Evaluating the Willingness to Pay for Urban Congestion Priced Zones (Case Study of Tehran)

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Received: 13.05.2013 *Accepted:22.07.2013*

Abstract

Congestion pricing is one of the major travel demand management policies to reduce traffic volumes in metropolitans. One of the main factors for effective implementation of this policy is to analyze users' response to different toll rates. In this paper, the willingness of users to pay for using their personal cars is evaluated. The stated preference method was applied for data gathering. Several pricing scenarios are developed for analyzing the willingness to pay of users, under different scenarios. Travelers' socio – economic characteristics as well as their trip chains and their mode choice according to different pricing scenarios are gathered by means of a questionnaire that was filled out by more than 4000 respondents. A binary logit model is applied to model choice behavior of users against different price scenarios. Results show that with 50000 Rials toll for Tehran CBD area; 27 percent of users will use their personal cars for entering the congestion priced area. This rate is reduced to 7 percent if the toll increases to 200.000 Rials.

Keywords: Congestion pricing, Stated preference method, Modal split models

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1. Introduction

By rise of population and vehicle ownership rates in urban areas, many routes, particularly in CBDs of the cities, deal with traffic congestion and its side effects such as noise and air pollution. According to the European UNITE Project, the overall traffic congestion cost in England is annually 15 billion Euros which is about 1.5 % of its gross domestic production [De Palma, 2009]. This number is estimated as 1.3 % and 0.9 % for Germany and France, respectively [Carey et al, 1993]. In a study conducted by Texas Transport Institution ontraffic congestion in major cities of the United States, it was reported that in 2007 traffic congestion has imposed a delay of 4.2 billion hour and extra fuel consumption of 2.8 billion gallons which costs 87 billion US dollars [Bowerman, 2007]. In Tehran, more than 30 percent of Tehran daily traffic enters the congestion priced area [Tehran Comprehensive Traffic Studies , 2006].

Typically, there are two ways of mitigating congestion which are related to supply and travel demand. Enhancing supply is equal to developing or increasing the capacity of infrastructures. However, it had been proven that by increasing supply, travel demands (of personal cars) will also increase, which in turn leads to further traffic congestion. Therefore, developing transportation supply requires significant economic sources which are often hard to be afforded by governments and authorities [Brownstone et al, 2003].

One of the most effective travel demand managementpolicies is congestion pricing. This policy was initially established in interstate routes by setting toll stations to provide financial sources for construction, repair and maintenance of the routes. The basic principle of congestion pricing is based on this concept that the major share of traffic congestion costs are formed by drivers cumulatively. In general, each user imposes a delay to other users and the whole system while he does not pay for these external costs.This, in turn leads to increased in delay of road network system [Carey et al, 1993].

In this regard, setting tolls for the entrance of users in these zoneis among strategies which can be used to reduce vehicle congestion, and also, using the earn benefits for further development of public transportation system. In this research, the willingness to pay (WTP) of the users entering the congestion priced area has been investigated. The main objective of this paper is to demonstrate the sensitivity of users' mode choice against differentpricing scenarios of the congested area.

2. Literature review

For decades congestion pricing remained largely an Impractical idea, but interest gradually spread outside academia and congestion pricing has come into limited practice. The main operating schemes are High Occupancy Toll (HOT) lane facilities in the US, the London congestion charge, the Stockholm cordon charge, and Singapore's Electronic Road Pricing system [Parseh Transportation Research Institute, 2010]. Few Cost benefit analysis of these (or other) congestion pricing systems have been undertaken. However, the limited evidence suggest that well-designed schemes can yield significant net economic benefits estimate the benefits from tollinga two-lane facility similar to the State Route 91 (SR-91) HOT lanes in Orange County, California.6. Optimal tolling of both lanes yields a welfare gain of nearly $3 per trip, while operating one lane as a HOT lane and leaving the other lane free yields still appreciable gain of $2.25 per trip.[Small et al. 1982].

A fundamental question in the debate is how much drivers are willing to pay to save time by avoiding congested roadways. Most revealed preference (RP) “value of time” estimates are based upon mode choice models for the tradeoff between transit and auto travel. Brownstone found that the median willingness to pay to reduce the travel time for the population of regular morning drivers is roughly $30 per hour [Brownstone et al, 2003].

Calfee and Winston attempted to estimate willingness to pay to reduce travel time that is specific to automobile travel. They use stated preference data because they lacked RP data for the choices involved with congestion pricing. Based on this approach, they concluded that commuters have a lower valuation of time saving than previously thought [Calfee and Winston, 1998].

