FURTHER RESEARCH ON THE NATIONAL SWEDISH VALUE OF TIME STUDY

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Abstract

The analysis show that the difference in value of time between willingness to pay and willingness to accept is due to resistance to pay more money and a difference in variance which can be eliminated in modelling work. The analysis also show that it is possible to estimate 2nd order terms as well as 3rd order terms and that the inclusion of socio-economic variables is motivated and reduces the effect of 2nd order terms. In addition, the results indicate that in stated preference data the standard deviation of the value of time, and hence the confidence interval, is underestimated by about 50 percent if regard is not taken to the fact that the choices are not independent.

INTRODUCTION

In Sweden, cost benefit evaluations have been part of the planning process for many years. In these cost benefit evaluations, the value of time (vot) plays an important role. In 1994, the Swedish Institute for Transport and Communications Analysis (SIKA) initiated a comprehensive vot study based on stated preference data. The study (hereafter referred to as vot project 1994/95) was commissioned to the Transek consultants and was completed in 1995. The work was carried out within a very narrow time frame, which meant that every aspect could not be dealt with as thoroughly as would be desirable. This paper reports further research of the existing set of data. In the present paper we deal with the following aspects: a) inertia, b) alternative model specifications, and c) the stability of the results with respect to confidence intervals. The paper focuses on methodological issues rather than additional vot results, although results will be used as examples. We have chosen to concentrate on car trips longer than 50 km which yielded a vot of more than twice the previously used value.

THEORY IN THE ORIGINAL STUDY 1994/95

The theoretical base for the original study was in principle the same as had been used for the studies in the UK and the Netherlands (Bates et al 1987, HCG 1990). For private trips, this is the neoclassical model of individual utility maximisation, under budget and time constraints. The vot can then under certain assumptions be derived as the ratio of the time and cost parameters in a discrete choice model for choice of alternatives involving different cost and time requirements. Based on previous experience and recommendations from earlier vot-studies (UK and Netherlands) the stated preference (SP) technique was chosen as the most suitable technique to obtain such data. The data was then analysed using logit models, yielding the relevant time and cost coefficients. Two important vot issues are the distribution of vot and the specification of the utility function (which are also interrelated). It may be of interest to see to what extent different approaches affects the vot, and in this paper, several approaches are applied to analyse the vot. First we start with presenting the final model for private trips received in the original study. We restrict the analysis to car trips over 50 km and undertake some sensitivity tests. Then we compare results given in models containing cost, time, and socio-economic variables and models estimated on subsamples. The particular way in which the survey was designed - a base alternative resembling the current trip compared with other alternatives - made it easy for the interviewee to adopt a "no change" strategy. It was therefore also quite clear what alternative implied a time gain and a time loss respectively. The importance of this has also been looked at. Some years ago, Jara-Díaz et al (1989) pointed out that to be consistent with microeconomic theory, a correct treatment of income effects required the utility function to be developed at least to the 2nd order. More recently, Jara-Díaz (1996) proposed an expansion of the theory of time allocation to include the activity concept in the microeconomic framework. This approach also requires 2nd order cost and time effects to be estimated in order to identify important properties of the model. Hultkrantz et al (1997) propose more generally that linear models should only be used if higher order terms are empirically rejected. One reason for the overwhelming use of the linear models may be that the correlation between 1st and 2nd order terms can be quite high in models based on Revealed Preference (RP) data, and thus make it impossible to estimate parameters for both. However, SP-data seems to suffer less from this and models including such terms are presented and compared to linear models. While the vot study 1994/95 was finalised, alternative approaches were discussed. One such approach was the Random Hicksian Variation approach (Hultkrantz et al 1996), also called the bid-price approach. The econometric model of this approach estimates directly the vot that maximises the likelihood of the chosen alternatives. In the context of the last approach on alternative model specifications and in context with the segmentation exercise, the issue of willingness to pay (wtp) and willingness to accept (wta) is studied. In the literature, wtp and wta are found to have different properties and to be valued asymmetrically (e.g. Hanemann 1991). This was an important issue in the discussion of the original study. Moreover, when the SP-technique is applied the standard deviations of the parameters become underestimated. This is due to the fact that each respondent yields several observations which implies that the assumption of independence is violated. Finally, the jackknife method will be applied to correct for this matter.

THEORETICAL FRAMEWORK

There are several ways to take for example income into account. The original analysis, which was based on a first order approximation of the utility function, yielding a linear income-independent model formulation, implied different cost parameters depending on different levels of income in order to identify the income effect. In this project, more general models according to recent theoretical developments will be tested. However, we will make an attempt to develop models step by step so that the influence on the parameters and the vot due to changes in model specification may be rather clear. First of all, we present the result given in the original analysis based on a 1st order approximation including only cost and in-vehicle time as well as an inertia parameter, all estimated on pooled data (the inertia parameter will be described further on). Then, we will set up a platform by presenting a 1st order approximation estimated on the segment, car trips over 50 km. After that 2nd and 3rd order approximations will be evaluated. Let us start out with theoretical foundations. Linear random utility models are widely used when dealing with the vot estimated on RP-data. One reason for this is that the correlation between 1st and 2nd order terms (including higher order terms) can be quite high and make it impossible to estimate separate coefficients. Linearity is though a strong assumption in estimation of the vot and may hence be inadequate. As we deal with SP-data which, in contrast to RP-data, is based upon a less correlated design, a non-linear functional form will be developed and analysed. In our theoretical model, we will follow the standard setup used in the literature (see, e.g., Train & McFadden (1978) and Hultkrantz et al (1998)). Assume that the utility function for an individual i is defined by $U_i\ (G, L, S)$, where G is private consumption, L is leisure, and S is socio-economic status of the individual. We let the individual maximise utility subject to money and time constraints: $max\ U_i\ (G, L, S)\ s.t.\ G + c_{ij} = E + wW,\ L = T - W - t_{ij},\ (j \in M)$. In words, the first constraint implies that the expenditure on consumption, G, and travel cost, c_j, is equal to labour income, wW, and exogenous income, E. The next constraint state that time spent on leisure, L, is equal to the total amount of time given, T, minus time working, W, and time travelling, t_j. There are M travel alternatives. The individual chooses the travel alternative, and hence c_j and t_j, and the number of hours worked so as to maximise utility $U_i\ (G, L, S)$ subject to the identities. Inserting the first order conditions from the maximisation problem as well as the optimal working time, $W^* = f\,(c_{ij}, t_{ij}, w, E, T)$, into the direct utility function, $U_i(G, L, S)$, yields the following indirect utility function: $V_{ij}(c_{ij}, t_{ij}) = U_{ij}(E + w\,f\,(c_{ij}, t_{ij}, w, E, T) - c_{ij},\ T - f\,(c_{ij}, t_{ij}, w, E, T) - t_{ij}\ , S)$. Let us approximate V_{ij} with a 2nd order Taylor expansion around the reference states c_0, t_0 and s_{0x} (which is a socio-economic vector including K characteristics, where x=(1,...,K)) for travel alternative $j \neq 0$ and individual i:

