# Modeling the mobility choices of older people in a transit-oriented city: Policy insights

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**Abstract:** Hong Kong is a transit-oriented city with an extremely high public transportation share (approximately 90%). Additionally, in this city, the percentage of older people aged 60 or above is predicted to reach 38.0% in 2064. Thus, the provision of age-friendly public transportation is timely and enormously significant. Only with a better understanding of mobility behaviors of older people, it is possible to tailor transportation systems and optimize market strategies to cater to their actual needs and preferences. Based on the 2011 Travel Characteristic Survey data, this paper calibrates a mixed binary logit model and a conditional logit model to uncover older people's travel propensity, as well as destination and departure time choices. The findings are: (1) a host of socio-demographic variables and land-use attributes affect travel propensity; (2) owning an automobile and driving license are too weak to exert significant influence. This finding is in contrast with the conventional wisdom in car-dominant cities where car ownership and license-holding status are significant predictors of mobility; (3) there are random taste variations among respondents regarding travel propensity; and (4) time-constant destination and time-variant origin-destination pair characteristics influence older people's destination and departure time decisions. Based on the results, a few policy suggestions (e.g., reducing the actual and perceived costs associated with interchanges, time-varying public transport service) are discussed. We believe that these policy sights can act as a valuable reference to transportation planning which addresses the mobility of older people, especially in the metropolitan cities which provide similar public transport services.

**Keywords:** mobility of older people, population ageing, public transport service, transit-oriented city, transfer, travel propensity

## 1. Introduction

Population ageing is a common, notable and inevitable demographic trend virtually everywhere, particularly due to long life expectancy and low fertility rate. Hong Kong is no exception, evidenced by the second highest percentage of people aged 60 or above (21.7%) in Asia in 2015, only behind Japan which tops the world in this ranking (33.1%) (United Nations, 2015). The percentage of older people is predicted to reach 38.0% in 2064 (Census and Statistics Department, 2015).

Transportation is an indispensable dimension of urban sustainability, owing to its integral role in, and lasting impacts on economic, environmental, social and physical conditions. In an era of population aging, providing better transport which caters to older people's needs and preferences becomes of utmost importance. For older people, the availability of adequate transportation is a necessary condition of living independently in the community (Whelan et al., 2006; Liu et al., 2016). Nonetheless, the impact of aging population on the transportation system is normally ignored by government officials and decision makers. Understandably, older people have never been incorporated into the mainstream of thinking, planning, and policy (Buffel and Phillipson, 2016).

Transportation mobility refers to the ability to travel from one location to another in an independent and safe way, which typically decreases as people age (Rantakokko et al., 2013). It is a significant element in overall life satisfaction, essential for independence, good health, quality of life, well-being, and social integration, for older people (Tacken, 1998; Metz, 2000; Banister and Bowling, 2004; Kim and Ulfarsson, 2004). Improving the mobility of older people is an indispensable part of facilitating the development of a society. Indeed, in the last few decades, the Hong Kong government has made efforts to improve the mobility of city residents. In 2002, the vision of "Transport for All" was put forward to guide stakeholders in planning and designing transport services which suit all people, including the disabled, older people and others in need, of which the intention is to make transport system more accessible to all by ensuring the provision of barrier-free access facilities such as fixed ramps and wheelchair aids (Wong et al., 2018). In the same year, the concessionary fare scheme was initiated, the target beneficiaries of which are older people and eligible persons with disabilities. This scheme enables its target beneficiaries to travel on four designated public transport modes (railway, franchised bus, green minibus, and ferry) anytime at a concessionary fare of HK$2 per trip. By and large, general transportation policies, though not necessarily targeted at older people, are beneficial to them. Unfortunately, to date, the needs and preferences of older people have not been considered adequately in planning, design, and implementation of transport policies.

Particularly with the goal of understanding and/or enhancing the mobility of older people, various studies have focused on their mobility patterns and behaviors in some advanced or emerging economies, the United States and Europe in particular (Broome et al., 2013; Collia et al., 2003; Schmöcker et al., 2008). In most of the countries concerned (e.g., the United States, Canada, Australia), automobile is the dominant transport mode, and few older people use public transport. In stark contrast with car-dominant cities, transit-oriented cities (e.g., Hong Kong, Curitiba, and Tokyo) have a dense and advanced network of public transportation and offer frequent, efficient, and reliable public transport services, which also has wide spatial and temporal coverages (Wong et al., 2018). Obviously, Hong Kong is an example of transit-oriented cities, evidenced by the fact that nearly 90% of people use public transport. Moreover, relative to young adults, older people use public transport services more often (Szeto et al., 2017). There is no doubt that two widespread notions in most Western countries, *life depends on driving* and *owning a private car is crucial in* *order to not be socially excluded* (Özkazanç and Sönmez, 2017), are not applicable to transit-oriented cities such as Hong Kong. So are the transport policy measures suggested to car-dominant cities. In addition, mobility behaviors of the older people in Hong Kong largely remain uncovered by literature. Two exceptions are Szeto et al. (2017), who have described older people's travel patterns and visualize their spatio-temporal travel dynamics, and Wong et al. (2018), who have interviewed hundreds of older residents regarding their travel decisions using designated modes of public transport to attend social activities in a few hypothetical games. Moreover, it is essential to establish statistical models to understand what critically shapes older people's mobility choices for targeted policy-making. Notwithstanding, very few studies have used modeling methodologies to analyze older people's travel behaviors and preferences in transit-oriented cities like Hong Kong. Furthermore, to the best of our knowledge, there do not appear to be any published papers focusing on travel, destination and departure choices of older people in Hong Kong.