Khattak and colleagues analyzed the willingness to pay of users for receiving traffic information. The results indicated that customized travel information, longer trips, work trips and listening to radio traffic reports have greater willingness to pay for information [Khattak et al. 2003].

This fact is further confirmed by the data recorded in some European cities where a road pricing scheme has been implemented. For instance, congestion charging in Central London [Transport for London, 2004] has produced a daily average reduction between 65,000 and 70,000 in the number of drivers entering the charging area. Less than 5000 of them have travelled to other destinations or have reduced their trip frequency, so that the overall transport demand has remained substantially unchanged. Less than 5000 have travelled outside the charging hours, while for the largest group, between 40,000 to 50,000 drivers have shifted to other modes of transport, largely to public transport. Similar results have been obtained in Milan [Commune di Milano, 2008], where the imposition of road pricing on some particular categories of cars has caused a daily average reduction of 20,540 passengers entering by car into the charging zone, while 19,083 more trips are carried out by public transportation.

Ferrari, using a theoretical model of urban transport system, examined the influence of distribution of willingness to spend within the urban population on road pricing rates. Results showed that the rates that must be imposed in an urban area in order to maintain poleutant concentration and congestion respect to traffic within acceptable levels is heavily dependent on the distribution of the urban population’s willingness to spend [Ferrari, 2010].

Ahmadi and colleagues explored travelers' responsiveness to congestion pricing (cordon pricing) and parking attributes in deciding whether to drive and park in the central business district (CBD). Employing the stated-preference method, data were collected and preferences regarding mode of transportation and parking choices were determined using a multinomial logit model, which was used to estimate elasticity values and the willingness-to-pay among attributes. The results indicate that drivers are highly sensitive to cordon charge, significantly more than to parking cost [Azari Ahamadi, 2013].

Chang jou and colleagues considered the willingness of users to pay for using electronic toll collection system. They had defined three level of use and based on Stated Preference (SP) method, different scenarios were defined for estimating the willingness to pay [Chang jou et al. 2013].

Lopez and colleagues used stated preference analysis in the form of contingent valuation to examine the willingness-to-pay (WTP) of individuals living in small Spanish villages for noise and atmospheric pollution mitigation [Lopez et al. 2012].

In general, through review of the previous works, it can be resulted that:

- Discrete choice models are widely applied to calculate WTP.
- Data gathering through SP method for WTP assessment is acceptable.
- Few studies have been conducted in developing countries.

3. Methodology

Unlike market services and commodities, a group of commodities and services may not have a particular market and obviously have no specific price. In cases where the market fails to offer such relevant information, price determination requires finding a willingness to pay criterion (MIT Portugal program, 2009). All pricing approaches in lack of market are based on either demand curve, or are independent from demand curve. The models for determination of individuals’ willingness to pay can be categorized into modal split models. Modal split models are applied based on socioeconomic conditions, type of service and other effective factors to determine share of each mode. Transportation modechoice is performed based on a very complicated process controlled by trip chain, traveler characteristics and properties of transportation system. There are a large number of affecting factors in each group of these properties. To obtain such information, there are typically two available approaches including revealed preference (RP) and SP method. Revealed preference method is mainly based on observing the decision made by the users. This means that the required conditions have to be provided for all or a major share of users to allow performing data sampling process, based on decisions. For policies not performed yet, application of this approach seems to be very difficult and costly. Hence, stated preference can be used in most cases. Through this approach, an illustrative market is designed, and then the individuals are asked about their willingness to pay (WTP) or willingness to accept (WTA), to improve or not improve the quality of a given product. Since this approach directly deals with people's perspective about non-market commodities, it is also called as direct pricing. In this method, an illustrative market is designed for unrated commodities and their demand for a given commodity, and service is evaluated through their applications (extracted from specific questionnaires). The most common method to achieve stated preferences of the users is to conduct interviews with individuals about their WTA or WTP to maintain, or improve the quality of the studied commodity or service. To model the information collected through stated preference technique, based on the nature of the model objective, discrete choice modeling approaches are applied. As the main objective of this research was to determine the sensitivity of users against pricing scenarios for entering or not entering the congestion priced area, a binary logit modelhas been chosenas an appropriate model for modeling users' behavior.The logit model is developed by this assumption that each ε_jn (unobserved utility of choice i by nth individual) is independent and has a bounded value distribution.The formulation of binary logit can be written as follows [Louviere et al, 2003]

$$P_{in}=\frac{e^{V_{in}}}{\sum_j e^{V_{jn}}} \tag{1}$$

Where,

P_{in}: Probability of choosing i_{th} alternative by the n_{th} individual,

V_{in}: Systematic component of utility of i_{th} alternative for the n_{th} individual,

V_{jn}: Systematic component of utility of j_{th} alternative for the n_{th} individual,

It must be noticed that the selection probability of two items only depends on utility function of these items and is independent from likelihood of the other items.

