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CHALLENGES AND SOLUTIONS

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MODELING METRO USERS' TRAVEL BEHAVIOR IN TEHRAN: FREQUENCY OF USE

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ABSTRACT

Transit-oriented development (TOD), as a sustainable supporting strategy, emphasizes the improvement of public transportation coverage and quality, land use density and diversity around public transportation stations and priority of walking and cycling at station areas. Traffic, environmental and economic problems arising from high growth of private cars, inappropriate distribution of land use, and car-orientation of the metropolitan area, necessitate adoption of TOD. In recent years, extensive research into urban development and transportation has focused on this strategy. This research in which metro stations are considered as a base for development, aims to model metro users' travel behavior and decision-making procedures. In this regard, the research question is: what are the parameters or factors affecting the frequency of travel by metro in a half-mile radius from stations. The radius was determined based on TOD definitions and five-minute walking time to metro stations. A questionnaire was designed in three sections that include travel features by metro, attitudes toward metro, and economic and social characteristics of respondents. Ten stations were selected based on their geographic dispersion in Tehran and a sample of 450 respondents was determined. The questionnaires were surveyed face to face in (half-mile) vicinity of metro stations. Based on a refined sample on 400 questionnaires ordered discrete choice models were considered. Results of descriptive statistics show that 38.5 percent of the sample used metro more than 4 times per week. Trip purpose for 45.7 percent of metro users is work. Access mode to the metro stations for nearly half of the users (47.6 percent) is bus. The results of ordered logit models show a number of significant variables including: habit of using the metro, waiting time in stations, trip purpose (working, shopping and recreation), personal car access mode to the metro station, walking access mode to the metro station and being a housewife.

KEYWORDS: Transit oriented development, Metro, Ordered logit model

1 INTRODUCTION

In recent decades, achieving sustainability has been discussed as a general concern by many researchers, and various strategies and tools were specifically offered to achieve this goal in the field of urban transit planning. The public transit system is often regarded as an instrument that helps to attain sustainable urbanization. However, expanding these systems is a costly process that has different impacts on urban and regional areas (Miller et al, 2016). Transit Oriented Development (TOD) is a bundle of strategies to achieve sustainable transport in metropolitan areas (Barton, 1998; Calthorpe, 1993; Cervero, 2004). There is no accepted standard definition regarding both theoretical and operational aspects of TOD (Nasri, 2014). Different definitions of TOD include these factors: density, diversity, design and mixed land uses, walking and cycling priority and public transport system quality (Cervero et al., 2002; Arrington and Cervero, 2008; California Department of Transportation, 2001; Parker, 2002). Density captures the intensity of activity through such measures as residential units or jobs per unit area. Diversity captures the variety of land use in an area, such as the ratio of residential units to jobs or the distance from a residential unit to a retail destination. Design refers to street network patterns within an area, such as the percentage of intersections (Stewart and Moudon, 2014).

The growing trend of Tehran's population and focus of facilities, services and administrative centers have led to an increase in trips by residents (Tehran master plan, 2006 revised in 2013). Apart from cultural issues and the preferential use of private cars in Tehran, lack of a public transportation system with proper coverage and quality and also inconsistency between land use conditions and public transit infrastructure have lowered the share of the public transport sector in Tehran (Tehran master plan, 2006 revised in 2013).

