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Research Paper

Bicycle Demand: A Gender Analysis for Tehran, Iran

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Abstract

International studies on bicycle demand have shown that females and males can have different transportation behavior due to their innate differences, as in social responsibility and access to facilities. Considering the almost equal and significant share of females in urban trips, and also the cultural aspects, this issue is of even more importance in Tehran, which lacks detailed focused research studies. This paper aims to model bicycle demand for Tehran stressing on gender difference impacts.

Regarding the scope of the research, a questionnaire field survey was designed to gather the required data for modeling purposes. Using a random sample of Tehran citizens stratified by employment status, the field survey was conducted, in March 2013. Data collected include demographic, economic, environmental, and travel information. The survey included the question, “How much do you use bicycle for urban trips?” as the dependent variable. Choice answers include four alternatives: never, rarely, sometimes, and often.

Based on the collected data, ordered logit models are calibrated separately for males and females to analyse gender impacts on bicycle demand. Results indicate that age, number of cars, number of bikes and access to public transportation have different impacts on the demand of females and males for bicycle trips. Also, some variables such as education level and access to bike houses are found to be significantly related to males cycling but not females. It was also concluded that better and more in-depth information about gender differences in using bicycle is gained by estimating separate models for females and males.

Keywords: Cycling, Gender impacts, Non-motorized transportation, Ordered logit.

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1. Introduction

After the energy crisis and environmental problems, developed countries considered the issue of fuel consumption and use of non-motorized transportation instead of private vehicles even more seriously. Widespread planning for non-motorized transportation systems as part of a large urban transit system can lead to a decrease in e.g. energy consumption, public and private costs, and pollution. Use of non-motorized transportation in developed countries has set an example for such strategies in developing countries, as well.

In spite of these clear and well-known advantages of bicycle over other modes, and also Iranian cycling culture in the past decades, it currently has a rather low profile in modal share of trips in Tehran. According to urban transport information of Tehran municipality in 2015, approximately 22 percent of urban trips is done by taxi, 20 by bus and minibus, 18 by subway and 40 by car and other modes. More than 18.3 million trips are made in Tehran, making traffic congestion and air pollution, a major challenge for municipal officials of this city. Promotion of cycling as a green, safe and cost effective mode, in such circumstances, is a goal of transportation planners.

Impacts of different factors such as socio-economic, environmental, cycling facility, distance and travel time on cycling have been examined in the past. For example, Ortuzar, Iacobelli and Valeze, studied the use of bicycle as an alternative mode of transportation, indicating trip length as a fundamental variable, whose increase can decrease bicycle demand [Ortuzar, Iacobelli and Valeze, 2000]. Rodriguez and Joo, examined the relationship between travel mode choices and attributes of the local physical environment and showed, local topography and sidewalk availability are significantly associated with the attractiveness of non-motorized modes [Rodriguez and Joo, 2004].

Hunt and Abraham, surveyed the nature of various influences on bicycle use and observed that time spent cycling in mixed traffic is more onerous than time spent cycling on bike lanes or bike paths; and that secure parking is more important than showers at the destination [Hunt and Abraham, 2007]. Parkin, Wardman and Page, investigated the proportion of bicycle journeys to work for English and Welsh electoral wards to relevant socio-economic, transport and physical variables. They showed car ownership has a significant effect on bicycle use, also the physical condition of the highway, rainfall and temperature each has an effect on the proportion of bicycle trips to work [Parkin, Wardman and Page, 2008].

Sener, Eluru and Bhat, evaluated the importance of attributes influencing bicyclists' route choice preferences. Their studies indicated all bicyclists prefer no prking to any form of parking (angled and parallel parking) on their route, and that all bicyclists except young adults (18–24 years of age) prefer angled parking to parallel parking [Sener, Eluru and Bhat, 2009]. Jain and Tiwari, estimated riders' perception of route choice and observed that cyclists prefer wider arterial roads against narrow roads [Jain and Tiwari, 2010].

Also Winters et al., evaluated 73 motivators and deterrents of cycling and found that, routes away from traffic noise and pollution, routes with beautiful scenery, and routes separated from traffic are top motivators. Also ice and snow, streets with a lot of traffic, streets with glass/debris, streets with high speed traffic, and risk from motorists are top deterrents [Winters et al., 2010].

