2015

A Direct Demand Model of Departure Time and Mode for Intercity Passenger Trips

Fatemeh Nazari
The University of Texas Rio Grande Valley

Setedehsan Seyedabrishami

Amir Reza Mamdoohi

A Direct Demand Model of Departure Time and Mode for Intercity Passenger Trips

Fatemeh Nazari[1], Seyedehsan Seyedabrishami[2] and Amir Reza Mamdoohi[2]

Received: 03.05.2015 Accepted: 11.01.2016

Abstract

Travel demand is well announced as a crucial component of transportation planning. This paper aims to develop a direct demand model, denoting a more acceptable abstraction of reality, for intercity passengers in daily work and leisure trips in Tehran province. The model utilizes combined estimation across the data source, collected in 2011, of travelers originating from the city of Tehran and heading toward two destination clusters: intra-province and inter-province. The paper sketches a way to predict simultaneous choice of departure time and travel mode under the influence of zonal (origin, destination, and residence), individual and household socio-demographic, and trip-related variables. The time frame for analysis of departure time is [5-19] and available modes are auto, taxi, bus, and metro. Multinomial Logit (MNL) and Nested Logit (NL) models as behavioral models are selected from discrete choice family to provide appropriate direct demand structure. Besides, the paper discusses Independent Irrelative Alternative (IIA) assumption of the models and demonstrates choice order of NL; Travelers choose departure time prior to mode at first level and then decide on mode at second level. Finally, travel demand elasticity and marginal effect with respect to travel time, age, and auto cost are also highlighted.

Keywords: Direct demand, departure time, mode, multinomial logit, Nested Logit

---

Corresponding author E-mail: seyedabrishami@modares.ac.ir

1. Msc. Grad., Department of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran
2. Assistant Professor, Department of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran

1. Introduction

How can we decide on transportation system development and what will happen after executing these decisions? Answering this question requires predicting future travel demand as a crucial input, which is also an important step of transportation planning. Transportation demand is a derived demand of peoples' activities, which has different dimensions. Two major classifications of transportation demand are passenger/freight and urban/intercity transportation [Kanafani, 1983]. In this paper, we intend to scrutinize intercity passenger demand.

Travelers encounter different interrelated decisions, which can be modeled either sequentially or simultaneously. We suppose that distinctive features of intercity passenger trips (i.e. longer trip distance and fewer available modes of transportation) compared to urban passenger trips push us to opt for simultaneous models [Ortuzar and Willumsen, 2011]. Furthermore, in order to better consider travelers' behavior we use disaggregate models instead of aggregate ones. To put the whole paper in a nutshell, we primarily focus on disaggregate demand of intercity passengers to fit the best model describing travel decisions simultaneously.

There are different approaches to simultaneously probe into travel demand related decisions like destination, mode, and departure time (DT). One approach for direct demand modeling has multiplicative form, in which travel demand is a function of socio-economic and activity variables estimated for intercity passenger travel demand in the Washington-Boston corridor [Kraft, 1968; Manheim, 1979]. Furthermore, simultaneous decisions like destination and mode can be modeled in entropy maximization method as another approach [Wilson, 1974; Ortuzar and Willumsen, 2011]. Finally, another approach for disaggregate investigation of direct demand is applying discrete choice models, which are widely utilized in the literature and is intended for this paper.

After nominating discrete choice approach for disaggregate direct demand modeling, another question arises: which decisions of trip can be considered simultaneous? Researchers' motivation and the scope of data can be directions for determining the synchronized decisions, which are the basis of the remainder of this section illustrating a brief review of literature.

DT of urban shopping trips can be modeled in continuous form. This model supposes a probability function with specific distribution for DT and considers arrival time as a function of travel time and then calculates the probability of selecting DT. On the other hand, trip DT can be broken into discrete time intervals like morning peak hour, morning off-peak, evening peak hour, and evening off-peak to be utilized for discrete choice models [Bhat and Steed, 2002].

Parallel to DT, mode of travel impresses the total performance of system [Yang et al., 2013]. They are highly correlated and travelers usually make a simultaneous choice of them [Hess et al., 2007; Ozbay and Yanmaz-Tuzel, 2007; Habib, 2011], on which our principal focus is. Bhat (1998) inquired into essential features of direct choice of DT and mode for San Francisco shopping trips. His final model was a NL model with the upper level representing mode and the lower level indicating DT, which were modeled by MNL and ordered Logit, respectively. Bajwa et al. (2008) studied simultaneous choices of DT and mode of Tokyo daily trips in morning peak hour. They evaluated different structures of discrete choice models including generalized extreme value models with closed form (MNL, NL, generalized Logit, and generalized NL models) and a new structure of mixed Logit. Finally, mixed Logit, generalized NL, NL, and generalized Logit showed better performance, respectively. The results showed that travelers first decide on DT and then think about mode in the NL model structure. In addition, Vickrey (1969) and Bajwa et al. (2008) exhibited high correlation between DT and delay.

Habib (2011) combined continuous form of DT with discrete variable of mode to form simultaneous choice model because many choices of transportation, land use, and daily employment of people are inherently simultaneous and discrete-continuous. He based decision making of people on Random Utility Maximization (RUM) to consider individual behavior and analysis of applied policy [McFadden, 1973; Ben-Akiva, 1985; Wen, 2010]. This method can be implemented for simulation of other scenarios like tour or trip chain, activity scheduling, and interaction of transportation and land use [Miller, 2005; Habib, 2007]. After combination of DT and mode, budget limit can be considered for continuous part (DT). Such a model has an econometrics form and it can be used for modeling of activity-based trip demand [Habib, 2011].

Commutes are highly correlated with residential zone and mode choice [Brown, 1986], which should be considered in transportation planning and urban economics because of high effects on trip pattern [Guo and Bhat, 2001; Bhat and Guo, 2004; Khattak and Rodriguez, 2005; Kim et al., 2005; Vega and Reynolds-Feighan, 2009]. Yang et al. (2013) added residential location to simultaneous choice of DT and mode of Beijing people by using NL and cross-NL models. Considering house price, travel time, travel cost, and socio-demographic features as exogenous variables, cross-NL generates better results. As exogenous variables change, decision makers first change DT, then mode, and at last their residential location. Also, sensitivity analysis indicates that in long distance trips, increasing auto cost cannot transfer mode from auto to other modes.

Other choices of trip can also be regarded concurrent. For example, Hess et al. (2012) applied cross-NL model to stated preference data for appraising vehicle type and fuel type choices of Californians. Another example is simultaneous choices of destination and mode that can be modeled in shopping trips [Richards and Ben-Akiva, 1974]. Newman et al. (2010) used NL model structure for urban work trips. This model has three levels; At first, people choose between motorized (auto and public transportation) and non-motorized (walk and bike) modes; Then, they specify their travel mode and finally they select destination. In this model, the primary choice of travelers is mode and then they decide on destination. In other words, they tend to change destination more than mode because of fewer variety of alternatives for mode.

