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Women's mode and trip structure choices in daily activity-travels: A developing country perspective from Iran

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Abstract
Understanding the effects of gender differences on activity-travel patterns is important to design and monitor appropriate management policies of transportation systems. In addition to inherent psycho-physical gender differences, women in Iran also might face special constraints that force them not to be involved in all activity-travel patterns that men and women in developed countries usually undertake. We here analyze travel demand of Iranian women considering that the typical patriarchal views and specific social and cultural norms reveal travelers' behavior patterns that are different from those in western societies. We pay special attention to the role of marital and employment status of Iranian women on their activity-travel patterns. To this extent, we develop a joint mode and daily trip structure (DTS) discrete choice model. It takes the form of a mixed nested logit model. This paper also intends to show how different demographic factors in a patriarchal Muslim society like Iran affect or restrict women's types and structures of their activity-travels patterns, and more generally their freedom to make their journeys.

Keywords: Women; Developing country; Travel patterns; Discrete choice models; Mode choice; Daily trip structure choice.

1. Introduction

Women's activity-travel behavior differs substantially from men's in a variety of areas. It has considerable policy implications in different aspects (Rosenbloom, 2004).. Understanding dissimilarities in travel and activity patterns between men and women appear to be more important when evaluating effects of transportation policies on different categories of citizens.

Building up on scientific knowledge acquired from analysis of developed countries and adopting the derived governing paradigms to cope with women needs in developing countries may not be logically sound and not necessarily yield desired outcomes. The different pattern of behavior of women in developing countries highlights the need for significant efforts in conducting studies to adapt travel demand analysis. We here aim at identifying and quantifying the main determinants of Iranian women travel demand patterns.

Literature shows that that women and men have different travel patterns (see hereafter). Several studies have admitted the effect of gender differences on activity-travel patterns. There however are few studies regarding developing countries, where specific social and cultural norms make different gender issues, sometimes more

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pronounced. In Iran, there are social and cultural constraints that may alter or confine women's activity-travel patterns.

In Iran, traditionally and legally, women do not have equal political, economic, and social rights as men. These differences also emerge in transportation systems. Women are less secure in their urban trips, especially at night: they have their own separate public transportation (women-only metro cars and women-only bus services). They are also prohibited from cycling in the city. Living in different social and cultural environments affected by patriarchal norms implies that women have largely different activity-travel patterns than women in western societies. Also, women in Iran have less incentive to get in the labor market and the difference in wage with men is larger as compared to women in developed countries. Differences in beliefs, perceived and commanded social norms, and resulting lifestyles of Iranian women yield many differences in their activity-travel patterns.

Beyond the serious attempts made so far, the choice modeling techniques require investigating the activity-travel decision-making processes of women in the particular context of developing countries. In doing so, this paper tries to propose a tailor-made discrete choice modeling framework, especially through considering the marital and employment status of Iranian women on their activity-travel patterns. In this study, women are categorized into several groups based on their marital and employment status and, then, their work and non-work daily trip schedules are statistically analyzed. Subsequently, joint mode and daily trip structure choices are modeled and the results of the estimation are then scrutinized to see the different dimensions of women's travel behavior in a developing country.

Stated more precisely, considering the variables: (i) personal features, (ii) household characteristics, (iii) employment status, (iv) daily activities, and (v) residential and work place locations, we construct a joint discrete choice model of women's mode-daily trip structure choices. The results of the estimation address the fact that the key factors on women's daily activity-travel patterns are their marital and employment status.

The rest of this paper is structured as follows. In Section 2, we review previous researches that have dealt with the analysis or modeling of women's travel behavior or daily activities. In Section 3, we present women's activity-travel data in Iran and we provide some descriptive statistics and perform some statistical tests on the sample data. Section 4 covers the discrete choice modeling building phase of this study. In Section 5, we provide a more precise discussion on the estimation results. Finally, Section 6 closes the paper by offering conclusions and some suggestions for future research.

2. Women and urban travel: A review of the literature

Many researchers have examined determinants of women demands for daily activities and their related travel choices:

- Women tend to commute shorter distances and travel less than men for business and work related travel (McQuaid and Chen, 2012), Kim, Sang, Chun and Lee, 2012), Crane and Takahashi, 2009), Crane, 2007), Clark, Huang and Withers, 2003), Axisa, Scott and Bruce Newbold, 2012), Gordon, Kumar and Richardson, 1989), Cassel, Macuchova, Rudholm and Rydell, 2013), Prashker, Shiftan and Hershkovitch-Sarusi, 2008), Taylor and Mauch, 1996), Li, Guensler and Ogle, 2004), Collins and Tisdell, 2002), McGuckin and Nakamoto, 2004).. They also differ in terms of leisure purposes .

- Number of dependent children in a family has a significant effect on the time allocated to out-of-home activities by women (McQuaid and Chen, 2012), Taylor and Mauch, 1996), McGuckin and Nakamoto, 2004), Gliebe and Koppelman, 2002). Gossen and Purvis (2004). showed that housewives with children travel more than non-working men. Besides, McGuckin and Nakamoto (2004). showed that women are more likely than men to drop off or pick up children in dual income households. Furthermore, women may have less flexibility in departure time due to the school and day-care start and end times of children (McGuckin and Nakamoto, 2004).
- Size of families affects women's out-of-home activities (McQuaid and Chen, 2012), Axisa, Scott and Bruce Newbold, 2012), Meloni, Bez and Spissu, 2009). As shown by Zhang et al. (2012)., having a child reduces the time use of compulsory-contracted activities (e.g. paid work and schoolwork), and increases the time use of compulsory-committed activities (e.g. housework, caring or nursing, childcare, shopping, volunteer and community activities). Furthermore, the size of family is also associated with shorter commuting times (McQuaid and Chen, 2012).
- The employment status of women significantly affects women's activities out-of-home (Meloni, Bez and Spissu, 2009).
- Parental status of families affects women's patterns of activity-travel. Jointly observing the employment and parental status of families, Gossen and Purvis (2004). found that single working parents with young children spend more time on travel than do women in other life-cycle groups. In their study, the life-cycle groups were cross-classified by employment status (workers/non-workers), the parental status of families (single adult with no children/ two or more adults with no children/single adult with children/two or more adults with children), and the age of the youngest child.
- Geographical location of home, which directly determines the accessibility to private and public modes of transportation, affects the time women spend for non-work activities (e.g. recreation and leisure activities) (Meloni, Bez and Spissu, 2009).
- Woman's age is a contributing factor in the number of daily trips (McQuaid and Chen, 2012).
- Reasons for women's willingness to use or not to use a mode of transportation may differ from men. Heesch et al. (2012). and Krizek et al. (2004). have investigated gender differences in cycling and the reasons for such differences. However, it is not entirely accepted for any mode of transportation where, for example, Gordon et al. (1989). report a slight gender difference in travel mode choice in the USA.
- There are gender differences in the car availability (i.e. duration of car use over a week) (Scheiner and Holz-Rau, 2012), Vance, Buchheim and Brockfeld, 2004)., especially, for the households with fewer cars than drivers.
- Mohammadian (2004). showed that gender difference is a significant factor in automobile type choice behavior. He found that women usually tend to prefer better safety features and more storage in their vehicles, but men tend to prefer more power and performance.
- Women tend to be more concerned about safety and security (Clifton and Livi, 2004), Zhou, Outwater and Proussaloglou, 2004). They are more likely to account for safety and security issues in their travel choices. It has different effects. For example, women's fear of sexual harassment on transit affects negatively the way

they use it and more generally their travel behavior (Hsu, 2009). It has led to women-only transportation facilities (Dunckel-Graglia, 2013). Also, as women are more concerned about their security, they alter their walking behavior to conform to their environment (Clifton and Livi, 2004).

- Wage rates significantly affect married women commute times (Iwata and Tamada, 2008).
- Use of public transportation between men and women is different. Different results have been presented in this regard. While Gould and Zhou (2009). have found that women ride buses more than men in California, Prashker et al. (2008). and Patterson, Ewing and Haider (2005). have shown that women are less likely than men to use public transportation in suburban Montreal.
- Income and occupation are the two main causes affecting women commute times (Zolnik, 2010).
- Women appear to be less sensitive to time than men (Patterson, Ewing and Haider, 2005).
- Women are likely to make more grocery trips than men (Taylor and Mauch, 1996).
- Women make fewer stops and stop for shorter durations than men in morning commute trip chaining (Li, Guensler and Ogle, 2004).
- Women tend to have higher willingness for stress-free ride, and they are more constrained by fixed schedules (Zhou, Outwater and Proussaloglou, 2004).

Analysis of travel behavior of women is a topic of interest to transportation researchers. Applications however pertain to developed countries lifestyles. We here contribute by addressing non work-related travel behavior of Iranian women, accounting for strong cultural/religious norms.

3. Data, descriptive statistics, and statistical inferences

3.1. Case studies and travel surveys carried out

This study uses data drawn from the 2008 household travel surveys in three different cities of Iran: Arak, Mashhad, and Urmia, and all the data in this paper are consistent with this year. Arak is a medium-size city located in the central west of Iran with more than 500,000 inhabitants. It is one of the industrialized cities in Iran and most of the inhabitants work in factories and industries located in or near the city. It is one of the most polluted cities of Iran.