4. Modeling

To develop the predictive model, first the data was gathered and analyzed through formation of the database. The WTP model was calibrated based on socio – economic and trip chain characteristics.

4.1 Data collection

Information about societies characteristics are always required by politicians, planners, engineers, and managers. Because of time and financial purposes, these data are generally obtained through random samples surveys. The target society of this work was all the passengers in Tehran restricted traffic cordon. Within this information gathering process, specifications including socio economic characteristics of individuals, their mode of travel and trip chain were considered.

Since no pricing policy is applied in Tehran routes, the required information was gathered through design of stated preference (SP) questionnaires. In these questionnaires, the travelers were asked about the least price which they tend to pay to enter the traffic restricted zone by offering various levels of prices as well as their opinion about omitting trip or choosing an alternative mode instead of personal car for entering to Even-Odd traffic zone. The main parts of this questionnaire are as follows:

- Information about personal, social, and economic characteristics of the individuals,
- Trip information and their mode choice; and
- Information concerning individuals' response to the policies and changes expected by the researcher

Since the goal of this research was to determine the threshold of users' behavior change to pricing, it was required to design at least two pricing policies. Also, a low and high level as well as medium threshold was selected for pricing scenarios that made an appropriate judgment about behavior change of the respondents. The low pricing threshold was selected in a way that the majority of people with private cars could afford it; while, on the other hand, high threshold was selected in a way that very low share of respondents were willing to pay. A sample of proposed pricing scenarios is presented in table 1. The main reason for defining different pricing scenarios was to obtain various pricing points and to study the decisions made by users due to these scenarios. Also, as the pricing strategy was to define different prices for peak and off-peak hours; therefore, different combinations for pricing were needed.

Table1. A sample of pricing scenarios in peak and off peak hours (Tomans)

Time Period / Scenario	Price (Tomans)		
	Peak	Off Peak	Peak (Afternoon)
1	17000	17000	17000
2	9000	4500	9000
3	10000	6500	10000
4	14000	10500	14000

In this regard, some questions were designed and the respondents selected their choices based on their preferred prices to enter traffic restricted zone. About trip choice alternatives, all respondents were informed that each travel option consists of the following prices. By defining these alternatives for respondents, they can decide to use the private car alternative or other modes of transportation for entering the restricted area of Tehran. As the cost of every alternative differs, by making this assumption that only private cars drivers pay the entrance toll, users will change their trip choice due to their value of time. Following the information provided the respondents proper knowledge about costs which they should pay for every alternative.

1- Public transportation (bus and metro): In this state, the users prefer to use public transportation when facing the pricing scenarios. Based on type of access to public transportation, this might involve the following costs:

- Bus or metro ticket (when user walks to public transportation station)
- Bus or metro ticket and taxi fees (when user takes a taxi for accessing to public transportation stop)
- Bus or metro ticket and the cost of using personal car (when user drive with his/her car to public transportation stop)

2- Personal car: When users still decide to pay the determined toll and choose personal car as their mode of travel. This can involve the following costs:

- Parking fee
- Fuel fee
- toll

3- Taxi: This can only include taxi fee.

4.2 Determination of the required number of samples

One of the most important problems in data collection process is determination of the required number of samples. In this respect, the first step is to determine confidence level for the given estimations. Typically, the larger is the sample, the higher is the obtained the confidence levels. In this work, simple random sampling was utilized to determine sample size. The applied equation is as follows [Hensher, 2000]:

$$n \geq \frac{Z^2 (1-P_y)}{\varepsilon^2 P_y}$$

where:

P_y: Share of society which has the characteristic

N: number of the sample

Z: Confidence level

ε: Rational error

In this research, Z was assumed 1.96 (by 95 % of confidence level in normal distribution). Also, ε was assumed 0.05.