$$V_{ij}\,(c_{ij}, t_{ij}) = \left(c_0\,, t_0\right) + \left\|\left[(c_i - c_0)\frac{\delta V}{\delta c} + (t_i - t_0)\frac{\delta V}{\delta t} + \sum_{x=1}^{N}(s_{jx} - s_{0x})\frac{\delta V}{\delta s_x}\right]\right. +$$

$$\frac{1}{2}\left\|\left[\begin{array}{l}(c_i - c_0)^2\dfrac{\delta^2 V}{\delta c^2} + (t_i - t_0)^2\dfrac{\delta^2 V}{\delta t^2} + \displaystyle\sum_{x=1}^{N}(s_{jx} - s_{0x})^2\dfrac{\delta^2 V}{\delta s_x{}^2} + \\ 2\left\{\begin{array}{l}(c_i - c_0)(t_i - t_0)\dfrac{\delta^2 V}{\delta c\,\delta t} + \displaystyle\sum_{x=1}^{N}(c_i - c_0)(s_{jx} - s_{0x})\dfrac{\delta^2 V}{\delta c\,\delta s_x} + \displaystyle\sum_{x=1}^{N}(t_i - t_0)(s_{jx} - s_{0x})\dfrac{\delta^2 V}{\delta t\,\delta s_x} + \\ \displaystyle\sum_{\substack{x=1 \\ X \neq Z}}^{N}\sum_{z=1}^{N}(s_{jx} - s_{0x})(s_{jz} - s_{0z})\dfrac{\delta^2 V}{\delta s_x\,\delta s_z}\end{array}\right\}\end{array}\right]\right.$$

When a Taylor expansion to order n is assumed to be sufficiently accurate, then the rest term is close to zero, why this term is left out. The last equation will form the basis for our empirical investigation. Since factors that are constant over alternatives cancel out in the probability expression, we can only identify socio-economic variables when these are interacted with the cost and/or time variable. Let us turn to the results received in the original model approach.

ALTERNATIVE SPECIFICATIONS WITH FIXED PARAMETERS

Original model approach

The final model received for private trips in the 1994/95 vot study is presented in the following table. The values of in-vehicle time are presented for the three separate categories.

Table 1 - In-vehicle time values (sek/h)

	Car	Air	IC-train	X2000	Reg. Train	LD bus	Reg. bus
Commuting < 50 km	34	-	-	-	54	47	43
Other trips < 50 km	27	-	-	-	43	38	28
Trips > 50 km	81	88	74	102	70	65	50

The samples for the different modes were pooled. There was a strong distance effect implying a much lower vot for shorter trips. By separating the sample with respect to this distance criterion (and simplifying the utility function by taking away the distance dependence of the in-vehicle time parameter), it was found that both the time parameter and the cost parameter varied according to distance. The differences of the vot's for the two distance groups may be related to the frequency of the trips, where the shorter trips are likely to be more frequent, thus having a larger budget impact. It may also be that the time constraint is more binding for longer trips. Yet another reason may be that cost changes that are relatively small (such as those on longer and therefore more expensive trips) may have a lower effect. The shorter trips were further divided into separate samples of trips for commuting and other trips respectively. The mode car show the largest difference wrt trip lenght. A possible explanation may be that the convenience of the car mode is counteracted by fatigue effects when driving long distances. It can be assumed that in most cases the differences between work trips and other trips as well as the differences for longer trips between different modes are insignificant (although no jackknife variance estimation yet has been undertaken for this model). We will make an attempt to develop models step by step. As we only will deal with the car trips over 50 km it might first of all be a good idea to simplify the task and estimate a separate model in this segment keeping the specification unchanged.

Inertia

In the first model for car trips over 50 km we include one inertia parameter, cost, and in-vehicle time and receive a result similar to the original model. The vot equal 89 sek/h (compared to 81 sek/h).

Table 2 - Car trips (bm16x)

B.DAT	param	t-value
inertia	0.43340	(9.1)
$(c_i\text{-}c_0)$	-0.03038	(12.8)
$(t_i\text{-}t_0)$	-0.04489	(17.4)
LL model	-1319.74	
Observations	2243	

vot	88.7 sek/h

We have earlier described that the pairwise choices in the SP-games consist of a base alternative which was unchanged throughout the exercise as well as an alternative presenting differences (eg. 15 minutes longer than base alternative and 10 crowns cheaper). This may, however, produce a certain amount of inertia in favour of the base alternative. The matter was taken into consideration in the original analysis resulting in a significant inertia parameter not influencing the result at this point. Below a model is shown where the parameter is excluded. The vot equal 90 sek/h.

