Department for Transport

# Understanding and Valuing Impacts of Transport Investment

## Value of Travel Time Savings Consultation response

**Moving Britain Ahead**

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# Foreword

In October 2015 we went to consultation on our proposals for implementing the results of new research into the values of travel time saving in our appraisal framework.

The consultation ran for 3 months, during which time we a received a wide range of responses from different stakeholders. We have taken on board this feedback in developing our final set of updates to our appraisal guidance. This document summarises the responses received, the Department's response to the key issues raised and the rationale underpinning the definitive set of guidance changes.

There are also a number of areas where further research is required before guidance changes can made on a robust basis, which are discussed in detail below. We plan to take forward this research over the coming 12-18 months, and will report on progress in 2017.

The conclusion of the value of time consultation process represents a critical milestone in the development of the Department's evidence base for appraising the impacts of transport investment. For the first time, employers' business values of time are directly grounded in willingness-to-pay valuations, which is a big step forward in response to the on-going methodological debates around business values of time.

We are pleased to now be able to implement the research results as changes to guidance, and plan to continue working collaboratively with experts and stakeholders in order to continuously review the guidance and ensure it remains fit-for-purpose.

Amanda Rowlatt, Chief Analyst and Strategy Director

July 2016

# Executive summary

## Introduction

1 The Department's current guidance on valuing travel time saving is included in WebTAG.[1] This evidence base has been developed over many years and is internationally respected as best practice. In October 2013 we launched the 'Understanding and Valuing the Impacts of Transport Investment' (UVITI) Analytical Strategy which set out our approach to maintaining and enhancing this evidence base through open, transparent and collaborative working with academics, experts and stakeholders. This document is the latest in the series of publications that describe the progress we have made on delivering this strategy

2 In 2013 we made a commitment to undertake fresh, primary research on people's and businesses' willingness-to-pay for journey time reductions, and a range of other journey improvements. This research was undertaken in 2014/15, and was followed by a consultation in October 2015 on the Department's proposals for changes to WebTAG and future research into the values of travel time savings (VTTS).[2] Responses were received from wide range of stakeholders, both in relation to the specific questions the Department set out in the October 2015 consultation document as well as more general commentary on the research and the Department's proposed guidance changes.

3 This document summarises the responses received, the Department's response to the key issues raised and the rationale underpinning the definitive set of guidance changes. It also clarifies the areas where the Department plans to undertake further research before definitive updates to guidance can be made.

## Summary of key issues

4 Overall, the responses received following the consultation welcomed new evidence in this area. However, a range of concerns were raised covering practical implementation of the request for more a detailed breakdown of the data at a local level. Following this feedback, we commissioned advice from external expert practitioners and from the original value of travel time savings study team to respond to these concerns.

[1] https://www.gov.uk/guidance/transport-analysis-guidance-webtag

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470998/Understanding_and_Valuing_Impacts_of_Transport_Investment.pdf

5 The most commonly raised issue in the consultation was around the practical implications of implementing the new values of time in modelling and appraisal. Specifically, a number of the responses raised concerns with the three proposed discrete bands for employers' business VTTS, primarily due to issues with the 'cliff-edge' effect whereby there are large step changes in the values of time at the boundary points in between the bands. To address these concerns, we are implementing a continuous function for appraisal as the preferred option, as well as introducing a fourth discrete band for use where the continuous function is not feasible or proportionate.

6 In order to develop robust proposals for implementing the values of time in modelling guidance, we commissioned a review of the modelling implications of the new values of travel time savings from two expert practitioners.[3] Overall, the changes to the modelling guidance are minor, reflecting the fact that existing guidance already contains the framework and functionality for implementing distance-varied values of time in modelling.

7 There were also a number of respondents who were concerned with the use of distance to segment the VTTS for employers' business trips, which some felt was not in line with intuition and lacked a clear theoretical foundation. In part, the mix of views received on this subject reflects how different respondents have interpreted the somewhat subtle difference between the behavioural modelling work, which was underpinned by the stated-preference data, and the sample enumeration process which used National Travel Survey (NTS) data. This distinction is brought out more clearly in the following section to mitigate some of the concerns that subsequently arose, alongside further discussion of the rationale for varying the VTTS with distance.

8 Finally, some respondents were concerned about the transferability of the new values of travel time savings to specific contexts, such as different regions of the country or cases involving very small (or large) time savings. We welcome an open debate in these areas, which are clearly of importance to our stakeholders and have important potential implications for scheme appraisal. In certain cases, such as employers' business values of time, we recognise there may be a case for 'local' values of time. We are keen to work with our regional stakeholders to help them meet their evidence needs in this regard on a robust basis. Further discussion of these issues surrounding value transferability is included in section 8 below.

[3] The expert practitioner review can be found in annex C of this document.

# 1. Employers' business values of travel time savings

## Consultation Questions

1.1 The following consultation questions covered changes to the employers' business values of time:

> 1. On the basis of the evidence presented here, and in the research reports, do you agree that we should introduce distance-based business values of time?
>
> 2. And do you agree with the 3 distance bands being proposed?
>
> 3. Should distance be based on 'crow-flies' or 'network' distances?
>
> 4. What practical difficulties might there be in applying distance-banded business values of time in TUBA appraisals? And how might these be overcome?
>
> 5. Similarly for non-TUBA appraisals, what practical difficulties might there be and how might these be overcome?
>
> 6. The 'appraisal' values will likely also be used as 'behavioural' values. For transport modelling, what would be the most desirable form for the business values? Could the distance-banded values be practically implemented? Or would it be preferable to have a continuous function or single, average values for modelling purposes?