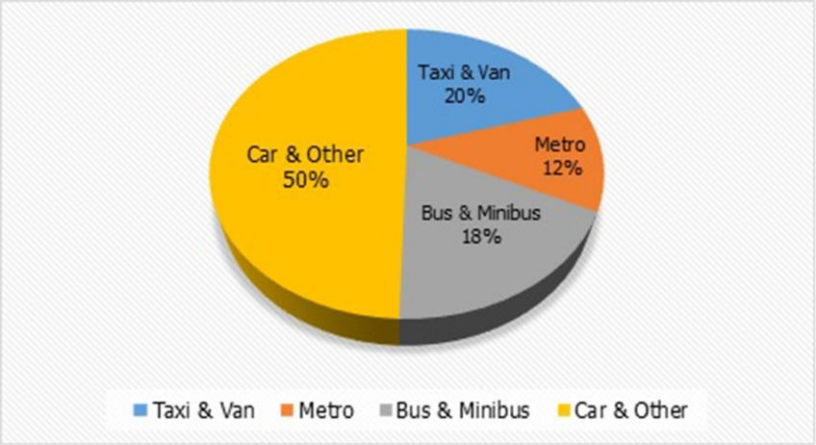

Fig. 1 The share of vehicles in daily trips in Tehran

Efforts for improving the current conditions and increasing the share of public transport, especially metro, have drawn the attention of decision-makers, authorities, urban development and transport planners to the strategy of TOD (TURPC, 2015). Planning to promote using the metro requires a true understanding of users' behavior mechanisms. This research, considering metro stations as a base for development, aims to model metro user's travel behavior and decision-making procedures. In this regard, the research question is: what are the parameters or factors affecting the frequency of travel by metro in a half-mile radius from stations. The radius was determined based on TOD definitions and five minute walking time to metro stations. In section 2 the literature is reviewed, followed by methodology in section 3 specifying the scope of the case study, questionnaire design, data collection and modeling. Section 4 is dedicated to research findings containing the results of descriptive statistics, modeling phases, and finally section 5 comprises the discussion and conclusion.

2 LITERATURE REVIEW

The TOD concept was originally developed by Peter Calthorpe (American architect) and the implementation history of TOD projects primarily goes back to the USA and the cities of San Francisco and Atlanta in this country. Following America, attention of the European countries was also drawn to this strategy and cases compatible with TOD were observed in the cities of Copenhagen, Munich, Stockholm and Zurich in Europe (Bernick and Cervero, 1997; Cervero, 1998; Curtis et al., 2009; Mu and Jang, 2012).

By implementing TOD projects and the pervasiveness of this strategy, the researchers measured various aspects of the current situation and results of TOD projects. Mu and Jang (2012) assessed the implementation conditions of TOD in Dalian, China. Along with the introduction of Dalian City as a case study and regarding the density and diversity of land use and the relevant maps, transportation infrastructure situation and mode choice of travel in this city, strengths and weaknesses of Dalian city are discussed in moving towards TOD.

Cervero and Kockelman (1997) studied the impact of environment structure characteristics (density, diversity and design) on changing trip styles in San Francisco and found that modern urbanism with proper density, diversity and design of land use reduces the share of travel by personal car and increases the use of non-motorized transport vehicles. Ewing and Cervero (2010) maintained that, after controlling for socio-demographic characteristics and other confounders, design variables have greater connection with walking and transit use than diversity or density measures.

Renne (2007) studied TOD based on a comprehensive vision and view of stability and livability. The study area included five public transportation stations in Perth, Australia. Data included two primary and secondary categories. The former included the data from 2503 households randomly selected from five areas to assess livability and sustainability and the latter included secondary data of local offices and organizations. Introduced indicators for measuring TOD were divided into six categories including travel behavior, local economy, environment structure, social environment and policy context.

Based on an analytical framework, Nasri and Zhang (2014) examined the differences in travel behaviors of TOD area residents in both Washington and Baltimore. In this context and in order to analyze the effectiveness of TOD in encouraging the area's residents to use public transportation, walking, cycling and other sustainable modes of transportation, changes in vehicle miles traveled (VMT) was investigated. For modeling travel behavior in TOD and NON -TOD areas, multi-level mixed effect regression modeling as well as the travel data between 2007 and 2008 in the above cities were used. The data included economic and social information, activities, travel distance, mode choice, travel time, purpose of travel and information of the origin and destination of households in the vicinity of metro. The results showed that people residing in TOD areas were less inclined to use private cars. Accordingly, VMT had respectively decreased about 38 percent in Washington and 21 percent in Baltimore compared to NON -TOD areas, even with the same pattern of land use. In order to measure the level of TOD in Arnhem and Nijmegen urban areas, Singh et al (2014) proposed the potential and actual indexes of TOD. The actual index is intended for the walkable area of the station and potential index is used for the whole area and identifying the potential of areas for connection to public transit. Given that all indexes cannot be quantified, all of them cannot be used for index calculation. Spatial data are obtained in GIS format and non-spatial data at the regional level are obtained from the secondary data. In data collection, there were problems such as isolation of resources, lack of full map coverage, incompatible administrative boundaries and conflicting classification of land use. Regarding such issues, indexes such as residential density, commercial density and diversity of land use, mixed use and number of commercial units are used.

Vale (2015) used three aspects to assess and categorize areas of stations: transportation, land use and walking conditions. He implemented the node-place model with an evaluation of the pedestrian connectivity

of station areas of Lisbon. Papa and Bertolini (2015) examined the relationship between TOD and rail-based access by comparative analysis of six European cities. Comparisons showed that rail-based access is higher in cities where residents and businesses are focused around the station or have higher connectivity networks.