Mode and destination choices can be related to trip frequency by accessibility concept to solve the inelastic demand problem and NL can model them simultaneously [Iglesias et al., 2008]. Another application of accessibility concept is for improvement of transportation conditions (level of service), which has short and long-term effects. Short-term effects contain DT, generation, destination, mode, and route changes and long-term effects consist of household car ownership and redistribution of activities. Yao and Morikawa (2005) conducted a study on integrated intercity travel demand composing of generation, distribution, mode, and route. The authors explained destination, mode, and route choices by accessibility concept to correlate it to the change in level of service. They estimated NL model by stated and revealed preference disaggregate data excluding generation step, which was modeled by regression.

Comparing sequential and direct demand models, Tahmasebi (2000) showed the better performance of direct models of mode and destination choice for Mashad case study. Also, Shahangian (2012) considered two transportation management policy sets including three deterrent policies for using auto and two encouragement policies for using public transportation. She investigated gender differences in response to policies targeting shopping and education trips going to automobile-restricted central business district in morning peak hour. She revealed that cross-NL model outperforms MNL and NL models to describe mode choice behavior.

Reviewed literature tells us that passengers have to make different simultaneous choices at the beginning of their trips. Hence, direct demand models, by integrating different decisions in one single framework, can denote a more accurate abstraction of reality. Besides, discrete choice models can represent a direct model for this mechanism better than other behavioral models. Numerous models exist in discrete choice category but NL model fits the data better than others. Eventually, based on the literature two choices of DT and mode can be investigated as endogenous variables.

2. Methodology

Choice is one of the building blocks of trip decision-making process according to the fact that travelers always have to make choices among a set of alternatives for every trip attribute such as destination, mode, DT, and route. Therefore, modeling trip choices is one of the important factors of trip demand analysis [Kanafani, 1983; Train, 2002]. To this end, discrete choice modeling approach is adopted to directly predict DT and mode choice of intercity travelers, the methodological background of which is briefly illustrated in this section.

Decision maker (*n*) makes his/her travel choice(s) by maximizing his/her utility (U_{in}), which is a function of the alternative and decision maker characteristics and environmental conditions. The utility is contributed to each alternative (i) of choice set (I), containing deterministic (V_{in}) and stochastic (ε_i) parts according to Eq. (1). This is called random utility maximization model and is suitable to directly predict travel demand. Assuming Gumbel distribution for stochastic part of the utility function leads to Logit model. If there are several alternatives, the Logit model is called MNL, which is the most applicable framework with simple mathematical structure and easy estimation procedure. The associated probability, P_n *(i)*, for MNL model is shown in Eq. (2) with scale parameter β [Domencich and McFadden, 1975].

$$U_{in} = V_{in} + \varepsilon_i \quad (1)$$

$$P_{in} = \frac{\exp(\beta\, V_{in})}{\sum_{i' \in I} \exp(\beta\, V_{i'n})} \quad (2)$$

MNL is derived with the assumption of the independence of irrelevant alternatives (IIA), based on which the share of new alternative (s) can be predicted. Some other models like Probit and NL relax this assumption, the latter of which is formed by grouping dependent alternatives as one set in separate levels and is utilized for the current research. Under NL setting, the probability of choosing alternatives can be calculated by Eq. (3) to Eq. (6).

Williams (1977) initially worked with a two level model in the context of two-dimensional situations, such as departure time-mode choice, defining utility function of the Eq. (3). Where i denotes alternatives at a lower level nest and j the alternative at the upper level that represents that lower level nest. In term of the representative utility and stochastic term, Eq. (3) changes to Eq. (4). Where the terms of the Eq. (4) can be described in Eq. (5).

$$U\,(i,j) = U_i + U_{i/j} \quad (3)$$

$$U\,(i,j) = V\,(i,j) + \varepsilon\,(i,j) \quad (4)$$

$$V\,(i,j) = V_j + V_{i/j} \quad and \quad \varepsilon\,(i,j) = \varepsilon_j + \varepsilon_{i/j} \quad (5)$$

A very popular NL specification in practice is one with just two levels of nesting and different scale parameters λ_j in each nest, whose functional form is given by Eq. (6) [Williams, 1977].

$$P\,(i,j) = \frac{\exp(\lambda_j V_{i/j})}{\sum_{i' \epsilon j} \exp(\lambda_j V_{i'/j})} \cdot \frac{\exp \beta \,\{\frac{1}{\lambda_j} \log(\sum_{i \epsilon j} \exp(\lambda_j V_{i/j})\}}{\sum_{j'=1}^{m} \exp \beta \,\{\frac{1}{\lambda_{j'}} \log(\sum_{i \epsilon j'} \exp(\lambda_{j'} V_{i/j'})\}} \quad (6)$$

3. Model Estimation and Results

As stated in previous sections, NL, as a discrete choice model, is deployed in this paper to predict intercity direct demand. Details of the case study (Tehran province intercity trips), the basic dataset, and data clustering are illustrated in the first part of this section. The second part delineates the estimated models and their comparison.

3.1 Data

The required disaggregate data were gathered during a week in July, 2012 by Parseh Transportation Research Institute as a part of transportation master plan of intercity travels in Tehran province. The survey was conducted in several roadside and passenger terminal stations, the coverage of each of which was limited to 12 hours from 7 am to 7 pm (Tarahan Parseh Transportation Research Institute, 2012).

A sample of 3210 individuals were interviewed to find out travelers’ revealed preferences such as origin, destination, trip purpose, mode, DT, income, age, etc. The sample of these data for this paper encompasses the information of travelers originating from the city of Tehran and heading toward destinations in either Tehran province (except the city of Tehran) or any of the neighboring provinces (i.e. Alborz, Mazandaran, Semnan, Qom, and Markazi). Trip purpose of these travelers is daily work or leisure trips with frequency of 1708 and 783 trips out of 3210, respectively.

The dataset gives us three kinds of variables as

Table 1.Trip frequencies of destination zones

Group	Zone	City/Town or Province	Trip Frequency (Relative Frequency %)	
Intra-Province	North and East of Tehran province	Firouzkooh, Damavand, Roudehen, Lavasanat, Oshan and Fasham, and Pardis	243 (13)	1811 (73)
	South of Tehran province	Aftab, Rey, Kahrizak, Hasanabad, Imam Khomeini International Airport, Sharif abad, Pakdasht, Qarchak, Varamin, Pishva	496 (27)	
	West of Tehran province	Eslamshahr and Chahardangeh, Robat Karim, Parand, Golestan, Boustan, Vahidieh, Shahriar, Qods, Malard	498 (27)	
	Alborz province	Alborz province	574 (32)	
Inter-Province	Mazandaran province	Mazandaran province	488 (72)	680 (27)
	Semnan province	Semnan province	36 (5)	
	Qom province	Qom province	56 (8)	
	Markazi province	Markazi province	100 (15)	

below:

1. Zonal: origin, destination, residence,
2. Socio-demographic: gender, age, household income, household size, car ownership, job (clerk, self-employed, university student, and other), and
3. Choice: distance, travel time, departure time [5-19], travel mode (auto, taxi, bus, and metro), and auto cost.

Assuming that every passenger car, depending on the type, consumes approximately [8-12] liters per 100 kilometers and the average gas price is about 7000 Rials per liter, the auto cost can be calculated with the use of distance. Furthermore, household income is categorized in four groups:

4. Group A: Less than 7.5 million Rials per month,
5. Group B: More than 7.5 and less than 15 million Rials per month,
6. Group C: More than 15 and less than 20 million Rials per month, and
7. Group D: More than 20 million Rials per month.

