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Exploring the effect of the built environment, weather condition and departure time of travel on mode choice decision for different travel purposes: evidence from Isfahan, Iran.

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Abstract

A growing number of researches from different fields have investigated the role of key factors that impact on transport mode choice. Scant studies, however, have tried to incorporate the built environment factors at origin and destination, weather condition, departure time, and different trip purposes into mode choice modelling. To address these shortcomings, we developed four multinomial logit (MNL) models to analyze travel mode choice decision for different purposes including work, shopping, social/recreational and personal/household business in the context of a developing country, Iran. Travel data drawn from household travel survey conducted by Isfahan municipality in 2012 and weather parameters was retrieved from five stations located inside the city. The results of models reveal some important insight. While entropy index and average block size at origin or destination strongly influence transport modes decision, other built environment factors have very weak associations with transport modes. Besides, low temperature and relative humidity decrease the probability of transit, motorcycle and bicycle over automobile. The impact of weather condition on discretionary trips is stronger than work trips. Apart from mentioned variables, socio-demographic characteristics and departure time of travel are other important variable in mode choice selection. Findings of this paper indicate that nonphysical strategies in tandem with land use policies should be considered based on local condition.

Key words: the built environment, weather condition, departure time, travel mode choice, Iran.

1. Introduction

Following an uncontrolled growth in the usage of private vehicles and its subsequent challenges including sprawl, congestion, oil dependence, and climate change (*Ewing and Cervero, 2010*) urban and transportation planner have attempted to understand the chief factors affecting individuals' auto-oriented behavior. The evidence shows that increasing car usage is not only result from increase in households' income and welfare but it is a consequence of poor and car-oriented urban form. The results of previous research confirmed the positive linkage between the built environment factors and mode choice selection (see *Ewing and Cervero, 2001, 2010; Stead and Marshall, 2001; Zhang, 2004; Badland et al., 2008*). Hence, researchers have tried to propose appropriate land use policies to contain rising growth of motorized mode usage.

Although the analysis of mode choice as one of travel outcome has been a subject of interest in recent years, there are still many research gaps about the relationship between physical and nonphysical variables and mode choice. The great majority of studies have been undertaken in developed countries such as North America, Europe, and Australia, while, limited research has been carried out on this subject in other parts of the world (see *Munshi, 2016; Manoj and Verma, 2016; Ding, Lin and Liu, 2014*). That's while, *United Nations Habitat* (2011) estimated that the majority of car use will be found in developing countries by 2050, especially China, India and other Asian countries. On the other hand, due to the differences in spatial characteristics in developing countries such as level of monocentricity, population densities, design and geographical locations (*Cervero, 2013*) and also differences in their socio-economic context, it is difficult to generalized the western finding and land use strategies to developing country. In order to address this shortcoming, this study aims to undertake Isfahan as a case study from a developing country, Iran. According to transportation ministry estimations, vehicle use in major cities of Iran has extended during past decade (*Etminani-Ghasrodashti and Ardeshiri, 2015*) and it has been one of the most important source of air pollution in these cities. Specifically in Isfahan, between 2000 and 2012 the number of residents' daily trips and vehicle miles travelled (VMT) increased by 27% and 40% respectively. Indeed, the share of trips by private vehicle increased by 65% and car occupancy coefficient decreased by 40% (*Isfahan Municipality, 2013*).

Considering aforementioned matters, this paper contributes to the literature in some other ways. First, a growing number of researches concerning the impact of weather condition on travel behavior have recently been emerged (see *Liu, Susilo and Karlstrom, 2017; Bocker, Dijst & Prillwitz, 2013; Böcker, L., Prillwitz, J., & Dijst, 2013; Dijst, Böcker and Kwan, 2013*). But, to the authors' knowledge, very limited research incorporated weather condition into classical travel behavior modeling (*Saneinejad, Roorda and Kennedy, 2012*). This combination can reveal new insights and give better policy guidance on travel behavior and the built environment. One important limitation of previous research in the field of travel behavior and weather condition is that they often used the data that were retrieved from weather stations located in outside urban areas(*Bocker, Dijst & Prillwitz, 2013*), while the weather parameters may be varied across urban regions according to building density, parks and open spaces, traffic congestion, etc. This paper collected the meteorological data from five stations located inside the city of Isfahan. Second, previous research mainly analyzed the role of the built environment characteristics at the origin of trips but this paper also take the built environment characteristics at the destination of trips into account (see *Zhang, 2004; Ding, Lin and liu, 2014*). Departure time of travel is another variable which have received less attention in previous works as independent variable. Since traffic congestion, working time of

commercial and service activities, availability and frequency of transit and free time available for individuals may be varied in different time sections of a day, it is more likely that this variation significantly impacts on individuals' mode choice selection. The final contribution of this paper is related to trip purposes and mode choice. So far, a considerable studies have investigated the relationship between the built environment and commuting mode choice (e.g. [Sun, Ermagun and Dan, 2016](#); [Munshi, 2016](#); [Schawanan and Mokhtarian, 2005](#); [Van Acker and Witlox, 2011](#)), but we need more knowledge on other trip purposes including shopping, social/recreational or other trip purposes ([Manoj and Verma, 2016](#)). Because of the flexibility and discretionary nature of different travel, it is more likely that explanatory variables impact on non-work mode choice and commuting mode choice differently.