The second city is Mashhad. It is located in the north-east of Iran and is the second largest city in Iran with a population of approximately 2.6 million inhabitants (in 2008). It is recognized as a holy city with a large number of pilgrims coming for ceremonies and observances of the holy shrine of a Shia Imam. Travel surveys showed that annually more than 32 million pilgrims travel to Mashhad.

At last, Urmia is a medium-size city located in the north-west of Iran. It has approximately 613,000 inhabitants in 2008. It is characterized as a multicultural city. In the city of Mashhad, the vehicle ownership rate per household is 97% in the sample and 98% in the population. These rates are respectively 96% and 97% for Arak and 87% and 86% in Urmia (All of statistics and data are related to sampling year (2008)).

We here focus on women aged more than 18. Table 1 reports descriptive statistics of the three samples. In this table the notations **E**, **U**, **M**, and **S** denote, respectively, "**E**mployed", "**U**nemployed", "**M**arried", and "**S**ingle" woman.

Table 1. Properties of the three samples

City	Sample size (people)	Number of households in the sample	Gender distribution (%)		Unemployment rates (%)		Share of each women category (%)			
			Female	Male	Female	Male	EM	UM	ES	US
Mashhad	39947	11073	49.7	50.3	38.4	10.2	29.39	31.16	31.68	7.77
Arak	28254	8335	49.2	50.8	39.1	9.8	29.18	32.06	30.51	8.25
Urmia	22212	6202	49.5	50.5	40.2	12.4	28.34	32.27	30.21	9.18

Table 2 points to the statistics of the percentage of family *activity-travel tasks* carried out by women. An *activity-travel task* is one that must be carried out to meet the needs of family members. We do not consider personal or non-mandatory tasks (e.g. personal excursion taken for leisure, or a personal visit to the doctor which is not going to meet the needs of other family members). We focus on (i) children care and escort, (ii) shopping for family, and (iii) other duties. Trips for receiving the services offered to household members by public or private administrations are included in "Other duties". Furthermore, spouse accompanying is also put in this category.

The statistics show that 66.83% of activity-travel tasks associated with children care and escort in families (e.g. getting kids to school, classes, recreation, and sport) are achieved by working mothers in Mashhad. The remaining 33.17% of these tasks are realized by other family members.

Table 2 Percentage of family activity-travel tasks carried out by women

City	Children care and escort (%)				Shopping for family (%)				Other duties (%)			
	EM	UM	ES	US	EM	UM	ES	US	EM	UM	ES	US
Mashhad	66.83	79.12	0	0.75	59.76	72.69	4.76	0.08	23.52	41.38	1.94	0.04
Arak	65.61	77.55	0	0.55	59.18	72.73	4.71	0.06	23.16	42.24	2.36	0.03
Urmia	66.36	78.72	0	0.51	58.16	71.94	4.88	0.06	24.68	41.02	2.25	0.03

Unemployed married (UM) women have the highest participation rates in activities associated with children care and family shopping activities. Employed and married (EM) women significantly reduce their contribution to other household tasks and activities. Also, unemployed and single (US) women almost do not participate in family activities. This is not surprising as, first, they have no children (the number of single women with children, e.g. widows, in the sample was so small that we dropped them out from the analysis) and, second, they do not accompany or help their relatives along their trips. When employed and single (ES), they increase their participation in family activities (excepted child care).

The questionnaires of the origin-destination travel surveys in these cities have been designed to know whether travelers were car users as drivers or passengers.

Drawing from the (origin-destination, O-D) trip databases of the surveys, Table 3 reports some statistics about car use of women by group (EM, UM, ES, US). The average daily driving time (in minutes) exclude trips by car as a passenger. Average number of daily trips does not distinguish car driver and car passenger. Average daily personal trips considers trips that are not carried out with other relatives. The results show that average daily driving time of women in the target study areas is short. Also, both marital and employment status of women play roles.

Table 3 Women's daily trips and driving time

City	I. Average daily driving time (minutes)				II. Average number of daily trips				III. Average daily personal trips			
	EM	UM	ES	US	EM	UM	ES	US	EM	UM	ES	US
Mashhad	28	12	17	10	4.6	3.3	5.5	4.2	2.2	1.5	4.7	4.0
Arak	31	12	19	11	4.5	3.3	5.7	4.3	2.2	1.5	4.8	4.2
Urmia	26	9	18	10	4.5	3.3	5.5	4.1	2.2	1.4	4.6	4.0

This table sheds light on the influence of both marital and employment status on car travel behavior of women. It shows that marriage has negative effect on the average number of daily trips of women: married women travel less than single women. Finally, within column III, by moving to the right of this column, the ratio of the daily personal trips (part III) to the total daily trips (part II) increases. It means that the proportion of personal trips to total daily trips decreases for employed or married women: the average ratios are 0.49 for EM women, 0.44 for UM women, 0.84 for ES women, and 0.97 for US women.

Figure 1 below depicts the average driving time per day by household's private car for all types of trips with respect to gender, marital and employment status. In this figure the first **M** denotes "**M**an" and the second **M** denotes "**M**arried". Furthermore, **W**, **E**, **S**, and **U** referred to "**W**omen", "**E**mployed", "**S**ingle", and "**U**nemployed", respectively. For example, M-EM refers to the men-employed-married travelers. M-EMs have the highest share in the use of private cars with 34% of the total driving time by private cars in these three cities. Moreover, it is observed that 71% of the average daily driving time by private cars belongs to men and 29% to women. It shows that gender is one of the most influencing factors in the use of a family car.

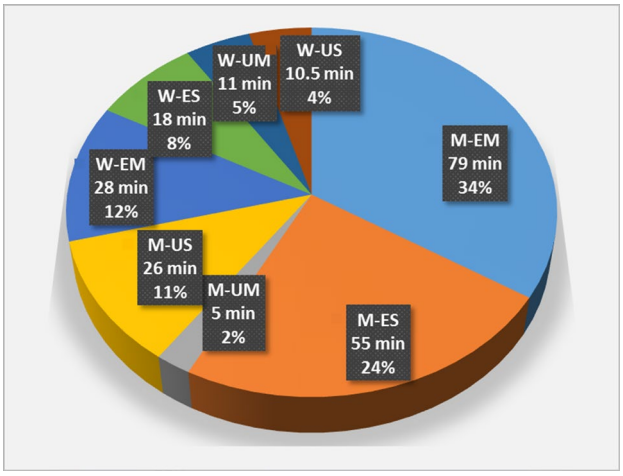

Fig. 1 Average daily driving duration.

3.2. Statistical inferences

We test whether there are differences in the three samples, focusing on the average daily driving time and the average number of daily trips. All test are done at the risk level of 5%.

3.2.1. Test I- Kolmogorov-Smirnov goodness-of-fit test

We first investigate whether the distribution of n_i records (average daily driving time and average number of daily trips in sample space i (i=1, 2, 3)) conforms to the normal

distribution. We use the Kolmogorov-Smirnov goodness-of-fit test (Sheskin, 2004).. The results confirm that such an assumption is not rejected.

3.2.2. Test II- Levene's test for equality of variances

Levene's test (Ho, 2006). is applied to assess the assumption that the variances of the travel data in three cities of Mashhad, Arak, and Urmia are equal. The equality of variances is not rejected.

3.2.3. Test III- Student's t-test

When the distribution of records in the samples conforms to the normal distribution and the variances of the records of the three cities (Mashhad, Arak, and Urmia) are assumed to be equal (as suggested by the former tests), we can use a *t*-test to evaluate whether the Bernoulli random variables, women employment and marital status, significantly influence women average daily driving time and average number of daily trips. The results are reported in table 4.

Table 4 Two sample t-test results

Activity-travel factor	Testing populations	Mean	Standard deviation	t-statists	p-value
Average daily driving time	Married women (M)	18.91	1.27	3.91	0.01
	Single women (S)	14.20	1.28		
Average daily driving time	Employed women (E)	23.41	1.31	5.11	0.00
	Unemployed women (U)	10.52	1.29		
Average number of daily trips	Married women (M)	3.76	0.32	3.82	0.01
	Single women (S)	5.01	0.34		
Average number of daily trips	Employed women (E)	5.11	0.35	5.01	0.00
	Unemployed women (U)	3.53	0.34		

Both employment and marital status of women play significant roles on their average daily driving time and average number of daily trips. However, the t-statistics in this table imply higher influence of employment status of women on both measures of trip making behavior (i.e., average daily driving time and average number of daily trips). Being employed and earning a personal income (i.e. not depending financially on other relatives) have a greater impact on women's activity-travel patterns than marital status.

3.3. Exploring some other behaviors about women's trip-making in Iran

Figure 2 hereafter depicts the shares of different transportation modes by employment and marital status of women. It clearly shows that for both EM and ES (employed-married/single) women, taxi is the prevailing mode of transport. UM (unemployed-married) women mainly use regular bus. US (unemployed-singles) women mainly walk and use taxi. The desire of employed women to use taxi can be attributed to the higher value of travel time for this group of women than unemployed women or their different daily activity travel patterns. Through the same reasoning, because of the need for faster modes of transportation, one can infer that employed women make fewer walking trips than unemployed women.

