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ON THE SOCIAL VALUATION OF TRAVEL TIME SAVINGS

T. E. GÁLVEZ
S. R. JARA-DÍAZ (*)

ABSTRACT: In this paper we propose a method to compute the social values of users' travel time savings within a cost-benefit framework. It is shown that the resulting values are related to three main factors: the travellers' subjective valuation of time savings, the taxpayers' valuation of the money paid, and a value judgement about individual welfare made by the political authorities. As a general result, the method yields social values of time which are group specific, with a single value representing a particular case. The proposed method hopefully puts an end to the old discussion between subjective and equity values of time. It isolates what is really a political decision (the social weight of individual welfare) from what is a technical issue (the measure of subjective valuations). A numerical example illustrates the method.

1. INTRODUCTION

The valuation of travel time savings has been an issue in the transport economics literature for decades. Its relevance comes from the obvious fact of travel time reductions being the main source of benefits in transport projects. The pioneering articles of Becker (1965), DeSerpa (1971) and Evans (1972) contributed to the establishment of a solid body of knowledge regarding

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(*) *Tristán E. Galvez, Assistant Professor at the Department of Civil Engineering, University of Chile; Sergio R. Jara-Díaz, Professor, Department of Civil Engineering, University of Chile, e-mail: jaradiaz@tamarugo.cec.uchile.cl.*

The essence of this approach pursued in our paper was first presented at the workshop on Value of Time within the Seventh International Conference on Travel Behaviour, Valle Nevado, Chile, June 1994. We thank for the encouragement and comments of David Hensher, John Bates, Mark Bradley and Juan de Dios Ortúzar. This research was partially funded by FONDECYT, Chile.

the role of time in individual behavior, extending consumer theory to encompass activities as well. The importance of reassigning time from some activities to others perceived as more pleasurable was shown to be convertible into monetary units. This fact is implicitly captured by those travel demand models from which a trade-off between travel cost and travel time can be calculated, obtaining the individual or subjective value of travel time SVT. The specific literature on the microeconomics of travel decisions provide the elements to interpret SVT in terms of the economic circumstances that can be associated to each individual. For example, the goods-leisure trade-off approach by Train and McFadden (1978) induces models in which SVT is linked to the wage rate of an individual that chooses working time freely, while the reformulation by Jara-Díaz and Farah (1987) relates SVT to an expenditure rate in the case of individuals who have a fixed working schedule. The microeconomics of travel decisions has been discussed with particular richness by Truong and Hensher (1985) and the subsequent interaction by Bates (1987), among others.

Thus, the economic foundations of travel demand provide a solid framework to formulate and estimate models from which the SVT can be obtained for many type of individuals under many different circumstances. This constitutes the basis of many studies at a national level which aim at providing values that are seen as basic input for transport project evaluation. But calculating SVT for a host of individuals and conditions does not solve the problem. "...while these values may be taken as evidence of willingness to pay, in line with the general theory of market economics, the decision as to how these individual assessments should be used in a social cost-benefit analysis exercise remains a political question, which can only be partly informed by the results obtained..." (Bates and Roberts, 1986, in their methodological summary of the British research project on value of time, commissioned by the Department of Transport). This type of discussion has sometimes taken the form of a choice between using individual values directly or a unique ("equity") value of time for project appraisal.

In this paper we want to face the challenge posed above, but we refuse to start the analysis by defending a priori positions; we want to start from the beginning, from the basics, which means going beyond the estimation of travel demand models. The main objective of this paper is to propose a framework to analyse transport projects which are "social", i.e. judged as if they were funded with money collected by the state from the taxpayers and decided collectively by the authorities, although alternative financial forms are also explored. The specific purpose is to apply this framework to the case of travel time saving projects, in order to obtain well defined social values of travel time. In doing so, we will assume that well founded, solidly estimated demand models will be available; this way, we will explicitly suppress the temptation to mix the social valuation issue with the problem of how to obtain good models in order to get the best estimates of the SVTs; the question is, in fact, how to use these as inputs.

In the following section we recover the framework of social welfare analysis in order to reorient the formulation towards the identification of the role of the different actors in this game, and also to explicitly state the options in terms of the social welfare measures of benefits in a project. Then we apply this framework to travel time saving projects, in which mode choice models play a most important role through the estimated parameters. We show there that the use of one or many values for project appraisal is a matter that can be faced empirically; in that section we limit the analysis to the usual case in which the traveller can freely reallocate the travel time saved. A detailed numerical example is provided in section four. Comments, extensions and conclusions are provided in the last section.