Considering many factors including urban and rural population, household size, employment, agricultural area, population density, transported freight, and geographic boundaries, the study area is divided to 12 traffic analysis zones. Each of the neighboring provinces (i.e. Mazandaran, Semnan, Qom, and Markazi) is considered as one traffic analysis zone. Also, the city of Tehran is divided to four separate zones (north, south, east, and west), the effects of which on travelers' choice can then be investigated. Finally, the remaining four zone are Alborz province, north/east, west, south of Tehran province. It should be noted that Alborz province is marked as an intra-province destination because of its recent dissociation from Tehran province, similar travel behavior, and close neighborhood.

These zones are labeled as origin, destination, and residential area. Four of these zones (i.e. north, south, east, and west of the city of Tehran) are contemplated as origin zones. The other eight zones are divided to two groups as destination zones: inter-province and intra-province zones. Obviously, the neighboring provinces are considered as inter province and the remaining are intra-province (Table-1 and Figure **1**).

According to Table-1, Intra-province trips comprise 73% of all trips. The most frequent trips are between the city of Tehran and Alborz province and the least frequent trips pertain to north and east of Tehran province as their destination. 27% of trips are inter-province, the most and the least frequent of which belong to Mazandaran and Semnan provinces as destination, respectively.

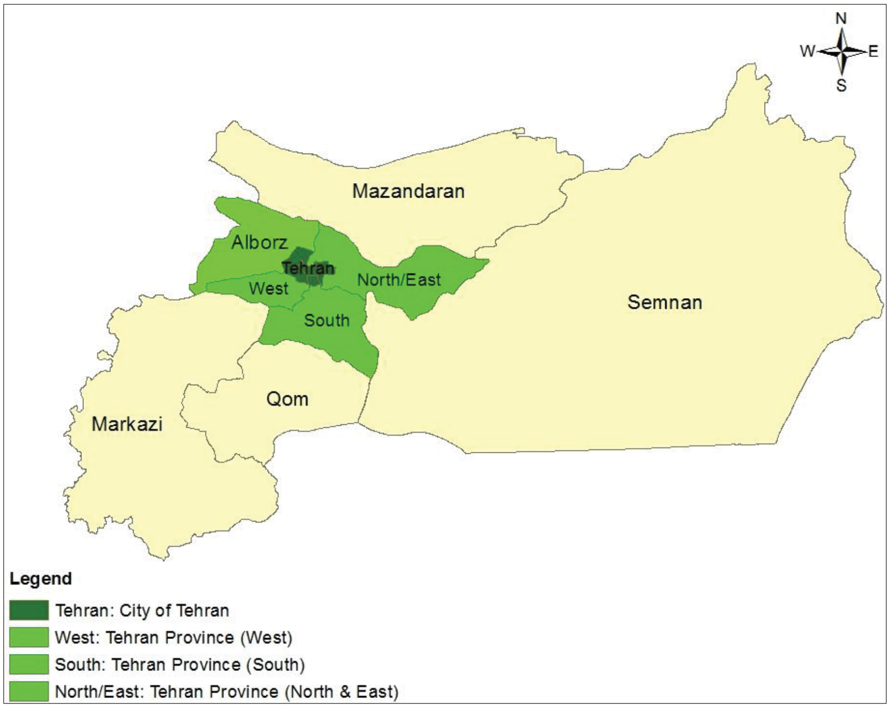

Figure 1- Traffic Analysis Zones

Table 2.Trip frequencies of home zones

Group	Zone	City/Town or Province	Trip Frequency (Relative Frequency %)	
Intra-Province	North and east of Tehran province	Firouzkooh, Damavand, Roudehen, Lavasanat, Oshan and Fasham, and Pardis	51 (3)	1811 (73)
	South of Tehran province	Aftab, Rey, Kahrizak, Hasanabad, Imam Khomeini International Airport, Sharif abad, Pakdasht, Qarchak, Varamin, and Pishva	130 (7)	
	West of Tehran province	Eslamshahr and Chahasdange, Robat Karim, Parand, Golestan, Boustan, Vahidieh, Shahriar, Qods, and Malard	148 (8)	
	Alborz province	Alborz province	297 (16)	
	City of Tehran	Tehran city	1185 (65)	
Inter-Province	Home in	Alborz province and Tehran province	433 (64)	680 (27)
	Home out	Mazandaran, Semnan, Qom, and Markazi provinces	247 (36)	

Home zones are categorized in a similar manner although with some differences. Table 2 illustrates each category and the associated frequency. In the case of intra-province trips, home zones have been extended with the inclusion of the city of Tehran zone. Home zones of inter-province trips have different classification from destination zone categorization due to non-uniform distribution of home zones. In-province home zone class is assigned to Tehran and Alborz provinces and out-province home zone class refers to other provinces. As indicated in Table 2, most of people involved in intra-province trips live in the city of Tehran and most of inter-province travelers live in Tehran and Alborz provinces.

3.2 Model Estimation

As mentioned in previous sections, this research enquires into the travelers' simultaneous trip mode and DT choice behavior for daily work and leisure intercity trips in Tehran province. DT range for collected data is from 5 of morning to 19 dividing into peak hour and off-peak hour for auto, taxi, bus, and metro modes. On the other hand, destinations are grouped into two categories, i.e. intra-province and inter-province. Based on trip purpose and destination category, four types of models are estimated in this section: intra-province daily work, intra-province leisure, inter-province daily work, and inter-province leisure trips. These models are estimated by discrete choice software of Limdep (version 4).

Having determined the endogenous variables, the exogenous ones are coded according to Table-3 to calibrate the models. We initially tried to fit MNL model, which is constrained by the IIA assumption, to dissect simultaneous travelers' DT and mode choices. P-values of Husman tests for all four models are 0.000, implying that the IIA assumption is violated. As a way to resolve this problem, we can break the choices into two levels with the use of NL model having closed form and good interpretability; DT is in the first level and mode is in the second level. This addresses the relaxing of the IIA assumption between peak and off-peak hour DTs. On the other hand, coefficient of Logsum or inclusive value (IV) parameter cannot be statistically 0 or 1 and p-values of the coefficient and Wald test show acceptable significance levels, respectively (**Error! Reference source not found.**).In addition, these p-values, for four models, verify correct choice order and splitting DT to peak and off-peak hour and related ranges. Moreover, $\square^2$ and $\square_c^2$ for NL model have improved compared to MNL model leading us to use NL Model.

The common characteristic of all model types is the choice order, which implies that DT is the upper level choice and lower level is mode. In other words, travelers first choose their time of departing from origin and then decide on mode. Apart from the destination group and trip purpose, these four groups differ in the available modes and peak and off-peak hour DT range because of different frequency distributions. For example, peak hour DT for daily work trips is from 7 to 11 while this range is 13 to 18 for leisure trips in the intra-province trips.

Details of models are described in the following sections that intra-province daily work trips are reported in first section and the second part deals with intra-province leisure trips. The third and fourth sections explain inter-province trips with daily work and leisure purposes, respectively.

