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Value of Travel Time :Theoretical and Empirical Method

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Abstract

The value of travel time savings (VTTS) is the monetary value attached to save a determined amount of travel time. VTTS is also the most important benefit category aimed at justifying investments in transport infrastructures by public administrations. Hence VTTS played a significant role in various economic studies, both analytical and empirical (Zamparini & Reggiani, 2007). "It is difficult to name a concept more widely used in transportation analysis than the value of travel time. Its theoretical meaning and its empirical measurement are fundamental to travel demand modeling, social cost analysis, pricing decisions, project evaluation, and the evaluation of many public policies".(small,2012)

In developing countries the lack of data regarding the economic value of time savings cause that it often be omitted from appraisal or relied upon proportion of market wage rate (the wage rate method) or using values obtained from developed countries. of course the values obtained from developed countries have serious drawbacks because existing research suggest that value of time is highly affected by preference, physical characteristic of geographical area and habit of particular society ,thus different situation require different modeling and attempt to transfer result from one area to another are fraught of danger, on other hand empirical and theoretical research indicates that the value of time can be significantly higher or lower than the current wage rate, depending on many condition .This paper uses a revealed preference approach to estimate the VTTS for work and educational trips by collecting 480 questioners from individuals that trip in morning peak time in Isfahan city in 1392, and use of discrete choice model for modeling individuals' preferences. Estimated results show, the value of travel time in Isfahan city in morning peak time is 350.50 Rials for each minute and 21030 Rials for each hour in this year.

Key Words: Value of time, Value of travel time, Discrete choice, Multinomial logit.

JEL Classifications: Dl, J2, R2, R4.

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1. Introduction

The day has 24 hours, and travel time consumes a subnational proportion of it. In general individuals would rather doing something else, either at home, at work, or somewhere else, than riding a bus or driving a car. Accordingly, traveler would like to diminish the number of trips, to travel to closer destination, and reduce travel time for given trips.

Therefore, individuals are willing to pay some amount for travel time reduction, which has a behavioral dimension that seems more a consequence of a general time-allocation problem than an isolated decision. On the other hand, individual reallocation of time from travel to another activity has a value for society as well, either because production increases or simply because the individual is better off and that matters socially. This implies that changes in the transport system that lead to travel-time reduction are important to understand from behavioral viewpoint and increase welfare which has to be quantified for social appraisal of projects.

In the goods-market context, the economic value of a commodity is defined as maximum amount of money an individual is willing to pay for an additional unit of that commodities. Applying this definition to the time-allocation problem, the value of time (VOT) is defined as the maximum amount of money an individual is willing to pay for an additional unit of time. Given the fact that total amount of time available is fixed, any time saved in an activity must be allocated to some other activities. In the other word, travel time is not as commodity that can be saved for future but it can transfer to other activities (Henser & Troung,1985). Thus, value of time saving (VTS) is defined as maximum willingness to pay for reallocation of time between two alternative (Huq, 2010). The article structure is as follows, Section 2 allocated to literature review, expansion of consumer theory with consideration of time, in framework of classic consumer theory; section 3 allocated to empirical model and estimation results. In this section we first introduce discrete choice model and usage of it in estimation and interpretation of value of travel time in this framework, and then the results emerging from the empirical model are illustrated. Finally, in section 4 results are discussed.

2. Literature Review

When time is considered in consumer theory, there are three important aspects to take into account: first, how time enters the utility function;

second, the need to include a time constraint; and third, the need to identify the relations between time allocation and goods consumption.

each of these aspects play an important role in the generation of money measures of time assignment. (Jara-Diaz,2007). Thus in laters section we review the most important theoretical models that take into account time in their consumer theory .

2.1. Time in Budget Constraint

In earliest derivations, the value of time was linked to the study of labor demand and supply. In this model the basic idea was that, time is a finite resource that can either be used for work or leisure. In the other hand this model assumes that total available time, M ,divided between work, w, leisure, L, and assume that an individual is free to chooses work for any number of hours at a fixed wage rate, w, thus if the quasi concave utility function is defined as u =u(X.L), where X stands for market goods measured in unit of money then the maximization problem of utility with respect to budget (labor and non-labor income) and time constraint is:

MAX: U(X.L)

$$\text{S.t} \quad \begin{cases} X = wW + Y \\ M = L + W \end{cases}$$

Thus result of optimization utility function with consideration of two constraint illustrates that value of time VOT= $\frac{\mu_L}{\mu_X} = \frac{\mu}{\lambda} =$ w, where μ representing the marginal utility of time (Lagrange multiplier of time constraint) while λ representing the marginal utility of money(Lagrange multiplier of budget constraint). (Huq,2010).