2. SOCIAL WELFARE ANALYSIS

According to welfare theory, a social welfare measure can be postulated as

$$W = W\,(W_1, \ldots W_q, \ldots W_n) \qquad [1]$$

which is a function of the welfare level W_q of each individual q in society. It represents conceptually the implicit manner in which society weights individual welfare for purposes of deciding what to do with social resources. The social welfare function W is hiding behind the decisions and actions of the legislative body, the executive power and the public bureaucracy. On the other hand, individual welfare is assumed to be a function of the quantity of goods X_{iq} consumed within a reference time period; in consumer theory, these quantities are demanded according to individual income Iq and goods prices P (in the simplest version of the model). Formally, then

$$W_q\,(X_{iq}) = W_q\,[X_{iq}(I, P)] \equiv V(I, P) \qquad [2]$$

where V is an indirect utility function.

When this framework is applied to cost-benefit analysis, it is normally assumed that the effect of a project can be summarised by money benefits dBq (positive or negative) perceived by each individual in society, relative to some reference situation. The change in welfare is then expressed as

$$dW = \sum_q \frac{\partial W}{\partial W_q} \frac{\partial W_q}{\partial B_q} dB_q \qquad [3]$$

From equation [2], it follows directly that the variation of individual welfare under a variation of money is the marginal utility of income λ_q. So, we have

$$\frac{\partial W_q}{\partial B_q} = \frac{\partial W_q}{\partial I} = \lambda_q \qquad [4]$$

$$dW = \sum_q \frac{\partial W}{\partial W_q} \lambda_q \, dB_q \qquad [5]$$

In equation [5], λq is the weight given by individual q to the money benefits perceived. This is of course a private or subjective issue. In contrast, $\partial W/\partial W_q$ is the social "weigth" attached to the welfare of individual q, which is really a political issue, implicitly decided by the political authorities (and revealed by their actions). So we can make a very clear distinction here between what is a social problem and what is a modelling problem. In what follows, it is implicitly assumed that each λq remains constant within the range of the project effects.

If we want to express social welfare in money units dB, we need to define a conversion factor λ_s such that

$$dB = \frac{dW}{\lambda_s} \qquad [6]$$

$$dB = \frac{1}{\lambda_s} \sum_q \frac{\partial W}{\partial W_q} \bullet \lambda_q \bullet dB_q \qquad [7]$$

We can reveal now the assumptions that are implicit behind the "innocent" approach, which expresses the money measure of social welfare as just the sum, over all individuals, of the money measure of individual welfare (variation in consumer's surplus), i.e.

$$dB_1 = \sum_q dB_q. \qquad [8]$$

From equation [7] the underlying assumption is

$$\frac{\partial W}{\partial W_q} \bullet \frac{\lambda_q}{\lambda_s} = 1 \qquad [9]$$

or

$$\frac{\partial W}{\partial W_q} = \frac{\lambda_s}{\lambda_q} \qquad [10]$$

This means that, in this approach, the social weight of individual q welfare $\partial W/\partial W_q$ is inversely proportional to his/her marginal utility of income. All empirical evidence (theoretically supported) states that the marginal utility of income decreases with income. So, adopting this innocent approach for project appraisal is equivalent to accept a social weight on individual welfare that increases with income. This is of course a highly regressive approach.

We will explore now the conseguences of adopting a neutral approach, which means equal social weight for each individual, i.e.

$$\frac{\partial W}{\partial W_q} = 1 \quad \forall q \qquad [11]$$

which leads to

$$dB_2 = \sum_q \frac{\lambda_q}{\lambda_s} \bullet dB_q \qquad [12]$$

This last equation shows that the neutral approach is equivalent to a weighted sum of individual benefits. So, the "innocent" and the neutral approaches lead to different ways of adding individual users' benefits. The choice between these two approaches (or among any others that one can come up with), is essentially a political issue.