Buehler and Pucher, analysed the variation in bike commuting in large American cities with a focus on assessing the influence of bike paths and lanes. Their analysis revealed that cities with safer cycling, lower auto ownership, more students, less sprawl, and higher gasoline prices had more cycling to work [Buehler and Pucher, 2012]. Heinen, Maat and Wee, studied the effect of work-related factors on bicycle commuting. Their results suggested that factors such as having a positive attitude towards cycling, presence of bicycle storage inside, and having access to clothes changing facilities increase the likelihood of being a commuter cyclist [Heinen, Maat and Wee, 2013].

A review of cycling literature shows that in most studies, gender impacts is analysed by introducing an independent variable in models. International studies have shown females and males have different transportation behaviour due to their innate differences, like social responsibility and access to facilities. Regarding the obvious differences between travel patterns of females and males, and the importance of gender in transportation, the relationship between gender and transportation has become an interesting topic for policy makers and planners in recent years. For example, Vance, Buchheim and Brockfeld, focusing on the role of gender in the use of private vehicles, found that generally women are less willing to use private vehicle, but if there are children in household, women's tendency to use private vehicles increases more than men [Vance, Buchheim and Brockfeld, 2005]. Ren and Kwan, examined the complex interactions between different types of internet and physical activities, with a special focus on gender differences and internet maintenance and leisure activities. They observed that Internet use for maintenance purposes has a greater impact on women's activity–travel in the physical world, while Internet use for leisure purposes affects men's physical activities and travel to a greater extent [Ren and Kwan, 2009].

Mokhtarian, Ye and Yun, showed that facing highway reconstruction they pass through every day, women have more changing behaviour [Mokhtarian, Ye and Yun, 2010]. Borjesson surveyed the impacts of physical conditions on walking time to public transportation facilities and observed that the environmental conditions are more important for females than males [Borjesson, 2012].

Obeng analysed gender differences in crash risk severities using data for signalized intersections and showed that driver condition, type of crash, type of vehicle driven and vehicle safety features have different impacts on females' and males' injury severity risks [Obeng, 2012]. Also Shahangian, Kermanshah and Mokhtarian, found significant variables affecting each gender's mode choice, based on stated preference mode choice data gathered for a sample of Tehran commuter drivers to CBD. They observed that from among policies discouraging car use, toll collection is significant for both genders, while policies encouraging transit use have little role on women's choice [Shahangian, Kermanshah and Mokhtarian, 2012].

Considering the importance of gender equity in transportation (equal and notable share of females in urban trips), and the research gap in this field for bicycle demand as a green and environmentally friendly transportation option, the current study intends to use revealed preference data for a sample in Tehran and calibrate ordered logit models separately for males and females to analyse gender impacts on bicycle demand.

The paper is structured as follows. After an introduction and a short review of the literature in this section, the research method is presented in section two, followed by case study introduction, survey design and data collection process. The last two sections present model results and conclusions and recommendations.

2. Research Method

The ordered choice model is an extension of the binary choice model in which there are more than two ordered and non-quantitative outcomes, such as scores on a preference scale. The basic ordered choice model is based on a latent variable typically specified as a linear function of explanatory variables as in equation 1 [Greene, 2002].

$$y_i^*=\beta x_i+\varepsilon_i, \quad for \;\; i=1,2,3,.....,N \qquad (1)$$

where,

$i \; (i=1,2,3,.....,N)$ is an index representing decision-makers,

x_i is a vector of exogenous variables (excluding a constant) for individual i,

β is a vector of unknown parameters to be estimated,

ε_i is the random disturbance term assumed to be standard logistic or gumbel,

y_i^* is an unobserved latent response variable related to the observable ordinal response variable y_i as in equation 2.

$$\begin{aligned} y_i \quad &= 0 \quad if\ y_i^* \le \mu_0, \\ &= 1 \quad if\ \mu_0 \le y_i^* \le \mu_1, \\ &= 2 \quad if\ \mu_1 \le y_i^* \le \mu_2, \\ &\dots \\ &= J \quad if\ y_i^* \ge \mu_{J-1} \end{aligned} \tag{2}$$

The μ_S are unknown parameters to be estimated simultaneously with β. These threshold parameters determine the different observed values of y based on the unobserved value of y* partitioned into *J-1* intervals.