## Disaggregating employers' business VTTS by distance

1.2 There was a mixed response from stakeholders on the proposed implementation of distance-based employers' business values of time in WebTAG. While a number of stakeholders welcomed the introduction of a distance relationship in the values, which they recognised was clearly supported by the new research evidence, others questioned the intuitiveness of the underpinning rationale. For example, a range of respondents believed that the fundamental driver of the VTTS is journey time or size of time saving, as opposed to journey distance per se.

1.3 The Department's view, which is supported by the evidence and the recommendations from the study team, is that there is strong evidence for varying the values by distance. Trip distance is highly correlated to total trip time and trip cost, reflecting that fact that longer distance trips tend to cost

more and take longer than shorter distance ones. Furthermore, trip distance and traveller income are also highly correlated as wealthier individuals tend to make more long distance trips than poorer ones. Jointly, distance, income, time and cost explain a large proportion of the variation in employers' business VTTS. In principle it is possible to segment the values of time by any combination of these four covariates (as well as a range of other variables tested in the study), but more complex segmentations would be disproportionately challenging to apply in most transport modelling applications.

1.4 Distance varied VTTS have been taken forward in guidance in line with the recommendation from the study team. As well as accounting for a significant proportion of the variation in employers' business VTTS, a distance relationship is relatively easy to implement in most modelling and appraisal applications.

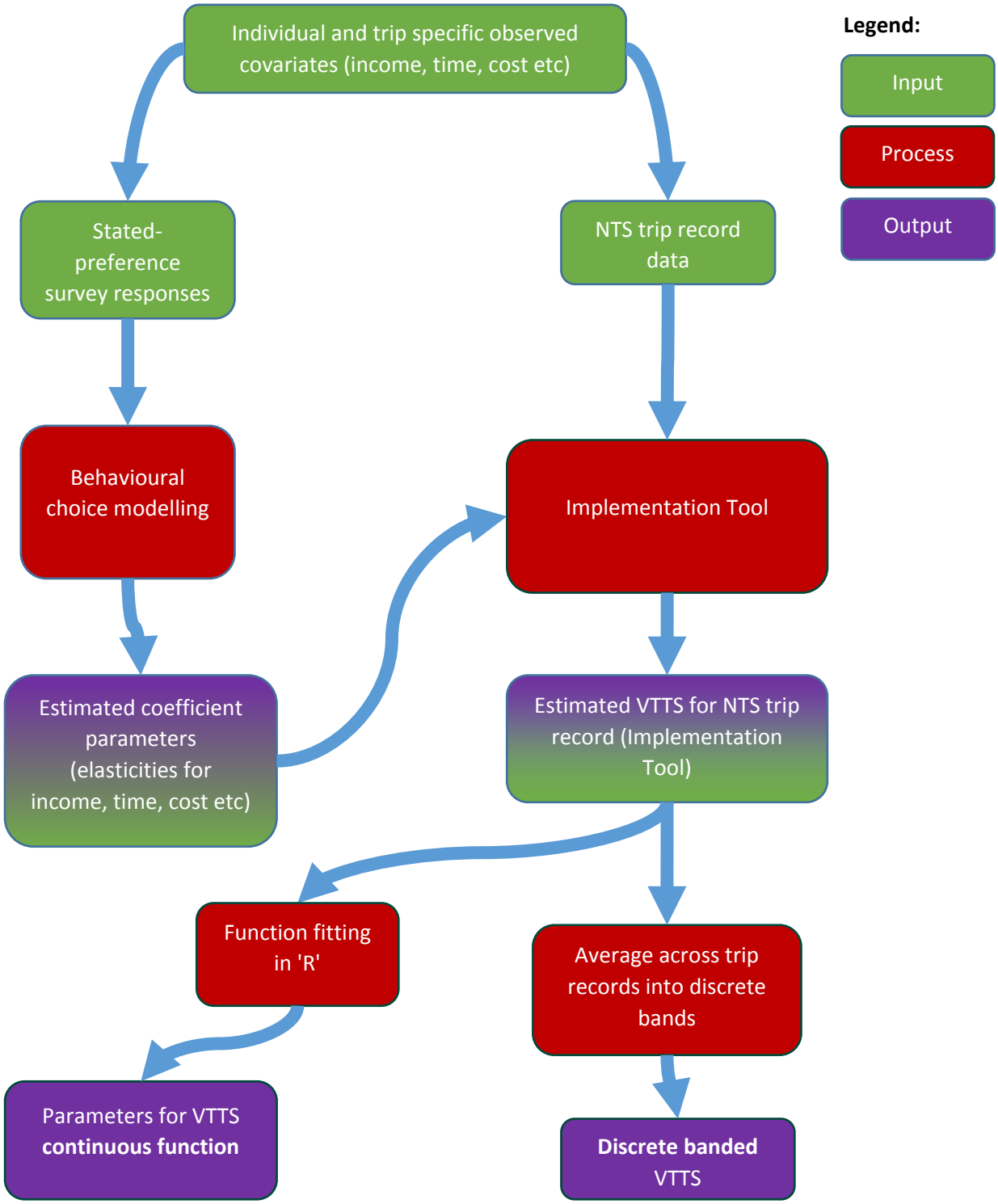
1.5 Some stakeholders were concerned that the distance relationship is not robust, on the basis that the distance elasticities from the behavioural choice modelling were not found to be statistically significant. However, it is important to be aware of the distinction between the behavioural choice modelling and the estimation of nationally representative values using the Implementation Tool. Figure 1 below explains the process for estimating appraisal values in more detail.