3.2.1 Intra-Province Daily Work Trip

The first type of the models captures travelers' behaviors in daily work trips generated from the city of Tehran heading toward intra-province destinations. Available modes (auto, taxi, bus, and metro) and DT (peak hour and off-peak hour) constitute eight choices. As displayed in Figure-2, upper level is departure time choice and the lower level is mode of travel. Peak hour is defined form 7 to 11 and off-peak hour ranges from 5 to 7 and 11 to 17. Also, the related frequencies are shown in the parentheses.

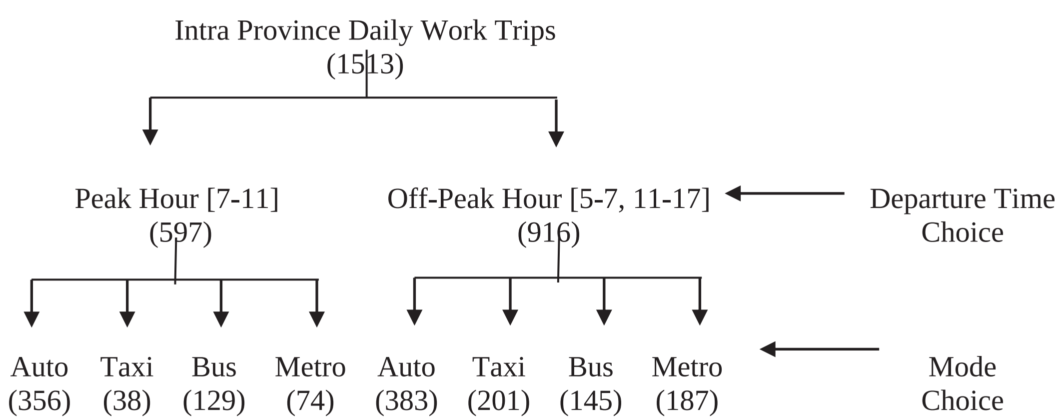

Figure 2.Choice Levels for Intra Province Daily Work Trips (Frequency)

Two variable types with acceptable significance levels fit the final models: continuous and discrete (dummy). The former includes cost and time while the latter includes car ownership, origin zone of trip, and gender. Table shows the value and sign of each of them in the utility function and the related p-value in MNL and NL models. As shown in **Error! Reference source not found.**, gender, cost, and travel time are important in both mode and DT choices. Females prefer to travel by metro in all existing DTs. Then, they tend to use bus and taxi about 5.8 and 3.6 times more than auto, respectively. In contrast to expectation, the sign of auto cost in the utility function of auto is positive. This implies that travelers still maintain their tendency to use auto for daily work trips even though auto cost increases, which was also addressed in the literature. The negative coefficients of travel time in auto and taxi utility functions indicate that bus and metro are more preferred for longer travel times than auto and taxi. The other three variables, i.e. car ownership, origin zone, and job, are appeared in DT utility function. The negative sign for car ownership exhibits that households without car do not tend to go to daily work during peak hours. Residents of north and east of the city of Tehran do not prefer to make their trips in peak hours owing to the negative coefficient (-0.235), while the residents of south and west behave conversely. Clerks, university students, retired persons, and self-employed people are considered in this model type treating in two manners; According to **Error! Reference source not found.**, self-employed people choose the off-peak hours whereas the others elect the peak hours.

3.2.2 Intra-Province Leisure Trip

In this type of trips, people depart from the city of Tehran during the peak or off-peak hours and go to intra-province destinations by auto, bus, and metro modes (Figure **3**). Peak hour DT is from 13 to 18 and off-peak DT is from 6 to 13 and 18 to 19.

This model comprises two continuous variables (time and age) and five discrete (dummy) ones (residential location, gender, household income level, and household size). All of the variables are statistically significant for DT choice. Influential variables for mode choice are gender, household income level, destination, and household size. Long time trips are done in off-peak hours because of the negative sign in the peak hour DT utility function (-0.003) whereas time is not influential for modal split. Logarithmic form of age is a significant factor for deciding on DT. As logarithm of age increases, traveling during peak hours becomes more desirable. Residents of north, east, and west of Tehran province tend to make their leisure trips during the off-peak hour DT. Females have inertia of using auto and metro; Auto inertia in off-peak hours is about twice the peak hours while it is equal for metro for the whole DTs. On the other hand, males have strong desire to use auto especially in off-peak hours. As expected, low-income people (lower than 7.5 million Rials/month) do not tend to use auto and prefer bus or metro while travelers with higher income prefer to drive auto in all available DTs. Regardless of peak and off-peak hour, travelers living alone have desire to undertake these trips by metro; On the contrary, auto and bus have the same inclination for people not living alone. Trips ending in north, east, and west of Tehran province are more conducted by auto compared to south of Tehran province, Alborz province, and the city of Tehran during the peak hour. Furthermore, the preference of modes for all destinations is equal in off-peak hours.

3.2.3 Inter-Province Daily Work Trip

The other type of daily work trips encompasses those trips originating from the city of Tehran to inter-province destinations, which is modeled in MNL with six choices containing peak hour and off-peak hour DTs and three modes (auto, taxi, and bus). Mode choice is accomplished in the lower level and DT choice places in the upper level, according to Figure **4** (i.e. 6 to 10 for peak hour and 5 to 6 and 10 to 19 for off-peak hour DTs).

Two variable types, the same as the intra-province daily work trips, model the daily work trips to the neighboring provinces. The continuous variables are time and logarithm of age and the discrete (dummy) ones are residential location, household income level, destination, gender, car ownership, and job. DT choice is influenced by all the aforementioned variables while mode is impressed by female, logarithm of age, job, car ownership, and time variables. People with low household income (under 7.5 million Rials/month) have higher propensity to make daily work trips in peak hours. Positive sign for Tehran province residents in peak hour DT utility function suggests that these travelers tend to make their work trips during the peak hours, no matter by which mode. People who work in Qom and Semnan provinces travel during the off-peak hours while the others (Mazandaran and Markazi provinces) pick out the peak hours. Females generate 17% of these inter-province daily work trips and are more inclined to adopt taxi and bus compared to auto. Moreover, time appears with a negative sign (-0.014), indicating that as travel time increases bus

