THE VALUE OF TRAVEL TIME SAVINGS

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1. Background

This chapter will look at the value individuals place on travel time savings. This is a surprisingly important topic because time savings form a very large part of user benefits identified in most transport schemes, and transport schemes are themselves very expensive. It is therefore sensible to spend larger sums on accurately identifying the value of travel time savings (VTTS) than many firms' total market research budgets. Given that level of spending, it is crucially important that the underlying theory is well understood.

It is important to realise from the beginning that VTTS values are required for two distinct purposes, and can be different depending on purpose. The first use is in determining the effect of policies on the ground. If a toll road scheme is to be implemented that saves 15 minutes for drivers currently making an equivalent end-to-end journey, but at a charge of 5 Euros a time, we need to know roughly how many drivers will switch to the tolled road. We say this is a forecasting value, or Willingness To Pay (WTP) value.

Quite separately from that, we need VTTS values for valuing time savings (and losses) that arise due to a scheme. These values should represent the public benefit from saving travellers' time. It is sensible that they should reflect WTP values, but if the public wants to take account of need then we must adjust for the fact that some people have more money to spend than others and so have a higher WTP for a given level of need. We shall see (in section 5) that when projects are being paid for (directly or indirectly) out of public funds we need to use an Equity Value of Time. This will prevent us from tending to build new roads in the richer parts of the country, for example.

This chapter begins by, very gently, setting out the underpinning of VTTS by economic theory. It is a simplified exposition that should appeal to those who have had difficulty with other expositions. Hardly any assumptions need to be made. In section 3, we look at how travellers respond to time savings and losses. The chapter then looks briefly at the survey methods used to determine VTTS for a population. Section 5 looks at the theory on why we use Equity Values when paying for time savings with public funds. Sections 6 and 7 briefly look at the contentious issues of treating time losses differently to time savings, and treating small time changes differently to large time changes. Section 8 looks at the special case of time savings that arise in the course of paid employment.

2. Neo-classical economic theory underpinning

The purpose of this section is to give a simplified theoretical underpinning to valuing travel time savings. If successful, readers should find they need to make no strange assumptions, and should feel that the theory is working for them. This should mean that they will be more accepting of the results derived and more able to see how the range of topics touched on in this chapter form a whole, and are well supported by conventional economic theory.

This is not to say that the conventional theoretical underpinning of VTTS is rejected, merely that having been demonstrated elsewhere to everyone's satisfaction, something simpler and more useful will suffice here. Neither shall we review all the attempts at theoretical underpinning, some of which may have been very similar to that presented here, but we say clearly that a debt is owed to Becker (1965), De Serpa (1971, 1973), Bruzelius (1979), Truong and Hensher (1985), and Bates (1987, or his chapter 3 in MVA/ITS/TSU, 1987). Readers wanting a more rigorous approach should look to those places.

In the simple approach presented here, we shall assume that individuals seek to maximise their Happiness or Satisfaction with life, conventionally called Utility (U). This latter is here taken to depend on consumption of goods and services X_i ($i=1, \ldots, I$) and the hours of time, t_j, they devote to various activities $j = 1, \ldots, J$. Of these activities, we will say that activity 1 is travelling, and activity 2 is working (for payment of wage w per hour). For any combination of activities there will be an associated minimum travel time, k. Note that spending longer in an activity (eg. work) does not necessarily mean that you need to spend longer travelling to and from that activity. Also, in the same way that each day must have exactly 24 hours in it, so any time period we work with must have exactly T hours. Goods and services (i) have prices p_i, and individuals can take an amount ΔS from unearned or previously saved income (or save $-\Delta S$) to balance their budget over the period.

In mathematical terms we have:

MAX	$U(X_i, t_j)$	$i = 1, \ldots, I,$	$j = 1, \ldots, J$
SUBJECT TO	$wt_2 + \Delta S = \Sigma p_i X_i$	(wages + Δsavings = expenditure)	
	$T = \Sigma t_j$	(we are always doing something)	
	$t_1 \geq k$	(our activities need at least k travel time)	

This last constraint is an inequality, which is helpful as all the theory of linear programming (particularly the Kuhn-Tucker conditions) are available should we need them, but will for now be sidestepped in this simplified presentation by assuming that we each have a fixed amount of non-essential travel time, n, possibly zero but definitely not negative. The third constraint then becomes:

$$t_1 = k + n$$

We are still linear programming since the X_i, t_j, p_i, w, T, ΔS, n and k must all be positive, but that is commonplace and we can proceed to form a standard Lagrangian Multiplier, L, to maximise, as:

$$L = U(X_i, t_j) + \lambda(wt_2 + \Delta S - \Sigma p_i X_i) + \mu(T - \Sigma t_j) + \theta(t_1 - k - n) \qquad (1)$$

The Lagrangrian has incorporated the 3 constraints, as though the 3 bracketed terms are all ‘zeros’ multiplied by symbols that have the following interpretations:

λ is the marginal utility of relaxing the budget constraint, effectively the 'marginal utility of income', which will always be positive;

μ is the marginal utility of relaxing the time budget, sometimes referred to as the 'resource value of time', which should never be negative;

θ is the marginal utility of having to spend more time travelling, which may be positive (in the case of a pleasure boat ride) but which is usually negative since travelling is usually less pleasurable than spending time in one of activities 3 to J.

