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Modeling Impacts of Network Characteristics on Maximum Acceptable Time for Cycling, Case of Work and Study Trips

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Abstract

Today, excessive increase in number of cars and urban trips has caused problems such as traffic congestion and air pollution leading to lower quality of life in metropolises. In such circumstances, using traditional systems such as cycling can be of high value. Previous international studies about cycling have shown that maximum acceptable time for cycling has received little attention. Considering this research gap, this paper aims to investigate impacts of different factors such as individual characteristic, land-use and built environment, on maximum acceptable time for cycling. Based on a field survey of 473 Tehran citizens conducted in one of the twenty-two Tehran municipality districts, mixed logit models were calibrated, validated and interpreted. Results indicate that people traveling through mixed land-use tend to use bicycle for thirty minute-trips more than the other land-use types. Also access to bicycle lane causes more tendency for thirty minute-trips by bicycle. Results also indicate that access to secure parking in destination and increasing number of intersection on the origin-destination routes increase travelers' tendency for cycling about fifty-minute.

Keywords: cycling, maximum acceptable time, environmental impacts, mixed logit.

1. Introduction

Nowadays, traffic congestion and air pollution are major problems in metropolises. This problem in Tehran is so serious. Tehran is capital of Iran; daylight population of this city goes to more than twelve million people, which makes the traffic situation much more complicated including more than fifteen million trips a day. Daily, more than four million vehicles are traveling through Tehran roads network. In this situation, promotion of cycling as a green, safe and cost effective mode of transportation can have a bold role.

To date, impacts of different factors such as socio-economic, travel and cycling facility have been examined on cycling. For example Ortuzar et al. [1] studied the use of bicycle as an alternative mode of transportation, their results indicate trip length is a fundamental variable and increasing trip length can decrease bicycle demand. Rodriguez and Joo [2] examined the relationship between travel mode choice and attributes of the local physical environment. They showed that local topography and sidewalk availability are significantly associated with the attractiveness of non-motorized modes.

Hunt and Abraham [3] 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 the secure parking is more important than showers at the destination. Parkin et al. [4] 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, and the physical condition of the highway, rainfall and temperature each have an effect on the proportion that cycles to work.

Sener et al. [5] evaluated the importance of attributes influencing bicyclists' route choice preferences. Their studies indicate all bicyclists prefer no parking to any form of parking (angled and parallel parking) on their route, also all bicyclists except young adults (18–24 years of age) prefer angled parking to parallel parking. Jain and Tiwari [6] estimated riders' perception of route choice and observed that cyclists prefer wider arterial roads against narrow roads.

Also Winters et al. [7] 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.

Buehler and Pucher [8] analyzed the variation in bike commuting in large American cities with a focus on assessing the influence of bike paths and lanes. Analysis revealed that cities with safer cycling, lower auto ownership, more students, less sprawl, and higher gasoline prices had more cycling to work. Heinen et al. [9] studied the effect of work-related factors on bicycle commuting. The results suggested that the following factors such as: having a positive attitude towards cycling, the presence of bicycle storage inside and having access to clothes changing facilities increase the likelihood of being a commuter cyclist.

Related literature review about cycling show, most studies examined impact of socio-economic and cycling facility factors on cycling, whereas maximum time that individual accept to cycle have received little attention. Today due to the expansion of the cities (high travel time and long travel distance) it is less possible to travel by bike from origin (home) to destination (work or study location). So this question is considered that "how many minutes do people tend to cycle and which factors influence it? So this paper aims to investigate demographic, built environment and land-use impacts on maximum acceptable time for cycling in work and study trips.

The rest of the paper is structured as follows. In the next sections, the research design and process of data collection are described. Then the research results are provided. The last section presents conclusions and suggestions.

2. Methodology

In this paper, we formulate a mixed logit (ML) model for the maximum acceptable time for cycling. Mixed logit probabilities are the integrals of standard logit probabilities over a density of parameters.

The mixed logit probability can be derived from utility-maximizing behavior in several ways that are formally equivalent but provide different interpretations. The most straightforward derivation, and most widely used in recent applications, is based on random coefficients. The decision maker faces a choice among J alternatives. The utility of person n from alternative i is specified as [10]:

$$U_{ni} = \beta'_n x_{ni} + \varepsilon_{ni} \tag{1}$$

where x_{ni} are observed variables that relate to the alternative and decision maker, β_n is a vector of coefficients of these variables for person *n* representing that person's tastes, and ε_{ni} is a random term that is IID extreme value. The coefficients vary over decision makers in the population with density $f(\beta)$. This density is a function of parameters θ that represent, for example, the mean and covariance of the β's in the population.