Based on travel pattern of Tehran citizens and with respect to the share of various transportation modes of city trips, the minimum number of observations required to calibrate model was estimated 2304.

$$n \geq \frac{Z^2 (1-P_y)}{\varepsilon^2 P_y} = 2304$$

In this research, 3596 questionnaires were filled out and by initial reviews and elimination of incomplete and unusable questionnaires, 3250 questionnaires were finally decided as appropriate for modeling.

As well as the number of questionnaires, the samples are required to correspond with the travel pattern of the society; this is because of being ensured of accurate generalization of the obtained results from samples to the society. Based on information obtained from travel pattern of Tehran, the share of each travel target in traffic program range is introduced in table 2. In this regard, the main share was allocated for work purpose while marketing, recreation and educational purposes are placed in the next orders.

For data collecting , the restricted area of Tehran was surveyed, due to dispersion of land uses and main trip attraction centers. As seen in figure 1, 7 regions for data collection were defined and 10 interviewers for every region were dedicated. The datacollection was performed mainly in governmental and nongovernmental bureaus, universities and education centers, and random samples which were encountered in streets or other trip attraction centers.

4.3 Definition of variables

The variables used in travel choice models for entering the congestion priced zone are categorized into two direct and indirect groups. The direct variables were extracted from the questionnaire and applied directly in utility function of trip makers without any change; e.g. travel goal. Indirect or converted variables are obtained through applying the changes and operations on the information obtained from the questionnaire. These variables are determined based on performed tests about parameter effect in the choice; e.g. vehicle ownership per capita which equals to the number of cars divided into the number of households. Depending on modeling need, used variables were defined on various forms to consider the different impacts of variables changes. For example, the age variable was used in both aggregate and dummy forms.

Table 2. share of each trip goal attracted to restricted traffic zone

No	Trip Purpose	Share of Tehran trips (%)	Filled questionnaire (%)	Share of filled questionnaire (%)
1	Work	67	2201	67.7
2	Market	13	436	13.4
3	Recreation	11	339	10.4
4	Education	9	274	8.4
Sum		100	3250	100

Figure 1. Zoning of restricted region of Tehran for data collection

With this point of view, travel time variable from origin to destination was also applied in aggregate form and 3 dummy variables for smaller time periods (time periods smaller than 30 minutes, time periods greater than 30 minutes and smaller than 60 minutes and time periods greater than 60 minutes). Some variables like sex and marital status were used in binary form. For example:

$$MAR=\begin{cases} 1 & \textit{If individual is married} \\ 0 & \textit{Otherwise} \end{cases}$$

A large number of variables are produced from obtained data by this approach. To determine appropriate parameters for modeling, correlation matrix between the parameters was created which a small sample of this matrix is shown in figure 2. Respect to design of several indirect variables based on a direct parameter, it is clear that there is a high correlation between these variables and choosing variables for model is performed through control of correlation coefficients with dependent variable and significance level of the model. The findings imply that the following parameters have the highest correlation values with dependent variable (dummy variable indicating 1 if users choose to enter the congestion priced area and 0 otherwise) in the database of traffic zone program: PER (a dummy variable in the case of having congested priced zone permit), TT (Travel time from origin to destination), NP (Number of passengers in the vehicle), PURD (dummy variable indicating 1 for mandatory trips and 0 otherwise), MODD (the average price group of the vehicle in million Iranian Rials), PTP (tolls for entering to congestion priced zone in peak hours) and JOBD3 (dummy variable indicating 1 if the job of respondent is manager or doctor and 0 otherwise). Table 3 shows the descriptive statistics of selected variables.

	SYN5-5	SYN5-5	QT	PUR	PURD
SYN5-5	0.715	1	-0.110	0.09	-0.082
SYN5	1	0.715	-0.02	0.034	-0.035
SYN5-4	0.224	-0.459	0.158	-0.1	0.085
SYN5-1	0.908	-0.437	0.009	-0.026	0.029
FTMD1	0.184	0.234	-0.074	0.011	-0.01
FT	0.148	0.239	-0.02	0.029	-0.014
SYN5-3	-0.081	-0.221	-0.051	0.019	-0.017
ACO	-0.138	-0.201	0.071	-0.077	0.079
MODN	-0.168	-0.184	0.028	-0.029	0.052
PND	-0.146	-0.178	0.053	-0.043	0.074
FTDM2	-0.135	.173	-0.043	0.067	-0.08
PN	-0.142	-0.164	0.017	-0.054	0.093
FTM2	0.079	0.162	-0.011	-0.01	0.042
SERN	0.069	0.158	0.216	0.009	-0.064
PEP	0.331	0.145	0.000	0.000	0.000
PEO	0.275	0.145	-0.164	0.014	-0.014
FTM1	0.055	0.14	-0.004	0.012	0.001
FTT2	0.079	0.137	-0.022	-0.036	0.064