It is important to mention that the taxi mode is here not similar to the conventional definition of taxi in developed countries. There are several types of taxies in Iran. The first one is named *shared taxi type I* or *rounding taxi* (Babaei, Schmöcker, Khademi, Ghaffari and Naderan, 2015).. It is shared by up to 4 travelers. There is no

terminus for this taxi: the traveler waits on the street side and shouts their destination to all taxis until one of them has the same route and accept boarding. There is no central planner for this type of taxi and the taxi drivers intuitively adjust the place and time of their services. The second type is named *share taxi-type II* or *fixed-route taxi* (Babaei, Schmöcker, Khademi, Ghaffari and Naderan, 2015).. It is a shared taxi that starts and finishes in fixed and pre-determined taxi terminals. Each car waits for a full load of passengers prior to departing. The routes and the number of taxis assigned to each route are adjusted several times per year and there is no real-time control and adjustment on the routes and the number of fleets.

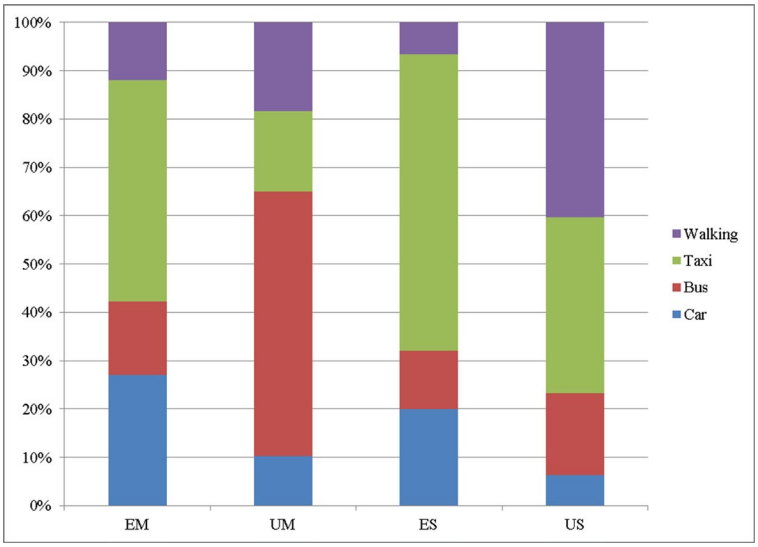

Fig. 2 Average modal share of women.

Table 5 reports statistics on distribution of employed women in the three considered cities along with work time (part time vs. full time), flexibility of work schedule (fixed vs. flexible) and marital status (single vs. married) for employed women. Table 6 reports distribution by occupation status (job types) of women in the three considered cities.

Table 5 Distribution of employed women by work status, type of work schedule, marital status

City	**Single women (S)**				**Married women (M)**			
	Working Time		Working Hours		Working Time		Working Hours	
	Full-time	Part-time	Fixed	Flexible	Full-time	Part-time	Fixed	Flexible
Mashhad	31.43	68.57	84.5	15.5	57.49	42.51	86.1	13.9
Arak	31.55	68.45	83.9	16.1	56.71	43.29	85.4	14.6
Urmia	27.22	72.78	81.1	18.9	55.55	44.45	83.6	16.4

Table 6 Employment status of women by job title

City	**i.** White/Blue-collar workers except for items **ii** and **iv**		**ii.** Research, education, and training careers		**iii.** Sales and retail jobs		**iv.** Emergency service occupations and medical and health professions		**v.** Housewives (homemakers) and unemployed women	
	M	S	M	S	M	S	M	S	M	S
Mashhad	32.7	29.5	9.9	33.4	9.2	10.2	2.6	3.3	45.6	23.6
Arak	32	29.7	9.5	33.6	9.7	10.5	2.6	3.5	46.2	22.7
Urmia	32.2	26.4	8.1	32.7	12.5	14.1	2.5	3.3	44.7	23.5

4. Model

The random components of the utilities of the different alternatives in the multinomial logit model are assumed to be identically independently distributed (iid) with a type I extreme value (or Gumbel) distribution (Train, 2009). The structure of the proposed model in this paper is a mixed nested Logit (NL) model. On one hand, the nested structure of the model relaxes the iid assumption of the multinomial logit and let the random components of the utility functions be correlated, while retaining the assumption that they are identically distributed. On the other hand, mixed nature of the model accommodate unobserved heterogeneity across individuals in their sensitivity to observed exogenous variables (Bhat and Guo, 2004). That is to say, the mixed NL structure accounts for the presence of inter-alternative correlation in the unobserved utility terms, and allow for a random distribution of tastes across decision-makers (Hess, Bierlaire and Polak, 2005).

4.1. Choice sets

We develop a mixed NL model with the two layers: (i) the top layer captures traveler's *daily trip structure* (DTS) choices and (ii) the lower layer accounts for the traveler's *mode choice* behavior. A DTS is a combination of trip purposes when accompanied with the frequencies of the trips.

To model the women's daily mode and DTS choices, work trips were relinquished from women's daily activity-travel type; however, a dummy variable indicating the presence of a work trip was added to the utility function of the DTS choice model. Trip purposes are classed as *shopping trips* (labeled with S), *children related trips* (labeled with C) like getting children to school or taking them to the doctor, *leisure trips and pilgrimages* (labeled with L), and *other trips*, those trips not included in the above categories, like referring to government departments, going to the bank, visiting the doctor (but not for the treatment of children), etc. (labeled with O).

All the observed DTSs are sorted based on their frequencies and those having at least 5% chance of observation are included in the women's DTS choice set. These DTSs encompass 89% of all the observations and 11% of the remaining observations are omitted from the analysis. In this manner, the choice set is composed of 9 different DTSs as:

(i) DTS1: S(1)C(1)O(1)
(ii) DTS2: S(2)L(1)
(iii) DTS3: S(1)C(1)L(1)
(iv) DTS4: S(1)O(1)
(v) DTS5: S(1)L(1)
(vi) DTS6: L(1)C(1)
(vii) DTS7: S(2)
(viii) DTS8: L(2)
(ix) DTS9: C(1)O(1)

As mentioned before, the numbers in parenthesis refer to the number of trips while letters refer to the trip types. For example, DTS2=S(2)L(1) refers to a daily trip set that consists of two shopping (S) and one leisure (L) trip.

Moreover, the observed travel behavior of women in three cities of Arak, Mashhad, and Urmia reveals that the mode choice set is comprised of three individual and four combined modes of transportation. The individual modes are private car, share taxi (type I and II), and regular bus, and the combined modes are walk+private car, walk+share taxi (type I and II), walk+regular bus, and bus+share taxi (type I and II).

It is important to note that a *regular bus service* is a conventional service using general road lanes and it may be subjected to delay as a result of traffic congestion, and it has no priority over other modes of transport. In addition, no express bus services, high-frequency all-day services, or bus rapid transit services existed at the time the travel surveys were conducted in these cities.

Another important note is that this study makes a difference between walking as an access way to other modes of transportation and when walking plays a role as an independent mode of transport. Figure 3 explains the difference between these two. In Figure 3.a, the traveler aims to go from home to a shopping center. In this case, walking is only an access way to the bus system and it is not considered as a distinctive mode of transportation while in Figure 3.b, walking from the shopping center to a park is considered as a typical traveling mode.

The main reason for invoking such a difference is that, in the three cities of Mashhad, Arak, and Urmia, the average access time from the origins to bus stations are 9, 6, and 6 minutes, and the average access time to share taxi stations are 5, 4, and 4 minutes, respectively. Taking 1.2 meters per second walking speed (Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD, 2009). includes this speed for calculating pedestrian clearance intervals for traffic signals), one can calculate the average access distance to bus stations equal to 0.66, 0.44, and 0.44 kilometers, and the average access distance to share taxi stations is equal to 0.30, 0.24, and 0.24 kilometers in Mashhad, Arak, and Urmia, respectively. Hence, these short walking distances of access to public transportation are not considered a unique mode of transportation.

It should be noted that the travel pattern in Figure 3.a is not in the women's DTS choice set as it does not have the minimum 5% chance of observation. However, the women's travel in Figure 3.b is DTS5 (S(1)L(1)) with the combined {walk+regular bus} travel mode choice.

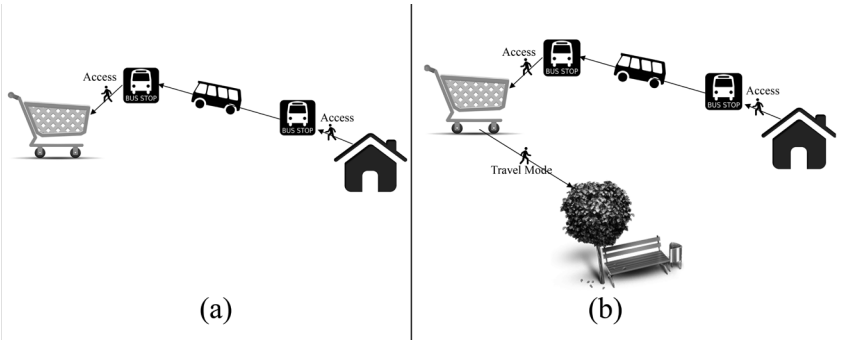

Fig. 3 Difference between walking as an access way to other modes and as an independent mode of transport.