According to abovementioned issues, this paper aims to explore the effect of the built environment characteristics (at trip origin and destination) and weather parameters including temperature and relative humidity on travel mode choice for four categories of trip purposes including work, shopping, social/recreational, and personal/household. In addition, this paper takes socio-demographics and departure time of travel into consideration. To achieve this goal, conventional multinomial logit (MNL) models were developed using a large survey data conducted in the city of Isfahan in 2012 and numerous built environment measurements.

2. Literature Review

Following increase in energy consumption, air pollution and lack of physical activity in recent years, travel mode choice has been a subject of interest in the fields of transport-related, public health etc. In this regard, multiple studies have been carried out to identify significant factors which shape individuals' decision for travel mode choice (e.g. [Munshi, 2016](#); [Cervero, 2002](#); [Chen, Gong and Paaswell, 2008](#); [Ding, Lin and Liu., 2014](#); [Ding et al., 2017](#); [Gim, 2015](#); [Nielsen et al., 2013](#); [Van Acker and Witlox, 2010](#); [Zegras, 2010](#)). In the most of previous researches the built environment and socio-demographics have been considered as key determinants of travel behavior. From another standpoint, as mentioned earlier, a growing number of studies have examined the impact of daily weather condition on travel behavior in recent years. Some review studies have summarized recent works in the both areas of the built environment-travel behavior relation (e.g. [Ewing and Cervero, 2001](#), [Ewing and Cervero, 2010](#); [Stead and Marshall, 2001](#) [Saelens and Handy, 2008](#); [Gim, 2012](#)) and weather condition-travel behavior relation (e.g. [Liu, Susilo and Karlstrom, 2017](#); [Bocker, Dijst and Prillwitz, 2013](#)). Accordingly, current section reviews the literature that are relevant to this study to provide some insight for developing the analysis models.

Based on enriched literature, It can be said that the built environment characteristics have significant association with travel mode choice. However, there is no comprehensive consensus about significance and importance of the built environment characteristics on mode choice selection. According to [Ewing and Cervero \(2010\)](#) the typical important built environment characteristics can be defined as density, diversity, design, accessibility, distance from transit stations and demand management. Compared to the built environment characteristics at trip origin, the built environment characteristics at destination trip have been investigated in fewer studies ([Cervero, 2002](#); [Limtanakool et al., 2006](#); [Chen et al., 2008](#); [Zhang, 2004](#); [Sun, Ermagun and Dan, 2016](#)). Here, we try to synthesize the related previous works and discuss how the built environment indicators impact on travel mode choice. Density, mainly measured by population and employment, is negatively associated with vehicle use, while these factors at trip origin and destination have a positive effect on bicycle, walking and public transit mode choices ([Cervero, 1996](#),

2002; Reilly and Landis, 2002; Bhatia, 2004; Milakis and Barbopoulos, 2008; Sandow, 2008; Moilanen, 2010; Yang et al., 2012). However, some other studies have also reported very low elasticity values between population and job densities and walk and bicycle choice (Boarnet et al., 2008; Munshi, 2016). Land use mix as another index has positive influence on choice of bicycle, walking and transit use (Frank and Pivo, 1994; Frank et al., 2009; Ewing and Cervero 2010; Etmnani-Ghasrodashti and Ardeshiri, 2016). Instead, some research have not found significant association between land use mix and travel mode choice (Kitamura et al., 1997; Zhang, 2004; Badland et al., 2008). As for urban design characteristics, the meta-analysis study of Ewing and Cervero (2010) indicated that intersection and street density have a significant influence on walking and transit choice. Nonetheless, Zhao (2013) and Etmnani-Ghasrodashti and Ardeshiri (2016) mentioned that increase in roads density would improve the probability of commuting by motorized modes. Furthermore, several studies found significant relationship between mode choice and distance to Central Business District (CBD) (Pushkar et al., 2000; Boarnet et al., 2004) and accessibility to transit (Frank and Engelke, 2005; Munshi et al., 2014).

Unlike the built environment variables, two travel characteristics including departure time and travel purposes have received less attention in previous works. Departure time of travel has mainly been modeled as dependent variables in some studies (e.g. Yang, Zheng and Zhu, 2013; He, 2013; Lemp, Kockelman and Damien, 2010), but it as independent variable may significantly impact on travel mode choice. For example, in the middle of the day commercial and service activities may be closed and frequency of public transit may be decreased due to lower passenger volume. Consequently, it is likely that these occurrences change individual decision for travel mode choice. As for trip purpose, the most of previous works mainly focused on commuting mode choice (e.g. Sun, Ermagun and Dan, 2016; Munshi, 2016; Ding, Lin and Liu, 2014; Habib, 2012) or a single non-work trip mode choice (e.g. Shatu and Kamruzzaman, 2014; Limanond and Niemeier, 2004; Van Acker et al., 2011). Because of the flexibility and discretionary nature of various trip purposes, it seems that the previous distinguishing between trips is not sufficient and it is essential to be more sensitive to the trip purposes (i.e. Shopping, Social, recreational, and personal/household business). It is hypothesized that the built environment and weather condition differently impact on mode choice for different purposes and this give us different policies implications.

