region than those living in a transit-friendly area. Second, the results suggest that once the older adults who formerly drove cease driving, they could possibly be more disadvantaged than those who have never driver because they chose and adapted to a certain lifestyle to accommodate their ability to drive [9].

Although our study finds that compact neighborhood designs may do little to the mobility patterns of older adults living in car-dependent regions, this does not mean that policy makers have no other alternatives to achieve the goal of aging in place. Innovative technology, for instance, could be one possible option. Mitra et al. (2019) have shown that older adults who use smartphones to access the Internet make more on-demand ride-hailing trips than other older adults [25]. The introduction of an affordable hybrid self-driving vehicle (i.e., the drivers can turn off the self-driving feature and drive the vehicle themselves if they wish) could increase older adults' willingness to use it, and thus help them driving safely [26]. Moreover, information and communication technologies (ICTs) could also be another option to help older adults more efficiently arrange their health, social, and shopping activities [72]. These flexible alternatives could compensate for the increasing physical limitations and decreasing driving skills of older adults as they age, in particular for those living in automobile-oriented, low-density environments [1,19,26,31,73].

This research is not without limitations. First, the sample sizes of the NTHS Types 1 and 2 older adults are relatively small compared to the PTS samples. This is because we attempted to make the sample selection criteria (e.g., the assigned month and day of travel) comparable between the samples. Second, the data limitation of NHTS only allowed us to examine the influences of urban size, population density, employment density, and rail accessibility, while existing literature suggests that destination accessibility seems to a have more significant influence on travel behavior than other built environment characteristics [41]. Finally, future research is encouraged to use different approaches to the residential selection bias, such as structural equation modeling (SEM), in order to more fully understand the influences of the built environments on older people's mobility.

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NOTES

Note 1) As of year 2015, the total population in the 23 special

wards in Tokyo Metropolis was 9,272,740 people. The designated cities with more than 1 million people in the Greater Tokyo were Yokohama City (Kanagawa Prefecture), Kawasaki City (Kanagawa Prefecture), and Saitama City (Saitama Prefecture).

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