An Analysis of Residential Location Choice Behavior in Bangkok Metropolitan Region: An Application of Discrete Choice Models for the Ranking of Alternatives

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Abstract: There has been an increasing interest in land use and transportation interaction in the past decades. Many substantial attempts have been made to empirically investigate the connection among those impacts can be interpreted in developed countries, yet few attempts in developing countries. The paper examines residential location choice behavior using a sample of households where their workplace is in the CBD of Bangkok Metropolitan Region. A stated preference approach will be employed, where each of a respondent is asked to imagine moving to a new location. Discrete choice models, i.e., rank-ordered logit (ROL) and rank-ordered nested logit (RONL) will be applied to treat the residential location choice behavior. The results confirm the applicability of the ROL and RONL models and support similar behavioral interpretations from other empirical studies in the residential location choice literature. This information is important for suggesting appropriate policy such as promote urban rail transit use.

Keywords: Residential location choice, Urban rail transit system, Rank-ordered logit, Rank-ordered nested logit, Bangkok

1. INTRODUCTION

Bangkok Metropolitan Region (BMR), also known as Greater Bangkok is the urban conglomeration of Bangkok, Thailand, consists of a large core so-called Bangkok Metropolitan Area (BMA) and the five vicinities of Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan, and Samut Sakhon. In the early period, most people settled along the Chao Phraya River and the canals. Waterway served as the main mode of transportation for Bangkoknians' commuting. By the mid-19th century, the commuting system was changed from water transport to land transport and had emphasized plans of transportation infrastructures such as bridge and road network since 1960. There have seen significant urban shifts in land use and travel behaviors. Specifically, this gradually converted Bangkok into a car dependency city and made the city spread outwards (Rujopakarn, 2003). According to that plans, Bangkok has undergone rapid population, urbanization and motorization. The population increased from 3.3 million in 1960 to 14.6 million in 2010 and the BMR produced a GDP of about US$0.16 trillion which accounts for 44.1 percent of country (National Statistical Office, NSO). Furthermore, the annual income per capita of the people in the BMR continues to be higher than those of other regions. For example, the Northeastern region has the lowest, though this region corresponds to about one-third of Thailand and the total population of its 19 provinces in 2000 was 20.1 million, equivalent to approximately 34 percent of Thailand's total population but the annual per capita income in the BMR was ten times higher than in the northeastern region in 2010. Such situation has made it possible for many individuals and households to purchase new house in suburban areas as well as new vehicles. Physically, employment locations are largely concentrated in the inner core. Such urban structure unavoidably generates huge amount of travel demand which are mostly made by long distance trips by private vehicles. The transportation in Bangkok is presently based on road and expressway network. The reason is that travel on private car is far superior to travel on crowded bus running in heavily congested traffic. The present 404 bus routes are still not enough to accommodate the travel demand especially from/to suburban areas. Then, the urban rail transit has been introduced to alleviate the traffic issues and mainly serves people between suburban to the central part of Bangkok.

The BMR is still young to its urban rail transit history although three lines, consist of BTS Skytrain, MRT Blue Line, and Airport Rail Link, are now operating. An important function of any rail transit system is to provide for people accessibility to residences; places for employment, recreation, shopping and so on; and for public goods and services. Consequently, it can refer that the structure and capacity of rail transit networks affect the level of accessibility. Then, the adjacent areas of the rail transit corridors especially around the stations, which are the premium of transit accessibility, become the attractiveness areas for commercial developments and residential developments which lead to increased land values as competition for the sites rises. For example, the urban rail transit has large influence on its surrounding area, especially around the stations. After the BTS Skytrain in Bangkok has opened, many buildings (e.g. office buildings, hotels, condominium, etc.) have been renovated and constructed by developers and land price along the corridor has remarkably increased (Vichiensan *et al.*, 2011). It was claimed that the premium of transit accessibility adding to the property value is approximately US$10 for every meter closer to the station (Chalermpong, 2007). More recently, Bangkok Metropolitan Region in Thailand has developed a long-range transportation master plan and placed the top priority to urban rail transit investments. Those benefits due to rail transit development also impact on the areas which is announced future extension. Such benefits make integrated models of land use and transportation very relevant for prediction of future urban structures. Residential location choice models can inform such models. The study of residential location choice model has received considerable attention for many years in developed countries, though less investigated in developing countries.

This paper focuses on workers in the central business district of Bangkok Metropolitan Region, which is known as the concentration of Bangkok business and commercial area, in order to obtain a clearer picture of the underlying factors for residential location choice decisions. A stated preference approached will be used, where each of a sample of worker in the CBD of Bangkok households are asked to imagine moving to a new home location and then to indicate preferences among hypothetical alternatives for this new location, with these alternatives described in terms of attributes associated with urban rail transit-related variables and location-related variables. The observations obtained were then used to estimate residential location model parameters indicating the sensitivities to those attributes and explaining these sensitivities by socio-demographic of each of sample households. As the intention is to gain an in-depth understanding of residential location decisions, the model does not consider other potentially interdependent decisions such as housing amenities. The current study is in the same direction as earlier research in the area of discrete choice residential location models, i.e., rank-ordered logit (ROL) and rank-ordered nested logit (RONL) will be applied to treat the residential location choice behavior.

The ROL is an extension of the multinomial logit (ML) form, where the property of independence from irrelevant alternatives (IIA) is assumed (Ben-Akiva and Lerman, 1985), and provides a better view on the preferences of a household (Beggs *et al.*, 1981; Hausman and Ruud, 1987). In more advanced, the RONL model forms suitable for the analysis of multi-dimensional problems, the IIA restriction is relaxed to allow for correlations among alternatives (Lee and Waddell, 2010) and analyzed the preferences by ranking alternative instead of only choosing the most preferred option. Hence the preferences can be estimated more efficiently in theory.

The rest of this paper is organized as follows. Section 2, an overview of previous studies and location decision related variables will be presented. Discussions of Bangkok Metropolitan Region (BMR) situation, various data used for the analysis and descriptive statistics will be presented in section 3. Section 4 provides an introduction to discrete choice model, namely rank-ordered logit and rank-ordered nested logit model. Section 5, the models are estimated with the sample data. Finally provides the conclusion.

2. LITERATURE REVIEW

2.1 Residential Location Choice

Models of residential location choice are important tools used in analyzing urban policy with respect to transportation and urban land use planning. Over the past four decades, researchers developed the mathematical modeling of residential location decision behavior. There is an abundance of studies that attempt to understand the residential choice behavior through discrete choice models. These studies are common and/or different in the model structure utilized, the significant choice determinants and the findings as follow.