Table 3 - Car trips, leaving out the inertia parameter (bm19x)

B.DAT	param	t-value
$(c_i\text{-}c_0)$	-0.02811	(12.2)
$(t_i\text{-}t_0)$	-0.04212	(16.8)
LL model	-1362.31	
Observations	2243	

vot	89.9 sek/h

However, at the final stage of the original analysis it was observed that the inertia might differ depending on whether there was a wtp- or a wta-question. The wtp is estimated by segmenting on time savings and wta by segmenting on time losses. This is done in the two models below. The segmentation renders a relatively low wtp in comparison to the wta. The same result was achieved in the U.K. vot study of 1994 (Gunn et al 1996).

Table 4 - Car trips, divided into wtp and wta resp when inertia is excluded (bm22x and bm23x)

	wtp		wta	
B.DAT	**param**	**t-value**	**param**	**t-value**
$(c_i\text{-}c_0)$	-0.02927	(8.4)	-0.03539	(10.1)
$(t_i\text{-}t_0)$	-0.03082	(10.1)	-0.06660	(14.0)
LL model	-713.52		-608.23	
Observations	1122		1121	
vot	63.2	sek/h	112.9	sek/h

The same segmentation procedure is undertaken including the inertia parameter.

Table 5 - Car trips, divided into wtp and wta respectively (bm17x and bm18x)

	wtp		wta	
B.DAT	**param**	**t-value**	**param**	**t-value**
inertia	0.54250	(5.0)	-0.03345	(0.3)
$(c_i\text{-}c_0)$	-0.02836	(8.1)	-0.03552	(10.0)
$(t_i\text{-}t_0)$	-0.04429	(10.4)	-0.06780	(10.7)
LL model	-700.68		-608.19	
Observations	1122		1121	
vot	93.7	sek/h	114.5	sek/h

The wtp equals 94 sek/h while the wta equals 115 sek/h, both higher than the vot obtained in the original model. Contrary to the unsegmented models inertia does influence the vot when segmentation is done. Yet, the inertia parameter is more associated with wtp than with wta. The difference between wtp and wta may be due to income and substitution effects (Hanemann 1991) or to preference uncertainty (Li et al 1996). Another way to deal with the existance of inertia is to introduce an inertia parameter for wtp and wta respectively in the same model. Introducing two inertia parameters generates a vot equal to 103 sek/h.

Table 6 - Car trips, leaving out the inertia parameter (bm442trx)

B.DAT	Param	t-value
inertia-wtp	0.70230	(7.5)
inertia-wta	0.17810	(2.0)
$(c_i\text{-}c_0)$	-0.03062	(12.8)
$(t_i\text{-}t_0)$	-0.05242	(14.9)
LL modell	-1314.07	
Observations	2243	

vot	102.7 sek/h

As there may be a scaleparameter difference between wtp- and wta-questions a nested logit model is formulated with respect to wtp- and wta-questions. Such a model result in a vot equal to 108 sek/h.

Table 7 - Car trips, a nested model taking the difference in variance into account (bm24)

B.DAT	Param	t-value
inertia-wtp	0.90460	(6.3)
inertia-wta	0.02843	(0.3)
(c_i-c_0)	-0.03675	(10.7)
(t_i-t_0)	-0.06590	(10.5)
wtpscale	0.68500	(7.6)
LL modell	-1310.00	
Observations	2243	

vot	107.6 sek/h

Model bm24 must be analysed with respect to the models bm17x and bm18x which are segmented models including one inertia parameter each. It is interesting to conclude that the segmented models do not exhibit significantly better goodness of fit. The parameter measuring the difference in scale, wtpscale, has the following interpretation: The wtp-questions exhibit a larger variation, i.e. the variance is larger, and there is a fix component in contrast to the wta-questions. This is also reflected by lower parameter values in the model segmented on only wtp-questions (table 5). The conclusion is that there is no difference in the vot between the wtp and wta-questions. The difference in vot is only due to resistance to pay more money and a difference in variance. At last, to conclude what model to use as the base for specification of further models in this paper log likelihood tests will be carried out. In the subsequent tables the log likelihood values and likeli-hood ratio test results are presented. The first column specify the number of inertia parameters included in the model; no inertia parameter, one or two inertia parameters. The second column rep-resent the unsegmented vot (i.e. the data include both wtp and wta-observations), while the third and fourth column represent the segmented vot (i.e. the dataset contain either wtp- or wta-observations).

Table 8 - Comparison of the effect of the inertia parameter on the vot.

Inertia param (ip)	Unsegm. VoT	Segmented VoT wtp	wta	scaleparameter
No ip	90	63	113	
One ip (β_{ip})	89			
Two ip (β_{wtp}, β_{wta})	103	94	115	108

Below we can follow how the log likelihood develop for each model and study the likelihood ratio test results. The log likelihood is presented in the second, third, and fourth column, all following the pattern from the table above while the fifth and sixth column contain the likelihood ratio test statistics, LRT = -2 (L_R -L_U). The restricted model bm19x (table 3) is estimated on two parameters, cost and in-vehicle time. We test the null hypothesis that all parameters other than cost and in-vehicle time are all zero. The log likelihood for the restricted model is marked with L_R. As the number of degrees of freedom varies among the models the number is accordingly noted together with the statistic. The conclusion is that the null hypothesis can be rejected at the 0.05 level of significance in all cases. A considerable effect on the goodness of fit is obtained by introducing one inertia parameter. However, this is still not the best model. The best goodness of fit is received when segmentation is done and each model is specified with an inertia parameter. The best goodness of fit in an unsegmented model is received when two inertia parameters are introduced, bm44-2trx. Its vot corresponds to 103 sek/h. Cells representing this best model are toned, both in the table above and below.