As for the relationship between weather condition and transportation, the most previous studies focused on network performance of transportation systems, while fewer studies focused on travel behavior. These studies mainly used objective parameters for weather condition including temperature, relative humidity, precipitation and wind speed (see Liu, Susilo & Karlstrom, 2017). However, some studies used subjective evaluation of weather condition. In current research we used two objective weather parameters including temperature and relative humidity and excluded other parameters due to lack of data or very little variation during travel survey periods. Regarding the results, most of previous research found that weather condition have stronger impact on active and open-air transport modes, particularly cycling, than in-vehicle modes (Sabir, 2011; Bergstrom & Magnusson, 2003; Brandenburg et al., 2004; Ahmed et al., 2010; Phung & Rose, 2008; Richardson, 2000; Phung & Rose, 2008; Richardson, 2000). Particularly, some studies concluded that temperature has significant positive effects on walking and cycling, and negative impact on car and public transport (Guo et al., 2007; Shih and Nichols, 2011; Tang and Thakuriah, 2012). In contrast to temperature, the earlier studies mainly reported insignificant association between the relative humidity and walking and hourly

bicycle ridership (*Miranda-Moreno and Nosal 2011; Liu, Susilo & Karlstrom, 2017*). Indeed, some studies showed that temperature differently impacts on travel behavior for different trip purposes as its effects for discretionary travel purposes are stronger than commuting trips (*Aaheim & Hauge, 2005; Sabir, 2011; Thomas et al., 2012*).

In addition to the issue of integrating weather condition with the built environment in mode choice modeling, we attempt to address two other shortcomings on weather condition-mode choice relations. First, previous research mainly retrieved the data from the stations located in outside of city (*Bocker, Dijst and Prillwitz, 2013*). Therefore, they have not been sensitive to the variation of weather condition within their study area. Second, most of the results on weather condition and travel behavior are based on research conducted in North-West Europe, North-America and Australia, while the research in other countries with different climate regime, cultural, economic, social and geographical characteristics may disclose different results.

3. Methodology

3.1. Study area and data source

This research is based on the city of Isfahan a case study from a developing country, Iran. Isfahan is the largest city in center of Iran with the population of 1.8 million, an area of 482 km² and 534256 households (*Isfahan Municipality, 2016*). In this research, the built environment factors are measured at traffic analysis zone (TAZ) scale due to land use data availability. Comprehensive transportation plan of Isfahan divided the city to 185 TAZs (*Comprehensive transportation plan, 2013*). These TAZs have a variety of urban forms from organic urban form to modern urban form with different socio-economic variables (*Revision of detailed plan, 2012*). Among the 185 TAZs, we excluded several TAZs due to the deficiency of the data related to the built environment, socio-demographics or travel behavior variables.

The travel data used in this study is drawn from a large household travel survey (HTS) conducted in Isfahan city in autumn 2012 by Isfahan municipality¹. In total, 6025 questionnaires were distributed among households and they were asked about travel behavior of household members including the origin and destination of trips, departure time, trip purpose, mod choice and individual/households socio-demographic characteristics. After removing the questionnaire with missing and deficient data, the final sample includes 4965 households that reported 14965 home based trips (*Comprehensive transportation plan, 2013*). Data related to weather condition were retrieved from five weather stations located within the city. Isfahan municipality installed these stations in the different regions of Isfahan to study microclimate variances in the city. They have registered temperature and relative humidity in five-minute periods since 2010. We will explain more about the characteristics of the sample, the built environment and weather parameters in the next sections.

3.2. Variables

The explanatory and dependent variables are classified into four groups: socio-demographic characteristics, the built environment characteristics at origin and destination of trips, travel behavior (i.e. travel mode choice, travel purposes and departure time of travel), and weather condition.

¹ Isfahan municipality conducted this survey for preparing comprehensive transportation plan in 2012.

3.2.1. Socio-demographics of respondents

Household and individual characteristics of the sample, collected by the household travel survey, are described in [Table 1](#). The proportion of male respondents comprised 58.6 of the sample. The average age is 37.9 (for the people above 15 years old). The average number of family member is 3.9 in the sample. 65.5% of respondents have driver's license. The average car ownership, bike ownership and motorcycle ownership are 0.94, 0.63 and 0.45 respectively. As for respondents' job, 15.5% respondents are officer and 12.5% are student. 29.6% are self-employed and 33.4% are non-worker (i.e. unemployed, retired etc.). It is noted that households' income was not gathered by the survey. It may be due to the fact most of individuals in our case study do not tend to report their income.

Table1: Descriptive statistics of socio-demographic variables.

Socio-demographic characteristics	Variable description	Frequency
Gender	Male (1 = yes)	58.6
Driving License	License (1 = yes)	65.5
	Officer	15.5
	Self-employed	29.6
Respondent's Job	student	12.7
	Non-worker	33.4
	Other	8.8
Mean (Std. Dev.)		
Age	37.9 (12.34)	
Family size	3.8 (1.2)	
Car ownership	0.94 (0.65)	
Bike ownership	0.63 (0.72)	
Motorcycle ownership	0.45 (0.59)	

3.2.2. The built environment variables

As mentioned earlier, the built environment variables were gathered in geographical scale of TAZ due to data availability in this scale for all variables. According to literature, eight built environment variables were calculated at the origin and destination of trips based on the detailed plan of Isfahan using ArcGIS 10.2 software ([Revision of detailed plan, 2012](#)). The built environment attributes are described in [Table 2](#). Population and job density characterize the compactness and sprawl level of activities. Entropy index represents the balance of different land use types across the TAZs and measures the accessibility to the various destinations. Block size and road density characterized the level of permeability within TAZs. Bus line density and distance to bus stations represent the accessibility to transit. Distance to CBD describes the spatial centrality of respondents ([Ding et al., 2016](#)). Traffic congestion represents the total number of trips generated and attracted to each zone.