Some studies have focused only on residential location choice (Gabriel and Rosenthal, 1989; Hunt *et al.*, 1994; McFadden, 1978; Timmermans *et al.*, 1992). For example, Hunt *et al.* (1994) constructed a model of residential location choice in Calgary, Alberta, Canada, using a stated preference experiment and specific findings were that travel time to work is worth approximately 25 Canadian dollars (C$25) per hour, travel time to work is about two times as important as travel time to shop. Some studies (Deng *et al.*, 2003; Gabriel and Rosenthal, 1989; Miller and Quigley, 1990) have focused on location choice for specific demographic groups (such as single worker, female and male households, Caucasian households). For example, Deng *et al.* (2003) found that African-American residential location outcomes are associated with lower than expected racial differences in homeownership. However, the choice of residential location is very complex and also relies on many other choices. For example, people who prefer to commute by transit would choose to live near a transit station. Likewise, people who prefer walking may be consciously choose to live in walkable neighborhoods. Similarly, people living in sprawling areas have to rely on cars to conduct their daily activities. This interdependency has lead researchers to model residential location choice jointly with other choice dimensions such as car ownership (Bhat and Guo, 2007; Pinjari *et al.*, 2011; Weisbrod *et al.*, 1980), bicycle ownership (Pinjari *et al.*, 2011), commuting mode (Kim *et al.*, 2003; Ng, 2008) work location (Freedman and Kern, 1997; Rivera and Tiglao, 2005), school location (Barrow, 2002), housing mobility (Lee and Waddell, 2010), housing tenure (Ioannides, 1987; Waddell, 1993), and housing attributes (Guevara and Ben-Akiva, 2006; Hoshino, 2011).

It is common for the previous studies to apply the discrete choice structure, namely multinomial logit. Another discrete choice family treating the residential location choice along with other choice dimensions is to apply the nested logit model such that one of the levels in the nesting structure corresponds to the residential location choice (Kim *et al.*, 2005; Lee and Waddell, 2010; Rivera and Tiglao, 2005; Vega and Reynolds-Feighan, 2009; Waddell, 1993).

2.2 Urban Rail Transit Service Availability in Residential Location Choice Decision

Over the past decades, it has become increasingly clear that living near the urban rail station is the determinant factor in residential location choice theory. Walmsley and Perrett (1992) found that in Washington D.C. homes near stations appreciated at a faster rate than similar homes further away. Similarly, they provided the evidence that the effects of LRT in the Portland, Oregon may indicate the beginning of a self-selection in residential location choice wherein persons desiring rail transit chose to live where it is available (van Wee *et al.*, 2002). Likewise, Bhat and Guo (2007) attempted to understand whether the association between built environment and travel behavior related variables is a true reflection of underlying causality to the relationship between the built environment and the characteristics of people who choose to live in particular built environments in the Alameda County in the San Francisco Bay Area. They found that among the local transportation network measures, it was clearly that households prefer to live in zones with transit service availability and with smaller access times to transit stations, but they did found the relationship between the demographic variables of households and the sensitivity to transit availability and access time to stations. Israel and Cohen-Blankshtain (2010) explored suburbanization and sprawling effect of commuter rail transit on the rural exurbia of the Tel Aviv metropolis by analyzing its effect on residential location decisions and the results indicated the suburban rail system was an influencing factor in residential location choice behavior of households. Interestingly, in de Palma *et al.* (2005) developed the model of residential location choice with endogenous housing prices and traffic for the Paris Region. Comparing results founded that the metro stations in a commune increase the probability of location but the railway stations decrease it. These results because metro stations may be more likely than railway stations to be located within clusters of shopping and service employment or adjacent to major cultural attractions. Barrow (2002) showed the positive effect of the number of metro stations in Washington DC on the location probabilities for White households but decrease for African-American Households.

2.3 Location and Neighborhood Characteristics in Residential Location Choice Decision

Previous literatures point to the attributes and characteristics which can be divided into two main groups: housing attributes (e.g. rent or price, housing type, housing size, number of rooms) and others related to the locational and neighborhood (e.g. accessibility to schools, commute time) where it is located. However, this paper does not consider potentially interdependent decisions such as housing amenities and tenure status. Therefore, the location and neighborhood characteristics in the literatures to be relevant in residential location choice were reviewed.

Location refers to the specific placement of a house which affects the preference of the individual. Since the house is fixed in location, it differs in terms of its surroundings (neighborhood and community setting). Facilities of transport, education, health care, shopping and recreation are factors to be considered when choosing the house in each location. Good locations and neighborhoods command higher demand than those in bad locations and neighborhoods. Lee *et al.* (2010) found that employment accessibility has strong and positive effect on residential choice behavior. Similarly, Bhat and Guo (2004) concluded that proximity to the employment location of the worker in the household except African-American households is an importance factor and 75 percent of households like to live closer to their work, but 25 percent prefer location farther away. However, (Waddell, 1993) found that households do not prefer high employment accessibility.

Among density measures, while (Weisbrod *et al.*, 1980); Kim *et al.* (2003); Vega and Reynolds-Feighan (2009) showed that households are less likely to reside in locations with high density, Waddell (1993); Bhat and Guo (2004) and Pinjari *et al.* (2007) found that high population density is preferred by households. In addition, Bhat and Guo (2004) pointed out that 77 percent of households prefer zones with higher population density, only 23 percent prefer lower population density. Furthermore, several studies indicated that households prefer to locate themselves in areas of low employment density (Pinjari *et al.*, 2007; Pinjari *et al.*, 2011; Waddell, 1993). But the total number of employment is not statistically significant in residential location choice behavior (de Palma *et al.*, 2005; Waddell *et al.*, 2007). The effect of employment density has also been found for different population groups as the population or household density. For instance, high employment density zones are less likely to be chosen for residential location, except for lower income households who may be compelled to choose lower cost housing (Bhat and Guo, 2007; Pinjari *et al.*, 2007; Pinjari *et al.*, 2011).

The recreation accessibility, school quality, median income and land value, incidence of crime, the noise level, number of markets and shopping centers, number of children's playground, number of recreation facilities, and number of parking facilities in the neighborhood were also chosen to be a representative attributes of locations and neighborhoods effect on the residential location choice with their methods. Previous research has provided mixed evidence including large positive, small positive as well as negative effects (Barrow, 2002; Bhat and Guo, 2004; Bina *et al.*, 2006; Pinjari *et al.*, 2007).