The decision maker knows the value of his own β_n and ε_{ni}'s for all J alternative and chooses i if and only if [10]:

$$U_{ni} > U_{nj} \quad \forall\, i \neq j \tag{2}$$

The researcher observes the x_{ni}'s but not β_n or the ε_{ni}'s. If the researcher observed β_n, then the choice probability would be standard logit, since the ε_{ni}'s are IID extreme value. The probability conditional on β_n is [10]:

$$L_{ni}(\beta) = \frac{e^{\beta' x_{ni}}}{\sum_{J=1}^{J} e^{\beta' x_{nj}}} \tag{3}$$

The unconditional choice probability is therefore the integral of $L_{ni}(\beta)$ over all possible variables of β_n [10]:

$$P_{ni} = \int \frac{e^{\beta' x_{ni}}}{\sum_{J=1}^{J} e^{\beta' x_{nj}}} f(\beta) d(\beta) \tag{4}$$

The researcher specifies a distribution for the coefficients and estimates the parameters of that distribution.

The probabilities are approximated through simulation for any given value of θ. The simulated likelihood function and simulated log-likelihood function are [10]:

$$SL(\beta) = \prod_{n=1}^{N} \prod_{i} (\check{P}_{ni})^{y_{ni}} \tag{5}$$

$$SLL(\beta) = \sum_{n=1}^{N} \sum_{i} y_{ni}\ ln(\check{P}_{ni}) \tag{6}$$

Where y_{ni} =1 if n choose i and zero otherwise. The maximum simulated likelihood estimator (MSLE) is the value of θ that maximizes SLL.

We apply quasi-Monte Carlo simulation techniques [11] to approximate the integrals in the likelihood function and maximize the logarithm of the resulting simulated likelihood function across all individuals with respect to the parameters β and σ.

In the current paper, we use Halton sequences [12] to draw realizations (1000 Halton draw). The possibility of different distributional assumptions for each attribute should also be investigated, so we examined normal, lognormal, uniform and triangular distribution for each attribute.

3. Case study characteristics and data

The mixed logit model for maximum acceptable time for cycling was implemented for a real case of Tehran municipal district. The interview questionnaire survey was carried out in Tehran municipality district number eight, where bicycling network has already been implemented. This district is located in East Tehran with a gentle slope, making cycling fairly feasible. Fifty percent of land-use in this region is residential (Fig. 1).

The field survey was conducted in March 2013, based on a random sample of Tehran citizens stratified by employment status (employee, teacher, high schools and universities students). The sample included people either working or studying in this district, whether they used bicycle or not. Data items include demographic, environmental, land-use and travel information. The survey included the question, "how many minutes do you tend to cycle for work or study trips?" as the dependent (response) variable for modeling purposes. Choice responses include six alternatives: never, 10, 20, 30, 40 and 50 minute, coded respectively from 0 to 5 [13].

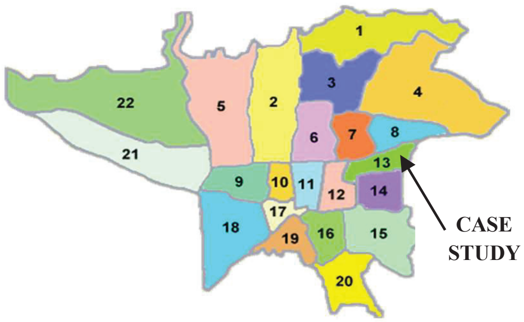

Fig. 1. Twenty-two municipality districts of Tehran and the study district

A total of 528 questionnaires were completed whose data were coded for data entry. Due to missing values or validation problems, 55 cases were excluded, leaving a final 473-case data base. Based on Cochran method, 384 observations required for this study. A descriptive statistics summary of this final data used for model calibration is presented in Table 1. As observed, for example, age distribution includes 63.6% in the 15–30 year range and 14.6% in the upper 45-year range.

Environmental factors including access traveler's to public transportation stations in origin, bike parking in destination, bicycle lane from origin to destination and number of intersections from origin to destination is measured on a Likert type scale from 'not access at all' (0) to 'very much' (5), but this variables (except number of intersections) used in modeling as binary variables that described in Table 1.