Mobility behaviors can be investigated from a host of aspects, including travel choice (trip generation), destination choice (trip distribution), departure time choice, and mode choice (modal split). In particular, we focus on travel propensity (whether to travel) and destination and departure time choices (where and when to travel), both of which can effectively predict older people's future travel demands. Yet, our understanding of them still remains descriptive for the most part (e.g., Szeto et al., 2017), and tools to project their future travel demands are missing (Stern, 1993; Páez et al., 2007).

To address these issues, based on the 2011 Travel Characteristic Survey (TCS 2011) data as well as local GIS data crawled from Google Earth, this study develops two discrete choice models to uncover the underlying behavior mechanism of older people's mobility behaviors in Hong Kong. The motivation of this paper is not only knowledge building, but also tentatively providing insights for policy intervention. Accordingly, a few policy implications are discussed.

The key objective of improving the existing public transport services for older people is not to get the final 10% (non-transit user group) into public transport modes. Instead, our research objectives are how to provide more age-friendly public transport services and enhance the mobility of older people to make more trips. The main contribution of this paper includes: *1) filling the research gap, adding a case study of mobility of older people in a transit-oriented city; 2) determining the importance of variables that influence older people' mobility choices and uncovering the underlying behavior mechanisms; 3) discussing several public transportation policy measures for enhancing the mobility of older people.*

The remainder of the paper is structured as follows. The ensuing section (Section 2) reviews the literature on older people travel behavior. Section 3 briefly introduces the TCS 2011 data. Section 4 describes modeling methodologies. Section 5 presents the modeling results. Section 6 discussed policy insights while Section 7 provides conclusions and limitations.

## 2. Related literature

A substantial body of scholarly literature has uncovered older people' mobility patterns, most of which has been carried out in car-dominant countries. Collia et al. (2003) present that in the United States, personal vehicle is the dominant travel mode of older people, constituting 89.3% of daily and long-distance trips, and state that public transportation is very unpopular (1.2%). They indicate that other than return-home journeys, social and recreation account for the highest percentage of daily trips (19.4%), followed by shopping (18.3%) and family/personal business (17.5%). Newbold et al. (2005) state that in Canada, automobile is the most popular option for older people while public transport is ranked least. They also suggest that the greatest proportion of trips are taken for goods or services (23.7%), followed by entertainment (11.7%). Rosenbloom and Morris (1999) demonstrate that in Australia, automobile accounts for 73% of trips while public transportation constitutes only 5%. Based on a large travel survey data, Zhang et al. (2007) observe that in Beijing, China, older people travel mostly on foot (58.3%), followed by cycling (18.3%) and public transportation (14.1%), and report that the proportion of car trips is 1.58%. They also report that shopping trips account for the greatest share of trips (48.8%), followed by entertainment and fitness trips (28.1%).

As noted, travel patterns of older people are markedly different in differing contexts. A variety of studies have devoted to comparing travel patterns of older people in different settings using either parametric modeling or non-parametric methods. Buehler and Nobis (2010) employ logit models to analyze car use in the United States and German and demonstrate that older Americans use private car more than their counterparts in German while controlling for a host of socioeconomic, demographic characteristics and spatial development patterns. They present that a possible explanation is different transportation policies in both countries. Hu et al. (2013) directly compare the aggregate data of older people' travel patterns across different countries (China, the United States, England, and the Netherlands), and suggest that a possible explanation for low car share in China was low driving license ownership. Yet, the direct comparison has been often challenged since this method implies ignorance of other characteristics (e.g., income, place of residence) that might have affected the outcome variable.

A few studies have compared the difference of travel characteristics between older people and young adults. Zhang et al. (2007) report that trip rates are significantly lower in the older group: the daily trip rate of young adults and older people is 2.34 and 2.03, respectively. Somenahalli and Shipton (2013) note that older people are less likely to make trips and take a long-duration travel due to loss of mobility.

Travel patterns of older people have been found to change over time. Rosenbloom (2001) reveals that in some countries like the United States, Australia, and Britain, older people nowadays are more likely to own driving licenses, take more trips, drive more but use less public transportation, relative to their counterparts a decade ago. The author further proposes a multitude of policy suggestions such as age-friendly public transportation, improved vehicles and roads. Rosenbloom (2004) focuses on the mobility needs of older Americans and indicates that older people are more mobile than ever before and there is a trend towards increased trip rates and distances. Newbold et al. (2005) report a decline in work-related trips and an increase in discretionary trips in Canada from 1986 to 1998 and suggest that it reflects older people's movement out of the labor force and into retirement.