3. DATA AND CASE CONTEXT

3.1 Bangkok Metropolitan Region and Case Context

Bangkok Metropolitan Region, a capital city of Thailand, is selected as a case study for the empirical analysis. The BMR has two major central business districts (Silom and Sukhumvit) and several commercial districts (e.g. Siam Square, Rama 4, and Petchaburi) situated in different parts of the city. Recently, detached and attached homes are common in outlying low-density area such as the suburban of Bangkok and the areas of the adjacent provinces, however, they have become increasingly rare in central Bangkok, where high-rise building for residence such as condominiums and apartments have become the norm.

Recently, the urban rail transit has been introduced to alleviate the traffic issues. In December 1999, the first 23.5-kilometer elevated rail transit, the so-called BTS Skytrain, has started its service. Five years later, the second 20-kilometer MRT Blue Line was launched at underground level in July 2004. The third 28.5-kilometer Airport Rail Link has opened in August 2010. Among of them are five transfer stations that is no track connection, namely Asok, Mo Chit, Sala Daeng, Phaya Thai, and Phetchaburi. Nowsadays travel by rail transit in Bangkok has increasingly obtained interest due to its safe, punctual, as well as convenient service. Although there are only three lines are currently in operation, the new urban rail transit lines consist of a 15-kilometer SRT Red Line, a 23-kilometer MRT Purple Line and a 27-kilometer extension of MRT Blue Line are now constructed in January 2009, November 2009 and June 2011, respectively. Moreover, a 12.8-kilometer of the extension of BTS Skytrain started in 2012.

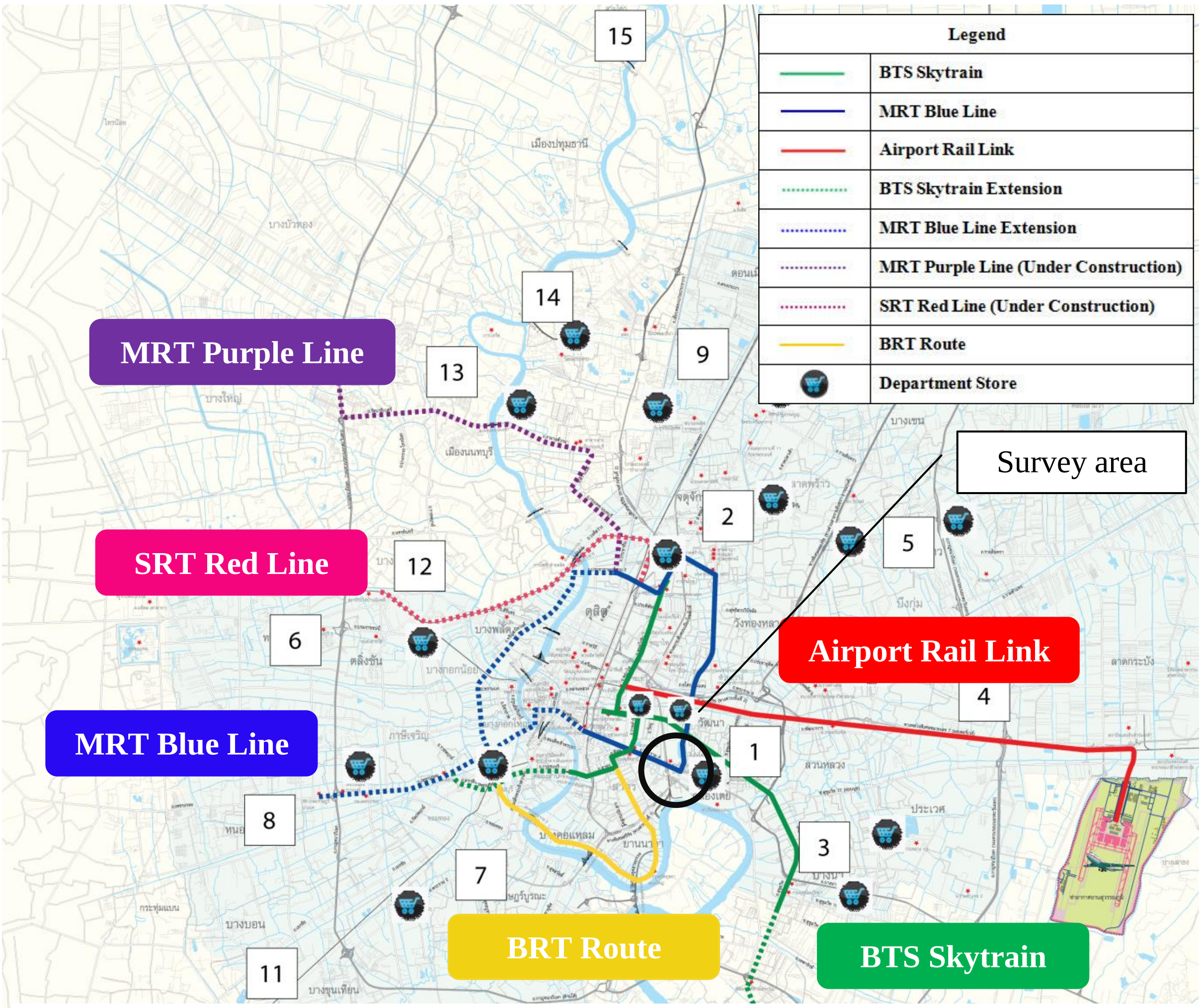
As stated, Bangkok Metropolitan Region and the households where their workplace are located in the CBD of the BMR were chosen as a case context for this paper for several reasons. One, due to the fact, the BMR has among the worst traffic congestion; travel speed by private car head to the inner city is less than 12 kilometer per hours (Office of Transport and Traffic Policy and Planning, OTP). Congestion increases commuting time and costs, which in turn likely draws households to rail-served locations. Two, mainly systems of rail service serves to the inner city where employment locations are largely concentrated physically. Last, the city of Bangkok metropolitan Region has developed a long-range transportation master plan especially urban rail transit, which has impact on a wide range of elements of urban form and transportation development. Understanding that development and corporate into the planning is necessary. Unfortunately, it is characteristics of developing countries including Thailand that do not evaluation and integrate the impact of transportation development as part of the transportation master plan. Therefore, it is necessary that planning and evaluation of transport project in Thailand need to be improved. On top of that, households whose workers work near the CBD may choose residential locations near the rail station because it is likely to be dominant mode to access their workplace in order to reduce the time and costs. The intention in this study specifically is not to consider what would best for the population, but, rather, to consider the sensitivities of the population to a specific set of elements addressed in the plan.

3.2 Database and Sample Frame

The database used to carry out this paper was obtained from various sources. Mainly data used for residential location choice decision obtained from the paper-based questionnaire was carried out by survey on-street. Figure 1 shows an example sheet presenting an alternative.

