Final version

THE VALUE OF TRAVEL TIME SAVINGS IN EVALUATION

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1. Introduction

For most of the post-war period, the valuation of travel time savings has been an important public policy issue. In the UK, for example, travel time savings have accounted for around 80 per cent of the monetised benefits within the cost-benefit analysis of major road schemes. Allowing for exceptions such as safety and environmental schemes, the rationale for and size of the public investment programme in roads and transport depends critically on the social valuation of travel time.

Within the overall process of investment appraisal and policy analysis, values of time enter the picture in two ways. First, they are implicit in the modelling of traveller behaviour. Individual willingness-to-pay or behavioural prices of travel time can be obtained from travel demand models as the implicit trade-off between time and money. If individuals choose routes or modes or destinations on the basis of some composite of time, cost and comfort, then the relative weights or values which they attach to these components have such an interpretation. Hundreds, if not thousands, of studies have been undertaken from which behavioural values of travel time can be deduced (for a review see Wardman, 1998). Second, given the demand forecasts, an evaluation scheme is required in order to determine whether expenditure of scarce public investment is socially warranted. What travel time price (or set of prices) is appropriate for the social appraisal of transport projects? This question is the subject of this paper.

Since the economic theory of the valuation of time was first worked out in the 1960s, the practical application in the social appraisal of projects has been controversial. Should time savings be valued at all? Atkins (1984) suggests not. Should behavioural values derived from individual willingness to pay be carried through unadjusted into evaluation? Sugden (1999) suggests so. But if not, how should they be adjusted? Should the social value per minute vary with the size or the sign of the time saving? Welch and Williams (1998) propose so. Should the value of time be assumed to increase proportionately with income or less than proportionately? A recently published report by Accent/Hague (1999) suggests that for the UK an income elasticity of the value of travel time savings of 0.5 is more consistent with the evidence than an income elasticity of unity. These are the questions which we survey in this paper. While our conclusions will be relevant to all localities, we rely heavily on UK evidence, and recent UK policy debates, to illustrate the points.

2. What lies behind the subjective or individual value of travel time?

Why do we care about travel time savings? Why do we attach a value to it? Is it because we do not like travelling? Or is it because we would like to be doing something more pleasurable instead? Or is it because we can work more and earn more money? The answer to these apparently simple questions has a story that covers and mixes many areas in economic thought, from the theory of labour supply to home production and transport. Succinctly told, the idea of a value attached to the time assigned to any activity goes back to Becker's (1965) theory of the allocation of time. There, he postulated that individual satisfaction did not come from goods consumed directly, but from the "final commodities" (e.g. a prepared meal) that use market goods *and time* (for preparation and consumption) as inputs. Thus, time entered utility through this window, and its presence made it necessary to introduce a time constraint in addition to the usual income constraint. According to Becker, the two constraints were in fact one, because time could be converted into money by assigning less time to consumption and more time to work (potentially, the whole of the time budget). In this manner, the first concept of a value of time emerged, which was the opportunity cost of assigning time to any activity but work, and that was the wage rate. Under this approach, the individual is seen as looking for equilibrium between the pleasure of assigning time to consumption (the value of leisure) and the money value of work. Thus, leisure had to be valued at the level of the wage rate; otherwise the individual would increase or decrease time at work.

What Becker had overlooked was that time at work could in fact be pleasant or unpleasant as well. In other words, working time could influence utility directly. If this influence was negative, then the value of work would be less than the wage rate and the opposite would happen if work were pleasurable. This was pointed out by Johnson (1966), Oort (1969) and, with a particularly clear style, by Evans (1972). As time assigned to any other activity had to equilibrate its value with that of labour, time continued to have a single value for all activities, given by the wage rate plus the money value of work itself in direct utility. Note that, under this approach, reassigning time among non-work activities would leave the individual equally satisfied. This is exactly the key to the next observation: there are activities that are assigned more time than wanted, because of some type of constraint, and this is inconsistent with the idea of indifference among activities at the individual equilibrium.

It was DeSerpa (1971) who first included a set of minimum time requirements for each activity explicitly (analytically). These requirements depended on the amount of goods consumed. Recognition of this led to a new dimension of time value, because not all activities could be adjusted until equality with the value of work; there might be activities that individuals would like to shorten but can not. This might happen, for example, because they are intermediate activities, undertaken not for their own sake but as necessary inputs to other activities (which is the case of most urban transport). It should be noted, however, that explicit relations among activity times are formally present in Evans' formulation only. In any case, this is a most important factor for the existence of a value attached to travel time savings. It makes evident that a new element has to be accounted for: the reassignment of time from one activity to another can be pleasurable not only because one does more of the latter, but also because one does less of the former. To be fair, Oort (1969) mentioned this first, at least conceptually.