A number of empirical studies have devoted to identifying the determinants of mobility of older people using modeling methodologies (i.e., multivariate analysis methods) which have been deemed to be better than a descriptive analysis in isolating the effect of a single factor. They have suggested that key factors include individual, household, and neighborhood characteristics. The majority of the literature concentrates on Western developed countries (Pettersson and Schmöcker, 2010), with few exceptions in China and the Philippines. Evans (2001) identifies the determinants of mobility of older Americans using the 1995 Nationwide Personal Transportation Survey data, bears out the significant connection between apartment living, neighborhood housing density, and mobility, and presents that public transportation availability has no bearing on mobility. Based on a region in Washington State, Kim (2003) uses structural equation modeling to uncover the relationship between personal, household characteristics, and urban form and mobility. The author presents that significant factors include age, gender, education level, transportation disability, license-holding status. Schmöcker et al. (2005) note that ethnicity, working status, difficulty walking, and difficulty understanding directions affect mobility level of older people in London. Páez et al. (2007) use mixed ordered probit models to analyze mobility of older residents in Hamilton, Canada. They find that key factors include not only personal and household variables such as age, driving license, car availability, having a spouse, but also zonal attributes. Many of their findings are confirmed by Mercado and Páez (2009), and Moniruzzaman et al. (2013). Su et al. (2009) use multinomial logit and nested logit models to study the mobility behaviors of older people in London and report that transit stop density and service quality do indeed play an important role. Roorda et al. (2010) adopts ordered probit models with spatially expanded coefficients to analyze mobility level of older people in Canada, confirms the significant influences of socio-economic and demographic attributes and urban form (though the effect of population density is found to be mixed), and reveals systematic variations in mobility over space, which has been paid little attention before. Pettersson and Schmöcker (2010) investigate trip-making behaviors in Manila, the Philippines, by employing ordered probit models, and intimate that socio-demographic characteristics (e.g., age, gender, driving license, household size) and land-use patterns are significant contributory factors. They also indicate that older people living in high-density neighborhoods have a relatively high level of mobility. Smith and Sylvestre (2011) investigate the mobility determinants of older people living in suburban areas of Canada and present that health-related characteristics and living arrangements are contributory factors. Morency et al. (2011) observe that interactions between location, various demographic factors, and mobility tools are significant predictors of mobility of vulnerable population segments in Canada. Comparatively, the contexts more comparable to Hong Kong have rarely received attention. Moniruzzaman and Páez (2016) present that the elements of streetscapes (e.g., slope) affect walk propensity of older people in Montreal, Canada. There are some empirical studies conducted in cities more comparable to Hong Kong. Feng et al. (2013) claim that living with the adult children lowers travel propensity of older people in China. Feng (2017) states that the determinants of mobility of older people in Nanjing are not only socio-demographics and built environments but also socio-cultural settings, and asserts that social and cultural settings make the mobility determinants in China vastly different from those in Western countries.

All in all, most studies have focused on mobility patterns of older people in car-dominant cities. Comparatively, transit-oriented cities seem to be out of the picture, and very few related studies have been conducted in Seoul (Choi et al., 2014), Taipei (Shiau and Huang, 2014), Nanjing (Feng et al., 2013; Feng, 2017), and China's large cities (Zhao, 2014). Regarding older people travel studies in Hong Kong, local scholars have concentrated on the description of general travel patterns (Szeto et al., 2017), travel patterns to health care facilities (Loo and Lam, 2014), public transportation satisfaction (Wong et al., 2017), and travel choice under hypothetical scenarios (Wong et al., 2018). To the best of our knowledge, there has been no scholarly literature focusing on travel propensity, destination and departure time choices of older people in Hong Kong. Revealing travel behaviors of older people in Hong Kong, an example of ageing and transit-oriented city, therefore, is of both theoretical and empirical significances.

## 3. Hong Kong's TCS 2011 Data

TCS is a self-reported survey conducted by Hong Kong government's Transport Department nearly every ten years, with the aim of gathering up-to-date travel characteristics data to support future transportation planning and policy in the region (Transport Department, 2014).

The latest one is conducted in 2011.

The TCS 2011 data comprises three parts: household interview survey, stated preference survey and hotel/guesthouse tourists survey. The first one is the mainstay of TCS, and the data were obtained from a random sample of 101,385 persons on normal weekdays between September 2011 to January 2012, excluding the Christmas and New Year holiday period (Transport Department, 2014). The sampling ratio is approximately 1.5%. The data collection method was the interview. For ensuring the highest quality of data collected, quality control measures were strictly applied (Transport Department, 2014).

There are three levels of data collected from household interview survey: (1). household data (e.g., availability of private vehicles); (2). household member data (e.g., age, gender, job availability, economic activity status, industry engaged for employed people); and (3). 1-day trip record of every person (e.g., departure/arrival time, origin/destination, travel mode). Totally, 20,062 older people aged 60 or above were sampled, and 19,703 samples have complete making-trip information on the referenced day.

As Figure 1 presents, TCS 2011 divides Hong Kong territory into 26 zones (broad districts) for subsequent transport planning and transport modeling analysis. 4, 6 and 16 broad districts are in Hong Kong Island, Kowloon and the New Territories, respectively. More detailedly, the 26 broad districts are further divided into hundreds of PDZ-454 zones, which serve as the smallest area unit in TCS 2011.

