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Project Appraisal Guidelines for National Roads Unit 6.10 - Reliability and Quality

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1. Overview

Travel time savings are the major component reflected in the Cost-Benefit Analysis. There is a well-developed methodology for valuing time savings; while some distinctions are made according to the circumstances of the time saving (in particular a higher value is applied to time spent walking and waiting for public transport), the general practice is to apply a uniform Value of Travel Time Savings (VTTS) , distinguishing only between the purpose for which the journey is made (Business, Commuting and Other non-commuting).

The theory underlying VTTS makes clear that the value depends both on the alternative use ("opportunity cost") and the circumstances in which the travel time is spent. In principle, travel time in less pleasant conditions should command a higher VTTS. This may be viewed as an aspect of "quality", which we can define as components of the journey which might be additionally valued. There are problems in defining this rigorously, for two main reasons. In the first place, many aspects of the "quality of a journey" are inherently time-dependent, in that their value is likely to increase with the time during which travellers are exposed to them (for example, quality of road surface). Secondly, current estimates of VTTS are inherently based on some average quality so that, to avoid double-counting, we should only be concerned with (positive or negative) additions in quality, relative to some base level.

Despite these cautionary remarks, there is plenty of evidence that VTTS is affected by quality, and also that there are other – not necessarily time-related – aspects of travel (e.g. improved information) which travellers attach a value to. In theory, a willingness-to-pay based appraisal should include these, with appropriate monetisation. There are some interventions such as variable message signs, provision of hard shoulders, dynamic speed control where the intervention may not necessarily be time-related but instead relates to improved journey quality.

In addition, there is evidence that travellers are concerned not merely with travel time but also with the reliability of travel time – that is, how predictable their arrival time is, given some allowance for prevailing travel conditions. In principle, this is a different dimension from the quality aspects just discussed, relating not to the circumstances of a particular journey, but to how the journey time is expected to vary relative to the average or expected time. Nonetheless, the factors affecting reliability (particularly, on the highway side, congestion) are likely to be associated with different qualities of time, while other quality aspects – in particular, information provision – may alleviate the inconvenience of unreliable travel times, either by giving a more accurate prediction of travel time for the current journey or by enabling avoiding action (e.g. alternative routes).

Finally, general practice in relation to incorporating both these areas into the CBA is not very advanced. As will be discussed, there has been some progress internationally on the valuation of reliability, but there are still major problems in predicting the impact of interventions on reliability. Some particularly relevant research was published by the UK Department for Transport in late 2015. As for quality aspects, while there is evidence from some studies, including the DfT research from 2015, virtually none of this evidence has yet been operationalised in national transport appraisal procedures. A useful assessment of the European position is given in Section 4.5 of the HEATCO Deliverable 54. While this relates to the position in 2006, there has been little significant development since then.

The Department of Transport, Tourism and Sport "Guidelines on a Common Appraisal Framework for Transport Projects and Programmes" (2016) identifies "Transport Reliability and Quality" as one of the components within the overall heading of "Economy". The DTTAS Guidelines list Transport Reliability and Quality under topics to be considered as part of a qualitative appraisal and state that these effects 'although not always quantifiable, are still important.'

This PAG unit covers the treatment of reliability and journey quality in appraisals carried out for TII. In each case it gives an overview of the current state of research in the area, describes how it is treated in some other jurisdictions and provides recommendations on treating the effect in TII appraisals.

2. Reliability

2.1 Background and Current State of Research

As congestion builds, road journey times become increasingly unpredictable. There is evidence that travellers perceive this “unreliability” or increasing Travel Time Variability (TTV) as conveying additional disutility over and above the actual delay, and that they are prepared, in principle, to pay to avoid it.

There is no universal definition for the term reliability in appraisal methodology. However, there are several critical concepts used in defining reliability: travel time variation; predictability; and the causes of variation.