A literature review of the TOD framework shows that the factors of land use condition (density and diversity), quality of public transport and pedestrian-oriented design of a TOD site are very important in reducing private car use and increasing the share of sustainable modes (public transport, walking and cycling). Since changing people's trip mode to public transportation plays a key role in TOD, identification of user behavior is very important. Lack of studies on the factors influencing metro use leads this study to evaluate the parameters affecting frequency of travel by metro, with a behavioral approach focusing on the city of Tehran.

3 METHODOLOGY

For modeling frequency of travel by metro, a questionnaire was designed. Ten metro stations were chosen based on geographic dispersion of stations for completing questionnaires in Tehran. An ordered discrete choice model was chosen to model the weekly frequency of metro use. Discrete choice models are powerful tools which consider the behavioral nature utility as a random variable (Ben-Akiva, 1985). They also have a high capability of modeling choice-making and dealing with utility. Discrete choice models include two general categories, ordered and un-ordered models (Ben-Akiva, 1985). The basic assumption of ordered models considers a continuous variable a hidden variable that shows intention value of a respondent to a specific option. In fact, what is observed is a reflection of the hidden desire of the respondent defined as a discrete variable (Mckelvey, 1993).

3.1 TEHRAN'S METRO CASE STUDY

With 20 years of history and 94 stations along five lines, Tehran metro was ranked 34th among the world metros in 2015 based on the number of stations (TUSROC, 2015). Line 1 of the metro with a share of 36.5% has the largest share of trips by metro (TUSROC, 2015). This line connects the north and south of the city. Figure 2 demonstrates the growing number of trips made by metro during the years 1998 to 2013.

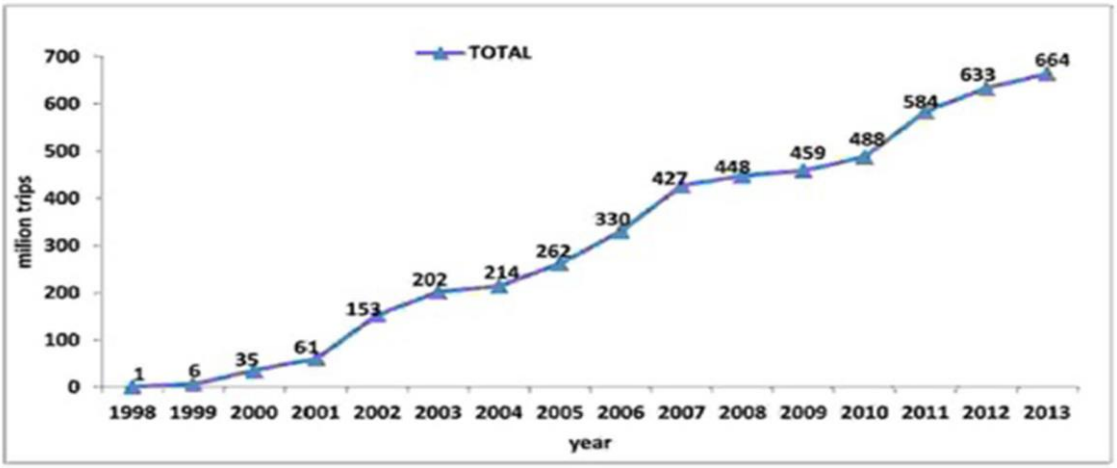

Fig. 2 Number of trips by metro in years 1998 – 2013

Nevertheless, the share of public transportation and especially the metro is very low compared to that ofprivate cars. Given the importance of metro stations and their capacity in creating development, Tehran

metro stations are considered a basis for development in this study. Ten metro station were chosen based on geographic dispersion of stations for completing questionnaires in Tehran.

Table 1 shows the specifications of ten metro stations and in figure 3 the locations of them are illustrated. Among the selected metro stations, four metro stations (Imam Khomeini, Sadeghiyeh, Theater Shahr and Shahid Beheshti station) are located at the intersection of two metro lines.