The richness of DeSerpa's work can be summarised by recalling the three types of time values that he defined, and the relation he established among them. He postulated a utility function dependent on all goods and all time periods (which he soon called "activities"), including work and travel. The technical constraints established that consumption of a given good required a minimum assignment of time. Within this framework, DeSerpa defined the value of time as a resource as the value of extending the time period, equivalent to the ratio between the marginal utility of (total) time and the marginal utility of income, μ/λ. The second is the value of time allocated to a certain activity (value of time as a commodity), given by the rate of substitution between that activity and money in the utility function. This would be equal to μ/λ only if the individual assigns more time to an activity than the minimum required; thus, μ/λ is the value of leisure activities. The third concept is the value of saving time in activity i, defined as the ratio K_i/λ, where K_i is the multiplier of the corresponding new constraint. One of his most interesting comments is related with "leisure", which he defined as the sum of all activities that are assigned more time than strictly necessary according to the new set of constraints. For these activities, the value of saving time is zero, and the value of time allocated to the activity (his "value of time as a commodity") is equal for all such activities and equal to μ/λ, the resource value of time or, what is now evident, to the value of leisure time. He showed that the ratio K_i/λ is equal to the algebraic difference between the value of time assigned to an alternative use (the resource value or value of leisure) and the value of time as a commodity.

Using a model where utility, U, depends on aggregate consumption, G, and on the amounts of time allocated to leisure, L, work, W, and transport, t, it can easily be shown that

$$\frac{\mu}{\lambda} = \frac{\partial U/\partial L}{\partial U/\partial G} = w + \frac{\partial U/\partial W}{\partial U/\partial G} \tag{1}$$

and

$$\frac{K_t}{\lambda} = w + \frac{\partial U/\partial W}{\partial U/\partial G} - \frac{\partial U/\partial t}{\partial U/\partial G} \tag{2}$$

where λ, μ and K_t have the interpretations given above and are the Lagrangians for income, time, and minimum necessary travel time respectively.

Equation (2), previously obtained by Oort (1969) in a footnote, says that the value of a reduction in the minimum necessary travel time is equal to the value of leisure minus the money value of travel time in U. The main corollary is evident: the value of a reduction in travel time would be equal to the wage rate only if both work and travel do not affect utility directly or if the marginal value of work and travel are equal in both magnitude and sign.

So far, the answer to the question of why we would like to diminish travel time is the following. An exogenous reduction in travel time provokes changes in utility because other (more pleasurable or more useful) activities can be done, and because the reduction in travel time itself has a direct effect. When substituting travel time, the individual will increase only the time assigned to those alternative activities which are not constrained at a minimum necessary (leisure according to DeSerpa) or work. If it is paid work, there is an effect through goods consumption (wage rate) and through work itself. There are cases, however, in which people are hired to work a fixed amount of time per period (say 44 hours a week), receiving a fixed salary. This can be seen as introducing a new constraint, namely a minimum assignment of work hours; if this minimum is in fact larger than what the individual would like to work (which is what we suspect if he/she works exactly the agreed minimum), the only reasonable time reassignment after a travel time reduction is to substitute for leisure, whose marginal valuation would be in fact larger than that of work. In analytical terms, the resource value of time μ/λ would be equal to the value of leisure only, and therefore, the total value of work should be replaced by the value of leisure in equation 2. Thus, the most general result for the value of saving time is

$$\frac{K_t}{\lambda} = \frac{\partial U/\partial L}{\partial U/\partial G} - \frac{\partial U/\partial t}{\partial U/\partial G} \qquad (3)$$

In our opinion, this (presently accepted) view of the determinants of a value attached to travel time savings still lacks two other dimensions, which, in fact, are present in the literature. One is the variation in goods consumption due to the substitution of travel for other activities. For instance, less travel by car replaced by more leisure might also mean trading motor oil for books. This type of effect has been rigorously developed by Jara-Díaz and Calderón (2000), and had been mentioned by Gronau (1986) in his review of home production, but only in relation with work. The other dimension lacking is the possibility of re-timing activities in order to undertake them according to a preferred schedule, an effect that is likely to increase the value of travel time savings in eq. (3). This aspect was addressed by Small (1982) in relation with trip departure and its effect on travel time. Further developments encompassing these new dimensions are to be expected in the near future in the area of travel time valuation.

For synthesis, a reduction in travel time potentially matters to the individual because of less travel, more of other activities, change in the consumption pattern, and change in activity schedule. If paid work is increased then there is also a change in the consumption level. If the sum of all these effects is positive, then there is a willingness to pay to diminish travel time. Note from eq. (3) that the last term reflects a direct effect of the type of activity time that is saved so that the values of saving in-vehicle, waiting or walking time are potentially different – see section 5 below.