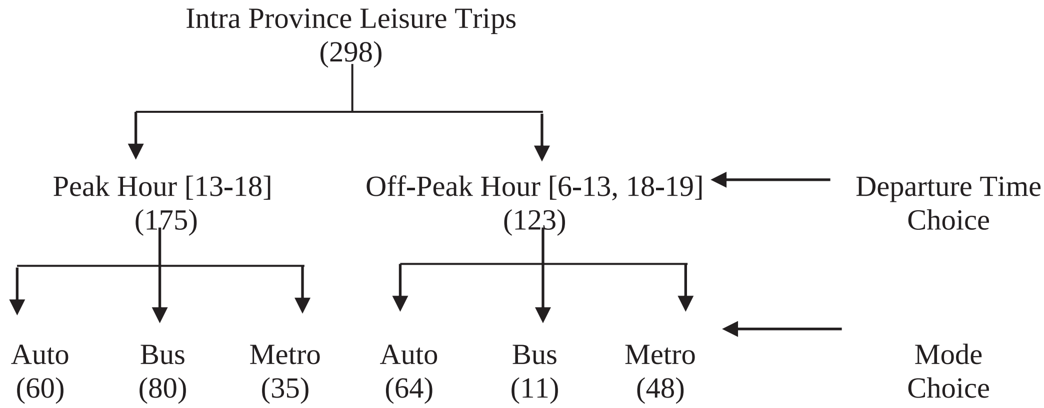

Figure 3-Choice Levels for Intra Province Leisure Trips

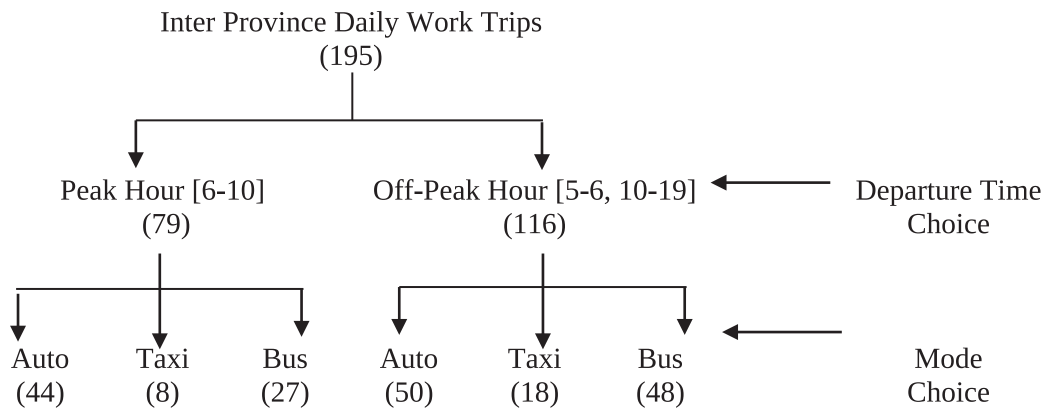

Figure 4. Choice levels for inter province daily work trips

becomes more preferred in all DTs. Taxi is the dominant mode for clerks, university students, and self-employed people departing in peak hours but bus and auto are chosen by all other daily workers. All three modes have equal preferences in off-peak hours for all inter-province daily work trips. Older workers (age is in logarithmic form) who depart during the peak hours prefer taxi to other modes. Intuitively, people without car do not tend to use this mode throughout all DTs while people with one car tend to use their private car just in off-peak DT. However, owners of more than one car would rather make their daily work trips by their private cars in all DTs.

3.2.4 Inter-Province Leisure Trip

Analogous to other model types, MNL model is first fitted to describe travelers' behavior departing from the city of Tehran to inter-province destinations There are four choices made up of auto and bus modes and peak hour (13-18) and off-peak hour (5-13) DTs (

Figure **5**).

Two variable types, continuous (time and age) and discrete-dummy (residential location, job, car ownership, and gender) are used for the estimation of the last model. Residents of Tehran and Alborz provinces opt for the off-peak hour DT to generate leisure trip by auto or bus because of the negative coefficient (-0.436) in peak hour utility function. The job variable sign is positive for clerks, university students, and self-employed ones for both modes, implying that these people tend to travel during the peak hours. However, the aforementioned variables, i.e. residential location and job, do not cause any preferences for mode choice. Travelers possessing more than one car are inclined to go to leisure trips by their car notwithstanding the DT. Moreover, persons without car or with one car prefer to use bus. Females have intense appetite to make their leisure trip to inter-province destinations by bus departing in all times. The negative sign of time in auto utility function (-0.014) implies that long time trips push travelers to choose bus. When people get older, they tend to use auto during the peak hours whereas aging has no effect on mode choice in off-peak hour DT.

3.3 Models Comparison

The fitted models can be placed side by side to being collated based on three proxies: variables coefficients, elasticities of demand, and marginal effects, all of which are described below separately.

3.3.1 Coefficient

Comparing all trips departing from the city of Tehran to either inside or outside of Tehran province, intended for daily work or leisure activities, reveals that females are interested in using auto in inter-province trips compared to other trips. On the other hand, bus alternative is valued differently for females in each model type; their first preference for using bus is inter-province leisure trips and the second is inter-province daily work or intra-province leisure trips. Eventually, intra-province daily work trip is less preferred for them. Taxi is females' favorite mode except for intra-province daily work trips. Also, metro is chosen for all trips eliminating intra-province leisure trips.