Figure 2- small sample of correlation matrix used for defining variables

Table 3. Descriptive studies of used variables in the model

Descriptive statistics					
variable	minimum	maximum	mean	Std. deviation	variance
TT	0	165	38.90	25.827	667.055
PURD	0	1	0.77	0.419	0.175
PTP	5000	20000	12500.00	4035.54	1628563.821
MODD	6	90	21.03	17.1296	293.387
PER	0	1	0.25	0.435	0.189
JOBD3	0	1	0.05	0. 209	0.44
NP	0	4	1.08	1.214	1.473

4.4 Model Development

For modeling WTP level of trip makers, binary logit-models were applied. The Nlogit Software was used for modeling. Based on obtained results from these models, it is possible to comment about elasticity and marginal effect of the toll rate on trip makers travel choice. Based on results summarized in Table 4, it can be stated that:

a) Sign of all parameters are as expected. For example, in utility function of private car choice, the cost variable (PTP) has negative coefficients which show utility reduction due to toll increasing. Sign of MODD variable shows that users with more expensive vehicles tend to pay more for entering the restricted zone. Users that experience longer travel times in their daily trips, tend to pay more for reducing their travel time by using their private cars. Also, users with higher paying jobs tend to pay more for using their own cars. This is because of their higher value of time. More discussion has been made in table 5.

b) Basically, all parameters are significant in confidence level above 95 %. Only variable "PURD" was found insignificant in this confidence level which was omitted from the model calibration results.

a) Likelihood ratio test: The log likelihood function evaluated at the mean of the estimated utility parameters is a useful criterion for assessing overall goodness-of-fit when the maximum likelihood estimation method is used to estimate the utility parameters of binary and multinomial models.Through this process, it is required to determine whether the difference between L* (β) and L* (0) is significant for the given model. This test performs based on chi square distribution. To apply this test we have [Louviere et al, 2000]:

$$-2\left[L^*(0)-L^*(\beta)\right]\succ \chi^2_{N,1-\alpha}$$

where, α indicates confidence level and N is the number of variables. As can be seen, the variable 2[L(β) – L(0)] which has x2 distribution with freedom degree of N, rejects the assumption that parameters are zero with confidence level of 99 %. Besides, the variable 2[L(β) – L(C)] which has distribution of x2 with freedom degree of N-m + 1(m = the number of selected vehicles) indicates that the designed model is superior to the market share model.

b) ρ2 index: This index is used to determinethe model fitness. Here, fitness level equals to 0.459 which is acceptable, considering the model nature and comparing it to models proposed in other works.

c) Correct percentile test: This test indicates reproduction of the individual choices by model. The higher values of this index, the better model fitness. In the proposed model, the obtained correct percentile was determined as 84.98 % which is appropriate.

Table 4. Model results for binary travel choice model for congestion priced traffic zone

Variable	Value	P[|Z|>z]	Variable definition
Personal car choice			
A	-0.88003	0	Constant
PER	0.69029	0	Dummy variable (0 if the user have the permit to enter the congestion priced zone and 1 otherwise)
NP	0.19121	0	Plate number (0 if the user have both odd and even and 1 otherwise)
MODD	0.01313	0	Average price group of vehicle (million Iranian Rials) (group 1=60, group 2=160, group 3=450, group 4=900)
PTP	0.00011	0	Entrance toll for entering congestion priced zone
TT	0.00588	0.0044	Average travel time (min)
JOBD3	0.46442	0.0207	Dummy variable (if job is manager, doctor and academic staff=1 and 0 otherwise)

Table 5.The validation of variables ' sign in utility function of personal cars

Variable	Sign	Description
PER	Positive	Having a permit for entering to congestion priced zone, can encourage the users to pay more. This result seems quite right.
NP	Positive	More passengers will increase the capita of using the private car and the justification for paying the toll will increase.
MODD	Positive	The price level of the car is a sign of wealth of users and it is obvious that by increasing it, the willingness to pay will increase.
PTP	Negative	By increasing the toll for entering the congestion priced area in peak hour, the utility for using private car will reduce.
TT	Positive	By increasing the Average travel time from origin to destination, the willingness to pay will increase due to parameters like convenience increasing the toll of alternative modes and etc.
JOBD3	Positive	Users have high income jobs have more willingness to pay.