A willingness to pay to diminish travel time by one unit is usually calculated from discrete travel choice models, as the ratio between the travel time coefficient and the coefficient of travel cost (if travel utility is linear). This represents the rate of substitution between cost and time for a given level of utility, and is also called the subjective value of travel time, SVTT. In order to understand what it represents, we have to recall that the utility of an alternative in discrete choice models is in fact a conditional indirect utility function, representing the maximum the individual can achieve if that alternative was chosen. Moreover, the coefficient of cost is minus the marginal utility of income λ, because increasing income is equivalent to diminish cost in a conditional indirect utility.

It can be shown that this ratio of coefficients in fact represents what DeSerpa called the value of saving time in an activity (for a general proof see Jara-Diaz, 1997, Jara-Díaz and Guevara, 1999, or Bates, 1987, using particular assumptions). Therefore, behind the value of time calculated as this ratio from discrete choice models, all the elements described above are potentially present. This means, among other things, that there is no reason whatsoever to expect that this willingness to pay for a reduction in travel time, or subjective value, to be equal to the (marginal) wage rate. Moreover, as explained, the second term in eq. (3) supports different values for the different components of travel (in-vehicle, waiting, walking).

Understanding what lies behind the value that an individual assigns to each travel time unit has a scientific merit in itself. From the point of view of the goodness of the underlying demand model, the value of a ratio of coefficients that has a clear microeconomic meaning can be used to verify how reasonable the results are, if compared against other available models and their corresponding time values. This is a particularly useful property if one considers that the coefficients themselves tell very little when they are looked at directly, because of the scaling factor that implicitly multiplies utility in discrete choice models. Surprisingly, though, the (subjective) value of travel time has been used mostly to feed the social appraisal scheme. Whether one should use individual willingness to pay for travel time reductions as a social price of time, is something we discuss next.

3. Value of (travel) time for social appraisal.

There is no reason for the value that the individual is willing to pay to reduce travel time to be equal to the value that society as a whole attaches to the reassignment of time of that individual to other activities. This is a relevant question when moving into the area of the appraisal of projects that are financed with social money, i.e. with money collected through taxes. In what follows in this section, we do not touch upon travel undertaken while at work.

From the point of view of a society as a whole, reductions in individual travel time can be looked at positively for various reasons. One is the potential increase in gross domestic product if such reductions translate into more work. Another is the increase in social welfare, as this includes individual utility directly, which increases as travel conditions improve. Under the approach that regards time as a productive resource only, the social price of time (SPT) would be the value of the individual's marginal product of labour (given by w in a perfectly competitive labour market) if travel time reductions induce an equivalent amount of additional work. On the other hand, if working time is unaltered by travel time changes, the social price would be nil; this would be the case in pleasure trips or trips made during the leisure period, i.e. out of the (fixed) work schedule. On the other hand, under the approach that views time as an element that influences individual utility, all gains should be accounted for, because they mean an increase in social welfare irrespective of changes in physical product.

Following the social welfare approach, Gálvez and Jara-Díaz (1998) showed that the variation in social welfare, ΔW_s, after a travel time reduction Δt_q for group q is approximately given by (see appendix)

$$\Delta W_s = \sum_q \Omega_q \lambda_q SVTT_q \Delta t_q \tag{4}$$

where SVTT is the subjective value of travel time (private willingness to pay), Ω_q is the 'social weight' on the utility of individuals in q, $\partial W_s / \partial U_q$, and l_q is their marginal utility of income (for the original price-quantity version of equation 4, see the synthesis in Varian, 1992, page 410). Equation 4 is very useful to see that willingness-to-pay values of time (SVTT) would be appropriate social time values if every group was assigned a social weight inversely related to their marginal utility of income; as this latter decreases with income, it means social welfare weights which are increasing with income. This reveals the highly regressive assumptions behind the acceptance of willingness to pay (or subjective) values as social prices of time to be used in social appraisal schemes.

In what follows we will put Ω_q equal one, a neutral weighting scheme reflecting the one person- one vote principle behind representative democracy (in fact, any scalar would yield the same results). As ΔW_s is in "social utility units", in general a factor λ_s is needed to convert ΔW_s into money. Gálvez and Jara-Díaz (1998) point out that the tax system provides a socially accepted empirical trade-off between the total welfare loss of those who pay taxes and the total bill collected. A social utility of money can be calculated as the ratio between that social loss and the tax bill, which, for equal social weights Ω_q, results in a weighted average of individual marginal utilities of income, using tax proportions as weights (this is an approximation, because marginal tax rates should be used as opposed to average). Irrespective of which social factor λ_s we use to divide W to convert it into money in eq. (4), the term that multiplies Δt_q modified by λ_s is the SPT of individual or group q under the welfare approach. In general, then

$$SPT_q = \frac{\lambda_q}{\lambda_s} SVTT_q \qquad (5)$$

As the subjective value of time is always equal to the ratio of the marginal utility of travel time $\partial V_i / \partial t_i$ over the marginal utility of cost, and this latter is identically equal to minus the marginal utility of income in discrete choice models, we get the most synthetic form for the social price of time under the welfare approach, which is

$$SPT_q = \frac{\left| \partial V_i / \partial t_i \right|_q}{\lambda_s}. \qquad (6)$$