1.6 As figure 1 makes clear, the continuous function now in guidance is not conceptually (or empirically) equivalent to the distance elasticities reported in the Phase 2 report, which is the key document summarising the findings of the new value of time research carried out in 2014/15.[4] The elasticities presented in section 4 of that report capture the relationship between the value of time and trip distance for a given individual, holding all else constant, whereas the continuous function now in guidance describes the relationship for trips and is largely driven by the variation in the mix of individuals making trips of different lengths. Hence, the continuous function represents the distance relationship observed in the 'sample enumeration' process, whereby NTS trip record data are applied to the behavioural choice modelling parameter estimates in order to derive nationally representative estimates of the VTTS.

1.7 Therefore, the continuous function in guidance captures not only the 'pure' distance effect, but also the impact of other covariates in the NTS that are correlated with distance such as time, income and cost. In this way, the distance relationship being put into guidance can be described as an 'unconditional' or 'observed' relationship, as opposed to a 'conditional' relationship where all other determinants of the VTTS are held constant. It reflects the effect of distance across the entire NTS sample, without controlling for correlation between distance and other determinants. By being constructed in this way, the continuous function in guidance captures a robust VTTS relationship over distance even though the behavioural choice modelling coefficients for distance are not always statistically significant.

[4] DfT (2015) 'Provision of market research for value of travel time savings and reliability: Phase 2 report', pp.228-9 [pdf], available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470231/vtts-phase-2-report-issue-august-2015.pdf

**Figure 1: Schematic of the process for deriving nationally representative VTTS**



### Distance versus trip weighting

1.8 A further consideration informing the choice of the distance relationship relates to the difference between trip and distance weighted VTTS, which are two approaches to deriving the average VTTS across a given set of trips. The 'trip-weighted' VTTS is a simple arithmetic mean of the VTTS across all trips, whereas the 'distance-weighted' VTTS is a weighted arithmetic mean where the weight given to each trip is equal to its distance.

1.9 As set out in the Phase 2 report, both trip and distance weighting are approximations to the 'true' representative VTTS (which typically lies between the two). Therefore, it is desirable to minimise the difference between the trip and distance weighted VTTS in order to increase the accuracy in applying the values to scheme appraisals. As table 7.14 of the report shows,[5] by introducing distance segmentation the discrepancy between the trip and distance weighted VTTS is significantly reduced compared to if no segmentation is used.

## Discrete bands versus a continuous function

### Concerns raised with the banded approach

1.10 A range of respondents were critical of the proposed implementation of three discrete distance bands for employers' business VTTS. The chief reasons cited for this were:

- there appears to be no clear empirical or theoretical justification for sudden changes in the values around the discrete boundary cut-off points;
- appraisal results could be highly sensitive to the banding of values, especially where trip distances are close to one of the boundaries; and
- there is potential for instability in models where distance changes across a boundary between the without-scheme and with-scheme cases.

1.11 The Department recognises these concerns. In part, the sensitivity of appraisal results to the specification of the distance bands is mitigated by the recommendation in guidance to carry out sensitivity tests where trip distances are close to a boundary. Furthermore, the risk of instability due to distance changes between the without and with scheme cases is mitigated by the requirement to calculate the appropriate VTTS on the basis of a single definition of trip distance across all modelled forecast years and scenarios (see Box 3 below).

1.12 However, there is a broader challenge around whether it is most appropriate to use discrete bands, when in principle the evidence base developed by the recent study does not directly support a categorical segmentation of values. In both the earlier 2003 study, which underpins previous editions of WebTAG, and the new study, the fundamental relationship between trip distance and the VTTS can be expressed as a continuous function.

1.13 Upon reviewing the consultation responses, and in light of the recommendations from the study team, the Department is recommending a continuous function in guidance as the preferred method for calculating car and

[5] Ibid, p.229

rail employers' business VTTS for use in appraisal. This function has been estimated based on analysis on Implementation Tool outputs and has been peer reviewed by academics from the Leeds Institute of Transport Studies.[6] For other modes there is no evidence of a distance effect so single average values will continue to be recommended. Box 1 below summarises the formulae and derivation for the guidance change being proposed, Figure 2 sets out the parameters of the function while Figures 3 & 4 plot the functions against the 4 bands.

### Cases where a continuous function would be infeasible

1.14 The DfT recognises that in some cases it may not be feasible to apply a continuous function in this way, for example due to the limitations of available software packages. For example, some public transport schemes may not have readily available matrices of trip distances on the required origin-destination basis.