4.2. Joint Model Structure

In this study, the decisions of women on activity-travel choices and also their decisions on travel mode choices are made simultaneously. That is to say, these two decisions are not independent of each other, but women make them jointly together at the same time and, therefore, according to Pinjari, Eluru, Bhat, Pendyala and Spissu (2008)., it is necessary to construct a mathematical structure that reflects the synchronization of such interrelated decision making processes.

Basically, our joint DTS and Mode choice model is a two-level mixed nested logit model, in which the upper nest takes the women DTS choices, and the lower nest takes

their mode choice behavior. In followings, the structure of the model is presented in separate sections, sequentially to better delineate the details; however, the proposed integrated mixed nested modelling system is estimated simultaneously using maximum simulated likelihood estimation.

A woman, labelled *n*, faces a choice among *I* modes of transport. She would gain a level of utility from each alternative. The utility that woman *n* receives from selecting mode *i* is u_{ni}, $i = 1,\ldots,I$. In the same manner, there are *K* DTSs and the woman would receive a level of utility, w_{nk}, as a result of selecting DTS *k*.

The joint model system is presented in Equations (1) to (8) in the following sections. The utility function of the mode choice model is presented in Equations (1). Equation (3) presents the utility function of the DTS choice model.

It should be noted that, in this study, mode choice alternatives are indexed by *i* (*i*=1,…,*I*), the DTS alternatives by *k* (*k*=1,…,*K*), women by *n* (*n*=1,…,*N*), decision attributes of the mode choice model by *m* (*m*=1,…,*M*), decision attributes of the DTS choice model by *l* (*l*=1,…,*L*), and women's household attributes by *h* (*h*=1,…,*H*).

4.2.1. The lower layer: Mode choice model

The transportation mode choice part of the modelling system takes the conventional multinomial logit (MNL) formulation. The associated utility function is defined as follows:

$$u_{ni} = \left(\alpha_i^T + \gamma_n^T\right) x_{ni} + \lambda_i \delta_n + \tau_i P_{ns}^w + \theta_i \eta_n + c_i + \varepsilon_{ni} \quad (1)$$

where

u_{ni} The utility that woman *n* obtains from transportation mode *i*;

x_{ni} (*M*×1) Column vector set of attributes (i.e. there are *M* attributes of transportation modes brought to the utility function, *m*=1,…,*M*) is associated with woman *n* and mode *i*;

α_i (*M*×1) Column vector of the mean effects of the elements of x_{ni} on women's utility for choosing mode i, in which the superscript *T* points to the transpose of the vector;

γ_n (*M*×1) Column vectors whose m^{th} element denotes the unobserved factor specific to woman *n*. γ_n capture unobserved causes of influence of the corresponding *m*th element of the vector set of attributes, x_{ni}. Each element of this vector has the normal distribution: $\gamma_{mn} \square N\left(0, \varsigma_m^2\right)$ where ς_m^2 is estimated;

δ_n Dummy variable equal to 1 if woman *n* is employed and equal to zero if she is unemployed;

λ_i Corresponding coefficient;

τ_i Corresponding coefficient representing the effects of the probability of choosing the DTS on the utility of choosing transportation mode *i*;

η_n Common factors influencing woman *n*'s utility for choosing any combination of modes and DTSs (more details on this are presented later in subsection 4.1.3);

θ_i Corresponding scalar coefficient;

c_i Model constant; and

ε_{ni} Idiosyncratic random error which is independently, identically distributed (iid) extreme value type I across women.

The (conditional to unobserved error terms) probability of choosing transportation mode *i* by woman *n* is derived from the following equation:

$$P_{ni}^{u} = \frac{e^{u_{ni}}}{\sum_{j=1}^{I} e^{u_{nj}}} \tag{2}$$

4.2.2. The upper layer: DTS choice model

Women's DTS choice part of modelling system also takes MNL formulation, as presented below:

$$\begin{aligned} w_{nk} &= w'_{nk} + \varphi_k \left(\ln \sum_j e^{u_{nj}} \right) + \omega_k \eta_n \\ w'_{nk} &= \left(\beta_k^T + \nu_n^T \right) z_{nk} + d_k + \xi_{nk} \end{aligned} \tag{3}$$

Where

w_{nk} The utility that woman *n* obtains from DTS *k*;

z_{nk} (*L*×1) Column vectors sets of variables related to DTS *k*;

β_k (*L*×1) Column vector of the mean effects of z_{nk}'s elements on women's DTS choice utility;

ν_n (*L*×1) Column vectors whose l^{th} element denotes unobserved factor specific to woman *n*, which captures unobserved causes of influence of the corresponding *l*th element of the vector set of attributes, z_{nk}. Each element of this vectors has the following normal distribution: $\nu_{ln} \square N\left(0, \psi_l^2\right)$ where ψ_l^2 is estimated;

$\ln \sum_j e^{u_{nj}}$ A logsum of the utilities (u_{nj}s) associated with all the transportation modes used as a measure of accessibility to show the influence of the overall accessibility of woman *n* to transportation modes on her DTS choices;

φ_k A coefficient representing the effect of the overall accessibility to transportation modes on the utility of choosing DTS *k*;

η_n Common factors influencing woman *n*'s utility for choosing any combination of modes and DTSs (more details on this are presented later in subsection 4.1.3);

ω_k Corresponding scalar coefficient;

d_k Model constant; and

ξ_{nk} Idiosyncratic random error which is iid extreme value type I across women.

Now, the conditional probability of choosing DTS *k* by woman *n* is derived from the following equation:

$$P_{nk}^{w} = \frac{e^{w_{nk}}}{\sum_{q=1}^{K} e^{w_{nq}}} = \frac{e^{w'_{nk}+\varphi\left(\ln\sum_j e^{u_{nj}}\right)+\omega\eta_n}}{\sum_{q=1}^{K} e^{w'_{nq}+\varphi\left(\ln\sum_j e^{u_{nj}}\right)+\omega\eta_n}} \tag{4}$$

or

$$P_{nk}^{w} = \frac{e^{\left(w'_{nk}+\omega\eta_n\right)} \times \left(\sum_j e^{u_{nj}}\right)^{\varphi}}{\sum_{q=1}^{K}\left(e^{\left(w'_{nq}+\omega\eta_n\right)} \times \left(\sum_j e^{u_{nj}}\right)^{\varphi}\right)} \tag{5}$$

The utility functions of travel mode and DTS choice models are considered to be estimated jointly and they are supposed to be interdependent. The dependency is created in two ways:

(1) Using a common component in the models (η): The common component in the models has two basic features. First, it contains common socio-demographic explanatory variables and the attributes of each woman about her current family depending on whether she is married or unmarried. This component makes the model also capable of capturing the marital status of women. Second, as this part exists in each part of the joint simultaneous equations model, the parameters of a common η in the joint DTS-mode choice model structure are estimated simultaneously, i.e. the joint estimation of the two models. For example, suppose that we have two utility functions $y = ax + bt + e$ and $z = cw + dt + f$ for two choice processes (where *y*, *z*, *x*, *w*, and *t* are variables and the others are parameters). These two functions have a common component $t = gv + h$, where *t* is composed of a variable term (*v*) and two constant estimated terms (i.e. the mean rate of effect *g* and the constant value of effect *h*). Explanatory variable *x* affects only the value of the dependent variable *y*, the same manner happens for *w* and *z*. However, both the variables, *y* and *z*, are dependent on a common explanatory variable *t* but with different magnitude imposed by the estimated parameters *b* and *d*. The existence of common factors (captured by *v* across the two equations) implies the joint nature of the model system.

(2) Putting the outcome of the lower level choice model (mode choice) into the utility function of the upper level choice model (DTS choice) as follows: Regarding the effect of woman's mode choice behavior on her perceived utility of available DTSs, the Logsum of the exponential of transportation mode utilities are brought into the DTS choice model. The Logsum measures the overall accessibility of a woman to available transportation modes.

4.2.3. The common component (η_n)

As mentioned above, the presence of common component across the two mode and DTS choice models, which are captured by common socio-demographic attributes of woman, provides the modeling system to be jointed. The common component in Equation 1 and 3 has the following form:

$$\eta_n = \phi \times e^{\left(\vartheta^T y_n + f\right)} \tag{6}$$

Where

y_n (H×1) Column vectors sets of variables related to woman n's household attributes;

ϑ (H×1) Column vector of coefficients;

f A constant;

ϕ A vector of random coefficients that is distributed bivariate normal with parameters μ and Σ, where μ is the 2-dimentional mean vector and Σ represents the 2×2 covariance matrix.

The common component of the modeling system allows the utility function of mode choice (Equations 1 and 2) and DTS choice (Equations 3 and 5) models to vary across women through capturing the women's household attributes by y_n (see Equation 6).

The effect of women's household socio-economic characteristics is captured by the joint component of the model system containing an H×1 column vector set of variables related to woman n's household attributes (y_n). Based on the marital status of each woman, these attributes are only related to parental household (for single women) or spouse household (for married women), so the women's marital status effects are captured by this joint component.