This means that the discussion on whether to use one or many values of time for social appraisal is not equivalent to that of making a choice between willingness-to-pay values and a single figure. Provided society agrees that the welfare of all individuals is equally important, the conditions under which a single social price of time happens to be appropriate, reduce actually to one: marginal utilities of travel time that are statistically equal across income groups (see appendix). By looking at equations (2) and (3), this depends on many aspects, among them the perceptions of leisure, work and travel, and, in a very flexible labour market, on the wage rate as well. So, a first relevant conclusion is that whether a single social time value is appropriate, is a question that could then be answered empirically. A completely different matter is whether willingness-to-pay values should be used instead of a single value; we have shown above that these private values are inadequate. The dichotomy between social prices and private values is, in essence, a choice of equal weights versus income-progressive weights on individual utility. The dichotomy single-many social prices of time is an empirical and philosophical matter.

To summarise, if we follow the resource approach (time as a factor of production), emphasis will be made on quantifying the net effect of travel time reductions on work. It is evident that travel time reductions could be re-assigned completely to (unpaid) home work, to recreation, or to basic activities in a more relaxed way. In all such cases there will be an increase either in gross domestic product in the long run (although difficult to measure) or in quality of life (which the resource approach tends to diminish or ignore), or in both. In the social utility approach synthesised by equation (6), all elements are implicitly considered, as the formation of a SVTT (and of a marginal utility of travel time) is influenced by objective quantities as the wage rate, income or time at work, and by the subjective perceptions of goods, leisure, work and travel.

The main implication from our exposition of the microeconomic foundations behind the social valuation of travel time savings, is that willingness-to-pay or behavioural values should not be used in general for social project appraisal (equation 5). This does not mean that a single value should be used either, as a proper social price of time would in fact depend upon the individual marginal (dis) utility of travel time, which is potentially different across individual groups (equation 6). This will be influenced in turn by the satisfaction derived from other activities including work, by the associated consumption pattern and by the potential rescheduling that might be made possible. Marginal disutilities of travel time and marginal utilities of income (which are necessary to calculate a social utility of money) can be obtained from the estimation of discrete travel choice models, i.e. from the same tool that is presently used to calculate the SVTT. For an example on how to use stated preference models in connection with social values within this framework, see Jara-Díaz et. al (2000).

4. The Incidence of Travel Time Benefits and the Value of Work Travel

An issue not considered in Section 2 of the paper is the point that the initial incidence of the time savings and the final incidence of the benefits may not be the same. A market economy contains many transmission mechanisms by which travel time savings may be converted via changes in productivity into changes in prices, or real wages, or profits. So, while the apparent benefit of a transport improvement might be a time saving to travellers – and while it is usually convenient and feasible to compute the benefits at that point – the final beneficiaries may be a mixture of travellers, property owners, consumers and workers.

Consider three cases. The first is the case of a saving in travel time on a leisure journey. This is the case where the conditions posited in Section 2 generally hold. A travel time saving made during, say, a journey to visit friends and relations, or a shopping journey, is likely to accrue to and be retained by the individual as an increase in the amount of time available for all final leisure activities. Assuming these are "unpaid" activities, equation 3 will hold. The value of transferring time from travel to leisure will equal the resource value of time less the marginal money value of travel as an activity. The general assumption that the initial and final incidence of the benefit are the same is in this case reasonable.

A second case is that of commuting. The conventional UK approach has been to consider this as a sub-category of leisure time similar in that the time "belongs" to the individual spending it, but different in that the disutility of travel might be higher in crowded, repetitive congested conditions than in leisure conditions. However, the basic assumption is that the benefit accrues to the individual making the saving. Is this correct? Suppose that workers need to be compensated for the generalised cost of working, being their total time and money commitment to the activity, then an improvement in travel conditions in a city reducing the generalised costs of working would be expected to reduce the equilibrium real wage, or equivalently, increase the quality/productivity of the pool of labour willing to work for a given real wage. This is a key part of the 'agglomeration economics/wage equation' story behind the case for transport infrastructure investment in cities. Without investigating this in detail, we can say that the conventional assumption that time savings are retained by commuters may not hold - they may be transmitted via second round effects into the labour market (lower real wages) or back into the land market (higher property rentals) depending on market conditions.

A third case is that of savings in travel time during the course of work. Let us begin by returning to equation 2. This says that the value of a saving in travel time equals the wage plus the difference between the marginal money values of working and travelling. How this is shared between employer, employee and Government, depends on the nature of the labour contract (piecework or timework) and the tax system (MVA, ITS, TSU, undated). In this context, it is common in practice to fall back on a special case of equation 2. Consider a labour contract in which the employer purchases the time of the individual, so that any savings in travel time accrue to and are available for exploitation by the employer. Then from a social point of view (ie including the interests of the employee as well as the employer) the social value of a unit travel time saving in business time is given by equation 2 specifically with w accruing to the employer and the net value of the other two terms (+ve or –ve) accruing to the employee.