In fact, in this model assumes that what individual dose, is looking for satisfaction, and is limited by income. Therefor if utility depends on consumption and consumption means expenses, consumer additional time can be assigned to work in order to increase income, but this process doesn't consider that consumption itself requires time. This point considered by Beckers model in 1965.

2.2. Time as Input for Preparation of Final Good

Becker (1965) was the first that introduced the allocation of time over various activities in analysis of consumer behavior and offering the microeconomic framework needed to establish the shadow price of time saving (Tseng & Verhoef,2008).

Becker (1965) postulated the idea of final good that directly induced satisfaction and focused on market goods and preparation time as a necessary inputs for final goods .

Becker in his model hypothesized that household maximize utility function and assumes that household combines time and market good to produce more basic goods that enter directly in the utility function. This commodity called Z_i and $Z_i = f_i(X_i, T_i)$ where X_i is vector of market goods and T_i is time input used in producing final commodities. in the other hand households are both producing unit and utility maximizer and they combine time and market good via production function f_i to produce basic commodities Z_i and chose the best combination of these commodities in conventional way by maximizing a utility function

MAX U=U$(Z_1, Z_2, \dots, Z_m) = U(f_1, f_2, \dots f_m) = U(X_1 \dots, X_m, T_1, \dots T_m)$

$$\begin{cases} \sum_{I}^{m} T_i = T_c = T - T_w \\ \sum_{I}^{m} p_i x_i = I = V + T_w . \bar{w} \end{cases}$$

$$\begin{cases} T_i \equiv t_i . Z_i \\ x_i \equiv b_i . Z_i \end{cases}$$

Where p_i is unit price of x_i, T_w is vector giving the hours spent in work, $\bar{w}$ is a vector giving the earning per unit of T_w and t_i , b_i , are vector giving the input of time and market good per unit of Z_i . The results of maximization of this function show that value of time equal to w=$\frac{\mu}{\lambda}$ where μ is Lagrange multiplier of time constraint and λ is Lagrange multiplier of budget constraint. Therefor value of time is equal to wage rate. The acknowledgment of time as an input has nontrivial consequences in the field of transportation research. By recognizing that the demand for travel is derived from the demand for goods and services requiring out-of-home travel, the value of time takes different meanings. In the other hand when individual deciding what to consume, how much and how frequently, in fact he must also consider that consumption requires travel and that travel alone requires time. This theory contrasts with the classical budget constrained utility maximization theory, where goods are the only source of satisfaction (Markovich,2009).

After Becker Johnson (1966) established that reason behind value of time equal to wage rate, was the absence of work time in utility function and entering it in budget constraint. He showed that correcting of this omission led to value of time equal to wage rate plus subjective value of work.

2.3. Time as Direct Source of Utility

Becker's model is starting point of 1971 Deserpa. He said that goods and time are inputs in prouduction founction of homgenious good. He assumes in his model that:

1.Utility is a function not only of commodities but also of the time allocated to them

2.The individual's decision is subject to two resource constraints, money and time constrain.

3.The decision to consume a specified amount of any commodity requires that some minimum amount of time be allocated to it, but the individual may spend more time in desirable activity.

In the other hand, the main objective in Deserpa model was determining amount of consumption goods and time needed for consumption of these goods, thus main object is determination a set of commodity bundles in the form of

X=$(x_1, \dots, x_n, T_1, \dots, T_n)$.

He expresses that if the individual possesses a complete, consistent preference that ordering among alternative commodities bundles and exhibits rational behavior the individual's preferences can be represented by a continuous, twice-differentiable real valued utility function U=U$(x_1, \dots, x_n, T_1, \dots, T_n)$.

Thus the main objective of consumer is maximization consumer utility with budget, and time consumption constraint, in the other hand:

MAX U=U($x_1, \dots, x_n, T_1, \dots, T_n$)

S.t

$$\begin{cases} \sum_{i=1}^{n} P_i X_i \\ \sum_{i=1}^{n} T_i = T^0 \\ T_i \geq a_i X_i \quad i = 1 \dots n \end{cases}$$

Where a_i may be interpreted as a technologically or institutionally determined minimum amount of time required to consume one unit of X_i and with introduction of this constraint separate time consumption constraint from time resource constraint, in reality this constraint represent that amount of time allocated to the consumption of any commodity is partly a matter of choice and partly a matter of necessity.