If we want to actually use the neutral approach, we need to derive a way to compute both λ_q and λ_s. We will start by the conversion factor l_s, and will follow the approach used in Strobl et al. (1994). We have to recall that, in the case of cost-benefit analysis of transport projects, the general situation is an investment being made in order to produce savings in the operation of the system. If the investment is made by the State or other public authority, and the money used comes from taxes, it means we are dealing in fact with the use of taxpayer's money. Paying taxes is equivalent to a reduction in taxpayer's income, and can be expressed as a welfare loss using the marginal utility of income of those who pay. Under the neutral approach we are using, total welfare loss can be expressed as

$$dW_T = \sum_q \lambda_q \bullet dT_q \qquad [13]$$

where dT_q represents the quantity paid (tax) by individual q. On the other hand, total tax collection dT is given by

$$dT = \sum_q dT_q \qquad [14]$$

Therefore, total money dT collected for social use is associated with a total welfare loss dW_T. The loss in utility derived from the collection of one money unit of tax is precisely the social conversion factor we were looking for, and it is given by

$$\lambda_s = \frac{dW_T}{dT} \qquad [15]$$

or

$$\lambda_s = \frac{\sum_q \lambda_q \bullet dT_q}{\sum_q dT_q} \qquad [16]$$

Therefore, λ_s is a weighted average of the taxpayers' marginal utilities of income; for this reason, λ_s *can be properly associated to a social utility of money*. Note that equation [16] holds even if the investment is made from a different source of funds. For instance, in the case of a private road charging tolls to users, dT_q would represent the amount of tolls paid by individual q. It follows that the conversion factor λ_s depends on the way the project is funded, but there is a single value for all projects financed from general taxation.

As a particular case, if a project is self financed such that each user pays exactly what he/she perceives as a benefit (dB_q) then from equations [12], [16] and [8] we get the trivial result

$$dB_2 = \frac{\sum_q dB_q}{\sum_q \lambda_q dB_q} \sum_q \lambda_q dB_q = \sum_q dB_q = dB_1. \qquad [17]$$

Analogously, if the riches (R) pay taxes and the poor (P) are favoured by a project, then the same set of equations yields

$$dB_2 = \frac{\sum_j dT_j}{\sum_{j\in R} \lambda_j dT_j} \cdot \sum_{i\in R} \lambda_i dB_i = \frac{\bar{\lambda}_P}{\bar{\lambda}_R} \sum_i dB_i = \frac{\bar{\lambda}_P}{\bar{\lambda}_R} dB_1 \qquad [18]$$

where

$$\bar{\lambda}_R = \lambda_s \wedge \bar{\lambda}_P = \frac{\sum_i \lambda_i dB_i}{\sum_{i\in P} dB_i}. \qquad [19]$$

As $\bar{\lambda}_P > \bar{\lambda}_R$, then $dB_2 > dB_1$ and, therefore, the "innocent" but regressive approach would underestimate the social benefits calculated with the neutral approach.

Regarding the set of values for λ_q, we have to state that, in general, this is problematic. However, in transport demand modelling, a widely used technique is the estimation of choice models based on the random utility theory. It will be shown in the next section that, in these cases, the marginal utility of income is a by-product of demand modelling, and it is usually available in most cost-benefit applications.

3. THE SOCIAL VALUE OF TRAVEL TIME SAVINGS

Now we are in a position to face directly the measure of social benefits in the case of travel time saving projects. To do this, we are going to use the microeconomic properties of travel choice models which, as known, are usually estimated in such a way that a travel utility is obtained. This utility is in fact a truncated conditional indirect utility function from an economic viewpoint (Jara-Díaz, 1994), and its arguments (for a given class of individual) are travel cost and all components of travel time, among other variables. If it is specified linear, then the coefficients of cost and time provide direct information on parameters that are very useful within the framework for social welfare analysis presented above. Let α_q be the coefficient of time and β_q the coefficient of cost; then the subjective value of time SVT_q and the marginal utility of income MUI_q are respectively given by

$$SVT_q = \frac{\alpha_q}{\beta_q} \quad \text{and} \quad MUI_q = \lambda_q = -\beta_q \qquad [20]$$

In the first equivalence, SVT is stated as the (marginal) rate of substitution between cost and time for a constant level of (indirect) utility. The second equivalence comes from the conditional nature of travel utility, in which disposable income is what would be available to the individual if he/she chose a particular alternative; as cost is substracted from income, the result flows clearly (see Viton, 1981, or Jara-Díaz and Farah, 1988).

As mentioned previously, the effect of a project on individual utility can be measured in monetary terms by means of the variation in consumer's surplus. As time is an argument in travel choice models, the variation of travel time induces variations in the probability of choice which, in turn, can be calculated as an individual benefit by means of the generalised line integral representing its money equivalent. In short, following Small and Rosen (1981), dB_q in the preceding section can be expressed as

$$dB_q = \frac{1}{\lambda_q} \int_{t^0}^{t^1} \sum_{i \in M} \pi_{iq} \, dt_i \qquad [21]$$

where t^j_i is travel time in alternative i, state j, p_{iq} is the probability of individual q choosing alternative i and M_q is the set of alternatives available to that individual. Let us note that λ_q should be independent of time for equation [21] to hold.