Results indicate that about 40% of individuals traveling through residential land-use and approximately 56% of respondents travel through mixed land-use.

Data about travel characteristics showed that approximately 69% of travel time for work or study trips is lower than thirty-minute and 80% of travel distance is less than ten kilometers.

As observed, 22% of travelers do not have tendency to cycle in work or study trips. Also, the most time that travelers accept to cycle is thirty-minute (21.1%) whereas minimum is fifty-minute (8%).

4. Mixed Logit model results

Based on the questionnaire raw data and for more precision, six alternatives were provided for maximum acceptable time for cycling namely 0, 10, 20, 30, 40 and 50, which regarding their frequency and market share (Table 1) needs aggregation. Further frequency analysis revealed that an aggregation to 3 alternatives of never, maximum thirty-minute cycling (10, 20 and 30 minute) and maximum fifty-minute cycling (40 and 50 minute) would be better choice.

From among more than 300 mixed logit models calibrated on the 473 observations, to analyze the effect of demographic, environmental, land-use and travel impacts on maximum acceptable time for cycling the final model was selected (Table 2).

As observe, employees, teachers and high school students have important and significance role on utility of never alternative. This shows they have lower tendency (versus university students) to cycle for work and study trips.

Results suggest that "Tibet" variable (travel time ≤ 15 minute or travel time ≥ 70 minute) have important and significance role on utility of never alternative. Maybe respondents with lesser fifteen-minute travel time prefer to use previous transportation mode (frequently walking). Also, cycling for travelers with upper seventy-minute travel time is tiring, so they have little tendency to cycle.

The findings indicate that respondents with high education (postgraduate) tend to use bicycle less than others. Perhaps they imagine, cycling lessen their social situation.

Access to public transportation in origin, is produces a random parameter with a mean of 0.762 and a standard deviation of 2.857, in utility of thirty-minute cycling. This means, the impact of this variable for travelers is difference and can be described with uniform distribution.

As observed, people traveling through mixed land-use tend to use bicycle for thirty minute-trips more than the other land-use types. Because these areas are busy and congested, so cycling is proper mode to get away traffic. But it seems use bicycle for fifty-minute in mixed land-use is tiring for users.

Access to bicycle lane from origin to destination has important (0.787) and significant role on thirty-minute cycling utility, namely if there is bicycle lane, travelers have more tendency for cycling.

The dummy variable indicating a distance of less than ten kilometers (Dist) is significant in thirty-minute cycling utility and shows respondents with less than ten kilometers travel distance (versus over ten kilometers) are more willing to use bicycle for thirty-minute.

Variable of travel time less than 30 minute has a significant role (0.765) on utility of maximum thirty-minute cycling. Namely with increasing travel time over 30 minute, due to fatigue and reduced physical abilities of cyclists, cycling decrease.

Results indicates, respondents upper than 45-year range tend to cycle fifty-minute, maybe this groups have more time and are usually more important to health, so they want to travel by bicycle more time.

Access to secure bike parking in destination has important and significance role (0.561) on utility of fifty-minute cycling. This shows that if there is secure parking in destination, travelers tend to use bicycle for more time, which shows the importance of secure parking for cyclists.

Observe that with increasing numbers of intersection on the origin-destination route, increase travelers' tendency for cycling about fifty-minute. Perhaps with increasing numbers of intersection, travelers spend more time at red light, so bicycle usage can decrease time loss.