Note that if we had more than one mode of transport, or varying conditions on a single mode of transport (say due to varying levels of crowding on public transport, or varying levels of congestion when driving) then we would have to specify a range of θs, and talk of the marginal disutility of travel in that particular circumstance.

Clearly, given our constraints, L = U, and we can proceed to take the first step (and our only step) along the path to maximising U by investigating the first order conditions obtained by differentiating L partially with respect to interesting variables, and setting each equal partial derivative to zero.

$$\frac{\partial L}{\partial X_i} = \frac{\partial U}{\partial X_i} - \lambda p_i = 0 \qquad i = 1, \ldots, I \qquad (2)$$

$$\frac{\partial L}{\partial t_1} = \frac{\partial U}{\partial t_1} - \mu + \theta = 0 \qquad (3)$$

$$\frac{\partial L}{\partial t_2} = \frac{\partial U}{\partial t_2} + \lambda w - \mu = 0 \qquad (4)$$

$$\frac{\partial L}{\partial t_j} = \frac{\partial U}{\partial t_j} - \mu \qquad = 0 \qquad j = 3, \ldots, J \qquad (5)$$

The source of a very high proportion of the errors that occur in mathematical Transport Economics arise due to failure to check the second order conditions. However, the present case has been well studied, and it is indeed a maximum. Let us look carefully at first order conditions (2) to (5), starting with (5). This just says that

$$\frac{\partial U}{\partial t_j} = \mu \qquad j = 3, \ldots, J \qquad (6)$$

which means that, for time uses other than travel and work, individuals should seek to equate the marginal utility of time spent in each activity. The value, μ, to which they are equated to, represents the utility gained by having a little more time available for use in one of these activities, or the utility lost by having a little less time available to spend in one of these activities. As we said above, it is sometimes referred to as the 'resource value of time'.

Moving back to condition (4), this says

$$\frac{\partial U}{\partial t_2} + \lambda w = \mu \qquad (7)$$

which says that, for the work activity, you should take account of the utility you gain from the wages before equating time spent at work with the resource value. Generally, the marginal utility of time spent at work will be negative, but the marginal utility of the wages (here equal to the marginal utility of income, λ, times the wages for that amount of time spent working) will more than offset that, bringing us back to μ.

Eventually we get to travel, with condition (3), which says

$$\frac{\partial U}{\partial t_1} = \mu - \theta \tag{8}$$

which says that the marginal utility of a travel time saving (MUTTS), measured in utils, is equal to the difference between μ and θ. The μ term says there are things we could be doing with that amount of time (the resource value) while the θ says how much utility is gained while travelling. Three cases might be looked at. Firstly, for a pleasure boat trip or a Sunday drive through stunning countryside, you might not like to hear that your journey time had been reduced. In those cases, θ would be positive and greater than μ and MUTTS will be negative. Secondly, you may gain some utility from travelling, but not as much as you would get from any of the activities 3 to J. In that case, θ will be positive but less than μ, and MUTTS will also be positive but less than μ. Thirdly, the travel time saved might be in unpleasant overcrowded public transport or in start-stop traffic on a heavily congested road. In those cases θ would be negative, and MUTTS greater than μ.

Lastly, we come to condition (2), which says

$$\frac{\partial U}{\partial X_i} = \lambda p_i \tag{9}$$

which says that you should keep buying goods and services up to the point that the marginal utility of buying that unit is just equal to the utility represented by the price of that unit. That gives us most of microeconomic theory, so our exposition is plugged into that body of work. Here, prices p are expressed in money terms, and converted into utils by multiplying by the marginal utility of income, λ.

That trick also works in reverse, so we can obtain VTTS in money terms by *dividing* our expression for MUTTS in utils by λ. We had, in eqn. (8),

$$\text{MUTTS} = \frac{\partial U}{\partial t_1} = \mu - \theta \qquad \text{in utils, so}$$

$$\text{VTTS} = (\mu - \theta)/\lambda \qquad \text{in money units} \qquad (10)$$

So, to conclude, we can say that VTTS is equal to the monetary value of time spent in an alternative activity less the monetary value of the travel time that has now disappeared.

3. <u>Possible responses to a travel time change</u>

When travellers experience a speeding up or slowing down in the travel modes currently in their choice set they can react in a number of ways. At the margin, for small time changes there will be small time gains or losses if the currently chosen mode is affected, and the departure time may change. For bigger changes, travellers may decide to:

(i) use a different route;

(ii) use a different mode;

(iii) reschedule activities;

etc.