To ensure natural ordering of observations and their being well-defined, thresholds need to be in ascending order, such that $\mu_0 < \mu_1 < \mu_2 < \dots < \mu_{J-1}$ where $\mu_0 = -\infty$ and $\mu_{J-1} = +\infty$. The probabilities associated with the observed outcomes are as in equation 3. Estimates are obtained by maximum likelihood with probability functions equation 4 [Greene, 2009]:

There are numerous variants and extensions of this model: the ordered choice model assuming either a standard normal distribution for ε_i, produces the ordered probit model or a standardized logistic distribution (mean zero, variance $\frac{2\pi}{3}$), which produces the ordered logit model. The underlying mathematical forms are shown in equations 5 and 6, respectively, where the CDF is denoted by $F(z)$ and the density (PDF) by $f(z)$ [Greene, 2002].

Two statistics ρ^2 and ρ_c^2 are often used with discrete choice models as goodness-of-fit measures to show how well the models fit the data and are defined as in equations 7 and 8, respectively, where, $LL(\beta)$, $LL(C)$ and $LL(0)$ are values of the log-likelihood function for estimated parameters at convergence, with only constant parameters (market share), and zero parameters (equal share), respectively. These goodness-of-fit measures range from zero to one and the model with the higher ρ^2 and ρ_c^2 fits the data better [Hensher, Rose and Greene, 2005].

Another goodness-of-fit statistic used is the “percent correctly predicted”. This statistic is calculated by identifying for each sampled decision maker the alternative with the highest probability (based on the estimated model) and determining whether or not this was the alternative that the decision maker actually chose. The percentage of sampled decision makers for which the highest-probability alternative and the chosen alternative are the same is called the percent correctly predicted [Train, 2009].

$$\text{Prob}\left[y_i=j\middle|x_i\right]=\text{Prob}\left[\varepsilon_i\leq \mu_j-\beta x_i\right]-\text{Prob}\left[\mu_{j-1}-\beta x_i\right] \quad , j=0,1,2,\ldots,J \tag{3}$$

$$Prob\left[y_i=j\middle|x_i\right]=F\left(\mu_j-\beta x_i\right)-F\left(\mu_{j-1}-\beta x_i\right)>0 \quad , j=0,1,2,\ldots,J \tag{4}$$

$$\text{Probit:} \quad F(z)=\int_{-\infty}^{z} exp(\frac{-t^2/2}{\sqrt{2\pi}})=\Phi(z), \quad f(z)=\emptyset(z) \tag{5}$$

$$\text{Logit:} \quad F(z)=\frac{exp(z)}{1+exp(z)}=\Lambda(z), \quad f(z)=\Lambda(z)[1-\Lambda(z)] \tag{6}$$

$$\rho^2=1-\frac{LL(\beta)}{LL(0)} \tag{7}$$

$$\rho_c^2=1-\frac{LL(\beta)}{LL(C)} \tag{8}$$

3. Case Study and Data Collection

Tehran, the capital of Iran, is a metropolis with more than 8.9 million inhabitants, an area of 751 square kilometres and a 10811/km^2 population density. The day population of Tehran goes beyond 13 million with more than 18.3 million trips a day, which makes the traffic problem much more complicated. The case study is one of the 22 Tehran municipality districts located in East Tehran with a general gentle slope where bicycling network has already been implemented.

Regarding the scope of the research, a questionnaire field survey was designed to gather the required data for modelling purposes. Considering that, work and study trips are one of the most important aspects of travel behavior in modern societies, they are also compulsory and take place at a fixed point and time and cause congestion. This issue in Tehran due to the large volume of work and study trips is very important and according to the origin-destination (O-D) survey in 2005 (for residents of 15-65 years of age in Tehran), 66% and 17% of trips respectively, are devoted to work and study trips. So, this study population included people working or studying in this region, whether using bicycle or not. The field survey was conducted by using a random sample of Tehran citizens stratified by employment status (employee, teacher, high schools and universities students) in March 2013 [Amini, 2013].