Table 1: Descriptive statistics analysis results of survey data

Category	Variable	Parameter	Description variable	Mean	Std.dev
Demographic	Age	un30	if (15≤age≤30)=1, ow=0	0.636	0.482
		Betw	if (30<age<45)=1, ow=0	0.218	0.413
		Up45	if (45≤age≤65)=1, ow=0	0.146	0.353
	Job	Emp	if (job=employee=1), ow=0	0.218	0.413
		Tea	if (job=teacher=1), ow=0	0.135	0.342
		Uni	if (job=university students =1), ow=0	0.224	0.417
		Stu	if (job=high school students=1), ow=0	0.366	0.482
	Education	School	if (education=high school=1), ow=0	0.423	0.495
		College	if (education=college=1), ow=0	0.423	0.495
		Pgra	if (education=postgraduate=1), ow=0	0.154	0.362
Environmental	Environment	Dastr	if (there is access to public transportation in origin=1), ow=0	0.901	0.299
		Lane	if (there is access to bike lane from origin to destination=1), ow=0	0.131	0.338
		Park	if (there is access to bike parking in destination=1), ow=0	0.569	0.495
		Inters	if (numbers of intersections from origin to destination =1), ow=0	2.463	1.364
	Land use	Resid	if (land use=residential=1), ow=0	0.402	0.491
		Admin	if (land use=administrative=2), ow=0	0.015	0.121
		Comer	if (land use=commercial=3), ow=0	0.021	0.144
		Mixed	if (land use=mixed=1), ow=0	0.562	0.497
Travel	Travel time	Tiun30	if (travel time ≤ 30 min)=1, ow=0	0.693	0.462
		Tibet	if (travel time ≤ 15 min or travel time ≥ 70 min)=1, ow=0	0.436	0.496
	Travel distance	Dist	if (travel distance ≤ 10 kilometers)=1, ow=0	0.797	0.403
Max time	Max acceptable time for cycling	Zemin	if (max time for cycling= 0 min), ow=0	0.222	0.416
		Tenmin	if (max time for cycling= 10 min), ow=0	0.197	0.398
		Twmin	if (max time for cycling= 20 min), ow=0	0.184	0.388
		Thimin	if (max time for cycling= 30 min), ow=0	0.211	0.409
		Foumin	if (max time for cycling= 40 min), ow=0	0.106	0.308
		Fifmin	if (max time for cycling= 50 min), ow=0	0.080	0.272

5. Conclusions and suggestions

Today, duo to traffic congestion and air pollution in metropolises, promotion of cycling as a green, safe and cost effective mode of transportation can have a bold role. International studies show, most studies examined impacts of socio-economic, travel and cycling facility on cycling whereas maximum time that individual accept to cycle have received little attention. So this paper by using the results of the 473 Tehran citizens in one of twenty-two Tehran municipality districts and mixed logit model investigated demographic, built environment and land-use impacts on maximum acceptable time for cycling in work and study trips and has taken the following conclusions and suggestions.

Results suggested that employees, teachers and high school students have little tendency (versus university students) to cycle for work and study trips. Also travelers with travel time less than fifteen-minute or upper seventy-minute and respondents with high education (postgraduate) have lower tendency for cycling.

As observed, people traveling through mixed land-use tend to use bicycle for thirty minute-trips more than the other land-use types. Also access to bicycle lane causes more tendency for thirty-minute trips by bicycle.

Results showed that respondents with less than ten kilometers travel distance (versus over ten kilometers) or less than thirty-minute travel time are more willing to use bicycle for thirty-minute.

Results indicated that access to secure parking in destination and increasing number of intersection on the origin-destination routes increase travelers' tendency for cycling about fifty-minute.

It is recommended to construct secure bike parking controlled by guards or CCTV.

Our research focused on only one district of Tehran municipality due to the limited spread of cycling network in Tehran and our emphasis on revealed preference data. Considering this limitation, it is suggested to collect a larger revealed preference data or design and gather stated preference type data for modeling, for further research.

Table 2: Results of mixed logit model for maximum acceptable time for cycling

Alternative (Max acceptable time for cycling)	Parameter	Coefficients	
		Value	P-value
Zero-minute (never)	Emp	1.259	0.0007
	Tea	1.550	0.0004
	Stu	1.747	0.0000
	Pgra	1.117	0.0057
	Tibet	0.581	0.0333
Thirty-minute	Dastr	0.762 (2.857)*	0.0144 (0.0098)*
	Lane	0.787	0.0725
	Mixed	0.722	0.0084
	Tiun30	0.765	0.0518
	Dist	1.444	0.0013
Fifty-minute	Up45	0.868	0.0233
	Park	0.561	0.0453
	Inters	0.331	0.0001
LL(0)= -519.644	LL(C)= -452.840	LL(β)= -408.600	
$\boldsymbol{\rho^2} = 0.21$	$\rho_c^2 = 0.098$		
$-\mathbf{2[LL(0) - LL(\boldsymbol{\beta})]}$ =222.1	$\chi^2_{14}(0.01\ \mathrm{d.f})$ =29.14		
$-\mathbf{2[LL(C) - LL(\boldsymbol{\beta})]}$ =88.5	$\chi^2_{14}(0.01\ \mathrm{d.f})$ =29.14		
Num. observations=473	Num. coefficients =13	Num. random parameter=1	

* Value and p-value of standard deviation of parameter with uniform distribution

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