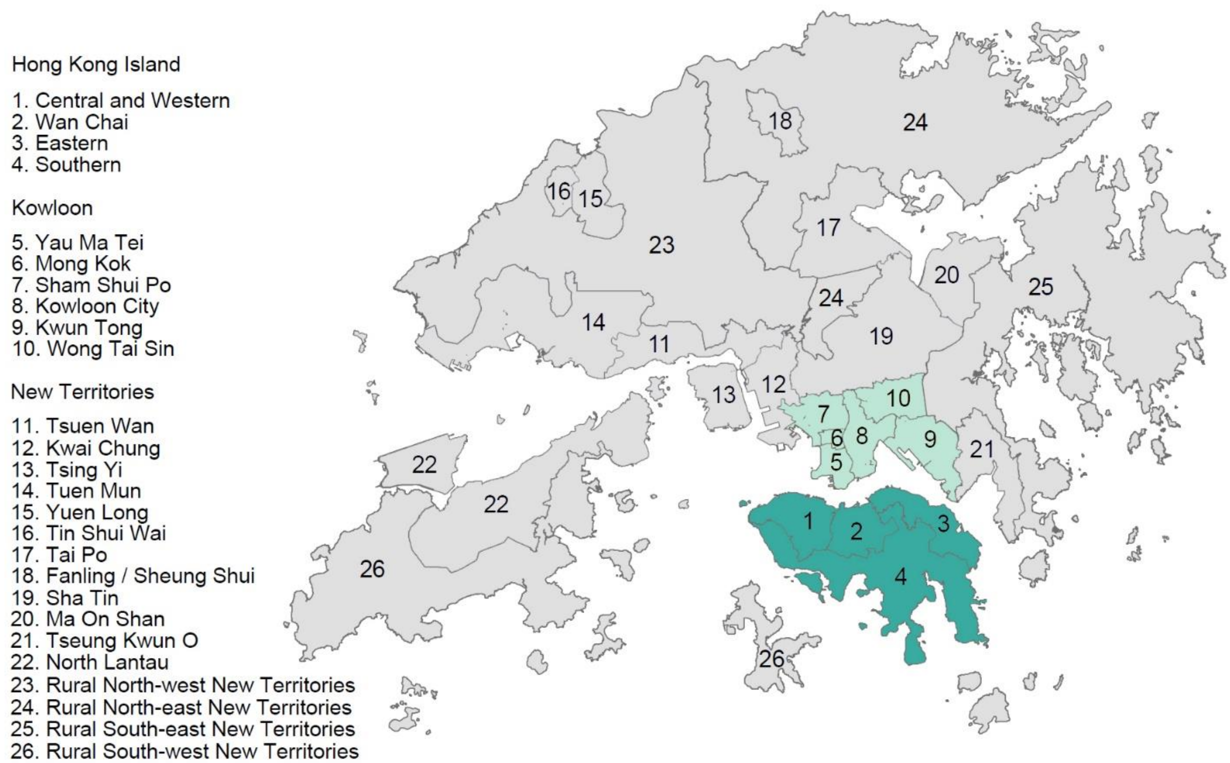


**Fig.1.** 26 broad districts defined in TCS 2011

## 4. Methodology

### *4.1. Mixed binary logit model for travel propensity*

The dependent variable is categorized as making trips and staying home during the referenced work-day. A mixed binary logit model, the extensions of the standard binary logit model, is thus employed to determine the associations between the probability of making trips and contributory factors concerned (e.g., gender and age) and estimate the random parameters due to random taste variations. The model takes the following form:

$$P_q = \int \frac{\exp\left(U_q\right)}{1+\exp\left(U_q\right)} f(\beta) d\beta \ ,$$

where $P_q$ is the probability that older person $q$ chooses to go out in the referenced 24 hours. $U_q$ is the deterministic utility, capturing the factors influencing the trip-making decision of older person $q$, and it is the linear combination of potentially contributory variables. $\beta$ is a vector of coefficients associated with explanatory variables, each allowing for individual-level variations. In this study, all explanatory variables are entered into the model as random parameters and pre-specified under the normal distribution, which is shown to outperform other statistical distributions, such as the uniform and log-normal (Haleem and Gan, 2013).

Table 1 provides the descriptions and descriptive statistics of variables. Existing literature on the mobility of older people suggests that level of mobility is affected by a number of individual, household, and neighborhood characteristics (Kim, 2003). Selection of explanatory variables for the analysis is informed by past travel behavior studies (e.g., Evans, 2001; Kim, 2003; Schmöcker et al., 2005; Páez, 2007; Roorda et al., 2010; Pettersson and Schmöcker, 2010), while considering data availability. Ten variables are included in the model, eight of which capture socio-demographic characteristics (e.g., age, gender) of the respondent. The remaining two variables are land-use characteristics, which are used to describe neighborhood design of older people's residence. Notably, the neighborhood herein is defined as PDZ-454 zone, which is the smallest area unit we can identify from TCS 2011. Initially, each observation is geo-coded into a PDZ-454 zone. Then, the numbers of bus stops and needed facilities of the zone are counted, and the densities are calculated as the ratio of the numbers to the size of the zone. Utilizing urban services (e.g., market, healthcare) becomes the dominant trip purpose of older people as they do not need to make work- or school-related compulsory (mandatory) trips. Markets, restaurants, and hospitals are identified as the urban services frequently utilized by older people in Hong Kong (Szeto et al., 2017). These two land-use variables are measured in *ArcGIS (v 10.2)*.