It is worth considering the special case where the social value is exactly equal to w. This is the so-called cost saving theory of the value of time (see for example Adkins, Ward and McFarland, 1967). This would hold if the employee's value of time in the activities 'work' and 'travel' was equal – a reasonable assumption for professional travellers such as truck drivers and salesmen for whom driving is a large part of the work task. In the more general case, there is some evidence to suggest that the cost saving approach is not a bad approximation to the social value of business travel time saving (Fowkes, Marks and Nash, 1991). More empirical work is required on this, but for the purposes of exposition we now consider the special case in which the SVTT on employers business is approximated by w.

Two points arise from this case. The first is that what happens to w – whether it accrues to the firm in higher profits or is passed on to consumers in lower prices or is partly returned to labour in higher wages – depends on labour and product market conditions. In general, even if we are willing to accept that equation 2 measures the size of the benefits (see below), to know the final incidence of the benefits would require a lot of information about the working of the market. In practice, the final beneficiaries of a business travel time saving are unidentifiable.

The second point is that if we are in fact relying on the cost saving approach to yield the social value of working time savings, then, as Hensher has pointed out, the proposition that the employer gains exactly w requires that

- 100% of the travel time saving is used for productive purposes
- travel time is totally unproductive, whereas work time is 100% productive
- the wage rate equals the value of the marginal product of labour (competitive conditions)

Unless the situation is equivalent to these three conditions holding, the value of the increment of economic output due to a travel time saving will not equal the wage rate of the individual, or class of labour which makes the saving. It then becomes an empirical matter, investigated by Hensher, (1977), Accent/Hague (1999), Fowkes, Marks and Nash (1991) among others, what the relevant parameter values are.

Having considered the empirical work, our view is that deviations from the above conditions are generally self-cancelling. There are so many uncertainties about these parameters that there is a lot to be said for sticking to the gross of tax wage rate (plus labour-related overheads) as the relevant <u>commercial</u> value of business travel time savings. There are swings and roundabouts in this – some travel time savings may go into leisure rather than work, some travel time may be productive (so that care is required in modal split studies where productivity on rail or air is higher than on car), but on the other hand the value of marginal product may on average exceed the wage rate.

However, an important potential source of divergence between the commercial value of a business time saving and the equivalent social value needs to be noted. The cost saving approach, in our view provides reasonable estimates of the commercial value. But to yield an appropriate social value requires the assumption of full employment of the relevant class of labour. That is, when a travel time saving occurs, either there is additional work for the labour to do, which can be valued according to the value of the marginal product of that labour proxied by the wage rate, or the labour is released into the market place where it is rehired elsewhere in the economy at the going wage rate for the relevant class of labour. If there is full employment with market clearing wage rates, then the commercial value of the time savings equals the social value, and it makes no difference whether the labour is retained or released. But in conditions of widespread unemployment, the cost saving to the firm releasing labour exceeds the social opportunity value of the labour released; there is a divergence between the commercial value of the time savings to firms and the value of the time saving to society. Properly a shadow price should be used to reflect the probability of productive employment of the relevant class of labour. An example of an attempt to calculate such a shadow price is given in Herrera (1991).

5. The Value of Non-Working Time Savings

Consider the case of a self-employed business person, free to allocate time as she wishes and with no dependents or relatives and a zero marginal income tax rate. She allocates time between work and leisure activities such that the marginal value of her time in each is equal (see equation 1). Now consider the special case in which the marginal utility of work effort (dU/dW) and of travel (dU/dt) are equal. In this case, the marginal value of time released from travel is equal to the wage rate whether it is used for additional work or leisure.

However, these conditions rarely hold. There are four key considerations which in practice mean that values of non-working travel time savings are different from the gross of tax wage rate of workers (typically well below in UK conditions):-

- marginal tax rates on income reduce the net wage, on which the individual balances his choices, significantly below the gross wage
- workers earn wages on behalf of their families. Since on average the wage must be spread across non-wage earners also, the value of time will more likely be related to household disposable income than to the individual wage
- many wage contracts are of an ‘all or nothing’ kind – work 40 hours a week or not at all; in this situation individuals have no opportunity to allocate their time in accordance with the marginal conditions set out earlier.
- for most people, the marginal disutility of travelling is probably less than that of working. It is often said that for people with bosses at one end and families at the other, the journey is their one oasis of peace in the day in which to commune with Beethoven, Whitney Houston or whoever. On the other hand, queuing, waiting, stopping and accelerating can be stressful. Obviously the nature of work plays a key role as well.

The last two of these arguments could go either way. But the first two arguments suggest that values of non-working time are below the wage rates of the working population, and probably considerably so. Since theory cannot tell us by how much, an empirical approach is needed. This requires an understanding of three things – the relevant wage rate measure, the marginal value of leisure, and the value of the marginal disutility of travel.