The questionnaire survey was conducted during 8-20 June 2012 on workdays at 10 am.- 8 pm. at (1) Sathorn and Chong Nonsi areas, (2) Silom area, (3) Ractchadamri area, (4) Phloen Chit and Wireless road area, (5) Sukhumvit area, and (6) Pecthaburi area where there are located in the two major CBD area of Bangkok, namely Silom and Sukhumvit. Six locations were chosen according to the purpose of this study, that is, all of locations cover most area of the CBD and also were surrounded by large numbers of commercial and office buildings. A stated preference approach was used, where each of a sample of a respondent was asked to imagine moving to a new home location and to indicate preferences among hypothetical alternatives for this new location by ranking (the respondents were asked to rank only 2 from 15 alternatives: first and second preferences), with these alternatives described in terms of attributes related to the options such urban rail transit station, shopping center, expressway network. In addition, 15 alternatives in the paper-based questionnaire were the representative of districts in the BMR. Three of them are from the inner city's district group, five of them are from the urban fringe's district group and the rest are from the suburban and vicinities' district group. Furthermore, this questionnaire was made based on the assumption when households are looking for a new house, their preferences maybe the alternatives that they were familiar because this is quite a characteristic of Thai. The respondents were asked to do the questionnaire by interview individually. The observations of choice behavior thus obtained were then used to estimate model parameters indicating the sensitivities to those attributes.

Furthermore, the respondents were asked general questions about: (1) their personal and household information such as household size, household income, car ownership and current home location and (2) travel mode choice by explaining the travel choice consideration from their house to their workplace and the travel time.



	District	Sub-district	Price range		District	Sub-district	Price range		District	Sub-district	Price range
☐	(1) Watthana	Phra Khanon Nuea	5-10 MB	☐	(2) Chatuchak	Sena Nikhom	3-8 MB	☐	(3) Phra Khanong	Bang Chak	3-8 MB
☐	(4) Saphan Sung	Saphan Sung	3-8 MB	☐	(5) Beung Kum	Khlong Kum	3-8 MB	☐	(6) Thawi Watthana	Sala Thammasop	3-8 MB
☐	(7) Chom Thong	Bang Mot	3-8 MB	☐	(8) Bang Khae	Lak Song	3-8 MB	☐	(9) Lak Si	Thung Song Hong	3-8 MB
☐	(10) Min Buri	Min Buri	1-5 MB	☐	(11) Bang Bon	Bang Bon	1-5 MB	☐	(12) Nonthaburi	Bang Kruai	1-5 MB
☐	(13) Nonthaburi	Tha It	1-5 MB	☐	(14) Nonthaburi	Ban Mai	1-5 MB	☐	(15) Phathum Thani	Amphoe Phathum	1-5 MB

Figure 1. Example choice experiment sheet

3.3 Descriptive Statistics

The final sample from questionnaire survey comprised 1,060 households. The general information of the respondents is described using descriptive statistics in Table 1. From the obtained data, there are three popular modes used in work daily trips: private mode (i.e., private car and motorcycle), public mode (in this study exclude rail transit mode: the BTS Skytrain, MRT Blue Line and Airport Rail Link) and rail transit mode. Among the 1,060 sample data will be used in the rank-ordered and rank-ordered nested logit analysis, the proportion of private mode use inclines as increasing the size of household. In contrast, rail transit mode is the most preferable for the smaller household size. Definitely, the sample comprised of the high proportion of private mode uses were found in the middle and high income household (approximately 30.89 percent and 54.85 percent, respectively). Additionally, income groups were divided regarding to the standard of National Statistics

Office (NSO)[1]. On the other hand, public transport mode has the highest shares for the low income households while they owned the lowest shares for the high income households. In term of the household car, the higher a household car ownership, the higher likelihood it will get around by private mode. Finally, only 15 percent of households live in areas served by the rail transit system. The proportion of households live near rail transit service with at least one car per household is around 61 percent. The results also reveal that 67.30 percent of those live near rail transit service get to work by transit while only 23.27 percent use a private car. Simple statistics suggests that home locations have a transit service availability strongly influence commuting.

Table 1. Descriptive statistics

Respondent characteristics	Private mode	Public mode (exclude rail transit mode)	Rail transit mode
	Frequency (%)	Frequency (%)	Frequency (%)
Household size			
1 person	18 (29.03%)	11 (17.74%)	33 (53.23%)
2 persons	91 (43.96%)	68 (32.85%)	47 (22.71%)
3 persons	144 (49.83%)	82 (28.37%)	63 (21.80%)
>3 persons	229 (45.62%)	131 (26.10%)	140 (27.89%)
Household income per month			
<20,000 baht or <US$670	6 (19.35%)	13 (41.94%)	11 (35.48%)
20,000-50,000 baht or US$670 – US$1,670	114 (30.89%)	138 (37.40%)	116 (31.44%)
>50,000 baht or >US$1,670	362 (54.85%)	141 (21.36%)	156 (23.60%)
Household car			
None	52 (17.81%)	130 (44.52%)	108 (36.99%)
1 car	293 (51.40%)	141 (24.74%)	136 (23.86%)
2 cars	100 (67.57%)	18 (12.16%)	30 (20.27%)
>2 cars	37 (74.00%)	3 (6.00%)	9 (20.00%)
Home served by rail transit system			
Served by rail transit system	37 (23.27%)	13 (8.18%)	107 (67.30%)
Non-served by rail transit system	445 (49.39%)	279 (30.97%)	176 (19.53%)

4. Discrete Choice Model

The discrete choice modeling paradigm, in particular multinomial logit, which has for decades dominated in the field of residential location choice analysis. In general, models of discrete choice analysis are usually based on the random utility maximization framework (RUM). Discrete choice models, namely rank-ordered logit (ROL) and rank-ordered nested logit, used in this paper have the features described below.

4.1 Rank-Ordered Logit Model (ROL)

The rank-ordered logit model (ROL), which is an extension of the multinomial logit model, was introduced in the literature by Beggs *et al.* (1981). Empirical applications describing preferences using the ROL model can be found in several fields such as school choice (Drewes and Michael, 2006; Mark *et al.*, 2004) and transportation studies (Calfee *et al.*, 2001; Kockelman *et al.*, 2009; Srinivasan *et al.*, 2006), but less intention in residential location choice studies in recently.

[1] The annual income per capita of Bangkok was 412,887 baht/year or 13,400 $US/year in 2010.

Traditionally, the application of discrete choice model for a choice experiment measures the importance of the features of a good or service by asking each individual to choose his/her preferred alternative from a number of choice sets while a rank-ordered experiment is achieved by asking the respondents to rank a number of alternatives within the choice sets. In this way, the respondents can be asked to state which alternative they would choose, then, after they made this choice, they can be asked to which the remaining alternatives they would choose, continuing through all the alternatives. This process can reflect the better view on the preferences of a household. The model specification (Fok *et al.*, 2010; Kockelman *et al.*, 2009; Train, 2002) will be describe as below.