4.3. Model Estimation

The input variables of the models are x_{ni}, δ_n, z_{nk}, and y_n, the set of random terms is $E=\{\phi,\varepsilon_{ni},\xi_{nk}\}$, the set of vertical stacks unobserved factors is $\Lambda=\{\gamma_n,\nu_n\}$, and the parameters that must be estimated are:

Γ The vector of all constant parameters (non-random coefficients) in the utility functions, i.e. $\Gamma=\{\alpha_i,\lambda_i,\tau_i,\theta_i,c_i,\beta_k,\varphi_k,\omega_k,d_k,\vartheta,f\}$

Θ The vectors that vertically stack standard errors ς_m and ψ_l, i.e. $\Theta=\{\varsigma_m,\psi_l\}$

Like before, suppose n as the index of women. The probability of woman n choosing the mode that she was actually observed to choose is formulated as:

$$\prod_{i=1}^{I}\left(P_{ni}^{u}\right)^{\Delta_{ni}} \tag{7}$$

where Δ_{ni} is a dummy taking the value 1 if mode i is chosen by woman n and 0 otherwise. This term merely indicates the probability of the chosen alternative, as $\Delta_{ni}=0$ for all non-chosen alternatives and then P_{ni}^{u} s are raised to the power of zero and become 1.

In the same manner, the probability of choosing the DTS by woman n that she was actually observed to choose is formulated as

$$\prod_{k=1}^{K}\left(P_{nk}^{w}\right)^{\Delta_{nk}} \tag{8}$$

where Δ_{nk} is a dummy which takes the value 1 if DTS k is chosen by woman n and 0 otherwise.

The conditional likelihood function of choosing modes and DTSs by woman n based on her observed choices is

$$L_n(\Gamma,\Lambda)=\prod_{k=1}^{K}\left(\left(P_{nk}^{w}\right)^{\Delta_{nk}}\times\prod_{i=1}^{I}\left(P_{ni}^{u}\right)^{\Delta_{ni}}\right) \tag{9}$$

where P_{ni}^{u} and P_{nk}^{w} are derived from Equations 2 and 5, respectively.

Then, the unconditional choice probabilities are

$$P_{nk,ni} = \int_{\Lambda} L_n(\Gamma, \Lambda) f\left(\Lambda \middle| \Theta\right) d\Lambda \quad (10)$$

The simulation approach using randomized and scrambled Halton sequences (Bhat, 2003) is applied to approximate the multidimensional integral in Equation 10 and calculate $\check{P}_{nk,ni}$ as the unbiased estimator of $P_{nk,ni}$. Assuming that each woman's choice is independent of decisions of other women, we insert $\check{P}_{nk,ni}$s into the log-likelihood function to give a simulated log likelihood as follows:

$$SLL = \sum_{n=1}^{N} \ln \check{P}_{nk,ni} \quad (11)$$

The resulting simulated log likelihood function (*SLL*) is used in the maximum likelihood estimation (for further detail, interested readers can refer to Train (2009). or Ben-Akiva and Lerman (1985).).

5. Results of the model estimation

5.1. Mode choice model estimation

Mode choice model estimation results are presented in Table 7. The absolute value of t-statistics is also given in parentheses. For this analysis, to calculate the *out of pocket cost*, monetary values are converted from Iranian Rials to US Dollar ($) based on the exchange rates in 2008 and 2009 (1 US dollar was equal to 10500 Iran Rials within the survey periods). The ticket fares paid by women is considered as the daily out of pocket cost (DOPC) of travelling by bus system; moreover, the cash fare paid to taxi drivers is the DOPC of taking share taxis.

For woman having a private car, depending on her car type and manufacturing year, the DOPC is computed based on the average daily fuel consumption, average daily vehicle repair cost, and average daily fees and taxes, which are normally calculated by dividing annual amounts to the number of days in a year.

It should be mentioned that *access and egress time* in Table 7 is not considered when the mode of trip is private car and walking, but in the combined modes, it is brought into the analysis only for the part of the trip taken by bus or taxi.

Table 7 Estimated parameters and corresponding t-statistic (in parentheses) of the mode choice model

Coefficients of components in the utility function of the model choice model	Modes of travel						
	1.Car	**2.Bus**	**3.Taxi**	**4. Car +Walk**	**5. Bus +Walk**	**6. Taxi +Walk**	**7. Bus +Taxi**
Travel time (hours)	-1.42 (-5.12)	-3.77 (-5.26)	-1.58 (-5.17)	-1.39 (-5.24)	-3.80 (-5.15)	-1.45 (-4.98)	-2.37 (-5.01)
Access and egress time (hours)	–	-1.18 (-3.16)	-0.33 (-2.80)	–	-0.91 (-3.14)	-0.27 (-3.12)	-0.69 (-3.28)
Waiting time (hours)	–	-1.74 (-3.70)	-0.51 (-3.87)	–	-1.75 (-3.78)	-0.48 (-3.69)	-1.19 (-3.71)
Out-of-pocket cost ($)	-4.95 (-6.17)	-9.47 (-6.23)	-4.56 (-6.16)	-4.82 (-5.89)	-9.43 (-6.24)	-4.14 (-6.19)	-6.47 (-6.09)
Availability of parking space at destination (a dummy variable)	2.57 (6.93)	–	–	2.10 (6.85)	–	–	–
Employment status of woman (coefficient of the employment dummy variable (λ_i))	3.88 (19.41)	2.25 (19.47)	2.97 (19.18)	3.16 (19.17)	2.11 (18.86)	2.81 (19.58)	2.66 (19.33)

Effect of common component on mode choice (spouse or parents' characteristics) (θ_i)	2.35 (22.41)	2.55 (22.57)	2.42 (22.19)	2.37 (21.97)	2.61 (22.47)	2.52 (22.85)	2.56 (22.76)
Model constant (c_i)	0.0 (–)	2.14 (2.88)	1.65 (2.74)	1.12 (2.95)	2.23 (2.82)	1.54 (2.91)	2.07 (2.68)

Notes: The values in parenthesis under the estimated parameters are t-statistics. All the coefficients are statistically significant at the 5% level of significance.

Once a trip has turned into a combined mode when jointed with the walking mode, *access and egress time* of this mode in Table 7 refers to the non-walking part of the mode. Similarly, the same holds true for *waiting time*.

From Table 7 it is worth noting that the most significant variable in the mode choice utility function is *the effect of common component that represent spouse of parents' characteristics* on woman mode choice. A comparison of the coefficients shows that regardless of the *out-of-pocket cost* variable which has the highest-coefficient in the utility function, *employment status of woman* is one of the variables that strongly influences the woman's decision of mode choice. The coefficient of this variable holds its highest value for private car and combine car+walk modes. On the contrary, the lowest value of this coefficient is for bus and bus+walk modes of transportation.

It can be observed that, women's employment is directly related to their use of family cars. That is, the higher the rate of employment among women, the higher the rate of car usage by them. Perhaps it is because of the higher state of economic independence of employed women leading to a shift from traditional household style to the new one. The evidence for this is that, on average, men obtained 83% percent of driving licenses, women have 68% percent of driving licenses, and employed women obtained 75% percent (McDonald and Aalborg, 2009).

Among all the variables in the utility functions, *out-of-pocket cost* is the most effective one. Besides, *availability of parking space at destination* accounts for the utility function of only car and car+walk modes of transportation. As can be seen (in Table 7) this variable is highly significant and has a substantial impact on women mode's choice behavior.

As discussed in section 4, interaction of mode and DTS choice in women's daily activity-travel behavior is brought into the modeling framework, first by the common component (η_n in Equations 1 and 3), and second, through $\ln\sum_j e^{u_{nj}}$ $ln\sum_j e^{u_{nj}}$ (the mode choice model Logsum of the utilities, in the DTS choice equation (Eq. 3)). High values of the t-statistic for the coefficient estimated for the joint model components (in Table 7) implies that the proposed joint model structure is a proper structure for modeling in this context.

The effect of women's household socio-economic characteristics on both mode and DTS choices is reflected through a joint component in the model system (η_n). The related coefficient in the mode choice utility function (θ) is estimated as provided by Table 7. The joint component of the model system contains (H×1) column vector sets of variables related to woman n's household attributes (y_n). Based on the marital status of each woman, various types of household attributes are brought into the model. The household type in this study could be one of the "parental", "sibling", "kin-headed", "individual", or "conjugal" households. By doing so, the effects of women's marital statuses are captured using the joint component of the women's DTS and mode choice models. The coefficient of the joint component (in the mode choice utility function) is

significantly high which confirms that the household attributes are influencing factors on women's mode choice behavior.

Value of time (VOT) for each mode is calculated by dividing the coefficient estimated for *travel time* to the *out-of-pocket cost* of traveling by that mode. The results indicate that, on average, car users have the highest VOT. The women's VOTs for car and car+walk modes of transportation are 3.49 Dollar per hour ($/hr) and 3.47 $/hr, respectively. These values become 2.51 $/hr and 2.48 $/hr for bus and bus+walk and, also, are 2.88 $/hr and 2.86 $/hr for taxi and taxi+walk modes, respectively. Finally the VOT for women whose daily travel mode is combined with taxi+bus is 2.73$/hr.