1.15 Additionally, in light of the concerns raised regarding the 'cliff-edge' effect, a fourth band for trips between 100-200 km has been added, with the upper band now applying only to trips above 200 km. Based on analysis carried out using the Implementation Tool and peer reviewed by the study team, this band has been found to be statistically robust. This reduces the step change in the VTTS between the previously consulted upon 50-100 km and 100 km bands, thereby helping to mitigate the potential for bias when the bands are applied in appraisal.

1.16 In such cases where the discrete bands are being considered, guidance recommends that survey data (where proportionate) could be used to support assumptions around typical trip distances, which could allow implementation of the continuous function.

1.17 Finally, the new guidance also recognises that there may be circumstances where no distance information is available or proportionate to collect (such as, for example, link-based, fixed-matrix appraisal). In these cases, it may be appropriate to use a single average value of time. Therefore, the Department will continue to publish these average values, by mode, in the WebTAG data book.

1.18 In any case where the continuous function is not used, the new guidance will make it clear that any departure from the continuous function should be fully justified by the scheme promoter, in terms of evidence of the distribution of affected trips across different distances.

[6] Their peer review can be found in Annex B of this document.

**Box 1: Continuous function for VTTS (car and rail employers' business only)**

The Department is recommending the following functional form for employers' business VTTS in appraisal, which is a logistic function of distance:

$$VTTS = \frac{U}{\left(1 + e^{\frac{x_{mid} - D}{k}}\right)}$$

**Where**:

$VTTS$ is the value of time, given an average trip distance

$D$ is distance

$U$ is the upper limit of the function (the 'asymptote')

$x_{mid}$ is the distance at the inflexion point of the curve (where ***VTTS = U/2***)

$k$ is a scale parameter which is inversely proportional to the steepness of the curve

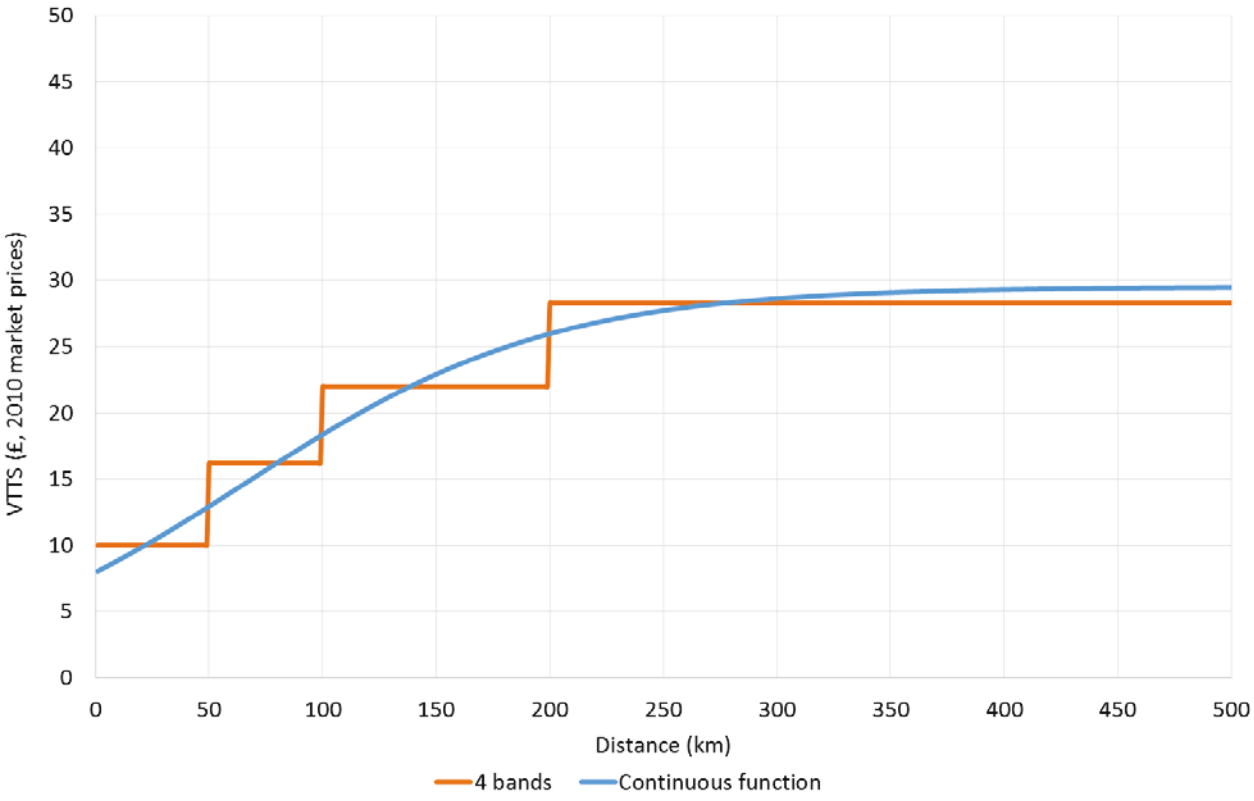
**Derivation of equation**

The parameters of the logistic function are estimated from the NTS sample enumerated dataset using non-linear weighted least-squares regression, where VTTS is the dependent variable and distance is the independent variable. The weights used in the regression correspond to the distance for each trip record multiplied by the NTS trip weight for that record.