- The term reliability is generally used informally, and the more accurate term of TTV is widely used in research and appraisal guidelines. Travel Time Variability is the difference in the distribution from the minimum time in which a journey can be undertaken (i.e. travel time without delays such as free flow motorway traffic) to the maximum journey time.
- The users of transport networks are assumed to be aware of predictable variation relating to varying levels of demand e.g. by time of day. These are not considered an issue of reliability and so are quantified as part of the general journey time i.e. predictable variations in journey times are not an issue to be addressed when considering reliability. Unexpected delays however, are less systematic and lead to unpredictable variation in travel times.
- The causes of unpredictable variation are composed of incidents (e.g. vehicle collisions, signal failures); demand related effects (e.g. the bunching of buses caused by an unexpected surge in demand); and supply considerations (e.g. random concentration of heavy goods vehicles). Unpredictable Travel Time Variability can be expressed as the sum of these three causes.

Therefore, reliability is a measure of variation in journey times that transport users are unable to predict, as opposed to the type of variation that might arise between peak and off-peak times.

Although there are various measures which could be used for TTV, there is currently some international consensus behind the standard deviation of travel time. Some practical justification for this is given in the HEATCO Deliverable 5, Section 4.5.1. It is important to note that the standard deviation should not be measured in a way which includes predictable variation, which might include that due to different times of the day (peak/off peak etc.), known daily variation and seasonal variation including holidays etc. For example, if the expected peak journey time from home to work in a city is twice the off-peak time, it is the variation around the average peak time which is relevant for peak journeys.

In order to use a measure of reliability within the overall appraisal procedure, we require a) an ability to predict the change in TTV resulting from an intervention and b) a valuation of the predicted change, in terms of a unit “value of reliability”. These requirements are, of course, additional to any assessment of time savings and the VTTS.

In practice the latter item b) (the value of reliability) is normally achieved by multiplying the relevant VTTS by a so-called "reliability ratio" (i.e. the value of the standard deviation of travel time versus travel time) typically residing in the range 0.4 to 1.1[1] . For example, a reliability ratio of 1.3 implies that a minute standard deviation of travel time is valued 1.3 times as much as a minute of travel time itself. The reliability ratio can then be used to factor the Value of Time (VOT) for any changes in the standard deviation of journey time, and incorporated as a monetised component into a CBA.

In relation to valuation, there remain some issues as to whether some of the value attributable to TTV is already implicit in existing values of time. For example (as is discussed in Section 3 of this PAG Unit), there is evidence that travel in congested conditions commands a higher value of time, but this could be partly due to the additional TTV associated with congestion.

Much greater difficulties, however, are associated with the prediction of change in TTV (i.e. item a) above). Various approximate measures have been proposed, and these will briefly be reviewed. A particular question is whether the methods should be applied on a link or O-D basis. In this respect, there are a number of related issues.

The underlying theory for the valuation of TTV is based on a variant of the "safety margin" hypothesis (for some discussion, see Bates et al, 2001, Fosgerau & Karlström, 2010): because of TTV, and the possible repercussions of arriving earlier or later than planned, travellers may need to allow for additional time, typically by departing earlier. Since this relates to loss of "utility" either at the origin or destination, it is essentially independent of the route followed.

However, highway times themselves are typically extracted from a network, based on route selection. Further, it is possible that TTV is primarily associated with particular links/junctions, and, in this case, there is also the possibility that considerations of TTV could affect route choice. For these reasons, there may be some interest in defining TTV on a link basis.

Unfortunately, this leads to considerable practical and theoretical problems, because, unlike travel time, the standard deviation time is not additive over the links comprising a path between origin and destination. In spite of this, much of the empirical evidence for TTV (which has become much stronger with the increasing development of electronic data capture) relates to links or sub-sections of the journey, rather than the full origin-destination movement.

Largely because of these problems, very few countries have initiated a full-scale incorporation of TTV into their CBA procedures. The countries which have made the most progress appear to be the UK, the Netherlands and New Zealand. Even in these cases, it remains unclear how much practical work has been done for actual appraisal.

2.2 New Zealand

In New Zealand, the NZ Transport Agency's (NZTA) recently updated Economic Evaluation Manual (EEM, 2016) discusses the treatment of reliability benefits in Section A4.5. The EEM must be used by approved organisations for economic evaluation to provide an efficiency assessment in the preparation of funding applications to the NZTA.

Under the guidelines of the current EEM, TTV is expressed as the standard deviation of travel time. In the case of roads, the standard deviation of travel time can be calculated using the volume/capacity ratio for that road, along with fixed values provided within the EEM.