STATION NAME	LINE NUMBER	AVERAGE NUMBER OF DAILY PASSENGERS
Sadeghiyeh	2 , 5	57873
Imam khomeini	1 , 2	38032
Shahid beheshti	1 , 3	23194
Theater shahr	3 , 4	39031
Niroo havaei	4	16889
Fatemi	3	-
Tehranpars	2	17060
Sarsabz	2	18741
Ghaem	3	-
Mirdamad	1	18589

Table.1 Specifications of 10 metro stations in Tehran (TUSROC, 2015)

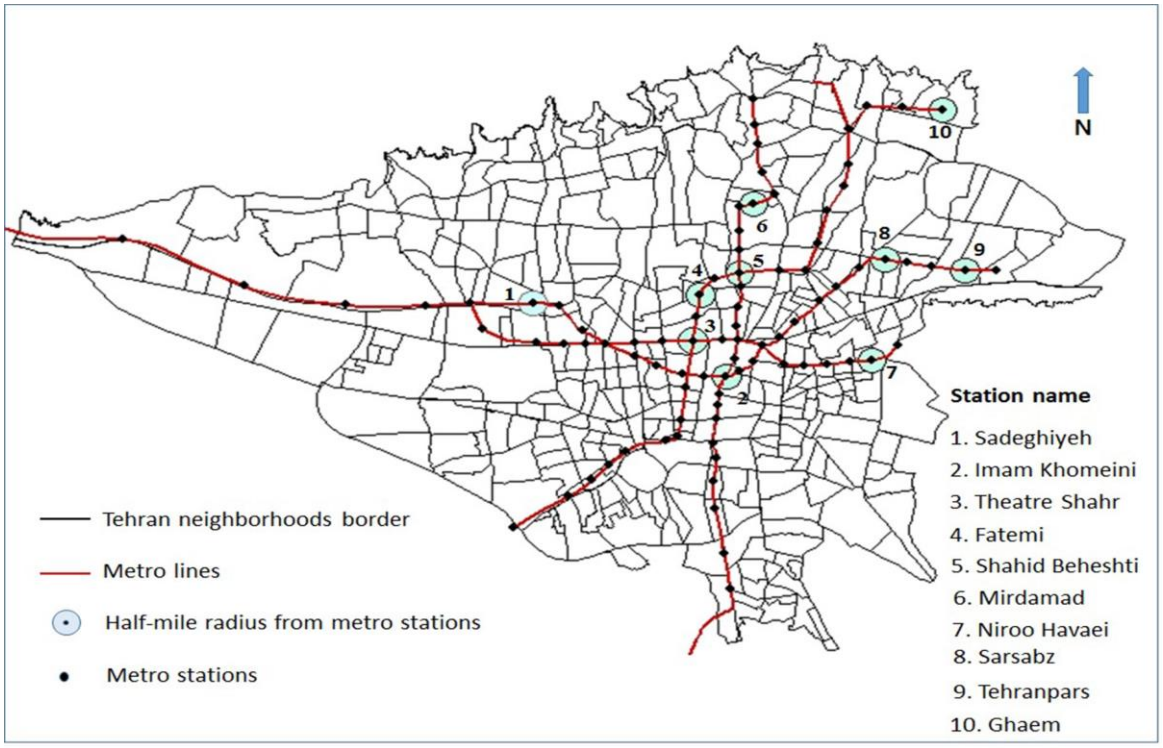

Fig. 3 Location of 10 metro stations in Tehran

3.2 QUESTIONNAIRE DESIGN & DATA COLLECTION

After reviewing the literature and consulting with experts and urban transport engineers, features affecting the use of metro were identified and a questionnaire was designed on this basis. Also the available questionnaires of reference (for example research of Renne, 2007) were reviewed and used as guides to design a set of questions modified for this study. The final questionnaire consisted of three sections: travel

features by metro (4 questions), attitude towards metro (16 questions) and social-economic characteristics of respondents (10 questions). After designing the questionnaire, two pilot experiments were conducted. At every stage, 20 questionnaires were distributed. The first took place in Shahid Beheshti station and was stopped according to the metro security guard interference. The second was conducted at a bus stop near the Sadegiyeh metro station. It was a good candidate for our survey as people waiting for buses after leaving the metro had more free time to answer questions than people leaving metro stations for different destinations. The pilots confirms that the questionnaire had no ambiguity.

Due to the lack of information on population variance, a Morgan table was used to determine the sample size required and 450 passengers were accordingly selected as the sample. The survey method, face to face and simple random, took place during three weeks in January 2016 within a half-mile radius from ten metro stations.The passengers determined the importance of the corresponding features (attitude) in the form of a 5-degree Likert scale including very low, low, medium, high, and very high. For descriptive analysis, codes 1 to 5 were respectively given to the options. Out of 450 questionnaires, 400 of them were used for statistical analysis considering the level of responses to questions.