In addition, the modal share for urban travel of each group of women (i.e. employed-married (EM), employed-single (ES), unemployed-married (UM), and unemployed-single (US)) has been presented previously in Figure 2. Taking all of the above into consideration, the value of time for each group of women (EM, ES, UM, and US) is calculated using the following equation:

$$VOT_g = \sum_{n=1}^{N_g} \sum_m \left(TT_{n,m} \times VOT_m \right) \Big/ N_g \qquad (12)$$

where g is the women's group index, VOT_g is the average value of travel time of women in group g, N_g is the population of group g, n is the woman's index in each group, m is the index of transportation modes, VOT_m is the value of travel time when making a trip by mode m and $TT_{n,m}$ is the average travel time of woman n for travelling by mode m.
From Equation 12, the *VOT* of EM, UM, ES, and US women becomes, respectively, 3.22 $/hr, 2.61 $/hr, 2.85 $/hr, and 2.56 $/hr. This leads to the conclusion that time is more valuable for employed women compared with the unemployed ones in Iran (like in the developed countries) and also has higher values for married women compared with the singles. However, it is worth mentioning that the employment status of a woman is a more influencing factor on the valuation of travel time than her marital status.

5.2. DTS choice model estimation

Similar to mode choice model, common component found to be the most meaningful variable, based on both value of estimated coefficient and t-test results.

Table 8 presents the estimated coefficients of 9 utility functions of the DTS choice model. As shown in this table, women's *age* is one of the most influencing factors on women's DTS choice behavior. For the first three DTSs, namely DTS1, DTS2, and DTS3, which consist of three activities, the value of the coefficient of *age* decreases with the increasing magnitude of this variable. This coefficient becomes even negative for elderly Iranian women. In contrast, other DTSs (DTS4 to DTS9) which comprise only two activities seem more suitable for elderly Iranian women (c.f. the positive coefficient of *age* in Table 8 for DTS4 to DTS9) on account of the fact that through choosing these DTSs, elderly women may not meet a busy daily schedule. Moreover, DTS7 which consists of only two shopping activities is in their favor.

For young women, DTS8 which consists of two leisure activities seems more preferred among other DTSs. However, DTS9 with one children related activity is the most preferred DTS for middle-aged women, as it is more probable that they are involved in child-rearing duties.

Another demographic variable, i.e. woman's *education* level, is found not to be statistically significant, even at the 15% level of significance, contrary to our intuition.

The next category of explanatory variables in the DTS choice model is related to women's employment status. The occupation types are categorized from the perspective of the transportation engineering. That is to say, they were divided on the

basis that the trip making behaviors of occupations in each group are more similar to each other than those in other groups.

The first and the most populous categories of occupation are white-collar and blue-collar workers except for the women having *research, education*, and *training careers, emergency service occupations, and medical and health professions*.

Research, education, and training careers include a wide range of jobs like college/university lecturers/professors, kindergarten/preschool/school teachers, special education teachers, educational administrators and staff, corporate trainers and educators, researchers, scientists, college presidents, deans, department chairs, students, etc.

Emergency service occupations include the professions like police forces, ambulance drivers, fire fighters, etc. Furthermore, in this table, *housewife* and *unemployed* women refer, respectively, to married and single women that do not work out of home. In other words, the married woman who is not a career woman is named *housewife*.

For the first three DTSs, which consist of three activities in a day, the estimated coefficient of occupation type are positive for both *unemployed* and *housewife* women and negative for all other occupation types. That is to say, unemployed single (US) or married (UM) women tend to make more trips than employed ones, as also expected intuitively.

The estimated coefficient for *emergency service occupations and medical and health professions* is negative for all of the DTSs. It means that these women are not interested in taking part in any shopping (or leisure) activities due to their physically strained and stressful jobs. DTS9 would be their preferred option if they have no choice but to make a trip in addition to the work trip. The same is true for all other career women. DTS9 consists of one child related activity and one activity as others.

On the contrary, housewives prefer, to a greater extent, to be involved in daily activity-travel patterns like DTS7 which consists of two shopping activities. Moreover, for unemployed single women, two leisure activities, namely DTS8, seems more interesting than others.

Another significant variable is *daily working time.* As shown in Table 8, the higher the daily work hours, the less the tendency of women to have busier activity schedules, i.e. DTS1, DTS2, and DTS3. Besides, women with work in less than six hours are more likely to choose the first three DTSs; since, they have more time and energy available for the busiest activity schedules. Finally, for working more than nine hours, DTS9 that consists of one children related activity and one other activity is the most preferred one.

Table 8 Estimated parameters and corresponding t-statistic (in parentheses) of the DTS choice model

Variable category	Variable	Daily trip structures (DTS)								
		DTS1	DTS2	DTS3	DTS4	DTS5	DTS6	DTS7	DTS8	DTS9
Demographic variables	**Age**									
	- Young (Up to 35 years old)	1.27 (4.12)	1.31 (4.16)	1.92 (4.07)	0.84 (3.85)	1.36 (4.19)	1.65 (3.99)	1.05 (4.13)	1.96 (3.81)	0.53 (4.26)
	- Middle-aged (36-59 years old)	1.11 (4.19)	0.79 (4.07)	1.07 (3.95)	0.85 (4.31)	0.61 (4.22)	1.73 (4.17)	1.05 (3.97)	-0.55 (-3.41)	1.82 (4.26)
	- Elderly (60 years old and more)	-0.91 (-4.33)	-0.97 (-4.62)	-0.79 (-4.04)	1.52 (4.39)	0.89 (4.16)	0.97 (4.41)	1.59 (3.88)	0.76 (4.65)	1.40 (4.19)
	Education									
	- Up to high school diploma	0.41 (1.43)**	0.43 (1.46)**	0.37 (1.25)**	0.42 (1.37)**	0.36 (1.41)**	0.45 (1.49)**	0.42 (1.28)**	0.38 (1.44)**	0.41 (1.37)**
	- Bachelor's degree	0.28 (1.20)**	0.23 (1.22) **	0.29 (1.31)**	0.19 (1.18)**	0.24 (1.29)**	0.22 (1.34)**	0.27 (1.37)**	0.17 (1.19)**	0.30 (1.25)**
	- Master's degree or PhD	0.13 (1.08)**	0.16 (1.11) **	0.08 (1.16)**	0.18 (1.12)**	0.11 (1.11)**	0.09 (1.19)**	0.11 (1.20)**	0.15 (1.23)**	0.20 (1.14)**
Transportation variable	Having a **work (business) trip** today?	-1.61 (-7.14)	-1.23 (-6.66)	-1.96 (-6.48)	0.80 (6.53)	0.72 (6.28)	0.83 (7.01)	1.07 (6.42)	0.36 (6.29)	0.52 (6.31)
Employment status	**Occupation type:**									
	i. White/Blue-collar workers except for items ii and iv, below	-1.47 (-4.17)	-1.56 (-4.48)	-1.49 (-4.39)	0.71 (3.55)	0.46 (3.27)	0.58 (3.63)	0.82 (4.03)	0.17 (3.58)	1.06 (3.71)
	ii. Research, education, and training careers	-1.31 (-5.16)	-1.37 (-3.99)	-1.32 (-4.89)	0.77 (3.26)	0.50 (3.37)	0.65 (3.03)	0.88 (3.22)	0.34 (4.01)	1.08 (3.85)
	iii. Sales and retail jobs	-0.59 (-3.47)	-0.31 (-3.66)	-0.47 (-3.55)	0.45 (3.05)	0.81 (3.12)	0.94 (3.07)	0.55 (3.15)	0.51 (3.19)	1.46 (3.61)
	iv. Emergency service occupations and medical and health professions	-2.23 (-3.55)	-2.37 (-3.61)	-2.27 (-3.23)	-0.65 (-3.18)	-0.47 (-3.56)	-0.42 (-3.52)	-0.72 (-3.38)	-0.91 (-3.31)	-0.35 (-3.14)
	v. Housewife (homemaker)	0.90 (3.36)	1.29 (3.05)	1.16 (3.22)	1.37 (3.27)	1.51 (3.01)	2.06 (3.41)	2.41 (3.45)	1.95 (3.28)	1.84 (3.01)
	vi. Unemployed	1.22 (2.94)	2.95 (3.01)	1.63 (2.88)	1.57 (3.17)	2.47 (3.12)	0.36 (1.88)*	1.98 (2.89)	3.55 (3.13)	0.25 (1.81)*

Notes: The values in parenthesis under the estimated parameters are t-statistics. All the coefficients are statistically significant at the 5% level of significance unless otherwise indicated:. One asterisk {} (which does not exist in this table) indicates that the coefficient is not significant at the 5% level, and two asterisks {**} indicates that the coefficient in not significant even at the 15% level of significance.*

Table 8 (continued)