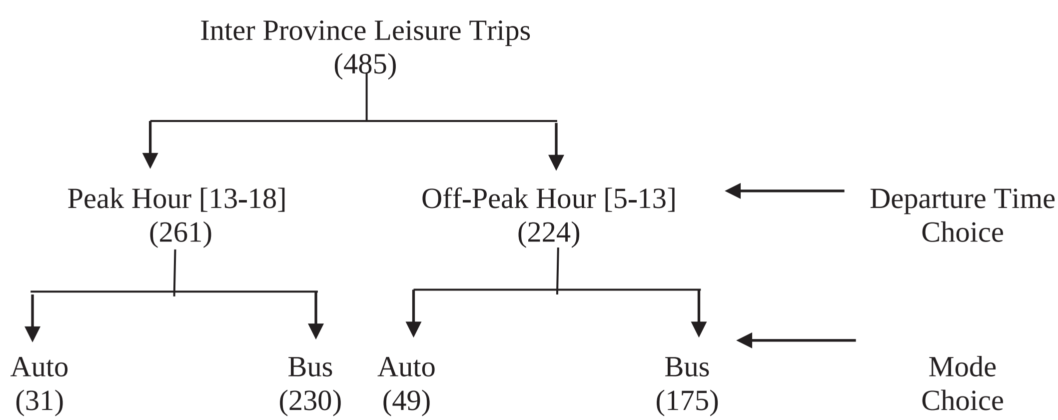

Figure 5. Choice levels for inter province leisure trips

Table 3. Coding of useful variables in models

Variable Category	No.	Variable	Variable Type	Variable Description	Variable Coding
Zonal	1	Home A	Dummy	Residence zone A (north and east of Tehran province)	Residence zone A (1), Others (0)
	2	Home B	Dummy	Residence zone B (south of Tehran province)	Residence zone B (1), Others (0)
	3	Home C	Dummy	Residence zone C (west of Tehran province)	Residence zone C (1), Others (0)
	4	Home D	Dummy	Residence zone D (Alborz province)	Residence zone D (1), Others (0)
	5	Home E	Dummy	Residence zone E (Tehran city)	Residence zone E (1), Others (0)
	6	Home In	Dummy	Residence zone In (Tehran and Alborz provinces)	Residence zone In (1), Others (0)
	7	Home Out	Dummy	Residence zone Out (Mazandarn, Semnan, Qom, and Markazi provinces)	Residence zone Out (1), Others (0)
	8	Origin A	Dummy	Trip origin A (west of Tehran city)	Trip origin A (1), Others (0)
	9	Origin B	Dummy	Trip origin B (east of Tehran city)	Trip origin B (1), Others (0)
	10	Origin C	Dummy	Trip origin C (north of Tehran city)	Trip origin C (1), Others (0)
	11	Origin D	Dummy	Trip origin D (south of Tehran city)	Trip origin D (1), Others (0)
	12	Destination A	Dummy	Trip destination A (north and east of Tehran province)	Trip destination A (1), Others (0)
	13	Destination B	Dummy	Trip destination B (south of Tehran province)	Trip destination B (1), Others (0)
	14	Destination C	Dummy	Trip destination C (west of Tehran province)	Trip destination C (1), Others (0)
	15	Destination D	Dummy	Trip destination D (Alborz province)	Trip destination D (1), Others (0)
	16	Destination M	Dummy	Trip destination M (Mazandaran province)	Trip destination M (1), Others (0)
	17	Destination N	Dummy	Trip destination N (Semnan province)	Trip destination N (1), Others (0)
	18	Destination O	Dummy	Trip destination O (Qom province)	Trip destination O (1), Others (0)
	19	Destination P	Dummy	Trip destination P (Markazi province)	Trip destination P (1), Others (0)
Socio-Demographic	20	Female	Dummy	Gender	Female (1), Male (0)
	22	Age	Continuous	Age	-
	23	Log Age	Continuous	Logarithm of age	-
	24	Income A	Dummy	Income A (Household income: 0-7.5 million Rials/month)	Income A (1), Others (0)
	25	Income B	Dummy	Income B (Household income: 7.5-15 million Rials/month)	Income B (1), Others (0)
	26	Income C	Dummy	Income C (Household income: 15-20 million Rials/month)	Income C (1), Others (0)
	27	Income D	Dummy	Income D (Household income: >20 million Rials/month)	Income D (1), Others (0)
	28	HH Size A	Dummy	Household size=1	Household size=1 (1), Others (0)
	29	HH Size T	Dummy	Household size >1	Household size >1 (1), Others (0)
	30	Car ownership A	Dummy	Household car ownership=0	Household car ownership =0 (1), Others (0)
	31	Car ownership B	Dummy	Household car ownership =1	Household car ownership =1
	32	Car ownership T	Dummy	Household car ownership >1	Household car ownership >1
	33	Job A	Dummy	Clerical job	Clerical job (1), Others (0)
	34	Job C	Dummy	Self employed job	Self employed job (1), Others (0)
	35	Job D	Dummy	University student job	University student job (1), Others (0)
	36	Job E	Dummy	Other jobs	Other jobs (1), Others (0)
Choice	37	Time	Continuous	Travel time	-
	38	Cost	Continuous	Auto cost	-

Table 4. Results of direct model of DT and mode choice

Variables	Intra-Province								Inter-Province							
	Work Trips				Leisure Trips				Work Trips				Leisure Trips			
	MNL Model		NL Model		MNL Model		NL Model		MNL Model		NL Model		MNL Model		NL Model	
	Parameter	t-Stat	Parameter	t-Stat	Parameter	t-Stat	Parameter	t-Stat	Parameter	t-Stat	Parameter	t-Stat	Parameter	t-Stat	Parameter	t-Stat
Constant																
Taxi-Peak Hour	-2.166	0.000	-2.063	0.000	-	-	-	-	-15.304	0.004	-	-	-	-	-	-
Taxi-Off-Peak Hour	-0.520	0.000	-0.565	0.000	-	-	-	-	-1.600	0.000	-	-	-	-	-	-
Bus-Peak Hour	-1.304	0.000	-1.221	0.000	-1.875	0.000	-1.398	0.001	-4.035	0.000	-	-	-	-	-	-
Bus-Off-Peak Hour	-1.178	0.000	-1.274	0.000	-3.859	0.000	-4.756	0.000	-3.447	0.000	-	-	-	-	-	-
Metro-Peak Hour	-2.002	0.000	-1.873	0.000	-1.192	0.000	-0.782	0.000	-	-	-	-	-	-	-	-
Metro-Off-Peak Hour	-1.083	0.000	-1.169	0.000	-0.911	0.001	-1.554	0.000	-	-	-	-	-	-	-	-
Auto-Peak Hour	-	-	-	-	-	-	-	-	-	-	-	-	3.143	0.000	2.242	0.009
Auto-Off-Peak Hour	-	-	-	-	-	-	-	-	-	-	-	-	3.571	0.000	3.668	0.000
Socio-Demographic																
Female-Auto-Peak Hour	-3.009	0.000	-2.933	0.000	-2.327	0.000	-2.297	0.000	-3.433	0.001	-	-	-	-	-	-
Female-Auto-Off-Peak Hour	-3.009	0.000	-2.933	0.000	-3.742	0.000	-4.649	0.000	-3.433	0.001	-	-	-	-	-	-
Female-Taxi	-0.708	0.001	-0.753	0.001	-	-	-	-			-	-	-	-	-	-
Female-Bus	-0.553	0.006	-0.467	0.022	-	-	-	-			-	-	2.258	0.000	2.227	0.000
Female-Metro-Peak Hour	-	-	-	-	-2.327	0.000	-2.297	0.000			-	-	-	-	-	-
Female-Metro-Off-Peak Hour	-	-	-	-	-2.327	0.000	-2.297	0.000			-	-	-	-	-	-
Household A-Metro	-	-	-	-	1.330	0.134	1.478	0.088			-	-	-	-	-	-
Income A-Auto	-	-	-	-	-0.674	0.012	-.0732	0.011			-	-	-	-	-	-
Logarithm of Age-Taxi-Peak Hour	-	-	-	-	-	-	-	-	3.210	0.019	-	-	-	-	-	-
Logarithm of Age-Bus-Peak Hour													0.005	0.061	-0.018	0.071
Job A-Taxi-Peak Hour	-	-	-	-	-	-	-	-	2.722	0.003	-	-	-	-	-	-
Job C-Taxi-Peak Hour	-	-	-	-	-	-	-	-	2.722	0.003	-	-	-	-	-	-
Job D-Taxi-Peak Hour	-	-	-	-	-	-	-	-	2.722	0.003	-	-	-	-	-	-
Car Ownership A-Auto-Peak Hour	-	-	-	-	-	-	-	-	-0.708	0.003	-	-	-0.911	0.089	-0.894	0.093
Car Ownership A-Auto-Off-Peak Hour									-0.708	0.003	-	-	-0.911	0.089	-0.894	0.093
Car Ownership B-Auto-Peak Hour	-	-	-	-	-	-	-	-	-0.708	0.003	-	-	-0.911	0.089	-0.894	0.093
Car Ownership B-Auto-Off-Peak Hour													-0.911	0.089	-0.894	0.093
Choice																
Cost-Auto (Rial)	$0.8*10^{-5}$	0.013	$0.8*10^{-5}$	0.009	-	-	-	-	-	-	-	-	-	-	-	-
Time-Auto (Minutes)	-0.297	0.000	-0.310	0.000	-	-	-	-	-0.014	0.000	-	-	-0.014	0.000	-0.014	0.000
Time -Taxi (Minutes)	-0.297	0.000	-0.310	0.000	-	-	-	-	-0.014	0.000	-	-	-	-	-	-
Zonal																
Destination A-Auto-Peak Hour	-	-	-	-	0.054	0.813	0.068	0.063	-	-	-	-	-	-	-	-
Destination C-Auto-Peak Hour	-	-	-	-	0.054	0.813	0.068	0.063	-	-	-	-	-	-	-	-