In practice, the essence of the UK approach is to seek to derive an average willingness to pay for in-vehicle time savings from a range of survey data, and, after appropriate modification for indirect taxation, to use this as a single standard appraisal value for use in public sector appraisal whether in wealthy or poor areas, buses or trains, industrial estate roads or airport access roads. Recalling section 3, such an approach might be interpreted as an attempt to correct the implicit regressive weights underlying willingness to pay values.

A number of policy issues arise from the standard value approach. First, there is the issue of what sort of average it should be – should it be an average over travellers or the whole population, should it include non-mechanised as well as mechanised modes, should it be weighted by use? To the extent that values are derived from Revealed or Stated Preference methods it seems reasonable to weight these by current usage. A random sample of current users would achieve that automatically but in practice a small number of cluster samples are taken.

Secondly, there are issues of consistency of treatment within the appraisal. None of the monetary costs or benefits, such as changes in fares or vehicle operating costs, are weighted in any way. Therefore the appraisal is a composite of willingness to pay values and standard values. This can be defended only on pragmatic grounds, not conceptually.

Thirdly, there is a stark difference between the values for use on public sector appraisal described above and the values which a commercial operator would wish to use in a willingness-to-pay analysis of the same project. The more we move into a regime of public-private partnership, the greater become the appraisal difficulties.

Finally, a problem of a different nature arises in that travel time involves different sub-components – like walking, waiting and travelling in-vehicle at different levels of comfort – which add up to a total. Thus behind $\partial U / \partial t$ there are potentially different values to be taken into account. These may be partly determined by the time of day and flow conditions as well as the value of leisure if activity schedule constraints are present.

Variation in an Individual's Value of Time Savings

It is clear from equation 2 that the value of travel time savings will vary over individuals, for example as the wage rate (w) varies over individuals, those with higher wages will have higher time values over things being equal. In this section we will, though, be looking not at that variation but the source of variation in time values for an individual with a given marginal utility of income (λ). It follows (from equation 2) that we will be looking at variations in K_t, where t denotes various travel activities, each having different marginal (dis)utilities. The aggregation problem can then be seen to be doubly complex, needing not just to average/sum over individuals but also to find a set of appropriate values for each individual depending on the sort of travel they undertake.

Six major influences on an individual's value of travel time savings are:-

- the time at which the journey is made
- the characteristics of the journey (congested, repetitive or free-flow and novel)
- the journey purpose (commuting or leisure)
- the journey length
- the mode of travel
- the size of the time saving

If values of time did vary in all these dimensions, then two things would follow. First, it would be necessary to carry out the requisite choice experiments to gather the relevant data on values. Second, and much more testing, it would be necessary to undertake scheme appraisals with all these dimensions in mind; the origin/destination matrix would in principle need to be broken down by time period and journey purpose and so on. Furthermore, correlation with personal characteristics would need to be allowed for – if people travelling at 8 am have high values of time because they tend to have higher than average incomes, this would need to be separated out. Overall, the UK tradition has been not to distinguish values of time in terms of any of the first four dimensions above, partly on grounds of lack of convincing evidence, and partly for reasons of conceptual complexity. The last two, however, are more controversial.

Mode of Travel

The fifth simplification within UK practice is to give all in-vehicle time equal value regardless of mode and to double weight both walking and waiting time. There is some doubt over the correctness of the double weighting - surveys often find walk time values less than double in-vehicle time values, but there is a suspicion that surveys tend to be conducted in good weather and under-represent mobility-impaired travellers. Regarding waiting time, with random arrivals at stops, double weighting is equivalent to adding the headway to the in-vehicle time, which seems reasonable. For long distance/low frequency services, the waiting time needs to be computed differently, but again an allowance needs to be added for the discomfort and anxiety associated with waiting.

As regards different main modes of transport, the well known paradox applies, namely that the less pleasant modes turn out in surveys also to have lower values of travel time savings. This arises because better-off people travel disproportionately more on the pleasant modes. For example, bus users tend to be poorer than average and so report low values for bus travel time savings. Car users will typically report higher values for car travel time savings but would have even higher values still for savings in bus travel time. Surveys have had limited success in disentangling such effects.

This issue is important in the context of multi-modal studies. Currently a set of sub-regional studies is under way in the UK. One of the tasks of these studies is to assess a range of projects and policies which involve changes in modal split. Clearly if the above situation holds then there is potential for error if different modal values are used and the switching traffic has different income and socio-characteristics from the base traffic on the mode. This is already a problem in the context of working time savings where different modal values are in use. Until the income effects can be properly disentangled from the 'pleasantness' effects, there is more to be lost than gained from subdividing in-vehicle time savings by mode.