[1] The evidence for this reliability ratio is almost entirely from Stated Preference (SP) research from which a trade-off between travel time and the standard deviation of travel time can be deduced. There is a lack of real life examples to adequately isolate reliability estimates using revealed preference (RP) data. A useful discussion of the evidence is available in the proceedings of an international meeting in The Hague in 20049. In addition, a major study was carried out in the Netherlands (Significance et al, 2012).

The claimable benefits from improving trip reliability are calculated by the following equation:

Reliability Benefits = 0.9 x travel time value ($/h)

x (reduction in the network variability (in min) / 60)

x traffic volume for time period (veh/h)

x correction factor.

The required values and factors are supplied in tables within the guidance. The reduction in network variability is defined as the difference between the sums of the variability for all journeys in the modelled area for the do-minimum and the initiative/option. The 0.9 factor is the value of reliability based on a typical urban traffic mix. For activities with a significantly different vehicle mix, the guidance recommends 0.8 for cars and 1.2 for commercial vehicles.

The travel time variability that may result from major incidents on the road network is not accounted for in this procedure. For example, where there are high levels of congestion on motorways, a major incident will produce large travel time delays. These delays are not included in the day-to-day variability calculations, but the guidelines state that the effect of a major incident will be related to the amount of spare capacity at the location and that a specific analysis should be undertaken to determine the economic cost of delays from major incidents.

2.3 The Netherlands

Reliability benefits are now quantified and monetised for use in CBAs. Two approaches have generally been used in the Netherlands.

In most project appraisals, the reliability benefits are simply calculated as 25% of the travel time benefits.

More differentiated guidelines for the value of reliability have been available in the Netherlands since 2004 (based on Rand Europe, 2004), but they are rarely used due to the difficulty in predicting changes in reliability.

Given the importance of obtaining accurate values for reliability, a new project - the so-called ‘VOTVOR project’ - was carried out to update the official values of time in both passenger and freight transport in the Netherlands and delivered the first values of reliability based on an empirical foundation. Although these values have been developed and are in circulation, it appears that the ‘25% rule’ above is still used in appraisals.

2.4 The United Kingdom

The UK recommended approach (TAG Unit A1.3, 2014, “the TAG”) varies by road type. Different methodologies have been developed for inter-urban motorway and dual carriageway roads, urban roads, and other roads.

For motorways and other dual carriageways, the sources of TTV are distinguished between incidents (breakdowns, collisions etc) and day-to-day variability. For the former, specific software (INCA) is available, sponsored by the UK DfT: the current version of the software also makes an estimate of the demand-related TTV.

For urban roads, the UK’s TAG offers a formula for the change in the standard deviation of travel time, calculated on an O-D basis: the formula takes account of actual travel time, distance, and free-flow travel time. The relationship is assumed to take account of both incidents and demand-based TTV (without distinguishing between them).

In the case of urban roads, the TAG recommends a reliability ratio of 0.8, as per the Guidelines in the Netherlands (originally sourced from Rand Europe, 2004).

For other road types (predominantly single carriageways outside urban areas), no formula for calculating TTV is currently available. Instead, a "stress" indicator is proposed, which is some kind of V/C ratio, and the change in the indicator resulting from an intervention is merely used in a qualitative sense, without any attempt at monetisation.

Note that even for those roads where, in principle, a monetary benefit can be calculated, the UK DfT guidance excludes the benefits from the calculation of Net Present Value and Benefit/Cost ratios.

More recently the UK Department for Transport has carried out additional research on the valuation of the benefits of transport investments, including reliability and journey time estimates. (Department for Transport 2015). This research suggests a lower reliability value than currently set out in the TAG of 0.4 as opposed to 0.8. However these results are still under discussion in the UK, so cannot yet be considered authoritative.

2.5 Recommendations for TII Project Appraisal

Based on this summary of international practice, a reasonable general case could be made for choosing to adopt a qualitative assessment of TTV, using data directly available from highway assignment programs. Exceptional cases would need to be demonstrated on materiality grounds.

Unreliability in road journey times is primarily associated with congestion. There is a case for including it in the appraisal whenever the intervention being considered is likely to have an impact on congestion. However, the relative approximation implicit in the method, particularly in relation to the particular intervention being appraised, may mean that it is less appropriate in some cases.

