Project Appraisal Guidelines

Unit 6.10 Reliability & Quality

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Reliability and Quality

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1 Introduction

1.1. Travel time savings are the major non-monetary 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).

1.2. 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.

1.3. 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 much of the case could relate to improved journey quality.

1.4. 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).

1.5. 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. As for quality aspects, while there is evidence from many studies, little codification has been carried out, and virtually none of the evidence has been operationalised in national transport appraisal procedures. A useful assessment of the European position is given in Section 4.5 of the HEATCO Deliverable 5[4]. While this relates to the position in 2006, there has been little significant development since then.

1.6. The Department of Transport "Guidelines on a Common Appraisal Framework for Transport Projects and Programmes" (June, 2009) identifies "Transport Reliability and Quality" (Section 4.2) as one of the components within the overall heading of "Economy". The discussion in that section provides an over-arching framework covering all transport modes. This PAG Unit relates to reliability for road transport only, but it is consistent with the principles in the DoT Guidelines.

1.7. For all these reasons, it makes sense to treat reliability and quality together in this PAG Unit, though each will be separately discussed in the following sections. Overall, the aim here is to provide general guidance, based on evidence and other international practice, bearing in mind the requirements and constraints of current procedures.

1.8. Paragraph 4.2.2 of the DoT Guidelines is particularly relevant in this context, and it is worth citing in its entirety:

> *Where project appraisers consider that these [Reliability and Quality] benefits arise and are significant, they may adopt one or more of the following approaches:*

- *Undertake project-specific research (through, for example, stated preference studies) to estimate the monetary value of these benefits;*
- *Use monetary values derived abroad in respect of similar transport services, taking account of the issues involved in the transfer of such benefit values; or*
- *Assess the benefits in a quantitative or qualitative manner.*

1.9. Because the approach to reliability is somewhat more advanced, we deal with it first.

2 Reliability

2.1. 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.

2.2. 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.

2.3. 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.

2.4. In practice the latter item b) (the value of reliability) is normally achieved by multiplying the relevant VTTS by a so-called “reliability ratio” typically residing in the range (0.8 to 1.3). 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. A useful discussion of the evidence is available in the proceedings of an international meeting in The Hague in 2004[9]. In addition, a major study is being carried out in the Netherlands (2006 to 2010): the survey design report is available[5], and the main study is in progress.

2.5. 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.

2.6. Much greater difficulties, however, are associated with the prediction of change in TTV (ie, 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.

2.7. 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.

2.8. 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.

2.9. 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.

2.10. 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 and New Zealand, while some attempts have also been made in the Netherlands and Sweden. Even in these cases, it remains unclear how much practical work has been done for actual appraisal. A useful discussion is available in Section 3 of the 2010 OECD publication “Improving Reliability on Surface Transport Networks”

2.11. In New Zealand, the NZ Transport Agency’s Economic Evaluation Manual (Vol 1) discusses the treatment of reliability benefits in Section A4.5. The underlying approach assumes that unreliability due to congestion is driven by the impact of uncertain traffic volumes on journey times. If travel time t is a function of V/C (volume divided by capacity) then assuming fixed capacity, we can deduce that

$$\text{var}(t) \approx \left(\frac{\partial t}{\partial [V/C]}\right)^2 . \text{var}(V/C).$$

2.12. Thus, taking the square root of this equation, the standard deviation of travel time is simply the standard deviation of demand, divided by capacity, multiplied by the slope of the effective speed/flow curve. The preferred generalised speed/flow curve in the New Zealand context is that due to Akçelik, which is easily shown with suitable parameters to match most other curves used in assignment programs. It may be observed that this is a link-based approach. Five different road types are recognised.

2.13. For OD pairs, the link variances are added across all links, without any allowance for correlation between links. This assumption was made on grounds of simplicity. Monetisation is in line with the current international consensus on the “reliability ratio”.

2.14. The UK recommended approach (WebTAG Unit 3.5.7) varies substantially 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 demand levels (V/C). 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 interventions such as provision of hard shoulders, crawler lanes designed to reduce incident-related TTV, the Department of

Transport Guidance (see paragraph 1.8 above) would suggest the use of a specific software tool (such as INCA).

2.15. For urban roads, the UK's WebTAG offers a formula for the change in the standard deviation of travel time resulting from an intervention, 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).

2.16. In the case of both dual carriageways and urban roads, WebTAG recommends a reliability ratio of 0.8: it is not clear whether this value applies to all vehicles or merely to cars – some proposals have been made that for commercial vehicles a higher value might be appropriate.

2.17. 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.

2.18. Note that even for those roads where, in principle, a monetary benefit can be calculated, WebTAG excludes the benefits from the calculation of Net Present Value and Benefit/Cost ratios, though the monetised benefits are used for the assessment of Value for Money.

2.19. 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.

2.20. 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

2.21. 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).

2.22. 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.

2.23. 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.

2.24. For the Do-Minimum demand without the scheme, in the most congested period being modelled, a limited number of (one-way) 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).

2.25. 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*).

2.26. 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 internationally agreed reliability ratio. However, this should only be done with the agreement of the NRA Strategic Planning Unit, who will be particularly concerned with whether the methods for predicting changes in TTV are robust.

3 Quality

Background

3.1. 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, or, in the case of public transport, improvements to stations or bus stops. 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 landscaping.

3.2. 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. In practice, of course, there are difficulties in knowing how far the higher values are associated with the unpleasantness of driving on lower quality areas of the network per se, and how much due to possible consequences associated with unreliability.

3.3. 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.

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

3.5. 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 have been formally incorporated within appraisal procedures anywhere in the world apart from New Zealand. Accordingly, both the evidence will need to be assessed and careful consideration given to the implementation requirements – which could be problematic.

3.6. With regard to highway "quality", there appear to be two principal dimensions, due to a) road type and b) traffic levels. Both dimensions have been investigated, using SP techniques.

3.7. It has been proposed that driving on dual carriageways as opposed to two-lane roads may convey benefit, though in practice it is difficult to control for the related effects of increased safety and speed. There are also issues in the presentation, within SP, of different road types, since even using high quality photographs may give a very different experience from the actual driving experience. Work by Hensher in New Zealand appeared to be consistent with a benefit for "medians" (i.e. a physical separation of the two carriageways) of NZ¢1.91 per Km for Cars, and NZ¢4.13 per Km for Trucks (1999 prices).

3.8. Following further SP work in New Zealand, Transfund NZ proposed values for "quality of ride", which are intended to reflect the user discomfort of travelling on rough roads. These values, on a NZ$/Km basis, are added to the vehicle operating costs when travelling on bumpy or rutted surfaces (defined according to an engineering measure of roughness). On average they amount to about NZ¢20 per Km for Cars, and NZ$1.00 per Km for Trucks (2001 prices). The methodology has been slightly updated in the NZ Transport Agency's recent Economic Evaluation Manual.

3.9. Apart from some recent work in the UK relating to the M6 Toll road, which suggests that some value for road surface quality and lighting can be identified, no other studies relating to the quality valuation of highway road type have been found.

3.10. Rather more work has been done in relation to traffic levels. 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."

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

3.12. 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."

3.13. 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.

3.14. 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.

3.15. 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 proposed 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 NRA Strategic Planning Unit.

3.16. 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 V/C ratio) which is likely to drive the variation.

3.17. 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.

3.18. Nonetheless, it may be open to promoters to consider how differential values of time – ideally on a sliding scale with the level of congestion – could be incorporated in the assignment process. 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.

3.19. 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.

3.20. Promoters wishing to consider this option are required to agree methodology in advance with the NRA Strategic Planning Unit.

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