Table 9 - Log likeL values vs likeL ratio test statistics.

Inertia param (ip)	Unseg. VoT (LogL)	Segmented VoT Wtp (LogL)	wta (LogL)	scale parameter	Likelihood ratio test (R=bm19x)	(R=bm19x)	(R=bm19x)
No ip	L_R=-1362, 31	L_R=-713,52	-608,23			81,12 $^{df=2}$	
1 ip (β_{ip})	-1319,74				85,14 $^{df=1}$		
2ip(β_{wtp},β_{wta})	-1314,07	-700,68	-608,19	-1310,00	96,48 $^{df=2}$	106,88 $^{df=4}$	104,62 $^{df=2}$

A proper way to continue the analysis would have been to refine either the two segmented models, bml7x and bml8x, or the nested model. However, to somewhat simplify further analysis we decide to base all further models in this paper on the model including two inertia parameters, inertia-wtp and inertia-wta. This is why the results from the chosen model are toned. This starting point is used with one exception. In the section where results are obtained by the bid-price approach no inertia parameter is used at all (as we do not know how this should be introduced).

Linear models: segmentation by variables vs subsamples

In application it is common to use group specific results to adjust to differences between segments. Therefore it is important to find methods for segmentation well adapted to its purpose. Here, we try to study segmentation done either by subsamples or by introducing socio-economic variables. In 1994/95 only some segmentation by socio-economic variables was feasible. More extensive such work was conducted in the U.K vot-study and some in the Norwegian vot-study. In the first example we study annual household income levels.

Table 10 - Segmentation: socio-economic variables vs subsamples wrt annual household income (divided into SEK 300.000 (USD 37 500) or less, and SEK 301.000 or more). * Sek/h

	subsample up to 300.000 bm2s3x		subsample over 300.000 bm2s4x		socio-econ: hhinc wrt cost bm2i2x		socio-econ: hhinc wrt cost and in-veh t bm3i2x	
	param	t-value	param	t-value	param	t-value	param	t-value
inertia-wtp	0.6128	(4.8)	0.8188	(5.8)	0.7035	(7.4)	0.7044	(7.4)
inertia-wta	0.2432	(2.0)	0.1087	(0.8)	0.1851	(2.1)	0.1850	(2.1)
cost	-0.0306	(8.7)	-0.0317	(9.4)	-0.0377	(12.1)	-0.0308	(8.8)
in-veh time	-0.0413	(8.9)	-0.0652	(11.8)	-0.0528	(14.9)	-0.0435	(10.3)
(hhinc over 300)*cost					0.0124	(4.0)	-0.0007	(0.1)
(hhinc over 300)*in-veh time							-0.0186	(3.5)
LL model	-691.22		-607.85		-1305.87		-1299.69	
Observations	1119		1124		2243		2243	
Hhinc	**subsample**		**subsample**		**socio-econ var**		**socio-econ var**	
VoT* < 300 000	80.9				84.0		85.0	
VoT* > 300 000			123.4		125.2		121.0	

When household income >SEK 300 000 interact with cost a significant parameter is given in model bm2i2x. When the same level of income is attached to the in-vehicle time, in model bm3i2x, this becomes significant instead, all contrary to intuitive expectations. A likelihood ratio test shows us that the latter model is a significantly better model. Comparing the vot results we receive no significant differences. The next table presents a model including additional socio-economic variables. We start out from model bm3i2 above. The variable hhinc was respecified as continuous (instead of a dummy variable) as it turned out with a better goodness of fit. Several background variables were combined with in-vehicle time and with cost. All socio-economic variables are dummy variables with the exception of hhkids and hhinc. The result in terms of vot is presented below. Some categories are active at the same time, e.g. persons undertaking work trips have for sure a paid job, why the parameters should be combined. It should be noted that all categories must be combined with household income, hhinc, and no kids, hhkids. This is also done in the vot-table. Each category assume a household income equal to 100 kSEK/year and no kids.

The fact that a worktrip is made is captured partly by $(s_{work}- s_0)*(t_i-t_0)$ illustrating a higher sensitivity to changes in time, and partly by $(s_{work}- s_0)*(c_i-c_0)$ reflecting a higher sensitivity to changes in cost. The vot for persons making work trips and having a paidjob is 57 Sek/h. The influence on the cost sensitivity is greater than on the time sensitivity which lowers the vot. One reason for this low vot compared to other private purposes might be the difference in trip length. Earlier it has been pointed out that the vot increase with trip length. Among trips > 50 km the trip length for work trips has the lowest average trip length equal 85 km (to be compared with e.g. 190 km for shopping trips and 115 km for personal business trips).

Table 11 - A linear approach with socio-economic variables. (bm166x)

B.DAT	param	t-value
inertia-wtp	0.8125	(7.4)
inertia-wta	0.1806	(1.8)
$(c_i\text{-}c_0)$	-0.02201	(-6.1)
$(t_i\text{-}t_0)$	-0.05931	(-9.1)
$(s_{hhinc}\text{-}s_0)*(t_i\text{-}t_0)$	-0.004415	(-5.6)
$(s_{age45\text{-}}\text{-} s_0)*(t_i\text{-}t_0)$	0.02240	(5.2)
$(s_{work}\text{-} s_0)*(t_i\text{-}t_0)$	-0.05555	(-3.8)
$(s_{work}\text{-} s_0)*(c_i\text{-}c_0)$	-0.08644	(-4.8)
$(s_{paidjob}\text{-} s_0)*(t_i\text{-}t_0)$	-0.02361	(-4.1)
$(s_{paidjob}\text{-} s_0)*(c_i\text{-}c_0)$	-0.01475	(-2.9)
$(s_{to\ purpose}\text{-} s_0)*(t_i\text{-}t_0)$	0.008735	(2.3)
$(s_{punctuality\ important} - s_0)*(t_i\text{-}t_0)$	-0.03050	(-2.0)
$(s_{punctuality\ important} - s_0)*(c_i\text{-}c_0)$	-0.05452	(-2.7)
$(s_{hhkids}\text{-} s_0)*(c_i\text{-}c_0)$	0.004938	(2.9)
LL model	-1213.9	
Observations	2243	