In the light of the foregoing discussion, it is recommended that in most cases an essentially qualitative assessment is carried out, supported where appropriate by quantitative evidence. The data and model requirements should not exceed those associated with the calculation of time savings (essentially an assignment program and appropriate demand matrices).

Because congestion is typically associated with peak travel times, it is expected that the calculations will be carried out for a peak period, except in cases where the modelling does not reflect different times of the day. In most cases, the morning peak will be sufficient, but the evening peak should also be included if it has significantly different characteristics.

Standard highway modelling will involve carrying out assignments for Do-Minimum demand without and with the proposed intervention: this will normally be done for the Design Year. In what follows, it is assumed that this is the case, though minor variations may occur in practice.

For the Do-Minimum demand without the scheme, in the most congested period being modelled, a limited number of links in the vicinity of the scheme with the highest volume-to-capacity ratios should be identified and indicated on a map. These ratios are preferably measured in Passenger Car Units (PCU's).

If none of these links has a V/C ratio greater than 70%, then no further information is required. Otherwise, the same links should be identified in the corresponding assignment with the scheme, and their V/C ratios presented in the reliability and quality section of the Project Appraisal Balance Sheet (See PAG Unit 7.0: Project Appraisal Balance Sheet).

In exceptional cases, where reliability is considered to be a key issue and potentially to contribute a significant proportion of the total economic benefits, project-specific research could be contemplated with a view to providing specific estimates of the change in TTV, which could then be converted into monetary values using the best available reliability ratio (currently 0.8, but may change in a future update of TAG).

Promoters wishing to consider this option are required to agree methodology in advance with TII.

3. Quality

In relation to a journey, quality effects can be of two principal kinds: constant effects and time-related effects. In the former case, there may be a “bonus” or “penalty” associated with a particular journey by a particular mode: this may be as a result of, for example, better signing, an improved method of paying for parking at a particular location. In practice, it is likely in most cases that the (dis)benefits will be time-related, but it may not always be possible to identify this. Cases where quality effects clearly are time-related might be smoothness of ride due to improved pavement surface, or improved visibility levels or signage.

Evidence of willingness to pay for “quality” is less well documented than the case of reliability, and exists mainly in the field of public transport (in connection with improvements to vehicles and stations). However, there is evidence for highway users that time spent in congested conditions conveys greater disutility than time spent in freely flowing traffic. Motorway toll studies often try to use this to account for the willingness to use tolled roads, over and above what might be expected based on pure time savings. However vehicle operating costs and safety considerations are also at play in the decision to use a tolled motorway.

In the case of time-related quality effects, the recommended general approach would be to modify the value of time, reducing it in cases of time spent in higher quality conditions, and vice versa.

In order to use a measure of quality within the overall appraisal procedure, we require a) an ability to predict the change in time for given quality conditions (e.g. time in free-flow conditions, time in congested conditions) resulting from an intervention and b) a valuation of the predicted change, i.e. a modification to the value of time. In the case of a constant effect, only a valuation is required.

While studies using stated preference methods have produced some evidence of quality-related variations in values of time (e.g. by road type), there does not appear to be any evidence that these are typically incorporated within appraisal procedures apart from in New Zealand.

With regard to highway “quality”, there appear to be two principal dimensions, due to a) road type and b) traffic levels.

The NZ Transport Agency’s recent Economic Evaluation Manual (2016) suggests accounting for road surface quality (“roughness”) can increase the Vehicle Operating Cost (VOC). The premise for this approach is that roughness costs are composed of two elements: vehicle costs and values for vehicle occupants’ willingness to pay to avoid rough road conditions. The guidance therefore proposes an additional monetary amount per kilometre (NZ$ 2015 prices) to be added to the standard VOC depending on:

- Whether the road is urban or rural (with higher values for rural roads);
- The vehicle type with the highest values assigned to HCVs; and
- The initial roughness of the road measured by the International Roughness Index (IRI). Values calculated where the initial IRI is less than 3.8 are not to be used in BCR since there is no actual value in these cases.

The values for an urban road vary from NZ$0.016 for a car on a road with a low initial IRI to NZ$1.26 for a HCV on a road with a poor IRI (an index value of 15).