Modellers will typically try to form a Generalised Cost estimate for each possible choice. By Generalised Cost we mean a measure (usually stated) in money terms representing the disutility of each choice alternative. It can be thought of as the negative of a simple (usually linear) Utility function. It is constructed by summing all the elements already in money terms (eg. fares, petrol costs, parking costs, etc) and adding on elements of time each monetised by multiplying by an appropriate value of time, plus some fixed cost elements for such things as having to change trains etc.

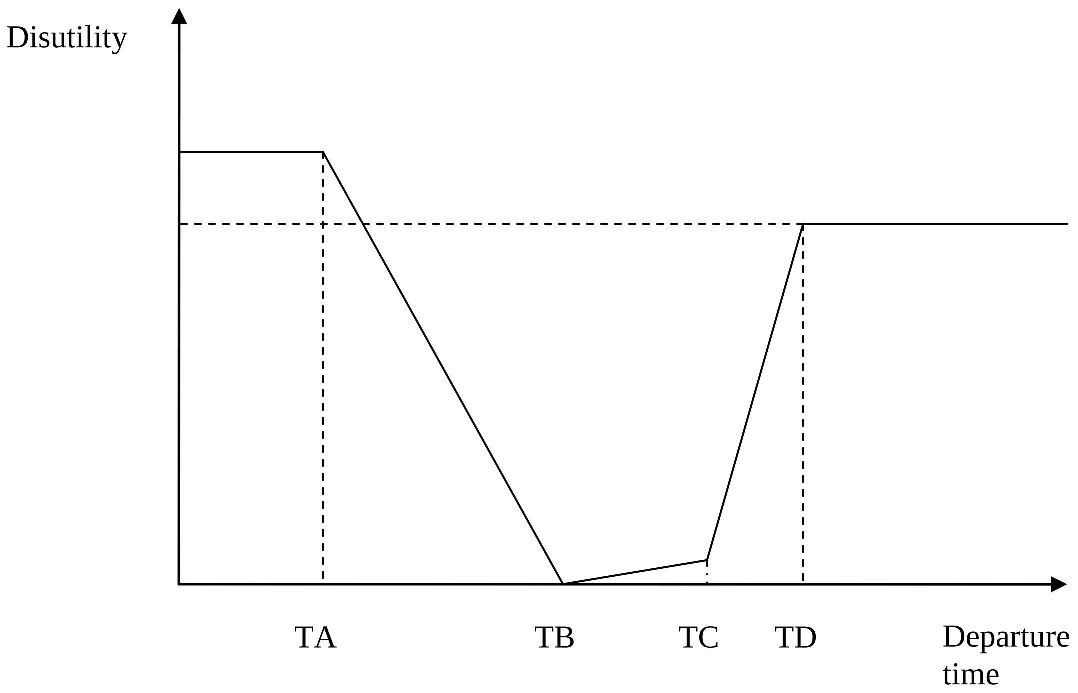
For example, in-vehicle travel time (IVT) on each mode will have its own level of marginal disutility per unit of time, and so its own value of time (VIVT). If we set VIVT the same for each mode it is not saying that bus passengers have the same value of time as car passengers, say, but merely that a given traveller has the same value of time when moving between modes. More usually, VIVT will differ between modes, for a given traveller, due to differences in pleasantness of travel conditions. If observed IVTs were used for modelling, the lower incomes of bus passengers would give a lower bus VIVT than car VIVT, which would work to reduce bus GC relative to car GC and thereby allocate too many travellers to bus. In fact, an average traveller tends to have lower VIVT in their own car, where they have considerable control over conditions, than for bus, which is usually held to be at the low end of comfort and ambience. VIVT values within mode are sometimes related to how crowded the service is (or how crowded the roads are), possibly turning them into a non-linear function.

Another example is ‘out of vehicle time’, which may be further subdivided into ‘walk’ and ‘wait’ time, with their separate values of time, usually 1.5 to 3 times VIVT. Then we have ‘rescheduling time’, which can be thought of as a penalty for not being able to depart exactly when you would want to. Again we might have a single monetary value for each minute you are away from your preferred time, or we may have functions of that amount of departure time adjustment, possibly with greater penalties for having to start out earlier rather than later, or vice versa.

Particularly complicated is ‘reliability’, which is important for travellers but which can be measured in many ways. One possibility is to estimate a monetary value for a one minute change to the standard deviation of travel times. Instead, we might choose to estimate a monetary value for an extra minute of ‘journey time spread’, measured from the scheduled arrival time up to the 98th percentile of arrival times. The purpose here is to try to distinguish between changes in ‘scheduled journey time’, which can generally be prepared for prior to travel, and changes in ‘actual journey times’, which are not so easily predicted and represent uncertainty prior to travel. We can think of the value of changes in scheduled journey time, where the traveller is free to replan their trip and possibly set out earlier, as a **long term** value. Conversely, if there are unexpected delays once the journey has started then only **short term** stratagems are available, and ‘starting out earlier’ is not one of them.