Data collected include demographic, economic, environmental, and travel information. The survey included the question “How much do you use bicycle for urban trips?” as the dependent (response) variable. Choice alternatives include: never, rarely, sometimes, and often coded respectively from 0 to 3. Considering age requirement for bicycle use, it is usually assumed that individuals aged 15 to 65 years, have the required physical abilities, and thus comprise the respondents in this research.

From among a total of 741 respondents, about 65 cases were excluded because of some missing value, yielding 675 cases (207 employees and 468 students) for subsequent analysis. Demographic variables used in modelling include age, gender, job, education level and driving license. A descriptive statistics summary of the data is presented in Table 1 by gender and further variable definition is provided in Table 2. It is observed that most respondents are young (less than 30 years). Travel characteristics analysis shows that males use bicycle more than females and on average, 91.73% of women and 55.34% of men never cycle. Also it is observed that 7.48% of women use bike for recreation and sport trips, whereas men use bike for shopping trips (13.06%) and education trips (5.46%) in addition to recreation and sport (24.23%).

For analysis of economic impacts on cycling, number of cars and bikes in household is used for modelling. Environmental factors including traveller’s access to public transportation stops and bike houses that are measured on a Likert type scale, from ‘no access at all’ (0) to ‘very much’ (5).

Table 1. Descriptive statistics analysis of the data by gender

Category	Variable	Value	Female		Male	
			Mean	Std. dev	Mean	Std. dev
Demographic		Age	26.89	11.71	24.25	12.83
	Age in groups	Under 30	64.57%	47.93%	77.91%	41.53%
		31-45	26.77%	44.36%	10.45%	30.63%
		Upper 45	0.09%	28.18%	11.64%	32.11%
	Education level	High school	48.03%	50.06%	63.66%	48.16%
		College	38.98%	48.87%	26.13%	43.98%
		Postgraduate	12.99%	33.69%	10.21%	30.32%
	Job category	Employee	27.56%	44.77%	9.98%	30.00%
		Teacher	0.01%	29.85%	8.55%	27.99%
		Uni-student	16.14%	36.86%	15.91%	36.62%
		School-student	42.52%	49.53%	59.62%	49.12%
	License driver	License	41.73%	49.41%	38.48%	48.71%
Economic	Car / Bike ownership	Car-num	1.13	0.839	1.26	0.87
		Car	83.86%	36.86%	89.68%	30.32%
		Bike-num	0.649	0.775	0.86	0.88
		Bike	49.21%	50.09%	60.33%	48.98%
Environmental	Access	acc-pub	3.33	1.31	3.49	1.31
		acc-biho	1.89	1.56	2.27	1.67
Travel	Trip purpose	Work	0.39%	6.27%	0.71%	8.42%
		Study	0.39%	6.27%	5.46%	22.75%
		Shopping	0%	0%	13.06%	33.74%
		Recreation	7.48%	26.36%	24.23%	42.89%
		Other	0%	0%	1.19%	10.85%
	Bicycle use	Not use	91.73%	27.59%	55.34%	49.77%
		Never	91.73%	27.59%	55.34%	49.77%
		Rarely	0.07%	25.04%	23.04%	42.16%

		Sometimes	0.02%	12.47%	21.61%	41.21%
		Often	0%	0%	0%	0%
		Emp-shopping	0%	0%	1.43%	11.87%
		Emp-recreation	0.39%	6.27%	2.61%	15.97%
Interaction	Job and trip purpose	Emp-work	0.39%	6.27%	0.71%	8.42%
		Stu-shopping	0%	0%	11.64%	32.11%
		Stu-recreation	7.09	25.71	21.62%	41.21%
		Stu-study	0%	0%	5.23%	22.28%

Number of observations= 675 individual (female: 254 and male: 421)

