Estimation of value of travel time savings using conditional Logit model

Petr Šenk[1], Stanislav Biler[2]

Abstract. This paper presents results of study focused on estimation of value of travel time savings in the context of leisure travel. The study refers to the concept of willingness-to-pay for reduction of travel time. Data on choice behavior were collected by means of stated preference survey on representative sample of population in the Czech Republic and analyzed using methods of discrete choice analysis.
Results of the study suggest that, in case of the most common type of leisure trips – weekend trips, estimated values of travel time savings obtained by the above mentioned methods are consistent with values recommended by literature, i.e. within the range of 25% and 50% of the average hourly wage.

Keywords: value of travel time savings, conditional logit model, stated preference survey, willingness-to-pay.

JEL Classification: R41, C25
AMS Classification: 91B06

1 Introduction

Value of travel time savings (VTTS) is one of the key inputs to transport planning models and tools for management and appraisal of road investments decisions. Information on VTTS is essential for parameterization of destination, mode, route and departure time choice components of complex travel demand models. This paper describes methodology and results of study aimed at valuation of travel time in the Czech Republic in the context of leisure travel by car.

Literature on estimation of VTTS refers to two main approaches, whose adequacy differs according to the purpose of travel [1]. So called cost saving approach is being used in case of business trips, during which the travel time of employees is viewed as unproductive. For such type of trips the VTTS is equal to the monetary valuation of employees' productive output. Cost saving approach is recommended also in case of commercial goods traffic, where the main trip characteristics (for example destination, route, and departure time) are given by the business policy of employer. On the contrary, non-work trips, including commuting, shopping or leisure trips, are to a large extent determined by the driver himself. Is such case it is appropriate to focus directly on preferences of drivers and their willingness-to-pay for reduction of travel time.

Section 2 presents in details the method of willingness-to-pay that combines stated preference method for data collection and discrete choice modeling for data analysis. Section 3 provides description of the data collection method and key descriptive statistics of the working dataset. Section 4 presents resulting values of travel time savings and section 5 discussion of results.

2 Methodology

2.1 Discrete choice model

In the study, valuation of travel time savings refers to basic economical concepts of utility theory and theory of rational choice. According to these theories consumer (in our case driver as user of transport infrastructure) choses from the finite set of all available options such that brings him or her the highest utility. Utility is understood as linear combination of attributes assigned to each option (travel time, comfort, fuel consumption, etc.) and individual preference weights that individuals assign to each attribute.

Regarding the fact that neither analyst nor the consumer (driver) himself or herself is not able to reliably identify all attributes influencing the value of perceived utility, the utility function is complemented with an error term that aggregates all factors unrecognized by the analyst. General form of the utility function has the form

$$U_i = V_i + \varepsilon_i,$$

[1] Transport Research Center, Lisenska 33a, 636 00 Brno, Czech Republic, petr.senk@cdv.cz.
[2] Transport Research Center, Lisenska 33a, 636 00 Brno, Czech Republic, stanislav.biler@cdv.cz.

where U_i represents utility of option i; V_i represents factors influencing decision making that are known to the analyst; and ε_i represents all remaining "unknown" factors.

The theory of rational choice suggests that consumer (car driver) who faces alternatives i and j with utilities $U_i > U_j$ always choses alternative i. However, if the utility function consists of the unknown component ε_i, as it is also in our case, the result of choice becomes more difficult to predict. The presence of random component in the utility function requires that the choice behavior has to be viewed as a stochastic process, in which given consumer (driver) choses the alternative i with probability $Prob_i$ that complies equation

$$Prob_i = Prob(U_i > U_j).$$

The decomposition of utility function to partial components leads to the equation

$$Prob_i = Prob[(V_i + \varepsilon_i) > (V_j + \varepsilon_j)]$$

that is due to the presence of random components called the rule of random utility maximization. Further adjustment leads to the equation

$$Prob_i = Prob[(\varepsilon_j - \varepsilon_i) > (V_i - V_j)]$$

that shows that the probability of choosing alternative i is equal to the probability that the difference between unknown sources of utility of alternatives j and i is higher than the difference between known sources of utility of alternatives i and j.