**Table 1**
Definitions and descriptive statistics of variables for travel propensity

| Explanatory variable | Description | Mean | Standard Deviation |
|---|---|---|---|
| Housing type | Dummy variable, 1 for private housing, 0 otherwise | 0.46 | 0.50 |
| Household size | Number of household members | 2.90 | 1.38 |
| Gender | Dummy variable, 1 for male, 0 otherwise | 0.48 | 0.50 |
| Age | Chronological age in years | 70.44 | 8.58 |

| | | | |
|---|---|---|---|
| Employment status | Dummy variable, 1 for person with job, 0 otherwise | 0.15 | 0.36 |
| Automobile | Dummy variable, 1 for automobile availability for household use, 0 otherwise | 0.08 | 0.28 |
| Driving license | Dummy variable, 1 for person with driving license, 0 otherwise | 0.12 | 0.33 |
| Illness | Dummy variable, 1 for person with illness (chronic or non-chronic), 0 otherwise | 0.01 | 0.11 |
| Public transportation accessibility | Neighborhood-level bus stop density (1/km$^2$) | 43.95 | 33.25 |
| Needed facilities accessibility | Neighborhood-level market, restaurant and healthcare facility density (1/km$^2$) | 254.78 | 2.1 |

### *4.2. Conditional logit model for destination and departure time choices*

A conditional logit model that simultaneously considers travelers' choice of destination and departure time, is proposed. This model relates the choice made by each person to attributes of alternatives available to the person. That is, variables incorporated must vary over alternatives. As such, individual-level attributes (e.g., gender, age) cannot be included. This model is often used when the number of possible choices is sufficiently large.

The destination zone is the broad district. In addition, instead of modeling department time as a continuous variable, we divide a typical day into four periods: morning peak hours (7 am-10 am), noon off-peak hours (10 am-5 pm), evening peak hours (5 pm-8 pm) and mid-night off-peak hours (8 pm-7 am), as Szeto et al. (2017) suggest, which is similar to Scott et al. (2009). Thus, every older person has 26 destination choices and 4 trip-making period choices. The model takes the following form:

$$P_q(ij) = \frac{\exp[U_q(ij)]}{\sum_{m,n} \exp[U_q(mn)]},$$

where $P_q(ij)$ is the probability that older person $q$ selects to travel to zone $i$ (=1, 2, …, 26) in time period $j$ (=1, 2, 3, 4). $U_q(ij)$ is the deterministic utility used to capture the factors affecting the decision of older person $q$. It represents the relative desirability of each travel, and it is the linear combination of characteristics of the alternatives rather than attributes of an individual.

Table 2 provides the descriptions and descriptive statistics of variables. We considered both past travel behavior studies and data availability when selecting explanatory variables for the analysis. The variables account for the attributes of destinations and origin-destination (O-D) pairs. Two travel-related destination attributes, reflecting the attractiveness of urban service facilities, are measured in *ArcGIS (v 10.2)*. Three variables are selected to represent O-D pair characteristics.

In contrast with time-constant destination characteristics, O-D pair characteristics vary with time. For the same origin and destination, the level of public transport service may be better in daytime than at night, travel time is shorter in the less-congested period, and number of transfers (the terms “transfer” and “interchange” are used interchangeably in this paper) may be larger when some public transportation options are unavailable.

**Table 2**
Definitions and descriptive statistics of variables for destination and departure time choices

| Explanatory variables | Description | Mean | Standard Deviation |
|---|---|---|---|
| # markets & restaurants | Number of markets and restaurants in the destination zone ($10^2/km^2$) | 8.97 | 0.78 |
| # healthcare facilities | Number of healthcare facilities in the destination zone ($10^2/km^2$) | 0.96 | 0.74 |
| Public transportation accessibility | Proportion of public transportation trips | 0.92 | 0.08 |
| Travel time | - (min) | 42.38 | 10.12 |
| Number of transfers | - | 0.18 | 0.15 |

## 5. Results

The econometric modeling software, *LIMDEP (v 9)*, was employed to estimate the coefficient of each variable in the two models. The results are as follows.

### *5.1. Travel propensity*

A pair-wise correlation analysis was undertaken to identify the association between explanatory variables, and its result shows the Pearson’s coefficient between public transportation accessibility and needed facilities accessibility is 0.7. Due to the highly positive correlation, the needed facilities accessibility variable was removed to avoid the multi-collinearity problem. 100 Halton draws were adopted in the modeling process.