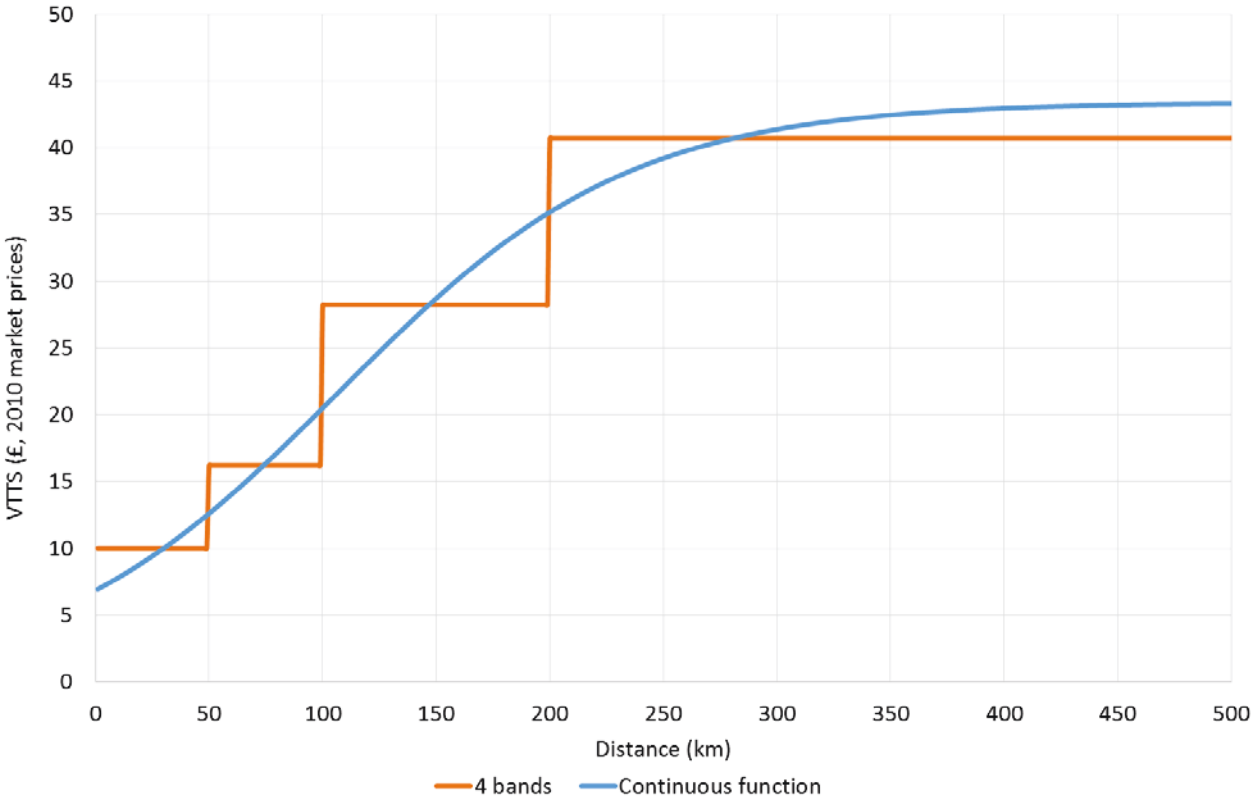
**Figure 2: Parameter values for VTTS continuous function (2010 market prices)**

| | Car | Rail |
|---|---|---|
| *U* | £29.52 | £43.40 |
| *x*mid | 66.53 | 107.04 |
| *k* | 67.02 | 63.95 |
| *VTTS where D=0* | £7.98 | £6.85 |

## Figure 3: Continuous function for car employers' business trips




## Figure 4: Continuous function for rail employers' business trips



## The definition of distance when deriving appraisal VTTS

1.19 Amongst respondents, there were a range of opinions about what definition of 'distance' should be used when deriving the appropriate appraisal VTTS for employers' business trips. Overall, opinion was evenly split between the 'crow-flies' and 'network distance' options set out in the October 2015 consultation. Generally, those favouring 'crow-flies' distances did so on grounds of practicality and stability, whereas arguments for 'network' distances emphasised the importance of consistency with the underlying research.

1.20 In order to provide context for the discussion, the approach taken by the current study is clarified in Box 2 below.

**Box 2: The treatment of distance in the VTTS research**

**Behavioural Modelling**

For the behavioural modelling that derived the parameter estimates for determining the VTTS, 'distance' is defined as the distance of the reference trip by road, based on the Google maps data and the respondent's stated mode, origin and destination. This therefore includes access and egress legs, but it is an imperfect measure for PT trips as it takes the road based distance as a proxy for the true distance.

**Sample enumeration using the Implementation Tool**

For the NTS data used to enumerate the behavioural results in order to produce representative national averages, each record represents one trip and the distance used to calculate the values is the overall trip distance (which therefore includes any access and egress legs). A trip can comprise of different stages, but the mode a trip is assigned to depends on the main mode of travel (by distance) for that trip. It can be seen, therefore, that the definition of 'distance' used by the study was total origin-destination distance.