Table 2. Research variables coding and value definition

Variable category	Variable name	Variable description
	Age	15-65 years
Age in groups	Age15-30	(15≤age≤30)=1, o.w=0
	Age31-45	(30<age<45)=1, o.w=0
	Age45-65	(45≤age≤65)=1, o.w =0
Education level	High school	High school=1, o.w =0
	College	College=1, o.w =0
	Postgraduate	Postgraduate=1, o.w =0
Job category	Employee	Employee=1, o.w=0
	Teacher	Teacher=1, o.w=0
	Uni-student	University students =1, o.w=0
	school-student	High school students=1, o.w=0
License driver	License	Yes=1, no=0
Car / Bike ownership	Car-num	Number of cars in household
	Car	At least have one car=1, don't Have car=0
	Bike-num	Number of bike in household
	Bike	At least have one bike=1, don't Have bike=0
Access	Acc-pub	Access to public transportation
	Acc-biho	Access to bike house
Trip purpose	Work	Work=1, o.w =0
	Study	Study=1, o.w =0
	Shopping	Shopping=1, o.w =0
	Recreation	Recreation and sport=1, o.w =0
	Other	Other=1, o.w =0
Bicycle use	Not use	Don't use=1, o.w =0
	Never	Never==1, o.w=0
	Rarely	Rarely=1, o.w=0
	Sometimes	Sometimes=1, o.w=0
	Often	Often=1, o.w=0
Job and trip purpose	Emp-shopping	((Job=employee or teacher) and (trip purpose=shopping))=1, o.w=0
	Emp-recreation	((Job=employee or teacher) and (trip purpose=recreation))=1, o.w=0
	Emp-work	((Job=employee or teacher) and (trip purpose=work))=1, o.w=0
	Stu-shopping	((Job=uni-student or school-student) and (trip purpose=shopping))=1, o.w=0
	Stu-recreation	((Job=uni-student or school-student) and (trip purpose=recreation))=1, o.w=0
	Stu-study	((Job=uni-student or school-student) and (trip purpose=study))=1, o.w=0

4. Model Results

This study uses ordinal logit model separately for males and females to analyse gender impacts on bicycle demand. Response variable is bicycle use with choice alternatives: never, rarely, sometimes, and often, which regarding their frequency and market share needs aggregation of the latter two alternatives, namely sometimes and often.

Table 3 sets out demographic, economic, environmental, and travel impacts on female and male cyclists, as compared with non-cyclists. This analysis is based on 675 observations (254 female and 421 male) and has a ρ^2 of 0.91 for females' model and ρ^2 of 0.61 for males. Also the results of cross tabulation of predictions by gender are shown in Table 4.

Findings indicate that aging can increase bicycle use for males, so that males less than 30 years old tend to use bike less than other groups. Females' cycling, however, decreases by aging, which is consistent with the fact that older women tend to have more domestic and household responsibilities than men and therefore rely more on motorized transportation modes.

Education level is an effective variable only for males indicating that males with higher education (postgraduate) use bicycle less, probably due to the general image associated with riding bikes.

Results suggest that females and males with at least one personal vehicle in the household use bicycle less. Corresponding coefficients are different (females -2.065 and males -0.960) indicating the rather more sensitivity of women to this variable.

Access to public transportation stops (subway and bus) have significant (negative) role on cycling showing that bicycle usage is reduced with increasing access to public transportation. This variable is significant in both models, but the coefficients indicate higher importance for females (-1.006 as compared to -0.316).

It is also observed that males with at least one bike in their households have a positive tendency for cycling. For females, however, higher number of bicycles available to the household, has such an effect.

Further, increasing access to bike house can increase males' cycling, but not females'. This can be an indication of lack of link between access to bike house and female cycling.

Results of interaction jobs and trip purposes for females' model indicate, they use bicycle only for recreation and sport purpose. Coefficients of model revealed employees (8.009) use cycling more than students (7.988). This indicates that in Tehran, females consider bicycle as a recreation vehicle not as a transport mode.

Males' model show, students use bicycle for study purpose (8.554) and employment use it for shopping purpose

(7.684) more than other purposes. Cycling for recreation and sport trips for male student (7.035) and male employment (5.447) is different. Observe that use of bicycle for work trips isn't important for men and women.