Table2: Definition and descriptive statistics of the built environment attributes

Built environment Variable	Variable description	Origin TAZ	Destination TAZ
		Mean (Std. Dev.)	Mean (Std.Dev.)
Population density	Population/area size (persons/hectare)	284.4 (237.16)	109 (55)
Job density	Employment/area size (jobs/hectare)	284.4(237.16)	370 (377)
Entropy index	Mixture of residential, commercial and services, parks and green spaces, educational, public (health and sport), cultural-religious	0.25 (0.071)	0.28 (0.094)
Street density	Street length/area size (Km/Km ²)	30.44 (6.66)	29.5 (7.12)
Block size	Average block size within TAZ (km ² /km ²)	0.48(0.17)	0.58 (0.29)
Distance to bus station	Distance to nearest bus station (m)	401.8 (231)	347 (281)
Bus length density	Bus length/area size (km/km ²)	11.62 (9.8)	14.98 (11.43)
Distance to CBD	Straight line distance from CBD (Km)	6.77(2.47)	-
Traffic Congestion	total number of trips generated and attracted to each zone	1490.9 (740)	2548(2927)

3.2.3. Travel behavior variables

We considered travel mode choice for different purposes as dependent variable. Travel mode included four modes, namely car (private car and taxi), transit, bicycle and motorcycle. In this study, we classified trips into four categories including shopping (food store, fruit store, clothes store, etc.), social/recreational (such as visiting friends/relatives, religious/social/civic, recreational, restaurant and coffee, etc.), and personal/household business (such as visiting service provider, children school, health centers, etc.). (see [Manoj and Verma, 2016](#)). Because of different motivation of individuals for various purposes and different flexibility and discretionary nature of aforementioned trips, this distinguishing gives us more guidance on individuals' decision for mode choice. In addition, we considered departure time of travel as dependent variable. In this regard, departure time of travel were classified into six time periods from 5am to 12midnight. Table 3 describes departure time of travel for different purposes.

It is worth noting, as mentioned in section 3.1, our original travel data source comprised 14965 home based trips, but after removing respondents younger than 15 years old, educational trips, and trips between 12 midnight and 5am (due to very few trips made in this period), the final sample includes 12790 trips.

Table 3: Frequency of mode choice and departure of travel for four types of purposes.

Travel characteristics		Trip Purposes				
		Work	Shopping	Social or recreational	Personal or household business	total
Mode Choice	Car	40.4	11.6	15.5	32.5	100
	Transit	24.9	20.3	17	37.9	100
	Bicycle	32.2	17.4	20.2	30.2	100
	Motorcycle	64.4	7.6	11.1	16.9	100
Departure Time of trip	5:00 -8:00	71	2.1	1.9	25	100
	8:00 -12:00	38.3	18.1	12.2	31.4	100
	12:00 -15:00	27.8	10.4	16.6	45.6	100
	15:00 -18:00	24.6	17.6	23.1	34.7	100
	18:00 -21:00	5.4	23.3	38.3	33	100
	21:00 - 24:00	8.8	15.4	47.8	27.9	100

Total	3285	3011	3146	3348
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3.2.4. Weather variables

In addition to mentioned variables, two important meteorological variables including hourly temperature and relative humidity were collected as independent variables. The weather data were retrieved from five stations within the city and were matched to the trips according to the closeness of weather stations to departure point and time of each trip. Table 3 shows the hourly average temperature and relative humidity for different stations. Indeed, both temperature and relative humidity were classified into four categories Table 4. According to 5, transit and motorcycle usage are made more frequent in temperature of 15-20 °c, while car and bicycle are more frequent in temperature of 3-9 °c. In addition, respondents have more frequently used all transport modes in relative humidity of 85-100.

Table 4: Descriptive statistics of weather parameters for weather stations

Weather Station	Weather Parameters (Mean, Std.Dev.)	
	Temperature (⁰ C)	Relative Humidity
Station 1	5.02 (4.98)	83.6 (12.8)
Station 2	5.48 (4.27)	80.5 (15.74)
Station 3	3.09 (4.83)	79.9 (17.88)
Station 4	7.1(3.9)	73.37(19.84)
Station 5	8.04 (3.65)	72.8 (19.59)
Total	6.41 (4.40)	76.17 (18.84)

Table 5: Frequency of mode choice in different temperature and relative humidity.