By use of first order condition we get $\frac{U_{n+i}}{\lambda} = \frac{\mu}{\lambda} - \frac{K_i}{\lambda}$

Where The lagrangian multipliers, μ and λ ,are shadow variables representing marginal utility of money and the marginal utility of time. $\frac{U_{n+i}}{\lambda}$ is marginal rate of substitution of T_i for money and it represents the value of time assigned to the consumption of X_i and is considered value of time as a commodity, not as a resource. Because it illustrate value of time for special activity and equal to rate of substitution between time of this activity and money in utility function, while $\frac{\mu}{\lambda}$ is rate of substitution between total available time and money and called value of time as resource because it represent money value of incretion of total available time and distinction between these is $\frac{K_i}{\lambda}$. They are equal if, and only if, K_i= 0. This condition will prevail if the individual elects to spend more than required amount of time for consuming X_i. Deserpa called this activity leisure in contrast when $K_i \geq 0$, time for this activity is equal to minimum amount of time for this activity and time can be saved and transferred to some alternatives usage of greater value, this activity called intermediate activity.

The algebraic difference between the value of time in alternative uses and the value of time in any particular use , $\frac{U_{n+i}}{\lambda}$, determines the value of saving time from that activity, in the other hand

$$\text{Value of saving time for consuming Xi} = \frac{K_i}{\lambda} = \frac{U_{n+i}}{\lambda} - \frac{\mu}{\lambda}$$

Thus, Deserpa made possible separation of time spend in leisure activity such as consumption of good from time spend in others intermediate activities such as travel that make possible consuming of this commodity.

It can be shown in Deserpa model framework that $\frac{K_i}{\lambda} = w + \frac{U_{Tw}}{\lambda} - \frac{U_{n+i}}{\lambda}$ This equation illustrate that if this activity related to travel, the value of travel time saving can be grater or less than average wage rate depending on sign of $U_{T_W} - U_{n+i}$ where U_{n+i} and $U_{T_W}$are marginal utilities of time spent in travel and work, respectively.

Truong and Hensher (1985) illustrated that Becker theory leads to the concept of a shadow price, or opportunity cost, of travel time which is uniform in all activities and under all circumstances while Deserpa allows the marginal utility (value) of travel time to diverge from this uniform shadow price, giving rise to an excess (or shortfall) of value in a specific circumstance. they said that travel time has a shadow price ($\frac{\mu}{\lambda}$) due to it being a scarce resource. But travel time allocation is not always at the optimal marginal level where its value is equal to its shadow price, Hence the DeSerpa concept of a value of saving travel time is important as a theoretical basis in accounting for this deviation of the actual value in a particular circumstance.

3. Empirical Model

In economic, discrete or quantal choice model is used for description, explanation and prediction of choices between two or more alternatives.

This choices are contrast to classic consumer theory that was made on assumption of Continues amount of demanded goods. In condition of classic consumer theory, continues space of alternatives allow the use of calculus to derive optimal amount of goods and modeling the empirical demand with use of regression analysis. However in discreet choice model that describe the discreet conditions, use of first order conditions for optimal solution are impossible and need to use other approaches.(macfaden,1976)

Discreet choice model, uses theoretical and empirical modeling of individual choices with deterministic Choice set and use the relationship between each individual choices, characteristics of individual and characteristics of each alternative[5]. In this article we use the discrete choice (mod choice) model for estimation of value of travel time for work and educational tripe in morning peak time with use of multinomial logit model for it's estimation. Because In this framework is assumed that individual i choses jth alternative in choice set that include bus, taxi and car. In the other hand individual choses among expensive and fast modes against slow and cheap mode, that maximizes a utility function, thus for better understanding of discrete choice model and value of time in this kind of model first section of this part allocated to introductions of value of travel time and interpretation of value of time in this kind of model, then in later section estimation results are illustrated.

3.1. Discrete Choice Model and Value of Time

As mentioned before Choice of different modes of transportation(mode choice) is one of the case that evaluate and modeling in framework of discreet(quantal) choice. In travel choice model, the utility of an alternative is usually written in a liner form as

$$u_i = \alpha_i + \beta c_i + \gamma t_{\ i} + \cdots$$

Where c_i and $t_{\ i}$ are travel cost and travel time of alternative i respectively. This function can be estimated with using appropriate data regarding travel choice and individual characteristic.