Constant																
Peak Hour	-	-	-0.004	-0.979	-	-	-3.411	0.015	-	-	1.032	0.000	-	-	1.442	0.018
Socio-Demographic													-	-		
Car Ownership A-Peak Hour	-	-	-0.472	0.001	-	-	-	-	-	-	-	-	-	-		
Job C-Peak Hour	-	-	-1.257	0.000	-	-	-	-	-	-	-	-	-	-	0.428	0.092
Job A-Peak Hour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.428	0.092
Job D-Peak Hour	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.428	0.092
Logarithm of Age-Peak Hour	-	-	-	-	-	-	0.859	0.029	-	-	-	-	-	-		
Income A-Peak Hour	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Choice																
Time-Peak Hour	-	-	-	-	-	-	-0.003	0.079	-	-	-	-	-	-		
Zonal																
Origin B-Peak Hour	-	-	-0.235	0.033	-	-	-	-	-	-	-	-	-	-		
Origin C-Peak Hour	-	-	-0.235	0.033	-	-	-	-	-	-	-	-	-	-		
Home A-Peak Hour	-	-	-	-	-	-	-1.180	0.047	-	-	-	-	-	-		
Home C-Peak Hour	-	-	-	-	-	-	-1.180	0.047	-	-	-	-	-	-		
Home In-Peak Hour	-	-	-	-	-	-	-	-	-	-	0.915	0.012	-	-	-0.436	0.098
Destination B-Peak Hour											-0.713	0.065	-	-		
Destination C-Peak Hour											-0.713	0.065	-	-		
Logsum																
Coefficient-Peak Hour	-	-	1.000	-	-	-	1.000	-	-	-	1.000	-	-	-		
Coefficient-Off-Peak Hour	-	-	0.644	0.000	-	-	0.785	0.000	-	-	0.461	0.018	-	-		
Wald Test-Peak Hour	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Wald Test-Off-Peak Hour	-	-	1.972	0.050	-	-	2.150	0.050	-	-	2.778	0.010	-	-		
No. of Observation	1513		1513		485		485		195		195		485		485	
Log Likelihood	-2722.752		-2682.681		-419.040		-419.040		-247.685		-231.767		-459.553		-447.430	
ρ^2	0.135		0.138		0.188		0.196		0.291		0.301		0.317		0.295	
ρ^2_{adj}	0.132		0.136		0.174		0.189		0.272		0.290		0.311		0.290	
ρ^2_c	0.047		0.050		0.160		0.138		0.229		0.243		0.161		0.135	
$\rho^2_{c\,adj}$	0.044		0.049		0.146		0.130		0.209		0.232		0.154		0.129	
p-value of Husman Test	0.000		-		0.000		-		0.000		-		0.000		-	

Time is a prominent factor for all trips excluding intra-province leisure trips, in which increasing time has a negative effect on riding car. Intuitively, travel time has decreasing effect on daily work trips compared to leisure ones either inside or outside of Tehran province. On the other hand, auto cost is an influential variable on intra-province daily work trips with unexpected positive sign, which insinuates decision makers' tendency to use it regardless of cost. Moreover, travelers' age in logarithmic form impresses inter-province trips with positive effect on daily work trips and negative effect on leisure ones. Finally, possession of car is important for inter-province travelers that people with more than one car tend to ride their car for these trips. Persons without car or with one car prefer to go to daily work trips by taxi or bus and also they tend to use bus for leisure trip.

3.3.2 Elasticity and Marginal Effect

Elasticity and marginal effect values provide another approach for evaluating the sensitivity of demand to continuous variables (cost, time, and age), which are presented in Table 5. The use of probability weighted sample enumeration technique has an important ramification for the direct point elasticity and direct marginal effect, which weights each individual decision maker differently to produce non-uniform direct point elasticity and direct marginal effect [Louviere et al., 2000].

In spite of expectation, intra-province daily work trips by auto is inelastic to cost variable. One percent increase in auto cost will not change the probability of selecting the auto alternative drastically. Also, auto cost has 0 marginal effect during all DTs. Age is the next continuous variable appearing in inter-province leisure trip with -0.26 elasticity for bus, implying that as age increases by one percent the probability of choosing bus in peak hour DT does not change so much. Besides, -0.36 marginal effect shows the decreasing probability value of choosing this alternative in effect of unit age increase. Age variable has logarithmic form in inter-province daily work trips with positive and elastic effect on taxi choice in peak hour DT. One percent increase in age logarithm increases the taxi choice probability during peak hours by 9.04 elasticity. In light of travel time, all trips except intra-province leisure trips are influenced by with negative sign. All inter-province trips are elastic to time while intra-province daily work trips are not.

4. Concluding Remarks

Travel demand is well reported as a crucial component of transportation planning. This research aims to develop a direct demand model for intercity passengers in daily work and leisure trips to capture a more acceptable abstraction of reality. The required data are collected in 2011 from Tehran province intercity trips, and the sample relates to travelers originating from the city of Tehran with destinations in either Tehran province (except the city of Tehran) or neighboring provinces. Clustering the destinations forms two model categories: intra-province (Tehran province, except the city of Tehran and Alborz province) and inter-province (Mazandaran, Semnan, Qom, and Markazi provinces). Besides, residential location zones are clustered to better interpret the results. The paper sketches a way to predict simultaneous choice of departure time and travel mode under the influence of zonal (origin, destination, and residence), individual and household socio-demographic, and trip-related variables. The time frame for analysis of departure time is [5-19] and available modes are auto, taxi, bus, and metro. These choices are combined to generate alternatives, which are dependent in Multinomial Logit (MNL). We use Nested Logit (NL) models to resolve IIA assumption between alternatives. DT places in the first choice level and mode appears in the second choice level in NL model. This means that the violation of the IIA assumption between peak and off-peak hour DTs is addressed, however modes of each DT category are still assumed to be independent. As expressed in previous sections, $\square^2$ and $\square_c^2$ in NL have improved compared to MNL in all four model types. Finally, travel demand elasticity and marginal effect with respect to travel time, age, and auto cost are also highlighted.

Table 3. Direct point elasticity and direct marginal effects of continuous variables

Model Type	Variable	Direct Point Elasticity								Direct Marginal Effect							
		Peak Hour Departure Time				Off-Peak Hour Departure Time				Peak Hour Departure Time				Off-Peak Hour Departure Time			
		Auto	Taxi	Bus	Metro	Auto	Taxi	Bus	Metro	Auto	Taxi	Bus	Metro	Auto	Taxi	Bus	Metro
Intra-Province Daily Work Trips	Cost	0.22	-	-	-	0.19	-	-	-	0.00	-	-	-	0.00	-	-	-
	Time	-0.22	-0.29	-	-	-0.21	-0.26	-	-	-6.16	-0.84	-	-	-5.64	-3.61	-	-
Inter-Province Daily Work Trips	Time	-1.09	-1.93	-	-	-1.11	-1.78	-	-	-0.27	-0.17	-	-	-0.23	-0.16	-	-
	Log Age	-	9.04	-	-	-	-	-	-	-	37.69	-	-	-	-	-	-
Inter-Province Leisure Trips	Time	-2.43	-	-	-	-2.13	-	-	-	-0.16	-	-	-	-0.22	-	-	-
	Age	-	-	-0.26	-	-	-	-	-	-	-	-0.36	-	-	-	-	-

As avenues for future research, necessary data for choosing destination and residential zone can be collected for Tehran province to estimate direct demand of destination, residential location, departure time, and mode. Furthermore, stated preference data can be gathered beside revealed preference to investigate short-term (i.e. mode, route) and long-term (i.e. destination, residential location, and generation) induced demand due to network changes. As another suggestion for future work, departure time of presented models can be considered continuous to utilize discrete-continuous models as another approach. Also, some budget limits can be applied for continuous part, i.e. time limit for departure time.