Weather Parameters	Category	Frequency of mode choice (%)			
		Car	Transit	Bike	Motorcycle
Temperature (⁰ C)	Below 3	12.1	8.2	12.5	8.7
	3 - 9	37	31.8	41.8	29.8
	9- 15	23.1	23.9	19.9	29.3
	15- 20	27.7	36.1	25.9	32.2
Total		100	100	100	100
Relative Humidity	40-55	18.2	19.3	17.1	19.4
	55-70	12.5	17.4	10.9	18.6
	70-85	15.3	18.4	14.1	18.6
	85-100	53.9	44.8	57.9	43.4
Total		100	100	100	100

4. Mode choice modelling

In this study, we developed multinomial regressions to determine the impact of socio-demographic characteristics, the built environment factors at origin and destination of trips, departure time of travel and weather condition on transport mode choice including car (private automobile and taxi), bus, motorcycle and bicycle. Multinomial logit (MNL) model is a common functional model for exploring a variety of independent variables on a category dependent variable (Schwanen and Mokhtarian, 2005; Munshi, 2016). According to Ben-Akiva and Lerman (1985), this model assumes that individuals have unobservable, latent preferences or utilities for different transport modes and they choose the mode that maximizes their utility. We developed the MNL models for four trip purposes including work, shopping, social/recreational and personal/household business. The statistic parameters show that all models fit the data well. Next sections discuss the

results for work mode choice and non-work (three types of purposes) mode choice separately. As shown in Table 5, average temperature varies across the city mainly due to difference in building density, presence of park and open space, traffic congestion etc. it is noted that station 3 has registered the lowest temperature among other stations.

4.1. Analysis of mode choice behavior for work trips

In this section, mode choice behavior for work trips is investigated. The results of the MNL model are shown in Table 6. The estimation results show that the model parameters have accepted magnitude in comparison to previous works (*see Ewing and Cervero, 2002; Munshi, 2013; Munshi, 2016*). The McFadden R^2 for our model is 0.318. Although the McFadden R^2 greater than 0.4 is considered as a very good goodness of fit (*Munshi, 2016*), this parameter within 0.2 and 0.4 is accepted (*McFadden, 1979*). Significant variables are presented in the table 6 and all variables with lower than 90% significance were dropped during the model estimation stage. Indeed, car choice was taken as a reference category because from a policy perspective it is interesting to compare other transport modes to this mode (*Bocker, Amen and Helbich, 2016*).

As shown in table 6, more number of socio-demographic variables significantly appeared in the model compared to other explanatory variables. It was found that a male traveler find lower utility in using transit and higher utility in usage motorcycle over automobile for work trips. With increase in age, the probability of car use increases over transit and motorcycle. This may be attributed to the convenience and security issues of this mode for elders. Our results relating to age and gender are consistent with some previous research (e.g *Pan et al., 2009; Sun, Ermagun and Dan, 2016; Munshi, 2016*). Family size has a positive association with transit but negative relationship with motorcycle. Those who are officer (working in government and private sectors) are more likely to take transit and less likely to use motorcycle in comparison to car. Since these people have a fix time of travel for work purpose, they can better adjust their departure time with transit schedule. Less usage of motorcycle may be rooted in social position of this type of employers. Consistent with most of previous research, the likelihood of bus and motorcycle usage decreases with increase in car ownership and presence of driver's license. Bicycle ownership also decreases the likelihood of transit and motorcycle use but increases use of bicycle mode choice over automobile. Increase in motorcycle ownership decreases probability of transit use but increase motorcycle usage for work trip purpose.

From the built environment attributes, job density at the origin of trip very slightly increases the odds of transit usage. This is consistent with *Etminani-Ghasrodashti and Ardeshiri (2016)* but inconsistent with *Sun, Ermagun and Dan (2016)*. It could be attributed to better accessibility to public transport in TAZs with higher job density. Bus lenght density at both trip origin and destination has very weak positive association with transit over automobile. Traffic congestion at destination increases the likelihood of transit usage compared to car. In general, traffic congestion sharply reduces driving speed and accessibility to a parking place. Indeed, population density and distance to bus station have very weak positive association with motorcycle usage, while distance to CBD has negative relationship with this transport mode in comparison to car. This indicates that respondents living further from the CBD tend to use car over motorcycle and bicycle modes. In addition to distance to CBD, higher job density at destination increases the odds of bicycle use. Larger block size decreases the probability of bicycle use. Larger block size can lead to low preambilty within TAZs. These results mainly confirm the finding of earlier studies. It is noted that departure time of travel between 5am and 8am has significantly positive effect on choosing transit but negative effect on motorcycle. The

result indicates that transit is favorite mode for worker in peak hours. As for weather condition, in a reasonable result, when temperature is below 3°C the likelihood of taking public transit and the open-air transport modes decrease over car. These results are consistent with the findings of previous studies (see [Bocker, Dijst and Prillwitz, 2013](#); [Saneinejad et al., 2012](#); [Liu et al., 2015](#)) Moreover, respondents resided near weather station 3 (with lowest average temperature among five stations), prefer to choose car for work trip purpose compared to motorcycle mode.