Further it may be shown that if random components ε_i and ε_j are drawn from type I extreme value distribution with probability function

$$Prob(\varepsilon_j \leq \varepsilon) = e^{-e^{-\varepsilon}},$$

after certain arrangements made under certain conditions (for details see e.g.[4]) it is possible to derive the alternative i is chosen over alternative j with probability

$$Prob_i = \frac{e^{V_i}}{e^{V_i} + e^{V_j}}.$$

The equation above is a specific form of discrete choice model for two alternatives – binary logit model.

2.2 Implementation of binary logit model in willingness-to-pay method

The method of willingness-to-pay consists in the estimation of maximum sum of money people are willing to sacrifice in order to gain certain merit, product or, conversely, eliminate negative consequences of their choice. In simple linear models, the willingness-to-pay may be derived as the proportion of parameter estimates related to one non-monetary attribute (in our case *time*) and one monetary attribute (in our case *travel costs*). Linearity of utility functions in discrete choice models thus enables implementation of such kind of models in the willingness-to-pay method.

In our specific case, the value of travel time during trips to leisure activities is formulated as the maximum amount of money that are people willing to sacrifice to save one unit of time, provided that all other trip related attributes remain constant. In our study we consider two hypothetical alternatives that differ on following attributes:

- Fuel related costs X_{costs} [in CZK];
- Travel time X_{time} [in *hours*];

The utility function of alternatives i and j has the form:

$$V_i = \beta_{costs} X_{costs} + \beta_{time} X_{time}$$

and

$$V_j = \beta_{costs} X_{costs} + \beta_{time} X_{time},$$

where β_{costs} and β_{time} represent respective parameters that are going to be estimated from empirical data.

Regarding the survey design (described in section 3), in which are both alternatives depicted only using values of attributes and abstract names (e.g. route G), the utility functions are free of alternative specific constants.

Parameters β_{costs} and β_{time} of the conditional logit model were estimated by the maximum-likelihood method using the *survival* package of statistical software R [5], namely the function *clogit()*. The final value of travel time savings $VTTS_{leisure}$ was obtained by substitution of estimated values of β_{costs} and β_{time} to the formula

$$VTTS_{leisure} = \frac{\beta_{time}}{\beta_{costs}} \cdot 60 \quad [in\ CZK/h].$$

3 Data

3.1 Stated preference survey

The aim of stated preference survey is to estimate weights that consumers assign to particular attributes of available alternatives. Respondents of the survey are introduced into hypothetical scenario, provided with hypothetical choice alternatives that differ on values of particular attributes and asked to choose one alternative based on their preferences.

The survey design consisted in the specification of hypothetical situation with respect to the objective of the study, i.e. estimation of value of travel time in case of leisure trips. In the study we focused on the most common type of leisure trips – weekend (two to three days) leisure trips. In the following text we will describe in details the survey design.

In the stated preference experiment we assumed several hypothetical destinations (scenarios) that can be accessed by two alternative routes i a j that differ in values of attributes X_{costs} and X_{time}. In order to reduce alternative specific bias, routes were labeled by randomly generated letters (e.g. route D and route B). Further, range of plausible values of attributes were calculated based on the assumption that one way trip in case of weekend leisure travel takes about 1 hour 40 minutes, which in case of average speed 70 km/hour correspond to 117 km. Adequacy of the assumption was later confirmed by outcomes of survey, in which respondents provided answer to the question "In case of weekend leisure trip by car, what is the average distance traveled (return trip in km)?". The average distance provided by respondents was 253 km (return trip). Travel time values were set within ∓ 30 minutes range around the average travel time, what corresponds to the average travel speed between ranging from 44 km/h to 119 km/h. The setting of travel costs was based on the average fuel consumption 8 liter per 100 km and fuel price 35 CZK per liter, what leads to the average one way travel costs approximately 330 CZK, 270 CZK for the shortest route and 390 CZK for the longest route.