We index the alternatives by j = 1, 2,.., J and individuals by n = 1, 2,.., N. As in the case of multinomial logit model, the rank-ordered logit can be motivated by a random utility model (RUM). Using RUM theory, the utility of an alternative j for person n can be written as follow:

$$U_{nj} = \beta X_{nj} + \varepsilon_{nj} = V_{nj} + \varepsilon_{nj} \qquad (1)$$

where U_{nj} is the utility of alternative j as perceived by individual n. X_{nj} is the vector of the attributes characterizing alternative j and individual n. β is the vector of coefficients to be estimated and ε_{nj} is a random unobserved component of utility, assumed to be independent and identically distributed (iid). The term $\boldsymbol{\beta} X_{nj}$ in equation (1) is known as the deterministic or systematic component of the utility function, denoted as V.

In the situation of the ROL model, the first rank alternative is imagined as the most preferred alternative with the highest utility in the standard multinomial logit model. The second rank is viewed as the preferred alternative from the entire choice set except the ones with a better ranking (a choice set without the first rank alternative). From this point of view, the ranking is deterministic. Then, the utilities for ranking can be expressed as:

$$U_{nj_{n1}} > U_{nj_{n2}} > \ldots > U_{nj_{nr}} > \ldots > U_{nj_{nJ}} \qquad (2)$$

where j_{nr} = { j_{n1}, $j_{n2}, \ldots, j_{nJ}$ }denotes alternative j that received rank r by individual n. For example, $U_{nj_{n1}}$ now denotes the utility of the first rank that individual n gives to alternative j and $U_{nj_{n2}}$ denotes the utility of the second rank that individual n gives to alternative j.

According to the iid nature of the error term[2], the probability that a given ranking of alternatives will be observed equals the probability of choosing the first ranked alternative from the set of J alternatives, times the probability of choosing the second ranked alternative from the remaining J-1, and so on.

Under the above assumption, the probability of the ROL can be written as follows:

$$\Pr[U_{nj_{n1}} > U_{nj_{n2}} > \ldots > U_{nj_{nr}} > \ldots > U_{nj_{nJ}}] = \prod_{j=1}^{J-1} \frac{\exp\left(V_{nj_{nr}}\right)}{\sum_{h=j}^{J} \exp\left(V_{nJ_{nh}}\right)} \qquad (3)$$

4.2 Rank Ordered Nested Logit Model (RONL)

An alternative to the conventional logit model is the rank-ordered nested logit model. The ROL model is derived from the assumptions about the characteristics of choice probabilities,

2 As is typical of ML models, an iid assumption on the Gumbel error term imposes the independence of irrelevant alternatives (IIA) property (Train, 2002).

namely the independence of irrelevant alternative (IIA) which implies proportional substitution across alternatives. Generalized extreme value (GEV) models constitute a large class of models that exhibit a variety of substitution patterns. The most widely used member of the GEV family is called nested logit model (NL). The mathematical formulation of this model follows the utility maximizing NL model developed by McFadden (1978). However, the current study is developed a nested logit (NL) framework for rank-ordered alternatives.

A conceptual two-tiered ranked-ordered nested logit model of residential location choice is shown in Figure 2. In this tree diagram, residential location is expressed in binary terms: either one resides in districts with a rail station or not. The bottom level of the tree, location choice, is represented as a part of area in Bangkok Metropolitan Region or generally called districts. Additionally, from the Figure 1, 15 alternatives were classified, into two groups: districts with rail transit station and districts without rail transit station. This nested model is hierarchical and sequential, treating the influences of proximity to transit station on location/district choice directly. As note, this paper focuses on location choice and rail transit service system. The model specification (Jafari, 2010) will be described as below.

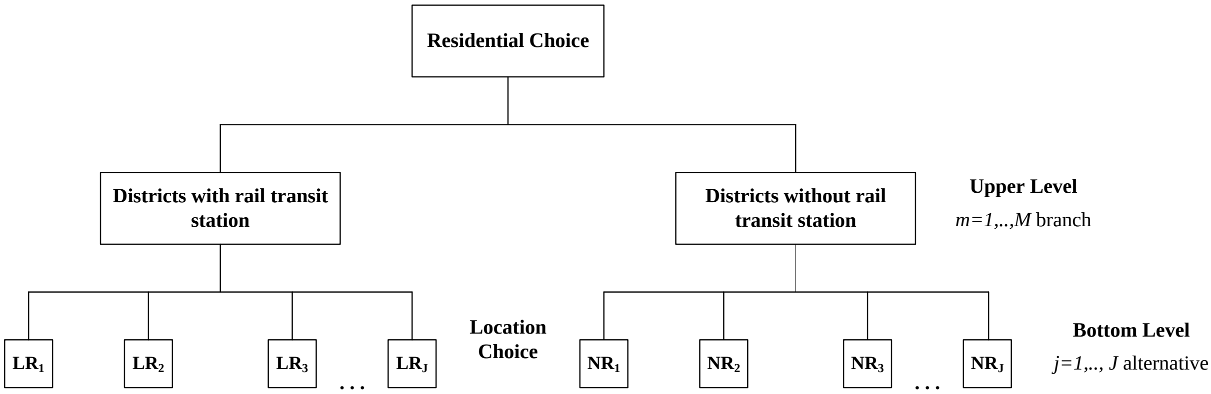


Figure 2. Two-Tiered Nested Structure of Residential Location Choice

From Figure 2, we index the alternative in the bottom level by j = 1, 2,.., J and the nest in the upper level by m=1,2,.., M. The utility for ranking can be expressed as equation (2). The probability of rank-ordered nested logit can be expressed as the product of two simple rank-ordered logits.

$$P_{nj_{nr}} = P_{nj_{nr}|m_r} \times P_{nm_r} \tag{4}$$

where $P_{nj_{nr}|m_{nr}}$ is the conditional probability that individual n ranks alternative j given in the upper nest m and P_{nm_r} is the marginal probability of ranking alternative in upper nest m.