It is sometimes helpful to consider Figure 1, which appears in a variety of forms in many places. It can be used in many ways, and so is very difficult to label. It describes the excess disutility of departing at non-ideal times. The horizontal axis is the departure time. The ideal time is marked as TB, at which (excess) disutility is shown as zero. Having to depart earlier than TB causes increasing disutility. Imagine the morning commute, where having to leave earlier than the ideal time means less time in bed, or disrupts the ‘school run’. Departing later than TB at first causes gently increasing disutility as ‘slack’ or safety margins in the schedule are used up (from TB to TC), followed by rapidly rising disutility as appointments are missed etc. Having to depart after TD voids the purpose of the trip. Any action that has an equivalent effect as a change in departure time will cause an equivalent change in utility.

Figure 1. An Illustration of the Total Disutility (to all parties combined) associated with different departure times, with journey time known and zero variability



The distinction between short run and long run now becomes clear. In the short run, when the journey has begun, any delay will be equivalent to starting out later. High values of time are likely to result as penalties for late arrival build up quickly. The long term response to an increase in unreliability will therefore be to set out earlier so as to build more slack time into the schedule. Similarly, if a longer journey time is scheduled, the traveller will choose to start out earlier. They will probably wish to preserve the slack time (TB to TC) to protect against unreliability, and the shallower slope between TA and TB will always win out over the penal slope from TC to TD.

The slope from TA to TB is therefore the 'resource value of time', μ, defined in section 2 above. In all these cases the disutility of the actual travelling time is additional, being equal to θ times hours spent travelling (not shown in Fig. 1). Being able to start out earlier presupposes the longer journey time is known about in advance, referred to here as long run. This point is at the crux of difficulties in measuring the value of time in surveys, so we will next briefly consider that topic.

4. Surveying to find estimates of the value of time

Building on the work of Samuelson (1953), the concept of Revealed Preference (RP) seeks to say things about individuals' preferences based on observed choice data. Usually only weak statements can be made about each individual, but if we assume we are dealing with a group of identically minded individuals each facing different choices then Willingness To Pay (WTP) values for the group can often be determined.

Imagine a traveller from Leeds to Antwerp, who faces a choice between flying for 200 Euros (return) taking 3 hours (each way, door to door) and taking the Channel Tunnel 'Eurostar' rail service at 100 Euros but taking 8 hours. She may choose the plane, in which case we can infer that (if we assume IVT is valued equally for plane and train and that there is no Mode Specific Constant utility in favour of either mode) her VTTS in this case is at least 10 Euros per hour, since she has saved 10 hours travelling time on the round trip but has had to pay 100 Euros extra.

If everyone in the sample faced exactly the same choice, then questioning them would elicit the percentage with VTTS above 10 Euros per hour, but that space is unbounded and it is usually unwise to attempt to derive a VTTS for the group in those circumstances. If exactly 50% chose plane we might say that the group's VTTS was 10 Euros per hour, but that is a rare special case.

In Fowkes and Wardman (1988), following Fowkes (1985), the VTTS values at which a respondent would be indifferent between two alternatives were referred to as 'Boundary Values', B. Each choice puts the respondent on one side or other of B.

Consider the model:

$$U_m = \beta_c COST_m + \beta_x TIME_m \tag{11}$$

where COST is the monetary cost, and TIME is the travel time of mode m. In the terminology of section 2, β_x is MUTTS and β_x / β_c is VTTS, and this is how values of time are usually calculated.

We can now define a boundary relative valuation of TIME in terms of money as

$$B(TIME : COST) = (COST_1 - COST_2)/(TIME_2 - TIME_1) \tag{12}$$

What we need in the sample is a wide range of Boundary Values, but this is not so easy to achieve as might be supposed. In many cases, the quicker mode is also the cheaper mode, so that no trade off exists, and nothing is learnt from observing the traveller to choose the quicker cheaper mode. Also, we usually find that alternatives have cost differences rising as time differences rise. Neither may be linear with distance (due to tapered fare scales and fixed access/egress times), and the relationship will not be exact, but it is usually serious enough to prevent the estimation of a satisfactory model. The 1980s UK Value of Time study (MVA/ITS/TSU, 1987) found a particularly good survey situation, for coach and train commuters from North Kent to London, where the coach stops and railway stations were sufficiently far apart that there was a good spread of journey time differences for each cost difference. Even in that case, the overall VTTS was only estimated with an accuracy of +/- 33% (Fowkes, 1986), equivalent to a ‘t’ score of 6.

That study therefore looked to find a better method of estimating VTTS, and settled on Stated Preference (SP). This was extremely influential for the acceptance of SP studies by the UK government and more widely. The method sounds unpromising. It consists of putting a range of hypothetical questions to potential and existing travellers. There are obviously worries about how reliable responses will be. However, by carefully choosing the questions to ask, and building up experience of studies over time, the method can be really useful.