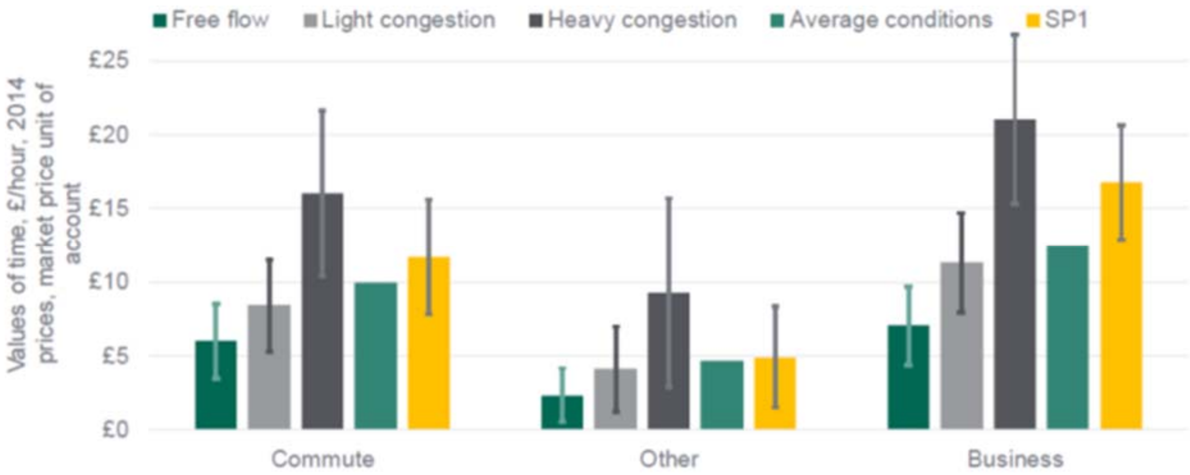
The values for a rural road vary from NZ$0.024 for a car on a road with a low initial IRI to NZ$1.26 for a HCV on a road with a poor IRI (an index value of 15). Note that the gap between urban and rural declines as the initial IRI increases.

These values are based on SP research into willingness-to-pay in New Zealand.

Guidance on highway quality in the UK recommends qualitative assessment on the grounds that there is limited evidence of monetary valuations of quality specific to road users. (TAG Unit A4.1, 2014). The guidelines for such a qualitative assessment recommend that the overall impact would be low where the number of individuals affected is low (less than 500 a day) and high where the number of individuals affected is high (more than 10,000) and moderate in all other cases. The impact should also be categorised as beneficial, adverse or neutral.

In 2015 the UK Department for Transport published the results of new research on journey quality benefits (Department for Transport 2015). This is still under consultation and has not yet led to changes in UK official guidance. However the results presented indicated that the value of time could be considered to change according the level of congestion. The effects found are summarised in the graphs below, taken from the Department for Transport publication:

Figure 6.10.1: Values of time by congestion level



Source: Department for Transport (2015)

With regard to the effect of traffic levels on journey quality it is worth citing the following from the HEATCO Deliverable 5 (§4.5.3 on Quality of Travel Experience) in the context of Road travel:

"*With respect to the aggregate effects of congestion on road travel Wardman (2001a, 2004) in his meta-analysis of 143 British studies found that travelling in congested conditions is valued 48% more highly on average than time spent driving in free flow traffic; Eliasson (2004) found similar values (about 1.5) for driving in queues, whilst Steer Davies Gleave (2004) found values ranging from 1.2 times in-vehicle-time (for busy conditions/light congestion) to almost twice in-vehicle-time for 'gridlock' conditions. The UK value of time study found that travel time in congested conditions was about 40% higher than in free-flow conditions for commuters though only just significant at the 95% level, whilst no significant effect was found for the 'other non-work' trip purposes (Mackie et al., 2003). Outside the EU the recent New Zealand value of time study and guidelines suggest that high levels of congestion may lead to values of time savings between 1 and 1.5 times in-vehicle-time depending on the degree of congestion and whether the congestion occurs on urban or rural roads. A value of 1.5 times standard in-vehicle-time would therefore seem a reasonable value to ascribe to congested conditions*."

More recent evidence has been made available in Wardman & Ibañez (2010) across a finer gradation of types of time than has been previously attempted. The paper also provides an extensive account of previous research into how congestion impacts on motorists' values of time.