Now, let r = 1 denotes the rank that individual n gives alternative j as the first rank. The probability of the first rank can be expressed as follow:

$$P_{nj_{n1}} = P_{nj_{n1}|m_1} \times P_{nm_1} \tag{5}$$

The conditional and marginal probabilities for the first ranked alternative can be written as follows:

$$P_{nj_{n1}|m_1} = \frac{\exp\left(V_{nj_{n1}|m_1} / \lambda_{m_1}\right)}{\sum_{j \in m_1}^{J} \exp\left(V_{nJ|m_1} / \lambda_{m_1}\right)} \tag{6}$$

$$P_{nm_1} = \frac{\exp\left(V_{nm_1} + \lambda_{m_1} I_{m_1}\right)}{\sum_{m=1}^{M} \exp\left(V_{nm} + \lambda_m I_m\right)} \tag{7}$$

where $V_{nj_{n1}|m_1}$ is the deterministic component of utility for individual *n* ranking alternative *j* given in the upper nest *m* as the first rank and V_{nm_1} is the measurable component of utility for individual *n* ranking the upper nest *m*, while λ is called the dissimilarity parameter, reflecting different correlation among unobserved factors within each nest. The range of this dissimilarity parameter should between 0 and 1 for all nests. A high λ means greater independence and less correlation. Therefore, a value of $\lambda_m = 1$ means complete independence in the upper level *m*. Obviously, if $\lambda_m = 1$ for all nests, then the GEV distribution simply becomes the produce of independent extreme value terms, i.e., the rank-ordered nested logit reduces to the standard rank-ordered logit model.

The inclusive value for the upper nest *m* (denoted this value by I_m) corresponds to the expected value of the utility that individual *n* obtains by consuming an alternative *j* in the upper nest *m*. is defined as:

$$I_{m_1} = \ln \sum_{j \in m_1} \exp(V_{nJ|m_1} / \lambda_{m_1}) \tag{8}$$

Next, let *r* = 2 if individual *n* ranks alternative *j* from the remaining *J*-1 in the upper nest *m* (after remove the first rank alternative) as the second rank. The probability of the second rank can be written as follow:

$$P_{nj_{n2}} = P_{nj_{n2}|m_2} \times P_{nm_2} \tag{9}$$

If the second rank alternative is not in the same nest as the first rank, the bottom level conditional choice probability can be written similar to the equation (6). Then, the marginal choice probability of ranking upper nest *m* (that containing the second rank alternative *j*) has the form the same as equation (7) and the inclusive value can be written as equation (8).

If the second rank alternative is in the same nest as the first rank, the bottom level conditional choice probability after remove the first rank alternative can be written as follow:

$$P_{nj_{n2}|m_2} = \frac{\exp\left(V_{nj_{n2}|m_2} / \lambda_{m_2}\right)}{\sum_{j \in m_2, j \neq j_{n1}} \exp\left(V_{nJ|m_2} / \lambda_{m_2}\right)} \tag{10}$$

The marginal choice probability of ranking upper nest *m* (that containing the first and the second ranked alternative in the same nest) has the form:

$$P_{nm_2} = \frac{\exp\left(V_{nm_2} + \lambda_{m_2} I_{m_2}\right)}{\sum_{m=1}^{M-1} \exp\left(V_{nm} + \lambda_m I_m\right)} \tag{11}$$

The inclusive value of for the upper nest *m* has the form:

$$\mathrm{I}_{\mathrm{m}_2} = \ln \sum_{j \in m_2, j \neq j_{n1}} \exp(V_{nJ|m_2} / \lambda_{\mathrm{m}_2}) \tag{12}$$

Also, to obtain the other choice probabilities with lower ranking, they can be treated in a similar way. Finally, the probability that a given ranking of alternatives will be observed equals the probability of choosing the first ranked alternative from the set of *J* alternatives, times the probability of choosing the second ranked alternative from the remaining *J*-1, and so on.

$$\Pr[U_{nj_{n1}} > U_{nj_{n2}} > \ldots > U_{nj_{nr}} > \ldots > U_{nj_{nJ}}] = P_{nj_{n1}} \times P_{nj_{n2}} \times \ldots \times P_{nj_{nr}} \tag{13}$$

5. EMPIRICAL RESULTS

5.1 Variable Specifications

The explanatory variables considered in the residential location choice decisions are broadly classified into five groups together with socio-demographics interactions and summarized in Table 2, described as below.

5.1.1 Local transportation accessibility measure

Local transportation accessibility measures relate to the urban rail transit and expressway facilities within zones: transit service availability, proximity to the rail transit station and the expressway ramp (as in access ramp). For the transit service availability within zones, the dummy variable is employed. The value is set to 1 if those alternative zones are served by urban rail transit, and set to 0 otherwise. The proximity to the rail transit station and the expressway ramp refer to the straight line distance to the nearest transit station and the expressway access ramp which are computed using the Geographic Information System (GIS) tools. These measures are included because they represent local measures of transit and auto levels of service which can impact the residential choice decisions.

5.1.2 Work accessibility measure

Work accessibility refers to commute time (minute) to the central business district where there are physically concentrated in the inner core of the Bangkok Metropolitan Region: Sukhumvit and Silom Area. This variable is computed from the TDMC V[3] model by making use of JICA STRADA[4]'s trip and transit assignment program. For this variable, we measured by using the dummy variable. The value is set to 1 if those alternative zones are located within 45 minute from the CBD, and set to 0 otherwise. The past studies revealed that the commute time to workplace influences on the residential location choice, however, they are unclear as to how long be acceptable.

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[3] TDMC V is the project that is to develop and maintain transportation and traffic model, transportation and traffic information including providing and developing GIS (Geographic Information System) data which emphasize Bangkok and suburban areas (http://www.otp.go.th/doc/project/tdmc%20V/EXECUTIVE%20SUMMARY%20REPORT_Eng.pdf)

[4] JICA STRADA (JICA System for Traffic Demand Analysis) is a package system for transport forecasting http://www.intel-tech.co.jp/strada/products/strada/indexe.html

5.1.3 Housing affordability

This variable refers to assessed land price (baht/sq.m) in each zone. The government appraised land value was obtained from the assessed land value reports, which were published by The Treasury Department, Thailand. The period time of land price is during the year 2008 and 2011. Typically, assessed value (price) is the value used by local governments to determine the property taxes. This is generally an unrealistic value. Often times too low, but sometimes high; however, it often bears relationship to the real value of property. Although the assessed land value is not a true market value, it is used in this study because the market transaction price data is not consistent and reliable in Thailand.