5. Acknowledgment

The authors would like to thank Tarahan Parseh Transportation Research Institute for providing the data used in our analysis.

6. References

-Bajwa, S., Bekhor, S., Kuwahara, M., Chung, E. (2008) “Discrete choice modeling of combined mode and departure time”, Transportmetrica, Vol. 4, No. 2, pp. 155-177.

-Ben-Akiva, M. E. (1985) “Discrete choice analysis: theory and application to travel demand”, Cambridge, MA: MIT Press.

-Bhat, C. R. (1998) “Analysis of travel mode and departure time for urban shopping trips”, Transportation Research Part B: Methodological, Vol. 32, No. 6, pp. 361-371.

-Bhat, C. R. and Guo, J. (2004) “A mixed spatially correlated logit model: formulation and application to residential choice modeling”, Transportation Research Part B: Methodological, Vol. 38, No.2, pp. 147-168.

-Bhat, C. R. and Steed, J. (2002) “A continuous-time model of departure time choice for urban shopping trips”, Transportation Research Part B: Methodological, Vol. 36, No. 3, pp. 207-224.

-Brown, B. (1986) “Modal choice, location demand, and income”, Urban Economics, Vol. 20, No. 2, pp. 128-139.

-Domencich, T. and McFadden, D. (1975) “Urban travel demand: A behavioural analysis”, North-Holland, Amsterdam.

-Guo, J. Y. and Bhat, C. R. (2001) “Residential location choice modeling: A methodological logit approach”, University of Texas at Austin, TX, USA.

-Habib, K. M. N. (2013) “A joint discrete-continuous model considering budget constraint for the continuous part: application in joint mode and departure time choice modeling”, Transportmetrica A: Transport Science, Vol. 9, No. 2, pp. 149-177.

-Habib, K. M. N. (2007) “Modeling activity generation processes”, University of Toronto, Canada.

-Hess, S., Daly, A., Rohr, C. and Hyman, G. (2007) “On the development of time period and mode choice models for use in large scale modeling forecasting systems”, Transportation Research Part A: Policy and Practice, Vol. 41, No. 9, pp. 802-826.

-Hess, S., Fowler, M., Adler, T., Bahreinian, A. (2012) “A joint model for vehicle type and fuel type choice: evidence from a cross-nested logit study”, Transportation, Vol. 39, No. 3, pp. 593-625.

-Iglesias, P. (2008) “A joint model of generation, distribution and mode choice for intercity travel”, Proceedings XIV Panamerican Congress on Traffic and Transportation Engineering, September, Colombia.

-Kanafani, A. (1983) “Transportation demand analysis”, New York, CA: McGraw-Hill.

-Khattak, A. J. and Rodriguez, D. (2005) “Travel behavior in neo-traditional neighborhood developments: A case study in USA”, Transportation Research Part A: Policy and Practice, Vol. 39, No. 6, pp. 481-500.

-Kim, J. H., Pagliara, F. and Preston, J. (2005) “The intention to move and residential location choice behavior”, Urban Studies, Vol. 42, No. 9, pp. 1621-1636.

-Kraft, G. (1968) “Demand for intercity passenger travel in the Washington-Boston corridor, north-east corridor project report systems analysis and research corporation”, Cambridge, MA: MIT Press.

-Louviere, J. J., Hensher, D. A. and Swait, J. (2000) “Stated choice methods: analysis and applications in marketing transportation and environmental valuation”, Cambridge, MA: MIT Press.

-Manheim, M. L. (1979) “Fundamentals of transportation systems analysis”, Cambridge, MA: MIT Press.

-McFadden, D. (1973) “Conditional logit analysis of qualitative choice behavior”, New York, CA: Academic Press.

-Miller, E. J., Roorda, M. J. and Carrasco, J. A. (2005) “A tour-based model of travel mode choice”, Transportation, Vol. 32, No. 4, pp. 399-422.

-Newman, J., Vincent, L. and Bernardin, J. R. (2010) “Hierarchical ordering of nests in a joint mode and destination choice model”, Transportation, Vol. 37, No. 4, pp. 677-688.

-Ortuzar, J. and Willumsen, L. (2011) “Modeling transport”, United Kingdom: Wiley Press, 4th edition.

-Ozbay, K. and Yanmaz-Tuzel, O. (2007) “Valuation of travel time and departure time choice in the presence of time-of-day pricing”, Transportation Research Part A: Policy and Practice, Vol. 42, No. 4, pp. 577-590.

-Richards, M. G. and Ben-Akiva, M. E. (1974) “A simultaneous destination and mode choice model for shopping trips”, Transportation, Vol. 3, No. 4, pp. 343-356.

-Shahangian, R. S. (2012) “Gender differences in response to policies targeting commute to automobile-restricted central business district: stated preference study of mode choice in Tehran”, Department of Civil Engineering, Sharif University of Technology, Tehran, Iran.

-Tahmasebi, S. (2000) “Comparison and evaluation of sequential and direct models of destination and mode choice: case study of Mashad”, Department of Civil Engineering, Sharif University of Technology, Tehran, Iran.

-Tarahan Parseh Transportation Research Institute (2012) “Transportation master plan of intercity road travels of Tehran province: data survey”, Tarahan Parseh Transportation Research Institute, Tehran.

-Train, K. E. (2002) “Discrete choice methods with simulation”, Cambridge, MA: MIT Press.

-Vega, A. and Reynolds-Feighan, A. (2009) “A methodological framework for the study of residential location and travel-to-work mode choice under central and suburban employment destination patterns", Transportation Research Part A: Policy and Practice, Vol.43, No. 4, pp. 401-419.

-Vickrey, W. (1969) "Congestion theory and transport investment", The American Economic Review, Vol. 59, No.2, pp. 251-261.

-Wen, C. H. (2010) "Alternative tree structures for estimating nested logit models with mixed preference data", Transportmetrica, Vol. 6, No. 4, pp. 291-309.

-Wilson, A. G. (1974) "Urban and regional models in geography and planning, John Wiley & Sons, Ltd Chichester.

-Williams, H. C. W. L. (1977) "On the formation of travel demand models and economic evaluation measures of user benefit", Environment and Planning, Vol. 9A, pp. 285–344.

-Yang, L., Zheng, G. and Zhu, X. (2013) "Cross-nested logit model for the joint choice of residential location, travel mode, and departure time", Habitat International, Vol. 38, pp. 157-166.

-Yao, E. and Morikawa, T. (2005) "A study of an integrated intercity travel demand model", Transportation Research Part A: Policy and Practice, Vol. 39, No. 4, pp. 369-381.