3.3 MODELING

The trip modeling approach used was discrete choice analysis. Several models with weekly frequency of metro use, as the dependent variable, were made using different coding for the dependent variable, which enabled us to estimate binary, multinomial and ordered logit. Depending on the fitting and significance of explanatory variables, the ordered logit model was selected as the final model. In general, three categories of explanatory variables were tested, including trip characteristics by metro (see table 2), attitudes towards the metro (see table 3) and socio-economic characteristics of the respondents (see table 4). In addition, dummy variables, composed, logarithm of attitudes towards the metro is made in the process of modeling.

4 FINDINGS

4.1 DESCRIPTIVE ANALYSIS

The results of descriptive statistics analysis of economic and social variables (table 2) show that 59 percent of the sample were male, 39 percent were married, 43 percent were tenants, 40 percent had no independent income and 54 percent own cars. According to table 3, some results of descriptive statistics analysis of characteristics of trip by metro include:

- 38.5 percent of individuals use the metro more than four times per week.
- The main trip purpose of 45.7 percent of the sample is work.
- Access mode of about half of the sample (47.6 percent) to the metro station is bus.

SOCIO - DEMOGRAPHICS	CODE	FREQUENCY	%
Age (years)			
15 to 19	1	16	15.4
20 to 24	2	126	31.8
25 to 30	3	82	20.7
31 to 40	4	71	17.9
41 to 50	5	46	11.6
50 to 60	6	10	2.5
Gender			
Female	0	164	41
Male	1	236	59
Marital status			
Not married	0	246	61.5
Married	1	154	38.5
Family housing			
Homeowners	0	224	57
tenant	1	169	43
Employment status			
Full-time	0	127	47.7
Part-time	1	139	52.3
Income status			
I have an independent income	0	238	59.6
No independent income	1	161	40.4
Job type			
Government employees	1	54	12.2
Private employee	2	81	18.3
Self-employment	3	122	27.6
Private employer	4	11	2.4
Housewife	5	35	7.9
Students	6	124	28
Unemployed	7	14	3.1
Other	8	3	0.6
Car ownership			
Without cars	1	214	54.9
One	2	154	39.5
Two	3	18	4.6
Three or more	4	4	1
Level of education			
Lower of diploma / Diploma	1	117	29.3
Associate Degree / Bachelor	2	201	50.4
Msc	3	57	14.3
P.H.D	4	24	6

Table.2 Socio-demographic status of the respondents

SPECIFICATION: TRIPS WITH METRO	CODE	FREQUENCY	%
frequency of use by metro per week			
One	1	88	22
Two	2	48	12
Three	3	62	155
Four	4	48	12
More than four	5	154	38.5
The purpose of trips by metro			
Work	1	180	45.7
Education	2	125	31.7
Shopping	3	49	12.4
Recreation	4	12	3
Other	5	28	7.1
time of trips by metro			
5:45 to 8:30	1	111	27.7
8:30 to 12:00	2	161	40.4
12:00 to 16:00	3	85	21.3
16:00 to 19:00	4	37	9.3
19:00 to 23:00	5	5	1.3
Access mode to the metro station			
walking	1	90	22.7
Bus	2	189	47.6
Car	3	30	7.6
Taxi / van	4	84	21.2
Other	5	4	1

Table.3 The results of descriptive statistics for characteristics of trip by metro

Table 4 shows the importance of some metro characteristics according to people's attitudes. For example, half of the respondents believe that congestion and bustle of the train has greatly affected their tendency to use the metro.

ITEM	ALTERNATIVE (CODE)					SUM	MEAN	SD
	1	2	3	4	5			
Route information in the train and station	2.5	4	26.6	36.4	30.4	100	3.88	0.972
Train safety	0.5	3	19	32.5	44.9	100	4.18	0.881
Lighting and visual space of station	1.3	7.1	35.3	40.4	16	100	3.63	0.880
Reliability	1	4.1	23.7	32.9	38.3	100	4.03	0.937
Congestion and bustle of the train	2	1.5	13.6	26	56.8	100	4.34	0.913
Train ventilation	3.6	7.6	26.6	28.2	34	100	3.81	1.095
Convenience and comfort of the trains	4.1	11.4	15.1	30.5	28.9	100	3.69	1.126
Train speed	1.8	6.1	33.1	35.4	23.7	100	3.73	0.949
Escalators and elevators at station	3	9.8	17.9	29.1	30.2	100	3.74	1.085
The waiting time at station	2.3	8.8	17.4	28.4	33.2	100	3.81	1.063