Table 6 : Multi-nominal logit model estimates for work trips (The reference category is: Car)

	Transit		Motorcycle		Bicycle	
	B	Exp(B)	B	Exp(B)	B	Exp(B)
Intercept	-15.838*		-2.37*		-19.718	
Socio-demographic haracteristics						
Male (ref=Female)	-1.225***	0.294	3.338***	28.17		
Age	-0.018**	0.982	-0.026***	0.974		
Family size	0.145**	1.157	-0.235***	0.791		
Officer (ref=Self-employed)	0.651***	1.918	-0.402**	0.669	-1.064**	0.345
Driving License (ref=No license)	-1.006***	0.366	-0.889***	0.411	-1.129**	0.323
Car ownership	-1.339***	0.262	-1.899***	0.15	-1.910***	0.148
Bicycle ownership	-0.072*	0.93	-0.198**	0.82	1.364***	3.911
Motorcycle ownership	-0.483***	0.617	2.400***	11.025		
Built environment at origin						
Population density			0.006**	1.006		
Job density	0.001*	1.001				
Distance to bus station			0.002*	1.002		
Bus length density	0.013*	1.014				
Distance to CBD			-0.085**	0.918	-0.075*	0.928
Built environment at destination						
Job density					0.001**	1.001
Average block size					-3.223**	0.04
Bus length density	0.019**	1.019				
Traffic congestion	0.001**	1.001				
Departure time (ref=8am-12noon)						
5am-8am	0.511**	1.667	-0.824***	0.439		
6pm-9pm			-1.535**	0.215		
Weather station (ref=Station5)						
station3			-0.816**	0.442		
Temperature 0C (ref=15_20)						
Below 3	-0.939*	0.391	-0.586*	0.557	-0.470*	0.625
Observation				3285		
-2 Log Likelihood Intercept Only				4970.548		
-2 Log Likelihood Final				3389.765		
Chi-Square				1580.783		
Pseudo R-Square(Cox and Snell)				0.499		
Pseudo R-Square(Nagelkerke)				0.563		
Pseudo R-Square(McFadden)				0.318		

Significant codes: * < 0.10; **< 0.05; *** < 0.01

4.2. Analysis of mode choice behavior for non-work trips

In this section, we developed three multinomial models for non-work trip purposes including shopping, social/recreational and personal/household business. The McFadden R^2 s for three models are 0.35, 0.28 and 0.307 respectively. These parameters indicate that all models have reasonably good explanatory qualities ([Munshi, 2016](#)). Like work trip purposes, the number of socio-demographic characteristics contribute in the models considerably more than other explanatory variables. To better comparison, the results of significant factors of three models are summarized in table 7. We found that those who are male find higher utility value to choose motorcycle and bicycle and lower utility value to choose transit over automobile for all non-work trip purposes. The probability of using bicycle by men is very higher than other transport modes. Presence of driver's license has negative association with all modes for all trip purposes. Increase in family size raises the odds of taking transit for shopping and personal/household business trips. Instead, increasing of this indicator reduces the likelihood of using motorcycle for shopping and social/recreational purposes over car. Students and non-workers are more likely to choose transit over car for non-work trip purposes. It may be due to availability of free time for the mentioned people. Self-employed job has no significant association with transport modes for shopping but has significant association with motorcycle for social/recreational and with transit for personal/household business respectively. As an expected result and like trips for work purposes, bicycle ownership and motorcycle ownership increase the probability of bicycle usage and motorcycle respectively over automobile.

From the built environment variables, population density at trip origin has significant positive relationship with transit and bicycle for shopping and also positive relationship with bicycle for personal/household business trips. Indeed, job density has positive association with bicycle for personal/household business. It is more likely that density intensification provides more frequent transit stops and shortens distance between activities. Although the associations are very weak, they are consistent with previous studies (e.g. [Schwanen et al., 2004](#); [Zhang, 2004](#); [Susilo and Maat, 2007](#); [Sandow, 2008](#); [Yang et al., 2012](#)). The entropy index that represents the balance of land use increases the likelihood of taking transit for shopping and social/recreational trips. This indicator also increases the odds of bicycle for shopping but lowers the odds of motorcycle for social/recreational in comparison to car. According to previous research, mixing of land use reduces the distance between activities and also it makes the built environment more attractive for walking, cycling and taking transit. This built environment measure has the highest influence on choosing transit and bicycle. Average block size at origin of trip has a significantly negative association with bicycle mode for social/recreational and personal/household business over car mode. It is noted that its impact on personal/household business is stronger than social/recreational purpose. In general, increase in average block size reduces street connectivity within TAZs and then encourages driving travel. This indicator at destination of trip reduces the probability of motorcycle usage for recreational/social trips over car. Street density at origin has a negative association with bicycle for personal/household business. Indeed, the road density at destination increases transit use for shopping and social/recreational over car. Our result on the impact of road density on bicycle mode is inconsistent with other previous research (e.g. [Sun, Ermagun and Dan, 2016](#); [Ewing and Cervero, 2010](#)). However, it confirms the result of another research conducted in Shiraz, Iran ([Etminani-Ghasrodashti and Ardeshiri 2016](#)). It was assumed that higher road density leads to high street connectivity