For persons having a paid job and not undertaking any worktrip the effect on the cost as well as the in-vehicle time, $(s_{paidjob}\text{-} s_0)*(c_i\text{-}c_0)$ and $(s_{paidjob}\text{-} s_0)*(t_i\text{-}t_0)$, is strengthened raising the vot. This is due to a quite large effect on the in-vehicle time. The vot equals 96 Sek/h. This higher vot may reflect an existing restriction in time for persons with relatively limited amount of leisure. Regarding $(s_{punctuality\ important} - s_0)*(c_i\text{-}c_0)$, $(s_{punctuality\ important} - s_0)*(t_i\text{-}t_0)$, and $(s_{to\ purpose}\text{-} s_0)*(t_i\text{-}t_0)$ there is no strong evidence for receiving a vot lower or higher than the base. Both these categories generate a lower vot compared to the base. The interpretation of the parameter reflecting travelling to a purpose combined with in-vehicle time is that the sensitivity to changes in in-vehicle time is reduced when travelling to the purpose. Kids <=18 years in the household raises the vot as the sensitivity in cost is decreased, $(s_{hhkids}\text{-} s_0)*(c_i\text{-}c_0)$. The effect may have to do with a time constraint as well as the fact that persons with kids in the household probably more often are accompanied by kids when travelling. hhkids was also significant together with the time parameter (which might be a more intuitive combination) but at a worse goodness of fit. Contrary to intuition household income, $(s_{hhinc}\text{-}s_0)*(t_i\text{-}t_0)$, gave the best goodness of fit when combined with in-vehicle time instead of cost. The vot increases with the level of household income. Persons belonging to the lowest household income group, 100 kSEK per year, have a vot equal to 95 sek/h. The vot increases with 21 sek/h for each higher 100 000. Besides household income we tested individual income as well as correction for purchasing power. None of these changes in specification gave significantly better models. The sensitivity to changes in in-vehicle time for persons =>45 years is represented by $(s_{age45\text{-}}\text{-} s_0)*(t_i\text{-}t_0)$ which has a positive sign. The vot is low at 42 sek/h. We must bear in mind that retired persons with less time restrictions are included in the category.

Table 12 - vot for different socio-economic categories .(bm166x) * Sek/h

Category	vot*
base hhinc equal 100 kSEK/year (+21.0 for each additional 100 kSEK/year)	95.3
worktrip (and having a paidjob)	56.6
paidjob (and not conducting any worktrip)	95.6
punctuality important	53.2
hhkids (one kid)	118.3
age45-	42.3
to purpose	74.6

The distribution of the vot in the sample is shown below. Most of the observations are concentrated to the interval 50-75 sek/h. The values lie between 25-500 sek/h. The mean vot is 95.5 sek/h.

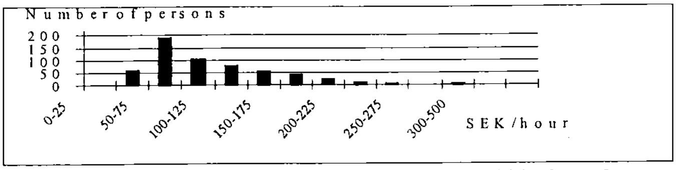

Figure 1 - Distr of vot in the sample of model bm166x based on socio-economic variables.

Non-linear models and segmentation by socio-economic variables

As linearity is a strong assumption in econometric estimation of the vot and as we deal with SP-data which is based on a more or less uncorrelated design a non-linear functional form will be developed. First of all, a 2nd order approximation of the conditional utility of a specific person will be tested for model bm44-2tr including only cost and in-vehicle time. All terms except of the interaction term between cost and in-vehicle time turned out significant. The interaction term was excluded and the result of the estimation on the remaining parameters is presented below.

Table 13 - A non-linear-approach. 2nd order approx. No socio-economic variables (bm137x)

B.DAT	param	t-values
inertia-wtp	0.883700	(8.1)
inertia-wta	0.068100	(0.7)
(c_i-c_0)	-0.031800	(12.2)
(t_i-t_0)	-0.061520	(14.3)
$(c_i-c_0)^2$	0.000005351	(2.9)
$(t_i-t_0)^2$	0.00002282	(4.1)
LL modell	-1304.35	
Observations	2243	

vot	115.7 sek/h

The extended non-linear model above produces a significantly better result in comparison to the original linear model. All parameters are significant at the 5 % risk level. Both the quadratic cost and the quadratic in-vehicle time have positive signs. Their effects are counteractive on the calculated vot. What we mean is that the vot increases with the size of the cost due to the positive sign of the quadratic cost, while the vot decreases with the size of the in-vehicle time due to the sign of the quadratic in-vehicle time. Earlier we mentioned that when a taylor expansion to order n is assumed to be sufficiently accurate, and rest term is close to zero, the term is usually left out. This may however be a doubtful assumption. Note that the size of both the quadratic terms are proportionately small. Thus, their effect on the vot is marginal and it might be an acceptable assumption that the rest term is close to zero. Calculating the mean of the vot using all parameters for the sample results in 115.7 sek/h while the mean becomes 116.1 sek/h when the quadratic terms are left out. The distribution of the vot among the persons in the sample has the following conical shape. The values are concentrated to the interval 100 to 125 sek/h and there is hardly any spreading because of the marginal influence of the quadratic terms. The mean vot equal 115.7 sek/h when the two negative values (-540 sek/h) are excluded. Including all values gives a mean value equal to 113.1 sek/h.