The McFadden pseudo $R^2$ is found to be 0.399, which indicates good model fit. Table 3 provides the modeling results. Overall, seven out of nine variables are significant at the 5% level and their signs agree with *a priori* expectations. This implies these seven variables significantly influence older people’ travel propensity. Owning an automobile and driving license was found to be not associated with travel propensity. In other words, the difference in travel propensity between the older people with and without a car (or driving license) is negligible. This finding is in sharp contrast with that in car-dominant cities in which car and driving license are perceived as mobility tools (Schwanen and Páez, 2010; Moniruzzaman et al., 2015a). In these contexts, car ownership and license-holding status are significant predictors of trip-making (e.g., Kim, 2003; Páez et al., 2007; Roorda et al., 2010). It can be explained by the astonishingly low car use and high public transportation use in Hong Kong. Moreover, the standard deviation associated with gender and employment status are significant at the 5% level, which indicates that unobserved heterogeneity between respondents exists regarding these two attributes.

**Table 3**
Results of the mixed binary logit model

| Variable | Coefficient | t-statistics |
|---|---|---|
| Housing type | $0.360^{**}$ (0.020) | 7.23 (0.06) |
| Household size | $-0.195^{**}$ (0.009) | -11.54 (0.11) |
| Gender | $1.034^{**}$ ($2.102^{**}$) | 4.11 (5.86) |
| Age | $-0.065^{**}$ (0.000) | -20.17 (0.01) |
| Employment status | $4.462^{*}$ ($2.932^{*}$) | 2.57 (2.44) |
| Automobile | -0.145 (0.557) | -0.77 (0.74) |
| Driving license | 0.739 (0.974) | 1.39 (0.88) |
| Illness | $-1.594^{**}$ (1.955) | -6.25 (1.75) |
| Public transportation accessibility | $0.002^{**}$ (0.000) | 2.76 (0.00) |
| Constant | $6.448^{**}$ | 25.45 |

Note: Standard deviations associated with random parameters are shown in brackets. N=19703. $^{**}$significant at the 1% level. $^{*}$significant at the 5% level.

Various socio-demographic characteristics are found to significantly affect older people's travel decisions. First, housing type significantly influences decisions to travel. Older people living in private housing are found to be more likely to go out. A possible explanation is that people living in private residences are more economically active (Wang and Lin, 2013; Leung et al., 2017), which can better support their unnecessary travel (Szeto et al., 2017). That is, the public housing residents often have financial constraints which may lower their mobility. In addition, older people who have a higher number of family members are less likely to go out. A possible explanation is substitution in trip making in households with multiple persons (Páez et al., 2007; Pettersson and Schmöcker, 2010; Feng et al., 2013). In accordance with the traditional Chinese cultural values, older people co-resided more family members tend to receive more material and spiritual support from others (Hui et al., 2014; Wang et al., 2016). In multi-person families, family numbers can share household tasks and significantly reduce older people's intention to travel, freeing older people from out-of-home chores in many cases. Moreover, males are found to be more likely to make trips than female counterparts. This is consistent with most gender-related travel studies (Collia et al., 2002; Zhang et al., 2007). A possible explanation comes to mind. It is possible that men conduct more out-of-home activities than women. And the result demonstrates that the standard deviation of the variable "gender" is significant at the 1%, which suggests that the intention to travel for male older people show substantial variation. Given that its coefficient and standard deviation is 1.034 and 2.102 respectively and the random parameter is normally distributed, 68.9% of male older people are more likely to travel compared to female counterparts. Furthermore, younger old are found to more likely to go out, which is consistent with Kim (2003) and Páez et al. (2007). It can be explained by the fact that typically, mobility declines gradually with advancing age (Rantakokko et al., 2013). In addition, employment status significantly affects travel propensity, and significant heterogeneity is identified. Older people still in the labor force have to make compulsory trips (commuting) and are not as free as retired individuals. Considering that the variable "employment status" coefficient and standard deviation is 4.462 and 2.932 respectively and the random parameter is normally distributed, 93.6% of employed older people are more likely to travel compared to unemployed peers. Last but not least, similarly expected is that older people with illness tend to spend more time at home and less likely to go out, perhaps due to physical constraints, limitations on activities of daily living and mobility impairment. This finding is in line with Smith and Sylvestre (2001).

The variable "public transportation accessibility" is found to be significant at the 1% level. This implies that older people with better access to public transportation are more likely to go out. This finding agrees with expectations, since in Hong Kong, over 90% of older people take public transportation (Szeto et al., 2017), whereas it sharply contrasts with previous findings in car-dominant cities: public transportation availability has no bearing on mobility (Evans, 2001; Hess, 2009).

### *5.2. Destination and departure time choice*

Table 4 reveals the conditional logit modeling results. All variables are significant at the 1% level and the signs of all coefficients are as expected. The signs of urban service variables are positive, which indicates that older people are more likely to travel to service-rich zones.

The coefficient of Public transportation accessibility is positive. This suggests that older people tend to choose the time period with higher public transport service supply for travel. In Hong Kong, the effect of Public transportation accessibility on travel behavior is expected to be more pronounced relative to the regions where private cars are used by the higher proportion of residents. In Hong Kong, only 14.4% of families have automobiles (Transport Department, 2014). Moreover, automobile ownership rate for older people is lower than the average: it is estimated that only 9.24% of older people have car(s) available for household use according to TCS 2011 data. Most of older people have to highly rely on public transportation due to lack of other feasible options.