The line integral can be approximately solved choosing a linear path, assuming a linear variation of the probabilities with t, and adopting the usual linear form for the conditional utility; the result for the case of variations in travel time only is (Jara-Díaz, 1990)

$$dB_q = SVT_q \sum_i \frac{1}{2}\left(\pi^0_{iq} + \pi^1_{iq}\right) \bullet \left(t^0_i - t^1_i\right) \qquad [22]$$

where the reader can recognize a time version of the well-known rule-of-a-half.

Note that if the variation of the probabilities is negligible, then equation [22] collapses into SVTq times the travel time saved by individual q. This means that the treatment of travel time as a physical quantity with a price, is an interpretation with limited validity. In any case, we will define the relevant measure for the travel time saved by individual q, TTSq, as

$$TTS_q = \sum_i \bar{\pi}_{iq}\left(t^0_i - t^1_i\right) \qquad [23]$$

Under this setting, the politically neutral measure of social benefits, dB_2, can be obtained from equations [12], [20], [22] and [23] as

$$dB_2 = \sum_q \frac{\lambda_q}{\lambda_s} SVT_q \bullet TTS_q = \sum_q \frac{|\alpha_q|}{\lambda_s} TTS_q \qquad [24]$$

while the regressive measure dB_1, from equations [8], [20], [22] and [23] is given by

$$dB_1 = \sum_q SVT_q . TTS_q = \sum_q \frac{|\alpha_q|}{\lambda_q} TTS_q \qquad [25]$$

From these results, it is clear that the use of subjective values of time as the social values of individual time savings, is a practice that would be sustained by the regressive approach only.

The main result is in fact represented by equation [24], as it reflects a neutral social weight on individual utility. According to this view, *different social values of travel time (group specific) are theoretically supported*, and they should be calculated as the ratio between the marginal utility of time of each group and the social value of money. On the other hand, if the marginal utility of time (i.e. the *absolute* value of one minute spent in travel) was equal across individuals, then a single value of time *could* be supported. Analytically, from equation [24], if

$$\alpha_q = \alpha \ \forall_q \quad \text{then} \quad dB_2 = \frac{|\alpha|}{\lambda_s} \sum_q TTS_q = VT \bullet TTS \qquad [26]$$

where VT is a (single) social value of time. This is an important result, because the neutral approach to benefits, which means that "all men are equally considered", *might* translate into a single price that can multiply total time savings. But this is subject to *empirical* scrutiny in terms of the possible equality of the (absolute) marginal valuation of time across individuals; in other words, the question is whether the coefficients of travel time are equal across different segments of the population.

Let us emphasize that an equitable view of individual welfare yields a measure of benefits given by equation [24]. This may or may not imply a single value of time for social appraisal of projects. When the marginal utilities of time differ across individuals that are affected by the project, then segment-specific values of time can be calculated which do not correspond to the subjective valuations in general, but to social values VT_q given by

$$VT_q = \frac{|\alpha_q|}{\lambda_s}. \qquad [27]$$

The sources for the α_q's are the coefficients of time in choice models for those affected by the project, and the inputs to calculate λ_s are the coefficients of cost in choice models for those that pay taxes (or those who contribute to pay for the investment), and a taxpayer table (or a table with individual contributions). Note that if a single value VT would like to be favoured for simplicity within the social appraisal procedure, it should be calculated by solving

$$dB_2 = \frac{1}{\lambda_s} \sum_q \left|\alpha_q\right| TTS_q = VT \bullet \sum_q TTS_q \qquad [28]$$

which yields

$$VT = \frac{1}{\lambda_s} \sum_q PT \bullet \left|\alpha_q\right| \qquad [29]$$

or

$$VT = \sum_q \frac{\lambda_q}{\lambda_s} PT_q \bullet SVT_q \qquad [30]$$

where PT_q is the proportion of total travel time saved by individual (segment) q. Equation [29] shows the input needed to calculate VT and equation [30] links VT with the individual subjective valuations.

Finally, as equation [22] can be easily extended to encompass all dimensions of travel time (and other quality dimensions as well) as shown in Jara-Díaz (1990), then the results obtained here can be extrapolated easily to *distinct social values* for in-vehicle, waiting and walking times.