Respondents are asked to choose between (or rank or rate) travel alternatives described by attributes set to various levels. The survey designer can choose the levels to ensure that each choice has a Boundary Value; in other words that it involves a trade-off. This alone makes the data richer than RP data. More importantly, though, each respondent can be asked to make several choices (at least 12), and each can have a different Boundary Value such that we can improve the accuracy of VTTS estimation quite easily. Provided respondents believe that they would actually have to pay the amounts stated in the questions to get the benefits shown, they should have no reason to attempt to deliberately bias the results.

Because the sort of errors that are made in SP experiments is different to those made in real life (and RP data), a rescaling is necessary before SP results can be used for forecasting. For SP VTTS values themselves, however, being the ratio of identically scaled time and cost coefficients, the scaling cancels and there is no problem on that score.

We saw in equation (10) that VTTS (via MUTTS) is made up of two parts, the resource value (from μ) and the utility of travelling (θ). A method for estimating these two component parts separately is proposed in Jara-Díaz and Guevara (2003).

5. The use of Equity Values of Time

In appraisal work, we need VTTS figures to value time benefits and losses, but directly estimated Willingness To Pay values will not do, and the key arguments are not widely understood. This section seeks to remedy that with a clear theoretical demonstration. It builds on results presented in Mackie, Jara-Díaz and Fowkes (2001), themselves developed from those in Jara-Díaz (1996) and Galvez and Jara-Díaz (1998).

From the theory of cost benefit analysis (see Pearce and Nash, 1981, especially Chapter 3) we may define Social Welfare (W_s) as being some function of the utility, U, enjoyed by members of society, i.e.

$$W_s = W_s\,(U_1, U_2, \ldots U_q, \ldots U_Q) \tag{13}$$

where there are Q individuals or homogenous groups in society, and a particular individual or group will be denoted q.

Utility (measured in utils) is gained, all else equal, by purchasing amounts of goods and services, and this is constrained by individual generalised disposable income, Y_q, and the set of prices in the economy, p_i. Hence we can write

$$W_s = W_s[U_1 (Y_1, p_i), \ldots U_q (Y_q, p_i), \ldots U_Q (Y_Q, p_i)] \quad (14)$$

We shall consider evaluating the case where individuals stand to receive travel time savings t_{1q} , compared to some base 'do-minimum' situation, for which they have to pay F_q (either through the fare box or as a contribution to public or private financing).

We can write

$$\frac{dW_s}{dt_{1q}} = \sum_q \frac{\partial W_s}{\partial U_q} \frac{\partial U_q}{\partial Y_q} \left(\frac{\partial Y_q}{\partial t_{1q}} + \frac{\partial Y_q}{\partial F_q} \frac{\partial F_q}{\partial t_{1q}} \right) \quad (15)$$

Taking these terms one by one, describing them and labelling them:

$\frac{dW_s}{dt_{1q}}$ is the rate of change of social welfare resulting from travel time changes dt_{1q}

$\frac{\partial W_s}{\partial U_q}$ is the relative weight society places on the utility of group q when determining social welfare. Following Jara-Díaz (1996) we denote it as Ω_q. The sum of the Ω_q will be Q, and giving equal weight to all groups implies $\Omega_q = 1$ for all q.

$\frac{\partial \mathrm{U}_{\mathrm{q}}}{\partial \mathrm{Y}_{\mathrm{q}}}$ is the marginal utility of income, for group q, and we will denote it as λ_{q}

$\frac{\partial Y_q}{\partial t_{1q}}$ is the equivalent income benefit for group q from the time savings t_{1q}. This is the willingness to pay of this group for those time savings. We will denote it $\mathrm{WTP}_{\mathrm{q}}$

$\frac{\partial \mathrm{Y}_{\mathrm{q}}}{\partial \mathrm{F}_{\mathrm{q}}}$ is the effect on the disposable income of group q of a change in the payment, F_q by that group. Since the effect of a 1 Euro payment is equivalent to 1 Euro of lost income, this term is by definition equal to minus one.

$\frac{\partial F_q}{\partial t_{1q}}$ is the charge per unit of time saving, which we will denote C_q.

Substitution gives us

$$\mathrm{dW}_{\mathrm{s}} = \sum_{\mathrm{q}} \Omega_{\mathrm{q}} \mathrm{dU}_{\mathrm{q}} = \sum_{q} \Omega_q \lambda_q \left(WTP_q - C_q \right) dt_{1q} \tag{16}$$

For a finite amount of time savings (Δt_{1q}) such as may arise from a transport scheme, we have

$$\Delta W_s = \sum_{q} \Omega_q \lambda_q \left(WTP_q - C_q \right) \Delta t_{1q} \tag{17}$$

where WTP_q and C_q are the correct average values relating to the change Δt_{1q}

The welfare change ΔW_S will be measured in utils. To convert to monetary units we should divide by the average marginal utility of income in society. We will denote this as λ_s.

$$\frac{\Delta W_s}{\lambda_s} = \sum_q \Omega_q \left(\frac{\lambda_q}{\lambda_s} \right) (WTP_q - C_q) \Delta t_{1q} \tag{18}$$

We can calculate λ_s by weighting the group marginal utilities of income, λ_q, by the utility weighting, Ω_q

$$\lambda_s = \frac{\sum_q \lambda_q \Omega_q}{\sum_q \Omega_q} = \frac{1}{Q} \sum_q \lambda_q \Omega_q \tag{19}$$

We now consider, in turn: using WTP values; using Equity values; and dealing with direct charges proportional to use.