The coefficient associated with travel time is significant. Travel time is an important concern in making departure time decisions. For the same origin and destination, older people would choose the time period with shorter travel time, which partially echoes Szeto et al. (2017)'s observation that older people tend to avoid travel during two peak hours. Our model also indicates that number of transfers is perceived negatively by users and does affect older people' travel behavior. Partially due to poor physical health, older people may find it more difficult to transfer frequently, and they are more transfer-averse compared to young residents[①].

**Table 4**
Results of the conditional logit model

| Variable | Coefficient | t-statistic |
|---|---|---|
| # markets & restaurants | $0.089^{**}$ | 5.26 |
| # healthcare facilities | $0.284^{**}$ | 15.78 |
| Public transportation accessibility | $3.343^{**}$ | 19.68 |
| Travel time | $-0.048^{**}$ | -22.62 |
| Number of transfers | $-1.336^{**}$ | -9.06 |

Note: N=14211. $^{**}$significant at the 1% level.

## 6. Policy insights

① According to TCS 2011 data, it is estimated that the average number of transfers per trip by young (18-59) and older people (60+) is 0.27 and 0.12 respectively and the proportion of boardings involving interchanges of young and older people is 20.03% and 11.38% respectively. This further implies that older people are relatively transfer-averse.

## *6.1. Diversified policy design*

A number of socio-demographic characteristics (e.g., age) of older people are found to affect travel propensity. As such, accounting for heterogeneity may be essential in allocating resource and formulating public transportation policy (Mercado et al., 2010). For example, the current transit concessionary fare scheme applies to all older people even with different socio-demographic attributes. In the future, different schemes can be designed for older people with differing characteristics. For instance, as Wong et al. (2017) suggest, the scheme can consider entirely waiving travel costs of oldest-old people (80+) and lowering travel costs (e.g., half-price) of youngest-old people (60-64) who are not yet eligible for the scheme. Similarly, reducing or exempting travel fares of older people with severe illness could be considered. Additionally, the government is suggested to deliver more infrastructure construction efforts to areas clustering a huge number of older people (e.g., Kowloon City in Kwun Tung). As older people have low residential relocation propensity (Hui et al., 2009), improvement of public transport service in neighborhood areas may attract both current and future older people to go out, thereby enhancing their mobility and quality of life.

## *6.2. Enhanced public transportation accessibility*

Public transportation accessibility has been found to affect older people' travel propensity, as well as destination and departure time choices. In transit-oriented cities like Hong Kong, older people are frequent public transportation users, highly relying on public transport, so public transport accessibility is of particular concern to them. This is in stark contrast to the trend in most Western countries where public transport usage is rather low (Collia et al., 2003). Therefore, more age-friendly transportation services with various favorable characteristics (e.g., available, accessible, reliable and frequent) (World Health Organization, 2007) are suggested to be provided to cover broader areas, especially areas with higher travel demands.

## *6.3. Activity-rich neighborhood design*

Public transportation accessibility picks up some of the effects of needed facilities accessibility due to highly positive correlation in our data. Lack of available activity destinations (opportunities) may suppress travel (Yang et al., 2016; Yang, 2018). Since older people spend most of the time in local neighborhoods (Sun et al., 2018), living in those with abundant services facilities that appeal to them (e.g., shopping, recreation, health care) can ensure the actual accessibility to the facilities (Páez et al. 2010; Paez et al. 2010; Rojas et al., 2016) and is therefore important for active ageing and living an independent life. Living in activity-rich zones provides incentives to older people for travel. Accessibility to needed facilities and the notion of proximity are of great significance for older people (Banister and Bowling, 2004).

## *6.4. Providing more direct public transport services (reducing the actual costs associated with interchanges)*

The conditional logit model reveals the significantly negative perceptions of transfers. A transfer disrupts travel experience and limits public transport use. Normally, it contains these procedures: alighting from one vehicle, walking to a new transit stop, waiting for another transit vehicle and boarding that vehicle (Iseki and Taylor, 2010). The associated costs include time, money, delay and attendant risks (Hine and Scott, 2000). Moreover, older people are not as easy as young cohorts to accept transfers and show a strong interchange resistance. "As age increases, one's requirements for a user-friendly system and seamless service typically increase" (Cheng and

Tseng, 2016, p. 400).

Transit transfer has been perceived as a new significance in the way towards seamless travel (Cheng and Tseng, 2016), so it can be an important area carefully considered by the city government with the aim of improving the mobility of older people. Directly reducing the number of transfers could be a focus of future transport policies. More direct public transport services are suggested to be introduced, especially between the O-D pairs which carry more older people flows (between older people clustering districts and highly potential destinations).

### *6.5. Improving transfer experiences (decreasing the perceived costs associated with interchanges)*

Not surprisingly, extensive transferring among lines and modes is fairly common in large multi-modal transport networks. In many cases, it is impractical to entirely avoid transfers between differing modes and routes to reach final destinations. In other words, transfer is an activity performed as part of a journey generally. Still, we can improve many aspects (e.g., ticketing and fare arrangements, travel information, safety and security) for better, easier and more convenient transfer experiences (Hine and Scott, 2000; Li and Loo, 2016).