4. A NUMERICAL EXAMPLE

In this section we present a relatively simple case to illustrate the mechanics of the approach introduced in the paper. Let us assume that we have two alternative projects: a general road improvement scheme (project A), and one that assigns high priority to public transport (project B). Our task is to compute the benefits due to travel time savings with respect to the do-nothing option. For the sake of simplicity we will assume that the projects have a negligible effect on flows (cars and buses). A choice model including travel time and cost for three income groups, is available. Data on flows, time savings and passenger split are shown in Table 1; the choice model is summarized in Table 2, including the subjective value of time by income strata.

TABLE 1

Base Data for the Numerical Example

Vehicle type	Flow (veh/day)	Occupancy (pax/veh)	Time savings (veh-hours/day)		Passenger split by income (%)		
			Project A	Project B	Low	Medium	High
Cars	1200	2	200	100	10	30	60
Buses	900	30	15	30	60	30	10

TABLE 2

Choice Model

Variable	Parameter	t stat	SVT ($/min)
Time	- 1.17	5.9	
Cost by Income			
• Low	- 0.1334	12.4	8.77
• Medium	- 0.0305	10.4	38.36
• High	- 0.0141	3.8	82.98

Values obtained from CITRA (1994).

It should be noted that project A evidently favours the high income group, while project B has advantages to the poor. Also, the marginal utility of income in the choice model decreases with income, as expected; therefore, the common time parameter yields SVT's that increases with income.

Under this setting, travel time savings due to each project can be easily calculated for each income group using the data in Table 1. The results in passenger-hours are presented in Table 3.

The conditions have been set in such a way that the politically neutral measure of social benefits (dB_2 in equation [24]) can be calculated directly from equation [26], which requires an estimate of the (single) social value of time as the ratio between the coefficient of time in Table 2 (in absolute value) and the social utility of money, λ_s from equation [16]. The calculation of λ_s requires information on the distribution of the tax burden TB_q across the population; let us assume that this corresponds to 5%, 30% and 65% for the low, medium and high income groups respectively. From this we get

TABLE 3

Travel time savings (passenger-hours) by income group for each project

Income Group	Low	Medium	High	Total
Project A	310	255	285	850
Project B	560	330	210	1100

$$\lambda_s = \sum_{q=1}^{3} \lambda_q . TB_q = 0.02499$$

and

$$VT = \frac{1.17}{0.02499} = 46.82\,\$/_{\min} \qquad [31]$$

and the politically neutral measure of benefits is $2,388,240 for project A and $3,090,660 for project B. Note that different marginal utilities of time for each income group would have required the calculation of social values of time for each group according to equation [24], as $|\alpha_q|/\lambda_s$.

It is interesting to calculate also the social benefits according to the politically biased measure dB_1 which, under the conditions of the example, is the addition over all income groups of their physical travel time savings weighted by the corresponding SVT (equation [25]). Therefore, from tables 2 and 3 we obtain benefits equal to $2,169,000 for project A and $2,099,760 for project B. A synthesis is presented in Table 4, where we have disaggregated benefits by income group.

The synthesis confirms what we had shown as a general result in equation [18], i.e. that the politically biased approach underestimates the calculation of social benefits obtained with the neutral criteria when the richs pay taxes and the poor are favoured. As our example is less dramatic than the extreme theoretical case in reference, the results present obvious variations by income group. From the numbers in table 4 is also obvious that an even figure on costs for both projects (including investment) would result in different decisions depending on the political criteria used: a neutral view would indicate that project B is better, and an income biased view would indicate A as the preferred outcome.

TABLE 4

Social benefits from travel time savings (Thousand $/day)

Approach	Benefits from Project A by income group				Benefits from Project B by income group			
	Low	Medium	High	Total	Low	Medium	High	Total
Politically neutral	871	716	801	2388	1573	927	590	3091
Politically biased	163	587	1419	2169	295	760	1046	2100

5. FINAL COMMENTS AND CONCLUSIONS

We have derived a sound method to compute the social values of users' time savings, which are related to three main factors: the travellers' subjective valuation of time savings, the taxpayers' valuation of the money paid, and a value judgement about individual welfare made by the political authorities. The social values are, in general, different across groups depending upon the (estimated) marginal utilities of travel time. A single social value could result if these marginal utilities are not statistically different.

The method hopefully puts an end to the old discussion between subjective and equity values of time. It isolates what is really a political decision (the social weight of individual welfare) from what is a technical issue (estimates of the subjective valuations).

Applications of this method are not limited to travel time savings. In fact, the same approach can be used to compute a social value for other components of the conditional indirect utility function, such as quality of travel. In more general terms, the approach can be extended to any cost-benefit problem in which choice models can be used to represent users' behaviour and from which marginal utilities can be obtained.

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