Table 2. Description of variables

Variables	Description
Local transportation accessibility measure	
DIST_STA	Straight line distance to the nearest transit station (meter x 10^{-1})
TRAN_AVA x TRAN_USER	Rail transit station (dummy variable, value is 1 if the distance to the nearest station is less than 2 kilometer, 0 otherwise) interacted with rail transit user households (dummy variable, value is 1 if transit user, 0 otherwise)
DIST_EXP x NO_CAR	Distance to expressway interacted with no car ownership (dummy variable, value is 1 if no car ownership, 0 otherwise)
DIST_EXP x CAR_OWN	Distance to expressway interacted with car ownership (dummy variable, value is 1 if at least one car ownership, 0 otherwise)
Work accessibility measure	
COM_TIME45m	Commute time to workplace (dummy variable, value is 1 if each zone of alternative can reach to the CBD within 45 minute, 0 otherwise)
Housing affordability	
LAND_PRICE	Zonal assessed land price (baht per square meter x 10^{-5})
Neighborhood amenities	
MED_INC	Median household income in each zone of alternative (baht per month)
EMP_DENS x LOW_INC	Logarithm of employment density interacted with low income households (dummy variable, value is 1 if low income households, 0 otherwise)
EMP_DENS x MID_INC	Logarithm of employment density interacted with middle income households (dummy variable, value is 1 if middle income households, 0 otherwise)
EMP_DENS x HIGH_INC	Logarithm of employment density interacted with high income households (dummy variable, value is 1 if high income households, 0 otherwise)
SCHOOL_DENS	School density (students per square kilometer)
INDUSTRIAL	Area of Industrial land use (square kilometer)
Household demographics	
LOW_INC	Low income households (dummy variable, value1 if income is less than 20,000 baht per month, 0 otherwise)
MID_INC	Middle income households (dummy variable, value1 if income is 20,000 – 50,000 baht per month, 0 otherwise)
HIGH_INC	High income households (dummy variable, value1 if income is more than 50,000 baht per month, 0 otherwise)
TRAN_USER	Household mainly get to work by rail transit (dummy variable, value1 if get to work by rail transit, 0 otherwise)
HOME_RPASS	Current home location (dummy value 1 if current home location is served by rail transit system, 0 otherwise)
MEMBER_LESS_3	Household size (dummy variable, value 1 if number of member less than 3, 0 otherwise)

5.1.4 Neighborhood amenities

These variables include the density of each zone (e.g. employment per square kilometer as well as student per square kilometer) and the land use composition measures (e.g. the zonal area in residential, commercial, industrial and other land uses). The density of the zones is also obtained from the transportation model of Bangkok Metropolitan Region (e-BUM) while the land use composition data was obtained from Department of City Planning and Department of Public Works and Town and Country Planning, Thailand. Both variables are chosen to determine the effect of neighborhood environment on residential choice.

5.1.5 Household demographics

An investigation into the relationship between housing preferences and choice of residential location is associated with the different groups of households. In this paper, household composition, namely, income level, car ownership, travel behavior, current home location, and size of household is an important variable to consider with regard to location decision. Specifically, income level was divided into three groups: low income (less than 20,000 baht or US$670 per month), middle income (20,000 baht – 50,000 baht or US$670 – US$1,670 per month) and high income (more than 50,000 baht or US$1,670 per month). Next, the TRAN_USER variable assigns to capture the behavior of daily trip for work purpose. In addition, this variable indicates by dummy variable: the value set to 1 if households get to work using rail transit and otherwise set to 0. While, the current home location (HOME_RPASS) also indicates by dummy variable in order to understanding the preferences of households, who presently live near the rail transit network and live far away, in residential location decisions. Finally, the member of household also measures by dummy variable (NUMBER_LESS_3): the value set to 1 if the member is less than three persons per households and otherwise set to 0.

5.1.6 Interaction of household demographics with attributes

Another important focus of this paper is to examine the variations in sensitivity across the households to attributes of alternatives such as local transportation accessibility, work accessibility, median land value as well as zonal density and land use structure. For example, housing price has a negative effect on location preference; however, this effect decreases as the household income increases (de Palma *et al.*, 2005). In the other word, households with high income earnings are less sensitive to the housing price than those with low income earnings. Thus, we combine the different groups of variables identified in the earlier sections with the household demographics such as income, household structure, as well as the household daily trips.

Rank-ordered and rank-ordered nested logit results are presented in Table 3. Full information maximum likelihood estimation was used in deriving estimates. Variables were included in models' utility expressions on the basis of econometric theory and statistical fits.

5.2 Rank Ordered Logit Model Results

After extensive experimentations with different specifications, one rank-ordered logit model was chosen based on the theoretical and statistical significance of the estimated parameters. The ROL model results show on the left-hand side of Table 3.

Table 3. Estimation Results of the ROL and RONL Models

Variables	ROL		RONL	
	Parameter	t-Statistic	Parameter	t-Statistic
Bottom nest				
Local transportation accessibility measure(including demographic interactions)				
DIST_STA	-0.3140	-7.0601	-0.1821	-5.2485
TRAN_AVA x TRAN_USER	0.4875	7.0314	0.0845	3.4225
DIST_EXP x NO_CAR	0.3475	4.2272	0.0978	3.7427
DIST_EXP x CAR_OWN	0.3304	5.4021	0.0789	3.5457
Work accessibility measure				
COM_TIME45m	0.2015	3.4138	0.0319	2.0473
Housing affordability				
LAND_PRICE	-1.7837	-8.3579	-0.3394	-3.7105
Neighborhood amenities(including demographic interactions)				
MED_INC	1.6495	3.0335	0.5226	3.0226
EMP_DENS x LOW_INC	1.2159	6.0490	0.2823	3.4840
EMP_DENS x MID_INC	0.6582	9.2109	0.1450	3.9831
EMP_DENS x HIGH_INC	0.3153	5.3248	0.0628	2.8941
SCHOOL_DENS	1.7516	12.1315	0.4168	5.3913
INDUSTRIAL	-0.1021	-6.8941	-0.0219	-3.9059
Upper nest				
Rail station within district				
TRAN_USER			0.4673	4.3991
HOME_RPASS			0.2972	3.5632
MEMBER_LESS_3			0.1675	2.1972
Dissimilarity				
Rail station within district (λ)			0.2825	7.5750
Rho-square (Nagelkerke)		0.2766		0.3020