Introduction of discrete choice model starts a new approach to estimate value of travel time .In this approach the subjective value of travel time can be calculate by $\frac{\frac{\partial U_i}{\partial t_i}}{\frac{\partial U_i}{\partial c_i}}$ i.e the rate of substitution between time and cost for constant utility, this rate of substitution equal to amount of money that individual willing to pay to reduce travel time by one unit.

For interpretation of rate of substitution in discreet choice model, we first present simple framework of Train and Macfadden (1978) for choice of mode in journey to work in form of good/leisure model, and then illustrate Jara-Diaz (2002) model in framework of good/activity model.

3.1.1.good/leisure model

In this model assume that the origin of utility is commodity, and leisure and consumer encounter with two budget and time constraint, in the other hand consumer:

5.For better understanding of discrete choice model refer to, "Discrete Choice Methods with Simulation ",Kenneth Train(2009).

MAXU(G,L)

$$\text{s.t} \begin{cases} G + c_i = wW \\ L + W + t_i = T \end{cases}$$

Where G, L ,t_i, c_i, represent expenses on commodities, leisure, time and cost of trip with mode i from set of m available mode. In this framework individual faces with choice t_i, c_i, w, and in his choices expensive and fast modes compete with cheaper and slower mode and effect of his mode choice transfer from time and budget constraint to commodities and leisure .

With replace of time and budget constraint in utility function and maximization of utility, on condition of choosing mode i, with respect to w we have

$$V_i(c_i, t_i) = U[(wW^*(\,(c_i, t_i) - c_i), (T - t_i\ - W^*(c_i, t_i)\,)]$$

This can be shown analytically from this equation and first order condition of maximization problem that

$$\text{SVTT} = \frac{\frac{\partial v_i}{\partial t_i}}{\frac{\partial v_i}{\partial c_i}} = w.$$

The result of good/leisure framework of Train–macfadden illustrate that it is nothing but discrete counterpart of Becker model.

3.1.2.good/activity model

Jara-Diaz (2002) said that introduction of only leisure in addition to good in utility function, in Train-macfadden framework suffer from some limitation as becker's model, thus he introduce good/activity framework and express that all activities have potential impact on utility function because the marginal utility of additional time assign to specific activity certainly depend on time and amount of goods used to actually perform the activity, therefor U=U(X,T).

He said that when using the good/leisure framework within activity approach we need introduce both W and travel time using mode i , t_i , as potential source of direct (dis)utility. There for the expanded version of model with endogens income is

MAX U(G,L,W,t)

$$\text{s.t} \begin{cases} G + c_i = w.\ W \\ L + W + t_i = T \end{cases}$$

With use of same procedure like Train-macfadden conditional maximization problem with respect to w, we get

$V_i(c_i,t_i)=U[(wW^* - c_i),(T - t_i - W^*),W^*,t_i)$

It can be shown with calculation $\frac{\partial V_i}{\partial t_i}$ and $\frac{\partial V_i}{\partial c_i}$ that

$$\text{SVTT} = \frac{\frac{\partial V_i}{\partial t_i}}{\frac{\partial V_i}{\partial c_i}} = w + \frac{\frac{\partial U}{\partial W}}{\frac{\partial U}{\partial G}} + \frac{\frac{\partial U}{\partial t_i}}{\frac{\partial U}{\partial G}}$$

this equation illustrates that subjective value of travel time is equal to wage rate plus subjective value of pure work minus subjective value of pure travel, in the other word the reduction in travel time is individually important because more work (more (dis) pleasure, more money) and less travel. Thus if individual likes job and dislikes traveling, VTTS is definitely higher than wage rate and saving one minute would mean more money, more pleasure from work and less displeasure from travel.

3.2.Estimation model

The results of expansion consumption theory in previous sections illustrate that not only value of travel time is different among individuals but also different for same individuals in different time and condition, thus use of average wage rate is not an accurate measure of value of time. In the other hand empirical researches indicate that the value of time can be significantly higher or lower than the current wage rate, depending on condition and time of travel. For example SDOT (2003) illustrated that value of travel time vary between 50%-120% wage rate depending on type of travel and Small et al (2005) illustrate that value of time in Los Angeles area is about 93% wage rate and so.

In this article we use the multinomial logit model for estimation of value of travel time for work and educational trips in morning peak time with use of data Collected form gathering questioners for 480 individuals that travel in morning peak time.

In framework of discreet choice model is assumed that utility of individual i for choosing jth alternative in time t or U_{ijt} is function of two socioeconomic characteristic of individual i and attribute of alternative J (Ben-Akiva & Lerman 1985).