USING WTP VALUES. Firstly, following Galvez and Jara-Díaz (1998), we can look at the effect on welfare of valuing time savings by a particular group by their willingness to pay, in the case of a scheme financed from public funds. The money value of social benefits (ΔB_s , from time savings Δt_{1q}) would then be

$$\Delta B_s = \sum_q WTP_q \Delta t_{1q} \tag{20}$$

Again, each group would be charged some amount, C_q, per unit of time saved, now assumed to be raised indirectly such as through the tax system. The utility impact of this charge will be $-\lambda_q C_q \Delta t_{1q}$ and the monetary value of the social welfare change would be

$$\frac{\Delta W_s}{\lambda_s} = \sum_q \left(WTP_q - \frac{\lambda_q}{\lambda_s} C_q \right) \Delta t_{1q} \qquad (21)$$

Equation (21) is only consistent with the theoretically derived equation (18) if λ_q is set equal to λ_s for all q, i.e. if everyone had the same marginal utility of money. In practice this is clearly not the case, and so we can reject equations and (20) and (21), along with the idea of valuing time savings of individuals by their Willingness to Pay when we are engaged in scheme evaluation and where the charges to be raised will be indirect (i.e. not directly related to use). The effect of using uncorrected Willingness to Pay values to value time savings would be to favour schemes disproportionately favouring rich people, i.e. those with low marginal utility of income, λ_q.

USING EQUITY VALUES. Secondly, let us consider using an ‘Equity’ value of time, defined here to be a sort of average value of time determined by the democratic system, with all time savings being equally valued no matter as to whether they accrue to rich or poor. The choice of a particular Equity value is clearly a political matter, but politicians may wish to be informed about what their voters are willing to pay. There would need to be special reasons for setting the Equity value much higher or lower than the values currently evinced by travellers. Taking too high a value might lead to the construction of grandiose ‘white elephant’ type schemes, whilst too low a value might lead to chronic congestion at a site where capacity might otherwise have been increased.

As a first approximation, we might suggest taking an average of current willingness to pay values as our Equity value, V. Something of the sort has been U.K. practice for some time. Discrete Choice Models are calibrated on Revealed Preference or Stated Preference data, and scaled coefficients of time, α_q, and cost, β_q, are estimated for groups (or occasionally individuals),

Note that $-\beta_q$ will be a scaled estimate of λ_q, i.e. $\lambda_q = -\theta\beta_q$.

If the sample used has been taken randomly from traffic on the network in question, no weighting may be needed, but usually it is necessary to weight. Willingness to pay for individual groups can be found

$$WTP_q = \frac{\alpha_q}{\beta_q} \tag{22}$$

where the scaling is identical for the α and β and so cancels.

Suppose we average over these WTP values in proportion to the mileage undertaken by each group, m_q

$$WTP_m = \frac{\sum_q m_q WTP_q}{\sum_q m_q} \tag{23}$$

Then $\Delta B_s = \sum_q WTP_m \Delta F_q$ (24)

and $\frac{\Delta W_s}{\lambda_s} = \sum_q (WTP_m - \frac{\lambda_q}{\lambda_s} C_q)\Delta t_{1q}$ (25)

It can be seen that eqn (25) is consistent with our theoretically derived equation (18) **provided**

$\Omega_q = 1 \qquad \forall q$ (26)

and

$WTP_m = (\frac{\lambda_q}{\lambda_s} WTP_q) \qquad \forall q$ (27)

or provided conditions (26) **and** (27) hold "on average".

In practice, it will usually be easier to find mileage weighted averages than travel time saving weighted averages, but they should not differ too much. If we were to assume that group travel time savings were proportional to group mileages, then we could calculate a revised V_m using:

$\Delta t_{1q} = km_q \qquad \forall_q$ (28)

$$V_m = \frac{\sum_q \frac{\lambda_q}{\lambda_s} WTP_q m_q}{\Sigma m_q} \qquad (29)$$

The measure, V_m, is similar to, but subtly different from, the mileage weighted willingness to pay measure proposed as equation (23).

DIRECT CHARGES CASE. Thirdly, we consider the case where direct charges are raised for the travel time savings. This does not just mean that the scheme is paid for out of revenue to the operator, but specifically that the charge or fare is to be higher after the scheme is implemented than if the scheme had not been implemented.