and provides more flexible and convenient routes for transit and cycling. But it seems that presence of more roads in our study area encourage more driving and then leads to traffic congestion that decreases the safety for cycling (*Etmnani-Ghasrodashti and Ardeshiri 2016*). Distance to nearest bus stop only decreases the likelihood of transit for personal/household business over car and it does not have significant relations with other modes. Also, Increase in distance to bus stop at destination slightly lowers the odds of transit for shopping and social/recreational trips. Traffic congestion at origin has positive connection with transit mode for personal/household business but negative association with bicycle for social/recreational and personal/household business. Due to lack of infrastructure for cycling in our cities, it was expected that traffic congestion reduced the probability of cycle over car. Bus length density at origin has significant positive with transit for social/recreational. Furthermore, this indicator at destination has positive association with transit for personal/household business. These results are consistent the work trips and confirm most of previous findings. Regarding to departure time of travel, the results show that individuals' decision for choosing transport modes, specifically transit, is highly sensitive to departure time of travel. The departure time between 8am and 12midnoon is chosen as a reference category. According to table 7, most of departure time categories have significant negative association with transit usage. The point is that the likelihood of transit decreases at both 9pm-12 midnight and 6pm-9pm periods more than other time categories. This reduction may be related to decreases in frequency and availability of transit service during these periods. In addition, closing of commercial and service activities could decrease access to destinations and may encourage driving. The likelihood of bicycle lowers at 5am-8am for shopping purpose and 6pm-9pm for both social/recreational and personal/household business over car. These lower rates could be attributed to insufficient cycling infrastructure for safety trips at peak hours and at night. Motorcycle mode has no significant association with departure time for shopping and social/recreational trips but the probability of using this transport mode significantly decreases after 3pm for personal/household business.

As for the weather condition, like work trip purposes, the respondents who resided near weather station 3 (with lowest temperature among other stations) are less likely to choose bicycle over car for social/recreational and personal/household business purposes. This result indicates that it is important to consider microclimate variances within study areas in the analysis of mode choice. The temperature and humidity variables provide some insights relating non-work mode choice. The temperature between 15-20 °c is chosen as a reference category. The results indicate that individual decision for using bicycle (for shopping) and taking transit (for personal household business) is not sensitive to temperature. But, the temperature lower than 9°c decreases the utility of transit and motorcycle for both shopping and social/recreational purposes and reduces the utility of bicycle for personal/household business. These results suggest that individuals find higher utility in using car over other mods in cold temperature. These results are reasonable because bicycles and motorcycles users are directly exposed to cold weather. Decrease in bus usage may be due to the fact that buses in our case study are not mainly equipped with heating equipment in cold temperature. Instead, the utility of open-air transport modes increases when temperature is between 9-15°c over car. In addition, our results confirm earlier finding that effect of weather condition on discretionary travel purposes is stronger than non-discretionary trips such as work trips (*Aaheim & Hauge, 2005; Sabir, 2011; Bocker, Dijst & Prillwitz, 2013*). In comparison to temperature, individuals decision for choosing transport modes are less sensitive to relative humidity categories. Low relative humidity decreases the utility of transit and motorcycle for shopping and

social/recreational purposes respectively. Additionally, relative humidity of 70-85 has negative association with bicycle for personal/household business.

Table 7: Multi-nominal logit model estimates for non-work purposes (The reference category is: Car)

	Shopping						Social/recreational						Personal/household business					
	Transit		Motorcycle		Bicycle		Transit		Motorcycle		Bicycle		Transit		Motorcycle		Bicycle	
	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)
Intercept	-5.13**		-5.16*		-16.08**		-5.55**		1.92*		-7.83**		-2.71**		-1.48*		-17.34***	
Socio-demographics																		
Male (ref=Female)	-0.48**	0.62	5.01***	149.59	4.30***	73.95	-0.51**	0.60	3.18***	24.11	5.00**	147.97	-0.54**	0.58	2.59***	13.37	3.61***	36.99
Age			-0.04**	0.96					-0.02*	0.98			-0.012**	0.99				
Family size	0.11*	1.11	-0.29**	0.75					-0.07*	0.93			0.151**	1.16				
Job (ref=Officer)																		
Self employed									0.49*	1.64			-0.76**	0.47				
Student			-2.61**	0.07			2.11**	8.23					0.71**	2.04			2.89***	18.01
Non-Worker	0.96*	2.62					2.09**	8.06			2.00**	7.37	0.50**	1.65				
Driving License (ref=No license)	-0.70***	0.50	-1.33**	0.26	-2.47***	0.08	-0.81***	0.45	-0.85**	0.43	-1.58**	0.21	-0.92***	0.40			-1.08**	0.34
Car ownership	-1.13***	0.32	-2.13***	0.12	-1.20	0.30**	-0.56***	0.57	-1.30***	0.27	-0.53**	0.59	-0.89***	0.41	-2.09***	0.12	-1.19***	0.30
Bicycle ownership			-0.53*	0.59	1.25**	3.48					1.05***	2.85					1.20***	3.32
Motorcycle ownership			2.27***	9.70	-0.91**	0.40			2.21***	9.13					2.67***	14.46		
Built environment at origin																		
Population density	0.005*	1.005			0.014**	1.014											0.02**	1.02
Job density																	0.002**	1.002
Entropy	4.97***	143.53			8.72**	6153.6	1.64*	5.16	-5.14*	0.006								
Average block size											-1.79*	0.17					-2.94**	0.05
Street density																	-0.11**	0.89
Distance to bus station	-0.001**	0.999											-0.001**	0.999				
Bus length density							0.02*	1.02									-0.07**	0.93
Distance to CBD																	-0.001**	0.999
Traffic congestion					-0.001**	0.999							0.08**	1.08	-0.15**	0.86	-0.29**	0.75
Built environment at destination																		
Population density									0.09**	1.009								
Job density			0.01**	1.001									0.001**	1.001			0.001**	1.001