Table 3. Results of ordered logit models for demand cycling by gender

Characteristic	Variable	Value	Female		Male	
			Coefficient	P-value	Coefficient	P-value
Demographic	Age in groups	Age	-0.054*	0.0647	-	-
		Age15-30	-	-	-2.692***	0.0000
		Age31-45	-	-	-1.074*	0.0810
	Education level	Postgraduate	-	-	-1.066*	0.0701
Economic	Car / Bike ownership	Car	-2.065**	0.0191	-0.960**	0.0122
		Bike-num	1.350**	0.0112	-	-
		Bike	-	-	0.733*	0.0558
Environmental	Access	Acc-pub	-1.006***	0.0013	-0.316***	0.0048
		Acc-biho	-	-	0.172*	0.0573
Interaction	Job and trip purpose	Emp-shopping	-	-	7.684***	0.0000
		Emp-recreation	8.009***	0.0099	5.447***	0.0000
		Stu-shopping	-	-	7.565***	0.0000
		Stu-recreation	7.988***	0.0000	7.035***	0.0000
		Stu-study	-	-	8.554***	0.0000
		$M_u(1)$	5.289	0.0001	3.738	0.0000
		LL(β)	-24.797		-181.661	
		LL(C)	-82.681		-419.621	
		LL(0)	-279.048		-462.516	
		ρ^2	0.91		0.61	
		ρ_C^2	0.70		0.57	

Depend variable: bicycle use, values: 0: never, 1: rarely, 2: sometimes or often.
Number of observations= 675 individual (female: 254 and male: 421)
***, **, * = Significance at 1%, 5%, 10% level.

Table 4. Cross tabulation of predicted and actual choice by gender

	Prediction									
	Female					Male				
	y(i,j)	0	1	2	Total	y(i,j)	0	1	2	Total
Actual	0	233	0	0	233	0	232	1	0	233
	1	1	16	0	17	1	3	58	36	97
	2	1	2	1	4	2	5	36	50	91
	Total	235	18	1	254	Total	240	95	86	421
	Percent correct prediction=98.4					Percent correct prediction=80.8				

5. Conclusions and Recommendations

In recent years, due to the increasing use of non-renewable resources and environmental pollution, an attractive strategy for solving urban transportation problems, is use of bicycle as an urban transportation system. In Tehran, due to increasing car ownership and its negative impacts, traffic congestion and air pollution have gradually become major challenges for municipal officials. In this situation, promotion of cycling as a green, safe and cost effective mode of transportation can have a bold role. Due to importance of gender in transportation behaviour (notable share of females in urban trips) and especially the different culture conditions in the country, traffic problems in Tehran and role of bike as a green and environmentally friendly transportation option, this study investigates gender impacts on cycling using the results of a field survey of 675 Tehran citizens (254 females and 421 males). Based on the revealed preferences data and ordered logit model, two separate demand models (one for females and one for males) are calibrated leading to the following conclusions and recommendations.

Aging can increase bicycle use for males and the opposite for females. Also education is an important variable only for males, decreasing bicycle use (with higher education, namely postgraduate studies). Results also indicate that females and males with at least one private vehicle in the household tend to use bicycle less. Also males with at least one bike in the household, and women with a higher number of bicycles, cycle more than others.

As expected, increasing access to public transportation decreases cycling for both females and males. Today due to the expansion of cities (high travel time and distance), it is less probable to travel by bike from origin to destination. Also most individuals use motorized transportation such as taxis and private vehicles to reach public transportation. Therefore, use of bicycle for partial trips (such as access to bus and subway stops) is proposed. Thus, construction of adequate facilities near bus and subway stops can encourage cycling and public transportation simultaneously because public transportation and cycling are sustainable modes of transportation.

It was observed that construction of bike houses and provision of free bicycle service have insignificant impacts on females. This can show the relatively less importance of construction policies as compared to the more effective cultural issues. This research shows that females use bicycle only for recreation and sport and do not consider it as a transport mode.

So, clarifying the role of bicycle as a healthy and low-cost vehicle without air and noise pollution may encourage females to cycle more. As observed, male students use bicycle for study trips more than other purposes, and male employees are more likely to travel by bicycle for shopping trips (due to the short length of these trips).

Importance of different cycling facilities, such as existence of bicycle lane, bicycle path, secure parking and sheltered facilities are suggested for further research. Also, factors such as weather conditions (rainfall, cold, hot, pollution) influence people’s day-to-day choices for cycling. Research can thus be conducted in order to test weather impacts on cycling.

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