Initial inspection of equation (16) might leave one imagining that $WTP_q > C_q$ for all q, and so time savings will always add to social welfare. This is not the case. A government might construct a grandiose scheme, yielding minimal time savings (and no other benefits) for which the addition to taxes (e.g. per minute) was greatly in excess of the willingness to pay (WTP_q per minute). Another situation where it might occur is when time savings are only available as part of a package. For example, if a slow cheap public transport facility were replaced by fast expensive one, some of the current passengers might not be willing to pay the fare increase, not valuing the time savings above the fare change. However, they still have to keep travelling as they need to get to work. This sort of thing is said to have happened when the Croydon Tramlink replaced lower fare buses to the New Addington council estate.

If a scheme is to be fully funded by groups of users each paying a C_q that is less than or equal to their Willingness To Pay, WTP_q , for the time savings involved, then these WTP values can safely be used to estimate benefits. If, however, there are some users not willing to buy the time savings at that cost, they will be disadvantaged by a reduction in Consumer Surplus (CS) if they need to use the new service. Care must be taken to include such CS losses, and not just the WTP values for these groups.

In some cases, a proportion of scheme costs might need to be covered from public funds. In that case the time savings should be split in those same proportions. The proportion funded from direct charges should then be valued at the average WTP of users (bearing in mind the point made in the previous paragraph). The remaining proportion should be valued at a either at the national Equity value, or at a local Equity value if local government money is used.

6. Appraising the valuations of gainers and losers

It is sometimes suggested that user valuations for losses should be higher than for gains. The reasoning for this is that surveys often find greater value placed on a loss of something to the equivalent gain from that same starting position. Economists are predisposed by the Law of Diminishing Returns to expect that having more of something will have reducing value the more you already have have. However, that is to miss the point. It is true that we would all dislike losing 100 Euros more than we would value gaining 100 Euros, starting from a given position. If, however, you were first to lose 100 Euros, you would surely value regaining those 100 Euros the same as the original loss. After all, you have ended up at the same point you started. We are paying out and receiving money most days, and it is silly to imagine that if we break even we are daily suffering a net loss of utility just because money flows out as well as in. For any sensible appraisal system to work we need to assume reversibility, ie that equal gains and losses cancel.

7. Should small time savings have a lower per minute value of time in appraisal?

Similarly to the case in the previous section, some commentators (eg. Welch and Williams, 1997) have suggested that large time savings should be valued more highly per minute than small time savings. In Germany, for instance, this is official government policy. It arises from two concerns. Firstly, surveys (particularly SP surveys) have had great difficulty in accurately estimating coefficients for small time savings, and the per minute values of those that are estimated are usually clearly below those for larger time savings. Secondly, it is clearly not so easy to find a highly productive use for a small amount of time that is saved for one reason or another. Looking at that last point the other way round, if travellers are assumed to generally have some slack time in their travelling schedules, a small time loss will have little adverse impact on their activities.

There are many counter arguments and explanations for the above, and only space here to briefly rehearse some of them. Firstly, it should be stated loudly that there is no agreement as to how small a time saving has to be to be "small". Some commentators talk of 5 minutes being small. Others think 5 seconds is small. Clearly, the ragbag of concerns put forward under this heading are self contradictory. Secondly, we should consider how awkward it would be if it were to be implemented in appraisal. Larger projects, covering a larger part of some long trips, would be likely to capture bigger time savings than a smaller project. This would lead to projects being combined, and found to have benefits greater than the sum of the parts. What would that imply? It is saying that unless you improve the road from B to C at exactly the same time as from A to B then A to C travellers will be worse off (once both improvements are completed). If the time savings on each section were 4 minutes, and time savings were valued at zero if less than 5 minutes, then carrying out the improvements independently would give zero benefits while completing them both together would give 8 minutes benefit to each traveller. What nonsense.

We each receive a myriad of time savings and losses each day, and it is no wonder that, when asked, we cannot say what we did with each saving or how we coped with each loss. Not noticing a small time change does not mean it has zero value any more than for a small change in accident risk.

Mathematically, if there is a threshold below which time savings have no value, then we must be doing nothing with them and have that amount of time available for combining with other small time savings (or losses) as they occur. Eventually, we will be pushed over the threshold and have a usable amount of time. Consider chickens laying eggs that have to be boxed in sets of 6 for sale daily. The chickens do not know this, and produce a Uniformly distributed number of eggs each day. What is the value of an extra egg? We could say “zero”, since without another 5 we cannot sell it. But we might (on a one in 6 chance) have exactly 5 eggs left over from that day’s production, and so now be able to sell 6 eggs. So 5 out of 6 times the extra egg is worth nothing, but once in 6 times it is worth 6 eggs. On average that means that an extra egg is worth one sixth of a pack of 6 eggs. Mathematically, this “threshold effect” means that in the long run we should value all eggs (and minutes of time) equally, no matter how many arrive at once.

As if that were not persuasive enough, we should remember that our appraisals are over many years (in the UK, 60). Any scheme we are evaluating will be helping travellers for all that time. What matters for a traveller in 50 years time are the travel times in 50 years time, not whether they have come about through a lot of small improvements or one large one. Similarly, it does not matter whether there have been “gains” and “losses” along the way. The traveller in 50 years time will know nothing of travel conditions prior to the scheme or in most of the decades between. All they will be concerned about are travel conditions then. Fowkes (1999) develops these points.