In this article we introduce this two group of factors on the base of previous studies such as Beira˜o and Cabral (2007), Dargay (2007), Huamin et al (2010) and so

The model variables are:

1.Socioeconomic variables: these variables include age, sex, education, number of cars, number of licenses in the household and income.
2. Attribute of alternatives:
2.1.Travel time: this variable is sum of walking time to station, in vehicle time, expectation time in station and walking time to destination for bus and taxi, and in vehicle time for car.
2.2.Cost: this variable for public mode is the amount of fright and for car users include fuel and repair cost.
2.3. Comfort
3. Distance from origin to destination.

3.3. Estimation results:

The result of estimated model on the base of multinomial logit model for mode of car is :

Table 1:results of parameter estimation of personal car utility function with use of multinomial logit model

Significance level	Prob z>|Z|	Wald-statistic values	Coefficient	Variable
99‰	.0004	3.56	.01659	COMFORT
99‰	.0001	-4.00	-.02409	Time
99‰	.0021	-3.08	-.00067	Cost

And for taxi is :

Table 2:result of parameter estimation of taxi utility function with use of multinomial model

Significance level	Prob z>|Z|	Wald-statistic values	Coefficient	Variable
95‰	.0174	2.38	.01322	Comfort
99‰	.0001	-4.00	-.02409	Time
99‰	.0021	-3.08	-.00067	Cost
99‰	.0075	3.28	.31414	Income
99‰	.0000	-2.67	-.06082	distance

And so, the results of estimated model base on multinomial logit modelfor bus is:

Table 3 :results of parameter estimation of bus utility function with use of multinomial logit model

Significance level	Prob z>|Z|	Wald-statistic values	Coefficient	ariable
99‰	.0000	4.09	1.95039	Constant
95‰	.0435	2.02	.0047	Comfort
99‰	.0001	-4.00	-.02409	Time
99‰	.0021	-3.08	-.00067	Cost
99‰	.0047	-2.83	-.07395	distance

The result of estimation parameter on base of multinomial logit model illustrate that:

1.socioeconomic variable such as age ,sex ,education, number of car in household and number of license haven't influence on utility of each mode. In the other hand coefficient in utility function of each mode is not significantly different zero from.

2.socioeconomic variable income has no influence on utility of car and bus, but it's effect on utility of taxi have expected sign at acceptable significant level.

3.time,cost,and comfort estimated coefficients have expected sign at acceptable significant level in utility of each mode.

4.distance estimated coefficient has expected sign at acceptable significant level in utility function of bus and taxi.

Thus utility of each mode in peak morning time for work and educational tripe are

$$U_{icar} = -.02409time - .00067cost + .01659comfort$$

$$U_{itaxi} = .02409time - .00067cost + .01322comfort + .31414\,income - .06082distance$$

$$U_{ibus} = 1.95039 - .02409time - .00067cost + .01659comfort - .06082distance$$

3.4. estimation Value of travel time

As mentioned above the value of travel time is rate of substitution between time and cost or ratio of marginal utility of time to marginal utility of cost, in the other hand

$$VOT_{ijt} = \frac{\frac{\partial U_{ijt}}{\partial t_{ijt}}}{\frac{\partial\, U_{ijt}}{\partial C_{ijt}}} = \frac{\beta_{ijt}}{\beta_{ijt}}$$

In general, the above derivatives allow VOT depend not only on the individual traveler i but also on the alternative j and the time t that a choice is made; but in our specifications we restrict variation on i and t thus

$$VOT_{i,morning\ peak\ time} = \frac{-.02409}{-.00067} = 350.50\,\frac{Rial}{minute}$$

Or $$350.50 * 60 = 21030\,\frac{Rial}{hour}$$

4.Conclution

Although The value of travel time (VTT) is extensively used in transport economics in order to perform cost–benefit analysis of transport infrastructure projects and of new or ameliorated public transport services, particularly when referred to commuters because (1) they represent the largest segment of the transport service demand; and (2) contributing to congestion problems and environmental deterioration, especially when the origins and/or destinations of their trips are typically located within urban areas (Rotarise et al, 2012), but there is few empirical and theoretical studies for value of travel time in our research thus This article is aimed at addressing this gap first providing the theoretical base for value of travel time and then use multinomial logit model to estimation value of travel time. The estimation result show that value of travel time for work and educational tripe in morning peak time in Isfahan city in 1392, equal with 350.50 Rials for each minute and 21030 Rials for each hour.

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