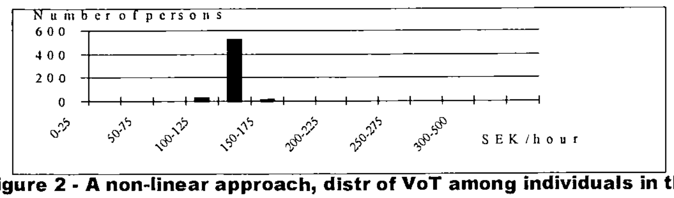

Figure 2 - A non-linear approach, distr of VoT among individuals in the sample. (bm137x)

As socio-economic variables are introduced as interaction terms with cost and in-vehicle time (see vector s in the Taylor-expansion) the 2nd order terms $\delta^2 V / \delta c^2$, $\delta^2 V / \delta t^2$, and still $\delta^2 V / \delta c \delta t$ become less and less significant. At some point these 2nd order terms become not significant at all and may be excluded. This imply that we end up in model bm166x presented in table 11, 12, and figure 1. One interpretation that may be made is that household income is enough to account for income effects. The 2nd order cost variable does not add information to the model. In later work it might be of interest to study background variables with respect to the non-linear cost and in-vehicle time parameters as well. Despite the result above a 3rd order approximation without socio-economic variables was conducted. The following result was received.

Table 14 - A non-linear-approach. 3rd order approx. No socio-economic variables (bm146x).

B.DAT	param	t-values
inertia-wtp	0.894700	(6.7)
inertia-wta	0.144400	(1.2)
(c_i-c_0)	-0.044400	(11.8)
(t_i-t_0)	-0.065250	(13.0)
$(c_i-c_0)^2$	0.00006401	(8.0)
$(t_i-t_0)^2$	0.00007071	(4.7)
$(c_i-c_0)*(t_i-t_0)$	0.00006599	(5.8)
$(c_i-c_0)^3$	-0.00000002466	(4.6)
$(t_i-t_0)^3$	-0.00000006016	(2.8)
$(c_i-c_0)^{2}*(t_i-t_0)$	-0.0000001353	(6.0)
LL model	-1263.24	
Observations	2243	

vot	95.1 sek/h

Higher order terms do also matter in terms of significance although their parameter values are very low and their contribution is marginal. The vot reduces to 88.2 sek/h when the higher order terms are left out. The distribution of the vot among the persons in the sample has the following shape with emphasis on the two intervals 50-100 sek/h. The spread is larger than for the case with a 2nd order approximation. The mean vot in the diagram below equal 95.1 sek/h when the two negative values (-484 sek/h) are excluded. When all values are included the mean value changes to 93.0 sek/h.

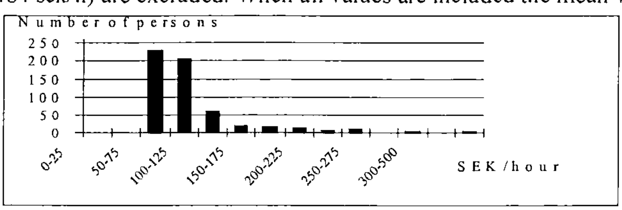

Figure 3 - A non-linear approach. 3rd order approx with only cost and in-veh time, distr of among individuals in the sample. (bm146x)

We continue developing the model by introducing socio-economic variables. This time they do not kill the influence of the higher order terms for cost and in-vehicle time. See the table below.

Table 15 - A non-linear-approach. 3rd order approx with socio-economic variables (bm178x) .

B.DAT	param	t-values
inertia-wtp	0.9626	(6.8)
inertia-wta	0.1176	(0.9)
$(C_i\text{-}C_0)$	-0.01252	(-2.4)
$(t_i\text{-}t_0)$	-0.06418	(-8.9)
$(t_i\text{-}t_0)^2$	0.00006702	(4.1)
$(C_i\text{-}C_0)^*(t_i\text{-}t_0)$	0.00003514	(2.9)
$(C_i\text{-}C_0)^3$	-0.00000003849	(-4.5)
$(t_i\text{-}t_0)^3$	-0.00000007986	(-3.2)
$(C_i\text{-}C_0)^{2}{}^*(t_i\text{-}t_0)$	-0.0000001052	(-4.3)
$(S_{hhinc}\text{-}S_0)^*(C_i\text{-}C_0)$	0.003697	(3.9)
$(S_{hhinc}\text{-}S_0)^*(C_i\text{-}C_0)^2$	-0.000004429	(-2.7)
$(S_{hhinc}\text{-}S_0)^*(t_i\text{-}t_0)^2$	-0.000006971	(-2.8)
$(S_{age45\text{-}}\text{-}S0)^*(t_i\text{-}t_0)$	0.02950	(6.3)
$(S_{age45\text{-}}\text{-}S0)^*(C_i\text{-}C_0)^2$	0.00002660	(3.4)
$(S_{work}\text{-}S_0)^*(C_i\text{-}C_0)$	-0.05599	(-3.0)
$(S_{work}\text{-}S_0)^*(t_i\text{-}t_0)$	-0.03618	(-2.4)
$(S_{paidjob}\text{-}S_0)^*(C_i\text{-}C_0)$	-0.03146	(-4.7)
$(S_{paidjob}\text{-}S_0)^*(t_i\text{-}t_0)$	-0.03276	(-5.4)
$(S_{paidjob}\text{-}S_0)^*(C_i\text{-}C_0)^2$	0.00003930	(4.4)
$(S_{to\ purp}\text{-}S_0)^*(C_i\text{-}C_0)$	-0.01989	(-4.4)
$(S_{to\ purp}\text{-}S_0)^*(C_i\text{-}C_0)^2$	0.00003424	(4.2)
$(S_{hhkids}\text{-}S_0)^*(C_i\text{-}C_0)^2$	0.00001210	(3.2)
$(S_{hhkids}\text{-}S_0)^*(t_i\text{-}t_0)^2$	0.00001889	(2.8)
LL modell	-1180.2	
Observations	2243	

VoT	103.2 sek/h

The mean vot equal 103.2 sek/h excluding negative values. Including the two negative values only has a marginal effect on the mean. It is reduced to 101.5 sek/h. See the distribution below.