1.21 Given the approach used to measure distance in the underlying data, the Department is of the position that a 'network' measure of distance should be used in deriving the VTTS as a function of distance. There are however a number of options for implementing this in practice. We have reviewed these in detail, and Box 3 below presents the definitive changes being brought into guidance. Annex A sets out the detailed rationale for these proposals, structured around a series of key questions.

## Implementing the new distance-varied VTTS in modelling guidance

1.22 Although the consultation focused on the VTTS for appraisal, the Department also sought feedback on how the new VTTS - specifically the distance

relationship now underpinning them - should be implemented in transport modelling. A small number of responses were received to this question and there was a spectrum of opinion with regards to the practicalities of implementing distance-varied VTTS in modelling. Respondents generally felt this could be done effectively for demand modelling in principle, although it was pointed out that an expansion of the capabilities of existing demand modelling software may be necessary to facilitate the implementation of a distance function in practice. Furthermore, a number of specific challenges were raised in relation to the possibility of applying distance banded values in assignment modelling.

**Box 3: Changes to WebTAG - treatment of distance for deriving the VTTS**

Given all of the issues discussed in annex A of this consultation response, in guidance we are recommending that the VTTS for each origin-destination pair is derived on the basis of the average distance from the base year assignment model. For each user class where distance based values of time apply (i.e. car and rail business trips), this should represent an average of distance skims for all modelled time slices (and income segments if income segmentation is used) weighted by the respective trip matrices.

Where this is not feasible or proportionate, the new guidance recommends that the base inter-peak distance matrix can be used. If inter-peak modelling is also judged to be disproportionate or unnecessary, peak period time slices may be used instead. These distance matrices should then be used in all modelled forecast years for all scenarios. This means that for any give origin-destination pair, the value of time will not vary between the without-scheme and with-scheme cases, or between low and high demand growth scenarios.

In cases where existing software or calculation routines do not support the calculation of assigned network distances, it may be proportionate to use other available distance information instead, such as the minimum network distance. It should be borne in mind that this could underestimate distances travelled, so where proportionate sensitivity tests should be conducted to understand the potential impact of using this simplified approach.

The above recommendations relate only to the appropriate distance skims for deriving the value of time used for monetising time savings in the appraisal, and not the regular skims of generalised costs required, for example, for the calculation of vehicle operating costs in the appraisal, or for demand/assignment modelling.

1.23 In response to the difficult technical nature of the questions raised, we commissioned two expert transport modelling practitioners to produce a review on the impact that the new VTTS could have on transport modelling practice.[7] Overall, the conclusion was that consideration of the most appropriate way to update WebTAG in response to these issues needs to be informed by the trade-offs between:

a. consistency between modelling and appraisal VTTS;

[7] The expert practitioner modelling think-piece can be found in annex C of this document.

b. consistency between the VTTS used in assignment modelling and those used in demand modelling;

c. proportionality - the extra modelling work that may be required to implement distance varied VTTS may be disproportionate compared to the impact of the extra analysis on decision making; and

d. feasibility - limitations in transport modelling approaches and/or software packages may inhibit full implementation of distance-varied VTTS.

1.24 These factors informed the detailed consideration below. As with all updates to WebTAG, the new guidance is based on the principle of proportionality. We would not expect already calibrated, validated and fit-for-purpose models to necessarily be updated immediately following the publication of this new guidance. In line with the proportionate update process,[8] scheme promoters may however find it is beneficial to implement the new recommendations in WebTAG as the analysis of a scheme develops. In new or redeveloped models, it is recommended that scheme promoters follow the new guidance. This is in order to ensure that the best available evidence is taken into account, and ensures greater consistency with the appraisal VTTS.

1.25 In order to help inform the decision about whether or not it is proportionate to update existing fit-for-purpose models in light of the new guidance, it may be useful for scheme promoters and sponsors to consider the following:

- sensitivity testing - applying the new VTTS in modelling in order to quantify the materiality of the guidance changes to the decision at hand; and
- whether any particular distance profile or user segment comprises a large proportion of demand or benefits and model responses (including trip redistribution effects) for this segment would be significantly affected by an update of the values.

### Detailed consideration for assignment modelling

1.26 For assignment models, in most cases it is unlikely that the improvement in explaining behaviour that would result from moving away from single average VTTS will be great enough to justify the very significant increase in segmentation and model run times. The preferred option in most cases, as set out in the new guidance, will therefore be a single average-distance VTTS. This is no different from the implementation of VTTS in assignment models according to current guidance. For schemes involving tolls, there is also no proposed change to the guidance on assignment modelling, where segmentation of VTTS according to income will continue to be required.

1.27 The new guidance does not mandate this approach however, as we recognise there may be circumstances where it is feasible and proportionate to capture differences in behaviour by varying the VTTS with distance. Although this is currently challenging in terms of discrete distance bands, and infeasible in terms of a continuous function, in the medium to longer term these approaches could be considered if it is believed that they would significantly improve assignment models. This would have the potential to reduce the inconsistency with appraisal - for which, as set out elsewhere in this consultation response,

[8] https://www.gov.uk/government/publications/webtag-tag-proportionate-update-process

guidance now recommends representing the variation of VTTS with respect to distance using a continuous function as the preferred option.