Table 6. Validation statistics for travel choice models

statistics	value	statistics	value
No of observations	3596	2[L(β)-L(0)]	2286.882
L(0)	-2492.557	2[L(β)-L(C)]	395.4846
L(C)	-1546.8583	$x^2_{0.99}$(N)	24.7
L(β)	-1349.116	$x^2_{0.99}$(N-m+1)	23.2
ρ^2	0.459	Percent of correct prediction	84.98
ρ^2_c	0.128		

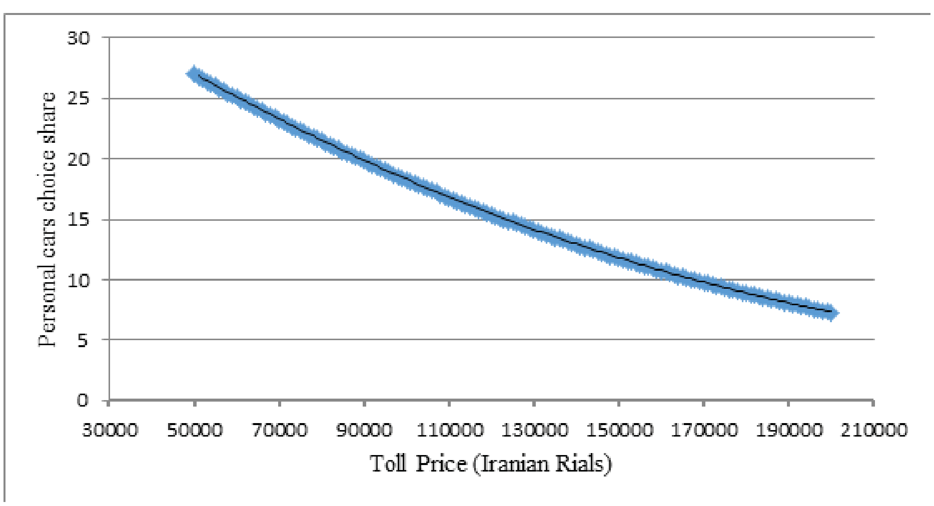

Figure 3. Private car demand changes according to toll pricing

Figure 3 shows the willingness to pay versus different prices. Based on consumer theory in econometrics, by increasing price for a commodity or service, the demand will reduce. As it can be seen, when the toll for entering to congestion priced area is 50000 Rials, about 25 percent of users still tend to pay for entering to congestion priced area. This will reduce to only 7 percent when the entering toll increases to 200000 Rials. It means that when the entering toll is set to unauthorized penalty to congestion priced zones, only 7 percent of users will use their private cars.

5. Conclusion and recommendations for further studies

In this paper, users' WTP for using their private cars was determined. To do so, SP technique was applied to collect the required information. Several pricing scenarios were defined using empirical design approaches and more than 4000 interviews were conducted and entereded a database. Since the main objective of this research was to determine trip maker's reaction to pricing, a binary logit model was developed. Finally, using the developed model and assigned prices in our scenarios,WTP curve of the trip makers has been presented. In general, other results obtained through this work can be listed as follows:

√ Variables such as trip makers' job or the average price of their vehicles are positively affecting their decision to enter to the congestion priced zone. The trip makers with more expensive vehicles and incomes are more willing to pay the toll, to use their private vehicles.

√ The findings of this research indicated that pricing can be highly effective in managing the demand for entering the priced zone. By assigning price of 50000 Rials for entering to the traffic zone, only 27 % of users still prefer to use their personal vehicles for entering to congestion priced zone.

√ Individuals with longer travel times are more willing to pay.

√ The proposed pricing policy can correspond with social justice goals as well as having significant effect on demand managing for entering to congestion priced zone. This means that each user who is willing to pay, i.e. anyone who has higher time value, will use his/her private vehicle.

In conclusion, the main contribution of this paper is applying stated preference method, new socio – economic variables and discrete choice models for predicting users ' WTP. As further recommendations for this research, the effect of pricing on modal split of userscan be mentioned. Therefore, determination of trip makers' value of time can be studied as a future research.

6. Endnotes:

- 12600 rials = 1US dollar
- Central Business District

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