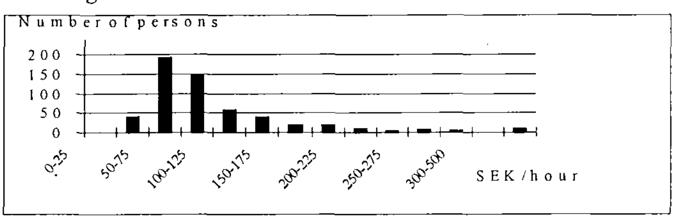

Figure 4 - A non-linear approach. 3rd order approx with socio-economic variables, distr of VoT among individuals in the sample. (bm178x)

Bid-price

At the final stage of the project alternative approaches were suggested (Hultkrantz et al 1996). One was to use a bid-price approach where the ratio between in-vehicle time and cost, i.e. the vot, is estimated directly. This could be an advantage as it actually is the ratio we are interested in. However, we must bear in mind that what the respondents really decided on doing the SP-exercise was the size of the cost and in-vehicle time and not the ratio.

Table 16 - A bidprice-approach (bm12)

B.DAT	param	t-value
bid	-0.0185	(15.9)
const	0.9380	(11.9)
wta	0.8468	(8.7)
LL model	-1308.03	
Observations	2259	

WTP*	50.7 sek/h	WTA*	96.5 sek/h

As there is an asymmetry in wtp and wta we introduce a wta-dummy variable to differentiate between wtp and wta. wta takes the value 1 for wta choices and 0 for wtp choices. The parameter for the bid presented to the respondent is called bid.The wta is calculated as wta = (const+wta) / bid. When wtp is calculated then wta is left out. wta is significant and imply that wtp and wta differ from each other. People value losses higher than gains, 97 sek/h versus 51 sek/h. Now lets introduce socio-economic variables. A likelihood ratio test shows that this model is significantly better than the model containing only three parameters, presented above. The fact that a worktrip is undertaken reduces the vot as the sign is negative, **worktrip**. Moreover the longer the trip is the higher the vot becomes, **length**. The same effect is obtained with higher household income levels, **hhinc**. Persons having a paid job have higher vot than others, **paidjob**, while the older you are the lower the vot is, **age**. Lastly the model shows that persons being accompanied by members of the household 0-18 years of age have higher vot than others.

Table 17 - A bidprice-approach, some socioeconomic parameters included (bm15)

B.DAT	param	t-value	mean (share)
bid	-0.0204	(16.2)	
const	0.1198	(0.5)	
wta	0.9271	(9.1)	
worktrip	-0.4900	(3.6)	10.4 %
length (continuous)	0.0020	(6.4)	214 km
hhinc (continuous)	0.0999	(4.9)	class 6.9
paidjob	0.5158	(4.1)	32.7 %
age (continuous)	-0.0103	(2.8)	47.3 years
comp0-18hh	0.3216	(2.8)	3.5 %
LL model	-1214.83		
Observations	2259		

The wtp for persons not making a work trip, not having a paid job, and not being accompanied by members of the household between 0-18 years equals 37 Sek/h and their wta equals 82 Sek/h. When they do a work trip and have a paid job the wtp and wta change marginally. Instead the wtp and wta change considerably when the person is being accompanied by young members of the household. The wtp then equals 54 Sek/h and the wta equals 99 Sek/h.

Table 18 - wtp and wta calculated for model bm15 for different categories. * Sek/h

	Param incl - length, hhinc, age	param incl - length, hhinc, age, work, paidjob	param incl - length,hhinc,age ,work,paidjob,comp0-18hh
WTP*	36.8	38.0	53.8
WTA*	82.2	83.5	99.2

The distribution of vot:s, divided into wtp and wta resepctively, in the sample is shown below. The wta values are the highest. The central point is still (similar to the result for non-linear models) in the interval 50-75 sek/h. The mean value of the time is 52 Swedish crowns per hour (54 excluding negative values) for the wtp and 97 Swedish crowns per hour for the wta over the sample.

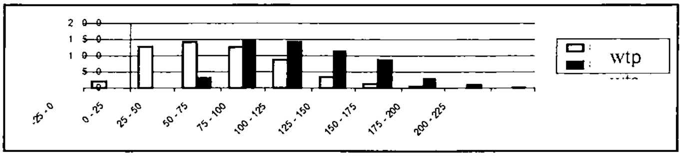

Figure 5 - A bid-price-approach, sample distr of wtp and wta (bm15)

THE STABILITY OF RESULTS – THE JACKKNIFE PROCEDURE

There are several ways of studying the stability of the vot results. One way is to calculate a confidence interval. The interval is an underestimation as the data contains several interviews per individual, and the assumption of independence between observations therefore is violated. There are different ways to re-estimate the variance. One way is by using the jackknife method. It may be used where the normality assumption is not met and can be applied to any statistic that is a function of n independent and identically distributed variables. The original procedure (Shao et al. 1995) is such that a specific parameter is repeatedly estimated using the full sample of N observations except one (each time different) observation which is not used. Then the variance is calculated from the N different parameter values obtained. To avoid problems associated with deleting only one observation at a time (many calculations and numerical problems), the procedure can instead be applied to groups of observations. In order to be able to treat the data as an independent data set, persons rather than choices will be used in defining the groups of observations. In this study, 8 choices were generated by each individual. The procedure can be applied not only to the estimation of the variance of the β-values in the logit model, but also directly to the ratio of parameters, such as the vot. This was done in a model estimated on car trips over 50 km. The original β-estimates and standard deviations and the jackknife standard deviations obtained are presented in the table below.