In terms of implementation, the relative robustness of the two "dimensions" (road type and traffic levels) is effectively reversed. While the values for road types are relatively weak, they are straightforward to apply, since road types can be explicitly identified in the network. By contrast, the "congested" values are relatively well-attested, but difficult to implement, as the HEATCO Deliverable goes on to point out in the immediately following paragraph:

"*As ever the difficulty comes in applying such a value in an appraisal. What does the term 'congested conditions' mean? And how can this be related to a traffic model with a basis in traffic engineering? In situations where route capacity is determined by the capacity of the road (rather than the capacity of the junctions) – as in many inter-urban routes – the ratio of volume to capacity of the link may be used as a measure of congestion. Volume to capacity ratios in excess of 1.00 are associated with congested conditions (level of service E as set out in the US Highway Capacity Manual (TRB, 1997), whilst volume to capacity ratios below 0.75 are associated with reasonable operating conditions (level of service C). We recommend that if the volume to capacity ratio for a link is in excess of 1.00 then travel time could be valued at 1.5 times standard in-vehicle-time. Clearly such a value includes the costs associated with reliability. Therefore if reliability is to be modelled explicitly some double counting of costs/benefits would occur. The VTTS value should therefore only be weighted if no explicit reliability modelling is undertaken. We also recommend, as with the reliability analysis, that such an approach is confined to the route of the upgraded TEN-T network, with the surrounding network excluded. Primarily this is because of the uncertainty as to what is considered to be congested conditions, particularly for parts of the network which will be influenced by the operation of junctions*."

In fact, this understates the problem, since it is by no means clear how easily standard assignment programs can operate with values of time which vary with link loadings. Not only is it likely to cause problems for minimum path calculations, but also the existence of rather severe discontinuities (as implied in the HEATCO citation) is likely to affect the convergence of standard multi-path congested assignment algorithms. As with TTV, it may be necessary on practical grounds to confine any allowance for congestion to a post-processing evaluation, only applying the higher values to identified links once the final assignment has been determined.

3.1 Recommendations for TII Project Appraisal

Allowance for quality effects within the appraisal should only be made when the proposed scheme involves a clear distinction in terms of quality, whether positive or negative. In any case, there must be some doubt as to whether the available evidence will support an explicit treatment of quality. Assuming this to be the case, a clear criterion is necessary as to the circumstances in which it is required.

While the "road type" dimension is straightforward to implement, the current evidence for quality variation cannot be considered very strong. In particular, it is likely that the road conditions in New Zealand to which the values are likely to be applied are hardly relevant in the Irish context. It is therefore recommended that no explicit allowance should be made for quality of road surface on different types of road.

In exceptional cases, where quality is considered to be a key issue and potentially to contribute a significant proportion of the total economic benefits, project-specific research could be contemplated with a view to providing specific monetary values. However, this should only be done with the agreement of the TII Strategic Planning Unit.

With respect to the "traffic level" dimension, it is, as with reliability, the implementation difficulties which predominate. In addition, it is clear that – despite the inherent difference between reliability and quality – it is the same indicator (essentially the volume to capacity ratio) which is likely to drive the variation.

Hence, for the standard case, it is recommended that quality generally not be monetised, and that in most cases an essentially qualitative assessment is carried out, supported where appropriate by quantitative evidence. In as far as this is already being done for Reliability, no additional information need be provided.

In some cases the benefit of reducing congestion levels can be very relevant to the appraisal of a project and it may be necessary to monetise this benefit by applying differential values of time. This might be worth considering, say, with holiday routes where the congestion on the worst 100 hours of the year is much worse than the next 500. In such cases an ad hoc scale of values based on CAF values of time, and the levels of variation found in Department for Transport (2015) could be considered.

It may be noted that this has something in common with the treatment of crowding in public transport, and similar techniques might be appropriate. Such an approach would be particularly relevant if it could be shown thereby that the quality of the assignment, in terms of routeing, was enhanced. Note that there is a question as to whether, in this case, demand responses to changes in quality need to be modelled: if so, this can be added straightforwardly to “generalised cost”, but this could have some repercussion for model calibration.

Promoters wishing to consider this option are required to agree methodology in advance with TII.

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