With respect to the fact that variables X_{costs} and X_{time} are continuous, it was necessary to select limited number of values so that we would be able to cover in sufficient detail maximal range of travel time values, while keeping the number of decision problems as low as possible. The range of travel time values was set within the range from 10 CZK/h to 360 CZK/h, with respect to literature [3] that recommends values covering the range of 25% to 50% of average hourly wage (143 CZK/h in second quarter of 2011 [2]). Finally fractional factorial design was used in order to generate minimum number of value levels. Table 1 shows selected values of attributes.

X_{time}	X_{costs}
1 h 10 min	270 CZK
1 h 35 min	310 CZK
1 h 45 min	350 CZK
2 h 10 min	390 CZK

Table 1 Attribute values used in stated preference survey

Each respondent of the survey was provided with 9 decision problems that according to fractional factorial design systematically combined values in Table 1 and asked to choose his/her preferred route. Table 2 shows an example of card with the decision problem.

Scenario 1	Route A	Route B
Costs related to fuel consumption	70 CZK	130 CZK
Travel time	1h 45min	1h 35min

Table 2 Example of card with decision problem used in the survey

3.2 Dataset

The survey sample was selected from the population of residents in the Czech Republic using stratified random sampling based on the register of addresses. 557 out of the total of 835 selected respondents agreed to participate in the survey, what corresponds to 67% response rate. Sample representativeness was confirmed by the comparison of socio-demographical characteristics of the sample with characteristics of the population.

Survey was executed using CAPI method. Each respondent was asked for his/her socio-demographic characteristics and basic characteristics of travel behavior in the context of leisure travel. Respondents who do not use car for leisure travel were excluded from the sample. Finally, respondents were introduced to the context of the decision problem and provided with nine decision scenarios. The final dataset consists of 2502 choices from 278 respondents.

4 Results

Table 3 shows final values of parameters β_{costs} and β_{time} estimated on the above described sample.

Attribute	Parameter estimate $\boldsymbol{\beta}$	SE	z-score	Pr (>|z|)
X_{costs}	-0,041527	0,002048	-20,27	< 0,001
X_{time}	-0,038672	0,002428	-15,93	< 0,001

Table 3 Estimated parameters of conditional logit model

Negative values of parameters correctly suggest that higher travel costs, respectively higher travel time, have negative impact on utility. Low p-values suggest that estimated values of both parameters are significantly different from zero.

The value of travel time savings in case of weekend leisure trips is

$$VTTS_{leisure} = \frac{\beta_{time}}{\beta_{costs}} \cdot 60 = \frac{-0{,}038672}{-0{,}041527} \cdot 60 = 55{,}87 \quad [CZK/h].$$

Estimated value of travel time savings is within the range referred in literature [3], i.e. 25% - 50% of average hourly wage in the Czech Republic.

5 Discussion

This study presented estimation of value of travel time savings in case of weekend leisure travel using willingness-to-pay method that combined stated preference survey and conditional logit model. It was shown that estimated values of travel time saving are consistent with values found in other countries.

However, it has to be noticed that the study leaves aside several important issues, particularly due to the small sample size and limited scope of the study. Further study should focus on the influence of socio-demographic characteristics and detailed characteristics of trip (e.g. trip length or other types of leisure travel) on perceived value of travel time savings.

References

[1] Bickel, P., Friedrich, R., Burgess, A., Fagiani, P., Hunt, A., Jong, G. D., and Laird J. (eds.): *Harmonised Guidelines for Project Assessment, Deliverable 5, HEATCO - Developing Harmonised European Approaches for Transport Costing and Project Assessment*, EC 6 FP. IER, 2006, University of Stuttgart.

[2] Informační systém Ministerstva práce a sociálních věcí. http://www.mpsv.cz/files/clanky/11523/ISPV_112.pdf.

[3] Litman TA, Doherty E. *Transportation cost and benefit analysis: techniques, estimates and implications*. (2nd edition), Victoria Transport Policy Institute, Victoria, British Columbia, 2009.

[4] Maddala G S. *Limited dependent and qualitative variables in econometrics*. Cambridge University Press, Cambridge, England, 1983.

[5] R Development Core Team. *R: A Language and Environment for Statistical Computing*. ISBN 3-900051-07-0, URL http://www.R-project.org, 2008.