As expected, the coefficient on the proximity to the nearest transit station has the negative sign, indicating that households strongly prefer zone with shorter distance to transit stations. Moreover, the model results reveal that households mainly get to work by rail transit are more likely to live in areas having stations within a 2 kilometer walking distance than those car dependent households. This suggests that rail transit service can play significant role in shaping residential location choices of households. Previous studies found the negative effect of highway and freeway on choice behavior (Bina *et al.*, 2006; de Palma *et al.*, 2005). Next, the results also show that higher levels of car ownership increase the chance of residing near the expressway access (relative to the categories of the distance to expressway access interacted with car ownership). In the other word, it is interesting note that car ownership likely influences the decision to live closer to the access. In fact, Bangkok is the most heavily congested cities; the expressway allows households to reduce journey time. In term of the work accessibility which is simply measured by the dummy variable of the commute time to the CBD. Trials of models were attempted for 45, 60, and 90 minute as well, however the best-fitting and most interpretable statistical results were obtained for the alternative zones can reach to the CBD within 45 minute. In fact, person living in Bangkok spends more than one hours travelling to/from work. This could reflect the willingness of households; however, the better should be less than 60 minute. Housing affordability is another major factor influencing residential location choice. As expected, the land price has a negative coefficient, indicating that more expensive locations are less likely to choose, i.e., as the land price rises, the likelihood of that zone being chosen by households as a residential location falls. A clustering effect is observed with respect to the zonal household income. The results support the income segregation phenomenon observed in previous study, e.g. (Bhat and Guo, 2004); Morrow-Jones and Kim (2009). Then, the employment density interacted with socio-demographic coefficients (EMP_DENS x LOW_INC, EMP_DENS x MID_INC, and EMP_DENS x HIGH_INC) indicate that households tend to reside in areas with high employment density however this effect decreases as the household income increases. As expected, the locations with higher school density are remarkably preferred to those with lower school density. Finally, the industrial land use measure is negatively associated with residential location choice, indicating that locations with higher number of industrial area are generally less preferred.

5.3 Rank Ordered Nested Logit Model Results

The rank-ordered nested logit (RONL) model results show on the right-hand side of Table 3. In general, the bottom level of RONL model reveals the same trend of the ROL model, i.e., both models offer similar effects. Specifically, coefficient signs are consistent with respect to the effects across two model specifications.

The upper level, live far away from the rail station nest, was considered the reference choice and three household specific variables were specified for this interpretations. All of these variables have the expected positive sign and they are all statistically significant. The first variable, TRAN_USER, captures the travel behavior in daily activity destination, namely, work location. As expected, this estimated coefficient suggests that households whose get around by transit are more likely to stay near the rail transit station than far away, which corresponds to the empirical evidence in the literature that says as the number of commuters in the household who have transit connectivity increases, the likelihood of residential location in a zone with transit availability increases as well (Sener *et al.*, 2011). The next variable, HOME_RPASS, is related to current home location of households. The estimated parameter reveals that households whose current home location is served by the rail transit system tend to be drawn to the rail transit station areas. This result reflects other studies that showed the strong preference of the households to move in the same district or the same neighborhood in which they lived before (de Palma *et al.*, 2005). The last variable, MEMBER_LESS_3, the model suggests that the households with three or more than shy away from locations near rail transit stations. Actually, trials of models were attempted for many such as one person, more than two persons, more than three persons, etc. however the best-fitting and most interpretable statistical results were obtained from the number of member is less than 3 persons per households. This could be reflect land use planning policies that promote high-rise building development especially near rail stations, i.e., residential (e.g. condominium and apartment) and commercial (e.g. office building). Specifically, the characteristics of condominium and apartment are typically smaller than houses (e.g. detached house, semi-detached house and townhouse) which might suitable for single and couple households.

From the Table 3, the dissimilarity or correlation parameter, λ_m, is an indicator whether nesting is appropriate or not. As stated in the derivation, the dissimilarity parameter for the ROL model is one as the multinomial logit (ML) model because both models assume independence across all choice alternatives. The RONL model partially relaxes the IIA assumption by maintain IIA for choices with same nest, but relaxing it for choices across nests. It was then found that the dissimilarity for the “rail station within districts” nest is small at 0.2825 and this parameter is statistically significantly different from one at the 0.05 level of significance which supports the hierarchical nest structure, i.e., the RONL rejects the ROL model. If we compare the estimated results obtained from using rank-ordered logit (ROL) with the results derived from rank-ordered nested logit (RONL) in term of significance level, it will find that both of them are all significant. Furthermore, we still compare across models using rho-square (ρ^2) which takes into account the outperformance. From the values, rho-square (ρ^2), reported in Table 3, it can be seen that the RONL model is much consistent with the obtained data than the ROL model which suggests that grouping subsets of alternatives that are more similar to each other with respect to excluded characteristics than they are to other alternatives can offer great benefits..

6. CONCLUSION

This paper develops a methodological framework in the analysis of residential location decision behavior. An application of discrete choice model, namely multinomial logit (ML) is widely used in many previous literatures due to its flexible and easy interpretation. However, the current study is developed logit framework for ranking experiment, i.e., the extension of the ML model namely rank-ordered logit (ROL) model. Ranking data provides more statistical information than choice experiments, which lead to tighter confidence intervals around the parameter estimates (Merino-Castello, 2003). The ROL model has been known and used for measuring consumer preferences for a long time, but so far has rarely been explored and employed for the context of analyzing location choices. Furthermore, the two-tiered rank-ordered nested logit (RONL) is an alternative to relax assumption of the ROL model namely the independence of irrelevant alternative (IIA), i.e., the development of a nested logit (NL) framework for ranking data. If we compare the estimated results obtained from using the ROL model with the results derived from the RONL model, the RONL model is much consistent with the obtained data than the ROL model which suggests that grouping subsets of alternatives that are more similar to each other with respect to excluded characteristics than they are to other alternatives can offer great benefits.

This paper aims to investigate the influencing factors impact on the residential location choice behavior using discrete choice frameworks as explained above. The important findings from the empirical analysis are as follows. First, local transportation accessibility does affect residential location decisions. For example, the models confirm the influencing of the proximity to rail transit station, i.e., the closer to them, the preferable to choose. Moreover, among travel behaviors, mainly get around by rail transit, is a key variable in affecting the sensitivity to the urban rail transit service availability. Furthermore, while the proximity to transit stations is generally recognized as the dominating factor in rail transit user group, car ownership likely influences the decision to live closer to expressway access. These imply that travel behavior and socio-demographics (i.e. car ownership) are the dominant factor in residential sorting. In contrast, residential location decision impacts on the travel behavior and car ownership decisions as well. Thus, policy decisions regarding changes in local transportation accessibility and neighborhood attributes have to be evaluated in the context of these decisions. Moreover, this information is important suggesting for appropriate policy such as promote transit use, i.e., improving station area to more effectively and provide feeder modes with cost effective and high security and safety. Next, another socio-demographic, i.e., household income is the determinant factor of segregation phenomenon in choice of residential location. Other demographic factors that impact residential preferences correspond to the size of household, such that single or couple households tend to draw themselves near the rail transit stations. Besides, households prefer to live in the same neighborhood in which they lived before. Finally, in term of future research, there is a great need for a better understanding of the complex interactions between residential location and other aspects such as middle term (e.g. car ownership) and long term (e.g. work location) decisions.

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