Variable category	Variable	Daily trip structures (DTS)								
		DTS1	DTS2	DTS3	DTS4	DTS5	DTS6	DTS7	DTS8	DTS9
	Daily working time									
	- *Less than 6 hours*	0.46	0.33	0.50	0.82	1.11	1.04	1.96	2.37	0.79
		(4.75)	(4.79)	(4.76)	(4.88)	(4.55)	(4.92)	(4.66)	(4.57)	(4.72)
	- *6 to 9 hours*	-0.52	-0.64	-0.55	0.53	0.96	0.87	1.27	0.36	0.66
		(-5.11)	(-5.16)	(-5.03)	(4.56)	(4.51)	(4.62)	(4.58)	(4.44)	(4.47)
	- *More than 9 hours*	-1.79	-2.03	-1.90	0.56	0.34	0.85	0.67	-1.41	0.91
		(-5.23)	(-5.14)	(-5.19)	(4.39)	(4.53)	(4.62)	(4.54)	(-5.27)	(4.41)
Employment status (continued)	Work shift									
	- *Morning*	0.32	0.41	0.36	0.66	0.52	2.17	1.37	0.95	1.94
		(3.62)	(3.66)	(3.52)	(3.47)	(3.69)	(3.61)	(3.53)	(3.40)	(3.55)
	- *Midday*	-0.81	-0.93	-0.88	0.05	-0.04	0.83	0.45	0.21	0.68
		(-3.97)	(-3.91)	(-4.01)	(3.52)	(-3.89)	(3.31)	(3.42)	(3.45)	(3.37)
	- *Evening or overnight*	-1.52	-1.63	-1.54	-0.37	-0.80	-0.60	0.43	-1.05	0.62
		(-3.97)	(-4.06)	(-3.89)	(-3.93)	(-3.99)	(-4.11)	(3.45)	(-3.87)	(3.60)
	Is the workplace located in the CBD?	3.13	3.55	-0.27	3.41	0.95	-1.51	2.47	-2.17	1.52
		(6.16)	(6.25)	(-7.14)	(6.25)	(6.41)	(-6.96)	(6.31)	(-6.85)	(6.19)
Mode choice effect (φ_k)		3.15	4.19	3.77	1.89	1.99	1.65	2.12	1.74	1.58
		(11.13)	(10.82)	(10.91)	(11.06)	(11.31)	(12.22)	(10.58)	(10.36)	(10.69)
Common component	Effect of common component on mode choice (Household characteristics) (ω_k)	5.07	4.01	4.18	3.86	4.61	4.88	4.27	4.05	5.16
		(19.22)	(19.17)	(19.13)	(19.31)	(19.16)	(19.45)	(19.28)	(19.11)	(19.27)
Model constant (d_k)		0.0	2.37	2.17	1,78	2.26	1.69	2.20	1.39	2.14
		(-)	(2.83)	(2.94)	(2.67)	(2.85)	(2.79)	(2.92)	(2.58)	(2.62)

Notes: The values in parenthesis under the estimated parameters are t-statistics. All the coefficients are statistically significant at the 5% level of significance

Work shift, the time period during which career women are at work is also one of the influencing factors on women's daily DTS choice behavior. In our study, only jobs with consistent shifts are brought to the modelling framework and the jobs with rotating shifts were omitted since they have very low number of observations in the sample. The jobs are categorized into:

- *Morning occupations*: Jobs with the starting time from 5:30 to 12:00 (after 10:00, in the sample, we do not have any observation of going to work)
- *Midday occupations*: Jobs starting time within the period of 12:00 to 18:00 (after 14:30 no case were observed in the sample)
- *Evening or overnight occupations*: Jobs that start within 18:00 to 5:30 (there is no case in the sample who starts the work shift after 0:00)

When the work shift is changed from morning to midday or from midday to evening-and-overnight, it causes the women to downplay the possibility of choosing the first three DTSs.

One of the most influencing factors on women's daily DTS choices is the presence of a business activity-travel in a day. The t-statistics of this variable (*having a work (business) trip today*) shows that it significantly influence the structure of the daily activities of women. The results shown in Table 8 revel that a women with a business activity-travel in a day does not tend to participate in more than two activities in the same day. That is why the estimated coefficients of *having a work (business) trip today* variable are negative for those DTSs including three activities per day (i.e. DTS1, DTS2, and DTS3). Furthermore, from Table 8, it appears that women with a business activity-travel in a day are more encouraged to take part in two shopping activities and choose DTS7 in the same day than women without a business activity-travel.

Among the variables of the *employment status* category, the dummy variable checking whether the *location of the work place is within the CBD* or not, is the most effective and significant variable, as it has the highest coefficient and t-statistic among the *employment status* variables.

The next variable is *mode choice effect*. The high t-statistic value of this variable indicates that the women's DTS choice behavior is greatly influenced by their mode choice decisions. The highest values of the estimated coefficients of this variable are found for the first three DTSs. It means that the DTSs with more trips are more affected by mode choice decisions. In addition, by making a comparison between different DTSs, it reveals that the estimated coefficients for these DTSs with a shopping activity-travel are higher than other ones.

As described previously, the effect of women's household socioeconomic characteristics for both mode and DTS choice models are captured through a joint component in the model system (η_n). High values of estimated coefficient of the joint component (ω_i) and the related t-statistic reveals that women's the DTS choice decisions are highly influenced by their household characteristics.

5.3. Estimation of the joint component

Table 9 summarizes the estimation results of the joint component of the model. As mentioned before, there are different types of households surveyed in this study (i.e. parental, sibling, kin-headed, individual, and conjugal households). Because of the small number of sibling, kin-headed, and individual households, only parental and conjugal households are brought in the modelling estimation presented in Table 9. Moreover, as explained later, the joint component reflects women's household attributes. For a single

women living with her parents, the most important variables are *parents' educational level* and the *age gap* between the single woman and her parents. From a sociological perspective, although traditional values may strongly influence cultural and social norms in a developing country like Iran, which restricts female activities outside the home, parents' educational level may alter traditional norms and could be highly influential on girls' lifestyle. For single women, variables like *is the home location home in the CBD*, and *having a little brother/sister* are found insignificant.

Table 9 Estimated parameters and corresponding t-statistic (in parentheses) of the joint component of the model

Variable category	Variable	Coefficient	t-statistic
Parental household socio-economic variables (for a single woman living with her parents)	- Household size	-1.24	-2.83
	- Number of employed adults in the family	1.32	3.16
	- Car ownership	0.66	2.31
	- Is the home located in the CBD	0.55	1.79*
	- Is the father employed?	0.93	3.47
	- Is the mother employed?	1.16	3.36
	Siblings		
	- Having a little brother?	-0.45	0.39**
	- Having a little sister?	-0.73	0.57**
	Father's education level		
	- Up to high school diploma	-1.17	-4.94
	- Bachelor's degree	1.22	5.37
	- Master's degree or PhD	2.24	5.51
	Mother's education level		
	- Up to high school diploma	-0.93	-4.81
	- Bachelor's degree	1.55	5.11
	- Master's degree or PhD	2.61	4.97
	Age gap between the single women and her parents (in average)		
	- Less than 20 years	1.17	6.16
	- 20-30 years	0.71	6.33
	- More than 30 years	-0.61	-4.87
Conjugal household socio-economic variables (for married women)	- Household size	-1.55	-2.24
	- Car ownership	2.38	5.15
	- Is the home located in the CBD?	0.33	1.21**
	Spouse's occupation type		
	-White/Blue-collar workers except for 2nd and 4th items, below	1.14	2.51
	- Research, education, and training careers	1.55	2.63
	- Sales and retail jobs	0.46	2.37
	- Emergency service occupations and medical and health professions	0.11	2.42
	- Unemployed	-1.25	-3.19
	Spouse's education level		
	- Up to high school diploma	-1.63	-6.19
	- Bachelor's degree	1.79	7.13
	- Master's degree or PhD	2.91	7.22
	Having a less than 12 years old child		
	- Boy	-2.77	-9.41
	- Girl	-3.19	-9.55
Model constant	(*f*)	0.21	1.47**

Notes: All the coefficients are statistically significant at the 5% level of significance unless otherwise indicated: One asterisk {} indicates that the coefficient is not significant at the 5% level, and two asterisks {**} indicates that the coefficient in not significant even at the 15% level of significance.*

On the other hand, for a married woman living in a conjugal household, *spouse's educational level*, *having a less than 12 year old child*, and household's *car ownership* are the most important variables.

One of the main findings from Table 9 is that in the patriarchal Muslim societies like Iran, the traditional perceptions of gender roles, which may even create barriers for woman's daily activities, is significantly constrained by providing for the people learning opportunities at school, college, or universities (e.g. see the t-statistics of *father's education level*, *mother's education level*, or *spouse's education level*).

Finally Table 10 shows goodness of fit statistics of the joint mode/DTS choice modelling system.

Table 10 Goodness of fit statistics

Statistic	Equation	Description	Value
Likelihood ratio (L^*)	$L^* = -2\ln(L(0) - L(\beta))$	– $L(0)$: Likelihood of the sample for the model when all parameters are zeros – $L(\beta)$: Likelihood of the sample for the estimated model	391.5
Rho-Square (ρ^2)	$\rho^2 = 1 - \frac{\ln L(\beta)}{\ln L(0)}$	– $L(0)$ and $L(\beta)$ are defined above ↑	0.388
Craig and Uhler's R^2	$R^2_{\text{Craig \& Uhler}} = \frac{1 - \left[\frac{L(0)}{L(\beta)}\right]^{2/N}}{1 - L(0)^{2/N}}$	– $L(0)$ and $L(\beta)$ are defined above ↑ – N: Number of observations in the model	0.375

Note: In some texts, L(·) is defined as the log-likelihood function. In this manner, in the Likelihood ratio, Rho-Square, and Craig and Uhler's R² formulas (above), L(·) should be replaced with exp L(·).