### Detailed consideration for demand modelling

1.28 In the case of demand modelling, there has not been a major change to guidance either. In practice, demand models treat the VTTS in a number of different ways, including:

- single average VTTS;
- single average VTTS with cost damping (various functional forms are recommended in TAG unit M2); and
- distance-varied VTTS (a form of cost-damping).

1.29 We are not making any significant changes to the demand modelling section of WebTAG or mandating any particular method of cost-damping. We are however expanding the available cost-damping methods to include distance-varied employers' business VTTS as an additional option (currently guidance only provides a function for varying non-work VTTS with distance).[9] In the longer-term we may consider research into the application and functional forms of cost-damping functions, in line with the recommendations from the expert practitioner review.

## Other employers' business values of time

1.30 As set out in the consultation document, the new research did not cover the values of time for freight or professional drivers. This reflects the conclusion of the 2013 scoping study in the VTTS for business travellers,[10] which viewed the cost saving approach (CSA) as appropriate for valuing time savings for professional drivers. Therefore, for these modes and journey purposes, the employers' business VTTS continue to be based on the CSA approach.

[9] In the medium term this option will be added to Department's DIADEM software.
[10] Leeds ITS (2013) 'Valuation of Travel Time Savings for Business Travellers: Main Report', Prepared for the Department for Transport, p.136 [pdf], available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/251997/vtts_for_business_main_report-dft-005.pdf

# 2. Non-work values of time

## Consultation question

2.1 The following questions consultation question covered the proposed non-work values of time.

> 7. On the basis of the evidence presented here, and in the research reports, do you agree with our planned implementation of the non-work values of time?

## Response

2.2 There was a mix of views amongst respondents to this question. While some were supportive of the proposal, a number raised some specific challenges. The primary concern was the scale of changes to the 'commute' and 'other non-work' values, as the new research suggests the relative magnitudes of the two values are significantly different to the current guidance. We recognise the scale of the change - in the latest version of the WebTAG data book[11] the commute VTTS is just 13% higher than the other-NW value, whereas it is over twice as high on the basis of the new research. However, the change being implemented in guidance is strongly supported by the new research evidence and in line with the recommendations from the study team. The significantly higher value for commuting time, which is similar to the 0-50 km value for employers' business, could be interpreted as reflecting the increasingly blurred boundaries between work and personal time that are becoming a feature of modern life. This is consistent with the findings from the qualitative research conducted by 2CV, which concluded:[12]

*Working hours are often fluid and the more traditional 'clock on clock off' culture is less and less prevalent. Employees are often managing their own time and workloads, and the focus is more on completing the tasks required rather than the amount of time being spent. Overtime is often not claimed, perhaps not even a consideration, and late working hours become 'part of the job', rather than an exception.*

[11] https://www.gov.uk/government/publications/webtag-tag-data-book-december-2015
[12] 2CV (2015) 'Value of Travel Time: What is really driving business travel decisions', p.11 [pdf], available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470263/dft-vtts-business-qual-final.pdf

2.3 Some respondents advocated further segmentation of the non-work values, on the basis that the broad average currently in guidance obscures important differences between different sorts of travellers, modes and trip purposes. There were also suggestions that the non-work VTTS should also be segmented by distance, as those respondents felt this was supported by the research evidence. We recognise that there is strong evidence for significant differences in VTTS within the 'commute' and 'other non-work' categories, but as set out in the consultation document there are potentially issues of self-selection into modes, as well as difficulties in accounting for the effect of income on variations in the VTTS. This is why one of the key areas of research we will be taking forward is further analysis of the non-work VTTS. Further details of this are set out in section 9 of the consultation document.[13]

2.4 This research will allow us to address the challenges raised in this consultation process, and potentially support a future update to guidance. However, the research values for non-work travel reflect the best, most up-to-date evidence available at this point in time and we are implementing them in WebTAG. This represents a significant improvement on the current values, to which all the above criticisms equally apply.

[13] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470998/Understanding_and_Valuing_Impacts_of_Transport_Investment.pdf

# 3. Uncertainty around the values of travel time savings

## Consultation questions

3.1 The following consultation questions covered uncertainty:

> 8. Do you agree with the proposed range for high/low testing around the values, based on their 95% confidence intervals?
>
> 9. Are there additional data or values (e.g. for different segmentations) that it would be useful for us to make available for sensitivity testing?

## Response

3.2 Respondents were supportive of our proposed sensitivity testing ranges, however some were concerned with the large range for 'other non-work' trips. The proposed sensitivity tests represent the uncertainty estimates around the values and are based on the standard errors in the stated-preference modelling. The range is based on the estimated 95% confidence interval around the mean non-work VTTS. Provision of information about uncertainty around values is driven by the knowledge that this will increase the quality of information provided to decision makers. For example, the best estimate of the value for money for scheme 'A' might be better that scheme 'B' but the uncertainty in 'A' is greater and may carry an unacceptable chance of a much worse outcome. The proposed sensitivity test allows the full range of potential outcomes associated with the estimates of VTTS to be provided, and if the value for money for schemes is robust to the sensitivity tests proposed, then we can have a very high degree of confidence in its conclusions with regards to the appraisal of time savings.