Table 19 - Estimates obtained from the original analysis and from the jackknife procedure.

Variable	Parameter	Original estimates		Jackknife estimates	
		Standard deviation	t-value	Standard deviation	t-value
Cost	-0.03064	0.002364	12.96	0.002714	11.29
Time	-0.04497	0.002574	17.47	0.003801	11.83
VoT	88.06 sek/h	4.31	20.41	6.88 sek/h	12.80

As can be seen from the table, the standard deviation estimated using the jackknife technique is larger than the standard estimation obtained using the standard method. The 95 percent confidence interval thus increased from 88 ±8,45 to 88 ±13,48 SEK/h, or from about 20 percent of the mean vot to about 30 percent of the mean vot. The t-value reduces to about 50 percent. The same experience was made during the Dutch vot study 1997 (Gunn et al 1998).

CONCLUSION

The wtp-questions exhibit a larger variation, i.e. the variance is larger, and there is a fix component in contrast to the wta-questions. This is also reflected by lower parameter values in the model in table 5 segmented on only wtp-questions. The conclusion is that there is no difference in the vot between the wtp and wta-questions. The difference in vot is only due to resistance to pay more money and a difference in variance. The analysis showed further that it is possible to estimate 2nd order terms as well as 3rd order terms. The model including 3rd order terms imply a wider vot distribution in the sample in comparison to the model based on only 2nd order terms. The inclusion of socio-economic variables is motivated and reduce the effect of 2nd order terms. The impact of different specifications on the corresponding vot distribution was illustrated by specifying several alternative models on the same set of data. The same pattern with respect to sign of parameters is shown by the linear model based on socio-economic variables, the non-linear model, and the bid-price model. When it comes to the distribution of the vot the models have the same log normal shape with a central point in the interval 50-125 SEK/h. The non-linear model based on 2nd order terms does not follow this same pattern. It exhibits a very steep shape. A restriction on the application of the bid-price model is the difficulty to specify a bid when more than two variables are included in the SP-exercise. The approach does not either take the choice situation in account, the inertia parameter can not be specified. However, the bid-price model gives a better fit to the data. It may be that there is some heterogenity in the data, for instance that the utility for longer trips is associated with a higher variance in the random component. Concerning the statistical stability of results, it can be concluded that the statistical drawback by obtaining several observations from the same individual implies that the standard deviation of the vot, and hence the confidence interval, is underestimated by about 50 percent if regard is not taken to the fact that the choices are not independent. The correction can easily be obtained by using the jackknife procedure. The simplest linear model for car trips longer than 50 km yields a vot of 88 SEK/h, with a 95 percent confidence interval of ±14 SEK/h. Practically all different specifications tested here yield a mean vot included in this interval.

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REFERENCES

Algers, S., B. Hugosson and J. Lindqvist Dillén (1995). 1994- ÅRS TIDSVÄRDES-STUDIE, Slutrapport, Del 1 Resultat.

Algers, S., J. Lindqvist Dillén, and S. Widlert (1996). The National Swedish Value of Time Study. Paper presented at the Value of Time Seminar, Easthampstead Conference, October 29-30, 1996.

Bates J. et al (1987). The Value of Travel Time Savings: A Report on Research Undertaken for the Department of Transport. Leeds University, England Institute of Transport Studies, Old Vicarage.

Gunn, H. And C. Rohr (1996). The 1994 U.K. VOT Study. Paper presented at the Value of Time Seminar, Easthampstead Conference, October 29-30, 1996.

Gunn, H., J.G. Tuinenga, Y.H.F. Cheung, and H.J. Kleijn (1998). Value of Dutch travel time savings in 1997. Paper presented at 8th WCTR 1998 in Antwerp, Belgium.

Hague Consulting Group (1990). The Netherlands "Value of time" Study: Final Report. Haag

Hanemann, W. M. (1991). Willingness to Pay and Willingness to Accept: how much can they differ? **American Economic Review 81**, pp. 635-647.

Hensher, D. A. (1977). Value of Business Travel Time. Pergamon Press Oxford.

Hultkrantz I., Li C-Z. And Lindberg G. (1996) Some problems in the consumer Preference approach to multimodal planning. Centre for research on transportation and society. Working paper 1996:5

Hultkrantz L. and R. Mortazavi (1997). The value of travel time changes in a random nonlinear utility model. Paper presented at a Value of Travel Time Seminar, Oslo, May 21-22.

Jara-Diaz, S. R and Videla, J. (1989) Detection of income effect in mode choice: theory and application. **Transportation Research 23B**, 393-400

Jara-Díaz S. R. (1996) Time and income in travel demand: Towards a microeconomic activity framework, invited paper presented at the International Conference on the Theoretical Foundations of Travel Choice Modelling, Stockholm, August 7-11.

Li, C-Z, K-G Löfgren, and W.M. Hanemann (1996). Real versus Hypothetical Willingness to Accept: The Bishop and Herberlin Model Revisited. Umeå Economic Studies No. 420.

Shao J., Tu D. (1995). **The Jackknife and Bootstrap.** Springer series in Statistics.