Social status using the metro	5.8	8	31.6	31.6	23.1	100	3.58	1.102
Social interaction with people	7.1	14.6	38.3	26.2	13.9	100	3.25	1.088
Metro ticket costs	3	10.1	41.9	24.2	20.7	100	3.49	1.025
Habit of using the metro	6.6	10.4	31.4	33.7	18	100	3.46	1.102
Culture of using of the metro	5.1	11.9	22	28	33.1	100	3.72	1.186
Environmental benefits of the metro	2.8	7.8	24.7	30.5	34.3	100	3.86	1.060

Table.4 Results of descriptive statistics analysis for characteristics of attitude towards metro

4.2 ORDERED LOGIT MODEL RESULTS

The results of the ordered logit model (see table 5) showed eight variables: waiting time, habit of using the metro, dummy variables of trip purpose (working, shaping and recreation), personal car access mode to the metro station, walking access mode to the metro station and being a housewife. The habit of using the metro and waiting time in station variables are significantly positive. Thus believing the important of the role of habit on using the metro has a significant positive effect on the weekly frequency of metro use. Also people who believe that the waiting time is an important issue on metro use, travel by metro more frequently. Other results of the model are:

- Work-trip purpose is significant positively. Hence the persons with the working trip purpose are more likely to use the metro.
- Shopping-trip purpose and recreation-trip purpose are significant negatively. Hence those with shopping and recreation purposes are less likely to use the metro.
- Walking access method to metro stations is significant positively. Hence the people who walk to the metro station are more likely to use the metro.
- Personal car access method to stations is significant negatively. Hence the person who reaches the station in a personal car is less likely to use the metro.
- Being a housewife is significant negatively. So the housewife are less likely to use the metro.

EXPLANATORY FACTORS (CODE)	COEFFICIENT
Constant	2.10***
Habit of using the metro	0.17***
Waiting time in station	0.12**
Work-Trip purpose (1) otherwise (0)	0.71***
Shopping-Trip purpose (1) otherwise (0)	-0.7***
Recreation-Trip purpose (1) otherwise (0)	-0.76**
Personal car Access mode to the metro station (1) otherwise (0)	-0.43**
Walking access mode to the metro station (1) otherwise (0)	0.24*
Housewife (1) otherwise (0)	-0.53**
$\mu_1 = 0$ $\mu_2 = 2.45$ $\mu_3 = 2.90$ $\mu_4 = 3.37$ $\mu_5 = 3.73$	
LL(0)= -644 LL(C) = -604 LL(β)= -544 $\rho_0^2 = 0.16$ $\rho_c^2 = 0.10$	

Table.5 Result of ordered logit model

****: Significant at 5%**

***: Significant at 10**

5 DISCUSSION AND CONCLUSIONS

TOD has emerged as one possible solution for sustainable urban transportation and can help to reshape the quality and form of urban growth towards enhanced accessibility and mobility, pedestrian friendliness, increased sustainability and potentially a higher degree of human interaction (Curtis et al., 2009). One main objective of TOD is promoting the use of public transport. Planning to promote metro use requires a true understanding of users' behavior mechanisms. In this study, metro users' travel behavior (frequency of use) in Tehran is studied using an ordered logit model.

For this purpose, a questionnaire was designed in three sections include travel features by metro, attitudes toward the metro, and economic and social characteristics of respondents. For the survey ten stations were selected based on geographic dispersion in Tehran. The questionnaires were distributed face to face in the vicinity of metro stations. After distributing and collecting questionnaires, 400 questionnaires given to the responses level. Results of descriptive statistics show that 38.5 percent of the sample used the metro more than four times per week. The main trip purpose for 45.7 percent of metro users is work. Access mode to the metro stations for nearly half of the users (47.6 percent) was bus. The results of the ordered logit model show a significant number of variables including: habit of using the metro, station waiting time, work-trip purpose, shopping-trip purpose and recreation-trip purpose, personal car access mode to the metro station, walking access mode to the metro station and being a housewife. With the increasing importance of waiting time for users, the possibility of using the metro increases. Thus from a user perspective, the metro is a system with more regular schedules than other travel modes (for example bus). The habit of using the metro increases the possibility of using the metro. People who walk to metro stations are more likely to use the metro during the week than others who reach stations otherwise.

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IMAGE SOURCES

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Fig. 1: Tehran transportation studies, 2013

Fig. 2: Tehran transportation studies, 2013

Fig. 3: Authors

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