At last, the null hypothesis of the test represents the case where all parameters are zero. The probability distribution of the test statistic (L^* in Table 10) is approximately a chi-squared distribution with degrees of freedom equal to the number of free parameters of the estimated model minus the number of free parameters of the model when all parameters are zero (i.e. the null model). It should be noted that, with the likelihood ratio in Table 10 and by taking 5% level of confidence, the estimated value of the chi-squared for our model exceeds the critical value of the specified level of confidence; hence, the null hypothesis is rejected, i.e., the $L(0)$ does not have a better model fit than $L(\beta)$, or in other words, we conclude that there is a statistically significant relationship between explanatory variables and travelers' choices.

As shown in this paper, marital and employment status are the two key factors that highly influence women's daily activity-travel behavior. According to previous sections, these two factors divide the women's population into four categories (EM, ES, UM, and US). Figure 4 presents a stock chart on the estimated and revealed choices of each woman in these groups. The vertical axis of this chart is $p_o - p_p$, where p_o is the probability of the observed choice of each woman in daily activity-travel behavior (DTS and mode choice) which is always equal to zero (if the women does not choose an alternative) or one (if she choose the alternative), and p_p is the predicted probability of the choice of the alternative using the proposed joint model structure. As shown in Figure 4, the mean value of $p_o - p_p$ is between 0.08 and 0.10. The variance of $p_o - p_p$

represents the variability of daily activity-travel behavior of each group from the results that models predict, and shows the diversity of observed individual behavior compared to the model predictions. It is important to note that $p_o - p_p$, by no means, is a goodness-of-fit measure. That is to say, when stating choice probabilities, we meant that if the choice situation is repeated many times, each decision alternative will be selected a determined portion of the time.

As the figure shows, employed- single (ES) women's behavior is more scattered and less predictable compared to other groups. On the contrary, unemployed-married (UM) women are very restricted with minimum diversity on their daily activity-travel behavior.

From Figure 4, on the one hand, one can deduce that marital status and, consequently, household responsibilities of women significantly affect their lifestyles. On the other hand, it is observed that when women are single and financially independent (i.e. employed-single (ES) women), it is more difficult to model their behavior, which indicates that they have more freedom compared with other groups of women, despite the fact that they have to devote hours to their jobs.

In traditional societies like Iran where mostly male dominated women's lifestyles are highly affected by their household structure, different household responsibilities, especially regarding children restrict them. Moreover, as mentioned previously, women's employment rate is much lower than men's and women depend more on their father or their spouse economically. In recent years, the number of females that prefer to live alone after finding jobs has risen considerably in most cities of Iran. Based on reported statistics, women that choose this type of lifestyle have risen from 3.4% percent to 7.2% percent during the last 10 years (McDonald and Aalborg, 2009)..

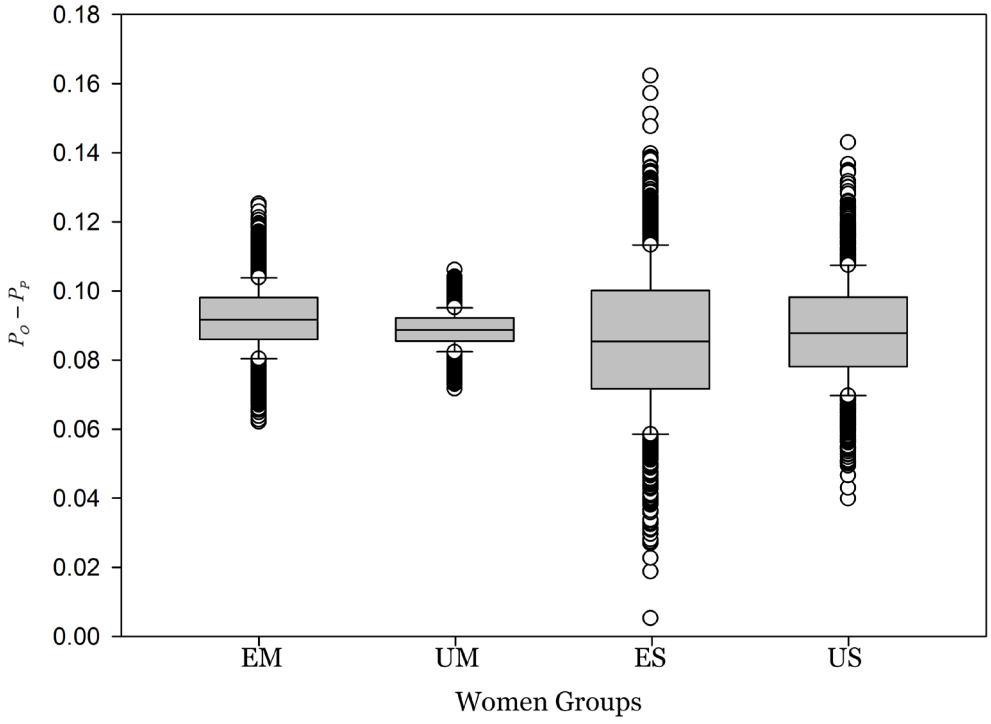

Fig. 4 Estimated and revealed choices of women groups by marital and employment status.

6. Conclusion and further remarks

It is important to study separately women's trip-making behavior as many potentially influencing factors of travel behavior are tied to gender differences. Investigating the women's behavior enables us to grasp the conceptual underpinnings of women's travel demand reactions to transportation system policies and to pinpoint, more accurately, the strategies alleviating the so-called gender equity dilemma in the transportation system, where mostly the developing societies across the nations face. To put it more clearly, studies on travel-activity behavior of women, especially in a developing country, can lead to the following achievements:

1. Setting up better transportation network analysis models, especially activity-based models and enhance the precision of the estimation of these models through taking into account the specific characteristics of women.
2. Improving the efforts for promoting safe and reliable transportation modes to women or managing the women-only transportation in the communities with extreme levels of gender inequality, where women may face sexual harassment and violence during their daily commutes.
3. Establishing scientific support and help for the integration of gender equality into transportation traffic policies in developing countries.

There are various obstacles in the way of such studies in developing countries like Iran. For example, women's activity-travel data are generally limited, and the data that address the different patterns of women's activity-travel is often scarce. Another problem is the scarcity of research funds on women's studies, which also suffers from the same problem of persistent and pervasive gender discrimination in financing the projects related to women's studies.

This study was one of the few studies supplied with appropriate data and attempted to examine the travel behavior of women in three cities of Iran. Our main achievements from the process of (i) data analysis and statistical inferences, (ii) a joint mode and DTS choice model estimation, and (iii) interpretation of the estimation results, are as follows:

- Mode and DTS (daily trip structure) choices of women in the study area in Iran are highly correlated.
- Women's employment directly affects their use of family cars.
- Time is more valuable for employed women compared with those who are unemployed and has higher value for married women compared with the singles.
- Employment status of a woman is a more influencing factor in the evaluation of travel time than the marital status.
- Woman's age is one of the most influencing factors on women's daily activity pattern, e.g. elderly women tend to participate less in daily activities and they mostly prefer to make shopping-related trips. But, young women tend to participate more in leisure activities.
- Existence of a business activity-travel in a day is one of the most influencing factors on women's daily activity structure. Having a business activity-travel in a day lessens the participation of women in other activities on the same day.
- The level of difficulty and responsibility of women's occupations and, moreover, the working time, shape the subsequent after-work activities. The physically strained and stressful jobs or jobs with long working hours reduce the tendency of women in voluntary activities or entertainment.
- Being unemployed or a housewife increases the number of non-business activities of women, which varies depending on whether they are married or

single. For singles, the number of daily leisure activities increases while for married women the number of shopping activities increases.

- Work shift forms the pattern and the size of women's activities. Midday, evening, and overnight shifts reduce the average number of trips or activities of women.
- The workplace location of women also influences the type and frequency of their activities.
- Women's household socioeconomic characteristics significantly affect women's activity-trip making behavior.
- From a sociological perspective, parents' educational level could lessen the strength of traditional/religious norms and values and could bring about more freedom for women in social activities, personal, and familial life, even in a special social and political context of a developing country like Iran, where women are prohibited or restricted from performing several activities outside the home. The same also holds true for married women (i.e. Spouses' educational level supports the freedom of women).
- Having a child, especially a less than 12 years old child, considerably affects women's transportation behavior and activity patterns outside the home.

These findings stress the need for incorporating such gender-related observations into the transportation demand models like car-ownership models, cooperative activity-based models, mode choice models, departure time choice model, etc.

To the best knowledge of these authors, studies on behavior and travel characteristics of women have not reached the level of maturity of other areas of transportation demand analysis and the situation is also worse in developing countries, especially those with a state-religion. Although this paper has tried to provide a perspective of women's activity-travel behavior in Iran as a developing country having patriarchal Muslim culture, considerable efforts are still required to understand the different aspects of women's behavior in transportation systems in these specific environments and to identify the hidden freedom and restriction causes of women's activities.

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