Decreasing the perceived costs (or burdens) associated with interchanges (i.e., ameliorating transfer penalties) becomes an important aspect for seamless public transportation journeys, complementary to directly reducing the number of transfers (lowering the actual costs) (Hine and Scott, 2000; Cheng and Chen, 2015). This approach has been implemented in other countries, such as Japan (Mercado et al., 2007). For instance, staffs can be recruited to help older people to get travel information, carry luggage and find their ways. Additionally, automated services can be introduced to guide, sell tickets and offer information. Moreover, waiting environment can be renovated to improve transfer experiences and user impression. Furthermore, transfers often involve multiple modes that provided by different operators (e.g., bus and railway) and a variety of cross-organization issues (Guo and Wilson, 2011). Therefore, the seamless integration and coordination between operators in terms of connections and ticketing becomes crucial. This effectively guarantees better intermodal connectivity and more favorable interchange experiences. The city government could establish policy measures to encourage operators to cooperate and decrease the cost associated with transfers. A few rewards can be put forward to motivate their cooperation (e.g., tax reduction or exemption).

### *6.6. Time-varying public transport services*

Older people tend to avoid relatively congested time periods to travel as our model indicates. Moreover, for older people, public transport services need to have greater flexibility in routing and timing (Alsnih and Hensher, 2003), so enhancing the level of public transport services by simply changing the timetable while keeping other factors fixed is suggested (Xu et al., 2015). More direct public transport services are suggested to be provided in the noon off-peak period, and it is necessary to recruit added drivers to serve within this period.

Unlike railways which are restricted to fixed routes and schedule timetables, bus and public light bus have their inherent implementation and operational flexibility (or variability) advantages. Yet, since older people do not favor rough, unstable and uncomfortable travel experiences provided by public light bus (Wong et al., 2017), it is highly suggested to the provision of flexible bus services which can be changeable in both alignment and schedules over time. Most notably, this policy measure requires very low investment costs.

## 7. Conclusions

Obviously, Hong Kong is an ageing and transit-oriented city. In this category of cities, the public transportation suited to older people's travel needs and preferences is of enormous importance. Yet, currently, Hong Kong prompts the implementation of age-friendly cities initiatives solely among non-government organizations, district councils, charities, as well as universities, which reflects a "grassroots" mode (Sun et al., 2017). Indeed, Hong Kong seems to be not well-prepared to offer adequate transportation for the rapid growth of the ageing population.

With the aim of contributing to a better understanding of the emerging demographic and travel trends, more specifically, mobility behaviors of older people in a transit-oriented city, based on the 2011 Travel Characteristic Survey (TCS 2011) data as well as GIS data of Hong Kong, this paper models older people' travel propensity by utilizing a mixed binary logit analysis and uncovers their destination and departure time choices using a conditional logit model. The results show that many socio-demographic variables and land-use attributes affect travel propensity of seniors. Owning an automobile and driving license has no bearing on travel propensity, which is in sharp contrast with the conventional wisdom in car-dominant cities where car ownership and license-holding status are significant predictors of trip-making. Moreover, a number of (time-constant) destination and (time-variant) O-D pair characteristics influence destination and departure time decisions. As per the abovementioned analysis, a few insights for policy intervention are discussed. Notably, the abovementioned policy measures would benefit not only older people (age-friendly) but also other public transportation takers (people-friendly). To wit, all residents would be affected in some way by the enhancement of public transportation system. More importantly, the policy insights can act as a valuable reference to the age-friendly transportation planning and policy development with the aim of coping with older people's mobility problems, especially in the metropolitan cities which offer similar public transport services.

There are a few limitations that warrant further research. First, the travel propensity model has included the variable "illness" to reflect older people' physical health. However, the severity of illness and degree of mobility impairment are unknown. Admittedly, examining the role of illness severity in travel may be more appealing, if with sufficient data. Additionally, the paper measures travel-related destination variables in the conditional logit model by counting the number of service facilities for representing attractiveness and treat those in the same category as homogeneous due to data availability. With rich data, we can differentiate the attractiveness of service facilities (e.g., clinic and comprehensive hospital), which may yield more accurate measures. Moreover, the TCS data set does not include some key variables (e.g., attitude, possession of mobile phone) (Moniruzzaman et al., 2015b; Zhou et al., 2018), which prevents finer measures for understanding the elderly's mobility choices. Last but not least, the TCS data we used in this paper for both parametric modeling and nonparametric analysis were obtained using the traditional data collection method. Yet, new technology (e.g., GPS, mobile phone, transit smart card) offers the data with various favorable characteristics (e.g., low cost, reliability, high-resolution, fine-grained) and opens an invaluable door for travel researchers to understand the underlying behavior mechanism of mobility patterns of residents. In recent years, merging the data from different sources (e.g., GPS and questionnaire survey) is perceived to be on the verge of becoming enormously important and popular in travel studies. We can try this for the better understanding of older people's mobility patterns in future research.

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