The Value of Small Travel Time Savings

This is a controversial issue. Standard practice in the UK is to assign a constant unit value per minute of time savings regardless of the size of the time saving. Where road schemes create a mixture of time gains and losses, the same value per minute is attributed regardless of sign. This approach has the obvious virtue of simplicity, but is it legitimate?

Earlier in the paper it was established that the value of travel time savings is composed of two effects – the benefit of a release of time for all other activities, and the benefit from a reduction in the disutility of travel. In most situations the value per minute of the disutility of travel may reasonably be taken as constant for different amounts of time saving (this is not the same as saying it is constant for all journey lengths). Empirical studies of arduous travel conditions such as standing on trains have found reported values per minute actually falling as the amounts increased, but it must be expected that the per minute value would eventually rise (Marks and Wardman 1991).

Most of the argument surrounds the first effect. For example, it is often argued that recipients of small time savings cannot make 'full' use of them, or go so far as to say that small time savings are not even noticed by the recipients and so cannot have any resource value to them. This last assertion is essentially bogus. The world is full of misperception. If we shop at a slightly cheaper superstore than usual, we get the benefit even if we don't notice the price differences. Society justifies safety schemes on the basis of changes in small probabilities of accidents which may well go unperceived by users – no-one argues that the benefits are therefore not real. Thus the issue of whether the benefits are or are not perceived seems to us neither here nor there.

Let us now consider the main proposition, that small time savings are not as much use per minute as large time savings in resource terms. This must be true in some instances, since not all activities can be moved in time and some activities take a minimum time to complete. Given this, a small time saving to an individual may be unusable, while a small time loss may trip a schedule constraint. It is very understandable that when asked about their willingness to pay for small time savings and losses in stated preference surveys, respondents will quickly see the latter, but may fail to see the benefit of a travel time reduction.

However, two arguments together completely counter the above proposition. The first is that over time people progressively reschedule their activities, and their ambient circumstances also change. Although there may be specific examples where time savings are unusable because of heavily constrained timetables, such examples are relatively unusual. The second argument considers the case where the first argument fails. Suppose there exists an activity, such as reading a magazine, which requires a minimum of 5 minutes to be worthwhile. Suppose further that all activities require this threshold. Then at any point in time there will be a distribution of idle time lying between zero and the threshold of five minutes. Fowkes (1999) has demonstrated that if there is a threshold below which a time saving has no (or a reduced) value because of inability to reschedule, then there must be a uniform distribution of such amounts of time from zero up to the threshold in the starting position. It is further demonstrated that a given small time saving in that range will move exactly the right proportion of recipients over the threshold that the outcome is the same as valuing all time savings at the same unit value.

Another argument, with which we have sympathy, is that valuing one 1000 second time saving equal to 10000 one-second time savings is invalid due to measurement error affecting the 10000 second time saving little but the one-second savings greatly. Fowkes (1999) has shown, however, that the magnitude of any resulting overvaluation of time savings is likely to be modest. If all time savings had a standard deviation of one second and the standard deviation of the estimate of total time savings was subtracted (from the total time saving) as a disbenefit, then the overvaluation would be [10000-1)/(10000-100)]-1, i.e. 99/9900, i.e. 1% time savings would have turned out to be time losses. All things considered, we see no justification for moving away from the constant unit value approach, nor the valuing losses differently from gains.

6. The Value of Time over Time

How should we expect the average value of time to change over time? Presumably at the broadest level, a relationship between the value of time and income is to be expected. More specifically, the question can be posed – what is the elasticity of the average value of travel time savings with respect to GDP? This is a non-trivial question – for an economy with a growth rate of 2.5 per cent and a discount rate of 6 per cent, the effect of assuming that the elasticity is 0.5 rather than 1 is to reduce the present value of a constant stream of time savings from a project with a 20 year life by 9 per cent.

It is also a topical issue within the UK appraisal context. UK policy for many years, as embodied in the COBA manual for road schemes, has been to take the GDP elasticity of the value of time as unity. In other words, all values of time (work and non-work) are uprated for each year of the evaluation period by the expected real rate of growth of GDP per capita. Past studies (for example MVA, ITS, TSU, 1987) have considered this position to be reasonable pending further evidence. However, more recent work, in particular the recent UK value of time study (Accent/Hague, 1999), found values of time which, though higher than those found in the 1980s work, had risen nowhere near proportionately with GDP growth. On the face of it, this is consistent with an income elasticity of the value of time significantly below unity, possibly as low as 0.5 (see both Wardman and Gunn, this issue).

But there is an alternative explanation. Looking at the three waves of UK studies, those in the 1960s and early 1970s produced results for the value of non-working time in the range 20-33 per cent of the wage rate, and were implemented as an average value of a quarter of the wage rate. The 1980s study led to a significant increase to around 43 per cent of average earnings, while the 1994 study produces results close to one-third of average hourly earnings.