	Shopping						Social/recreational						Personal/household business					
	Transit		Motorcycle		Bicycle		Transit		Motorcycle		Bicycle		Transit		Motorcycle		Bicycle	
	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)
Average block size	0.85**	2.35													-1.91**	0.15		
Street density	0.04**	1.04							-0.08**	0.92			0.02*	1.02				
Distance to bus station	-0.001**	0.999					-0.001*	0.999										
Bus length density													0.02**	1.02				
Traffic congestion	0.001**	1.001					-0.001**	0.999										
Departure time of travel (ref=8am-12noon)																		
5am-8am	-1.56**	0.21			-2.89**	0.06							-0.71**	0.49				
12noon-3pm	-1.56***	0.21											-0.84**	0.43				
3pm-6pm	-1.34***	0.26					-0.56**	0.57					-0.89***	0.41	-0.75**	0.48		
6pm-9pm	-1.33**	0.27					-1.42***	0.24			-2.02**	0.13	-1.36***	0.26	-0.87**	0.42	-1.02**	0.36
9pm-12midnight							-2.70***	0.07					-2.78**	0.06	-2.44**	0.09		
Weather station (ref=Station5)																		
Station 3											-2.01*	0.13					-0.87*	0.42
Temperature 0C (ref=15-20)																		
Below 3			-0.92*	0.40			-1.08*	0.34									-1.86*	0.16
3_9	-0.47*	0.62							-1.69**	0.184							-1.09*	0.34
9_15											1.22**	3.37			0.71*	2.03		
Humidity (ref=85_100)																		
40-55	-0.88*	0.41							-1.63*	0.20								
70_85																	-1.16**	0.31
Observation			3011						3146						3348			
-2 Log Likelihood Intercept Only			2624.85						4879.97						4879.97			
-2 Log Likelihood Final			1889.88						3380.48						3380.478			
Chi-Square			734.97						1499.49						1499.49			
Pseudo R-Square(Cox and Snell)			0.47						0.48						0.48			
Pseudo R-Square(Nagelkerke)			0.53						0.54						0.54			
Pseudo R-Square(McFadden)			0.28						0.31						.307			

Significant codes: * < 0.10; **< 0.05; *** < 0.01

5. Conclusion and policy implications

Following traffic congestion and air pollution in today's cities, analysis of travel mode choice behavior has received considerable attention in recent years. In this study, we attempted to develop this line of research in some directions. First, this study undertook a case study from a developing country to enrich exiting literature and strengthen the theoretical and practical bases for prescribing appropriate strategies for growing and motorizing cities. Second, we incorporated weather condition and the built environment variables at destination into mode choice models with classic explanatory variables (i.e. the built environment variables at origin and socio-demographics). Third, this study distinguished between trip purposes and developed the MNL models for each category to understand more about the importance of explanatory variables for different trip purposes.

The comparison of the results for four trip purposes (including work, shopping, social/recreational and personal/household business) in terms of significance, direction and strength of association reveals some important insights. First, explanatory variables often did not have significant association with a transport mode for four trip purposes. For instance, population density significantly impacts on choosing transit for shopping, while this variable has no significant relationship with transit for other purposes. Second, almost all significant explanatory variables influence transport modes for different purposes in same direction. However, as an exception, departure time between 5am and 8am increases the probability of transit for work trip but decreases the probability of this mode for personal/household business trips. Third, the strength of significant variables is not similar for all trip purposes. For example, increase in entropy index at origin increases the probability of transit for shopping very higher than social/ recreational trips. In addition to mentioned general conclusions, we here highlight the most important results and their policy implications. Many socio-demographic variables have high impact on almost all transport modes. Female has negative association with bicycle mode. This result is mainly rooted in social-cultural of our society as well as safety concerns in our city. Car ownership increases the likelihood of car usage over other modes, while bicycle ownership and motorcycle ownership mainly decrease the probability of car usage. Partial effects of the built environment variables are limited for all travel purposes in presence of other explanatory of variables. However, entropy index at origin and average block size at destination have considerably strength effect on the transport modes.

These results suggest planner and policy-making to consider various strategies in tandem with the built environment policies to reduce car and motorcycle use and encourage transit and bicycle usage. In this regard, the policies such as increase in fuel cost, congestion pricing, parking pricing, determining restricted traffic areas, subsidy for bicycle purchase along with starting campaign for supporting the use of transit (especially for men) and bicycle (especially for women) may be very useful. As for the built environment, the findings suggest that creating mixed-used environment, increasing population and job density in TAZs with lower density, improving internal connectivity within zones, providing public transit infrastructure in TAZs, especially in those have farther distance from CBD, providing cycling infrastructure such as cycling lane and lightening, especially in dense and congested areas are effective strategies for encouraging sustainable transport modes. With regard to departure time of travel, the odds of all transport modes decreases over car during all time categories. These reductions are sharper than during 9pm-12midnoon and post-peak hours (12noon-3pm). Hence, increase

in availability and frequency of transit in the mentioned periods may be helpful policies. When look at weather condition, respondents resided near weather station 3 find lower utility for cycling (for social/recreational and personal/household business purposes). This indicates that it is important to understand more about the effect of microclimate variances within cities on travel behavior. Low temperature and low relative humidity have negative association with transit and two open-air transport modes (see table 6, 7). Since travel survey, used in this study, was conducted in autumn, we lost the analysis of travel mode choice behavior in temperature above 20 °c due to lack of data. Nevertheless, it is more likely that individuals' decision for choosing transport mode tend to be sensitive to hot weather condition.

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