8. Valuing time saved in the course of work

Everything that has been said in the preceding sections applies equally to time saved while travelling on behalf of an employer. If the employer saves an hour's time (every day) by abolishing tea breaks, then the employer gains an hour's extra output but the employees will lose utility from no longer having the breaks. Exactly the same applies if the time saving arises from journey time reductions. For those whose work is "travel", for example bus drivers, the position is simple, and a one hour time saving is valued at the gross wage payable to that employee.

For "Briefcase Travellers", ie those employees travelling to business meetings etc, a more detailed treatment has been felt to be justified. The Hensher Equation (see Carruthers and Hensher, 1976, Hensher, 1977) is generally accepted as describing the situation:

$$VBTT = (1 - r - pq)\,MP + (l - r)\,VW + r\,VL + MPF \qquad (30)$$

where

VBTT = value of savings in business travel time

MP = Marginal Product of labour

MPF = value of extra output generated due to reduced (travel) fatigue

VL = the value to the employee of leisure time relative to travel time

VW= the value to the employee of time at the workplace relative to travel time

r = proportion of travel time saved used for leisure purposes

p = proportion of travel time saved at the expense of work done while travelling

q = relative productivity of work done while travelling compared to the office

In eqn (30) the "MP" term is contentious, since a journey time saving might yield some very productive extra time at the destination. Consider a firm conducting recruitment interviews at a location 200 miles from head office. Within the agreed working day each interviewer might only get 2 hours at the destination, so 6 hours of interviews will need 3 trips or 3 interviewers. If the journey time were reduced by 30 minutes each way then only 2 trips (or interviewers) would be needed, giving a saving much greater than one hour's wages.

Considering the "r" term, it must be a very odd firm where that is not zero. The need to travel to and from business meetings out of normal working hours must (according to economic theory) be taken into account when fixing remuneration, so any lessening of travel outside work hours will inexorably lead to wage reductions to exactly compensate. Conversely, those travelling more outside working hours will put in for a bonus. Many such travellers will effectively be working flexi-time anyway, so time can automatically be taken off in lieu in work journey times stretch beyond normal working hours.

The "pq" term has been the subject of much recent interest as it has been alleged that the possibilities for working while travelling, on trains at least, have greatly increased with wifi availability. However, it is not whether business travellers work on train or plane that is important, it is whether a reduction in in-vehicle journey times would cause them to work less. For long distance rail travel, pq might be as high as 0.2, but it is hard to see it being higher. For rail as a whole, an upper limit of 0.1 would seem sensible, given that much rail travel (even by "briefcase travellers") is for short distances in urban areas, but that is little more than a guess. For car, pq = 0 is a sensible assumption.

The "MPF" term is usually ignored, for want of data. The "VL" term is straightforward, being the standard VTTS from eqn. (10). The "VW" term has proved to be the most misunderstood. It is the value to the employee of switching time spent at work to time spent travelling on work purposes. Nobody has provided any evidence to show that VW is not zero on average. Some employees may welcome some time out of the office, while others will prefer the cosy office over the travelling environment.

Mathematically, in terms of the treatment in section 2, we have a new constraint:

$$t_1 + t_2 = E \tag{31}$$

This says that time savings/losses are swapped with work time exactly. We then amend our previous Lagrangian, L, to L*, where

$$L^* = L + \gamma(E - t_1 - t_2)$$

The only two conditions to change are (3) and (4) which now become:

$$\frac{\partial L}{\partial t_1} = \frac{\partial U}{\partial t_1} - \mu + \theta - \gamma = 0 \qquad (32)$$

$$\frac{\partial L}{\partial t_2} = \frac{\partial U}{\partial t_2} + \lambda w - \mu - \gamma = 0 \qquad (33)$$

From (32) and (33) we can find the relation between the marginal utility of time spent working (t_1) and time spent travelling (t_2) as:

$$VW = \frac{\partial U}{\partial t_1} - \frac{\partial U}{\partial t_2} = \lambda w - \theta \qquad (34)$$

This says that, having adjusted work hours so that the utility of extra leisure time just equalled the utility of wages (λw), the only gain/loss to the employee occurs to the extent that θ, the disutility of travelling (in the course of work), differs from the utility of wages. The simplest course is to say, on average, VW = 0, ie. you get paid to do your employer's bidding, whether in the office or out travelling.

9. Conclusion

This quick trip through the topic of valuing travel time savings has theoretically derived the accepted interpretation, and looked at several ancillary matters. Much attention was given to where and how to use Equity VoTs, but I should emphasise that these are only used because it is perceived to be impracticable to individually weight all costs and benefits (including money payments) according to the utility functions of all those affected by the scheme. Other matters covered were the treatment of gains and losses, small time savings, and time savings in the course of work. These are all currently ‘hot topics’ amongst transport professionals around the world. It is hoped that the present contribution will help clarify thinking on these matters.

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