The high values obtained from the 1980s studies may have been due to erroneously interpreting ‘values per car’ as ‘values per occupant’, thereby multiplying the values by the average car occupancy rate. It is plausible therefore, that the 1980s non-work time values – which (and are) still those recommended for use in practical UK evaluations – were and are simply too high and need to be adjusted downwards once and for all, with the future income elasticity remaining at unity.

Since the empirical evidence is clouded, it is worth revisiting this issue from first principles, considering first working and then non-working time. In section 4 we concluded that using the wage rate as an approximation to the employer's value of travel time savings during working time was reasonable. It follows from this, that we should expect the average value to the employer of working time savings to grow proportionately to the average growth in real wage rates. Note that as GDP per capita rises, wage rates are likely to rise faster with fewer hours being worked. This has been the case over a very long time period (Stigler, 1987). Therefore, we should expect the employer's value of working time savings to increase somewhat faster than proportionately to the growth in GDP per capita.

For the same reason, we would expect values of non-working travel time savings to rise less fast than wage rates, but nevertheless probably about as fast as GDP per capita. Consider the special case in which working hours per week (and therefore also leisure hours) are held constant as real income rises. In that case, one would expect the value of travel time savings to rise proportionately to wage rates. In practice, people take out some of their increased real wealth in extra leisure and part in extra income, so that per capita income will not rise as fast as wage rates. In other words the income effect is on average stronger than the substitution effect.

Thus a reasonable long-run expectation is for the value of savings in non-working time to increase less than proportionately to increases in wage rates, say proportionately to per capita income growth. Of course, this argument cannot be conclusive but the proposition that the value of non-working time savings grows significantly slower than GDP per capita – say at only half the rate – does seem to lie at one end of the range of possibilities. Consideration of the trends in the values of work, leisure and travel time is a subject which warrants a wide range of theoretical and empirical study.

7. Conclusions

In conclusion, let us give our answers to the questions which were posed in the introduction.

(i) Time is a scarce resource and should be valued.

(ii) Using individuals' or groups' willingness to pay as their value of time savings is inappropriate for social evaluation.

(iii) Using a single social 'equity' value of time savings would be appropriate if the marginal utility of travel time savings was constant over individuals or groups. Empirical studies could shed light on this.

(iv) In the case of working travel time savings, issues arise concerning both the size of the benefits and their final incidence. We would defend the continued use of the cost saving approach to yield the employers value. However, in conditions of widespread unemployment, shadow prices are required to adjust from the commercial to the social value of the cost saving.

(v) Theory cannot tell us the relationship between the value of non-working time and the wage rate; an empirical approach is required.

(vi) UK practice is to use a single standard value of non-working time per minute irrespective of journey purpose, journey length, size of time saving and mode used (except for walking and waiting). This is extremely simple, but, we consider, defensible.

(vii) First principles suggest that the growth of the value of time over time should be somewhat faster than the growth of GDP per capita for working time, and close to proportionality to GDP per capita growth for non-working time. There is no compelling reason to depart from the assumption of a unit income elasticity of the value of time. The trends in the values of work, leisure and travel time warrant wide-ranging theoretical and empirical study.

(viii) The outstanding research issue in the UK context is the valuation of changes in travel reliability. This is considered further in the companion paper by Bates et al; see also Lam and Small in this issue.

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Appendix: The Social Welfare Gain due to a Travel Time Reduction.

Consider a social welfare function W_s that depends on individual utilities U_i

which are a function of generalised income I and prices P, i.e.

$$W_s = W_s \left[U_1(I_1, P), \ldots, U_n(I_n, P)\right] \qquad \text{(a)}$$

Then a project that causes, for group q, time savings and losses dt_q leads to the following change in social welfare.

$$dW_s = \sum_q \frac{\partial W_s}{\partial U_q} \frac{\partial U_q}{\partial I_q} \frac{\partial I_q}{\partial t_q} dt_q \qquad \text{(b)}$$

where $\partial W_s / \partial U_q$ is a welfare weight Ω_q representing how much individual or group q matters to society, and $\partial U_q / \partial I_q$ is the marginal utility of income l_q, and dI_q/dt_q is the subjective monetary value of a unit of travel time saving, $SVTT_q$. Hence, following Galvez and Jara-Diaz (1998):

$$\Delta W_s = \sum_q \Omega_q \lambda_q SVTT_q \Delta t_q \,. \qquad \text{(c) and (4)}$$

This shows that the social utility of travel time for group q is given by the social weight, times the marginal utility of income, times the SVTT. If this is divided into the social utility of income, λ_s, a social price of time for group q is obtained.

If all groups had the same marginal utility of time savings, v, then

$$v = \lambda_q SVTT_q \qquad \text{for all q}$$

In that case, setting $\Omega_q = 1$ for all q, to represent the case where society values all its members equally, gives:-

$$\Delta W_s = v \sum_q \Delta t_q$$

and the single social price of time, v/λ_s, would be appropriate for economic evaluation.