3.3 The new uncertainty bands are wider than in previous guidance, but rather than reflecting a reduction in the accuracy of the valuation approach, they reflect an improvement in the understanding of the uncertainty around the VTTS estimate and a corresponding improvement in the quality of the information that can be provided to decision makers.

3.4 As we are recommending a continuous function as the preferred method of implementing the new employers' business VTTS in modelling, there are potentially implications for the appropriate form of sensitivity testing. In the consultation we proposed different sensitivity test ranges for each distance band, based on the 95% confidence intervals. In principle, the appropriate

sensitivity testing range should vary continuously across the range of the function, but this would be disproportionately complex for most applications. Therefore, the new guidance recommends a constant sensitivity test range of 25%, based on the 95% confidence interval around the average VTTS across the four discrete distance bands in guidance.

# 4. Car occupancy

## Consultation question

4.1 The following consultation question covered car occupancy:

> 8. Do you agree with the proposal to update the car occupancy assumptions in the TAG data book and to project no future change in occupancy?

## Response

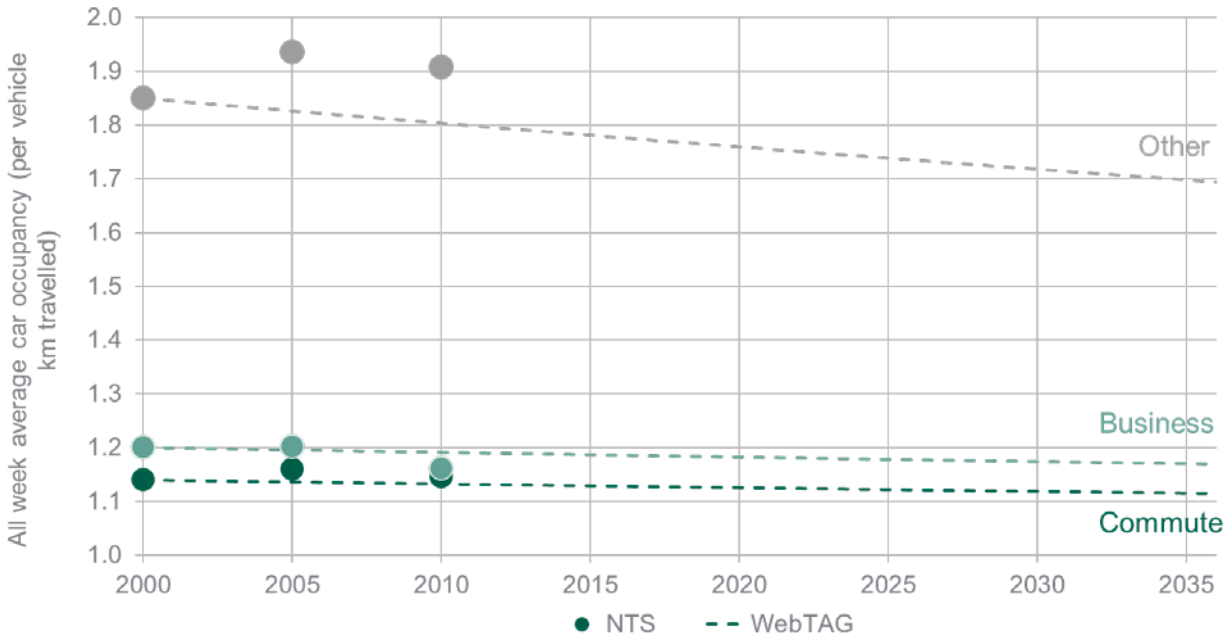



**Figure 1: Car occupancy - previous WebTAG projections against out-turn National Travel Survey data**

4.2 Respondents were supportive of the change to car occupancy assumptions, but also felt it would be worthwhile to continue to monitor the trend in order to ensure guidance remains robust. As set out in the consultation, we will revisit this assumption when more post-recession economic data is available, which will inform future potential updates to guidance.

# 5. Reliability, service frequency multipliers and the value of late time

## Consultation question: reliability ratios for road travel

5.1 The following consultation question covered reliability:

> 11. On the basis of the evidence presented here, and in the research reports, do you agree with our planned implementation of a reliability ratio of 0.4 for car travel?
>
> 12. The reliability ratio of 0.4 from this research, and the reliability ratio of 0.8 currently given in WebTAG, are both for car travel and no explicit guidance is currently given on reliability benefits for freight traffic. In practice, is the 0.8 ratio also applied for freight? And is there any other evidence we should be aware of when considering how the results from this research might or might not be applied to freight?

## Response

5.2 The vast majority of respondents were supportive of the change to the reliability ratio, as a reflection of the best available evidence. A small minority were concerned that it was premature to make such a significant change to the value without undertaking further research.

5.3 However, the evidence base underpinning the previous reliability ratio is out of date and less robust than the new study. The previous value of 0.8 was confirmed at an expert workshop on the value of reliability held in 2004,[14] but is sourced from a 1993 study of the value of reliability in London which had a sample size of 354.[15] The new reliability ratio is based on a much larger sample and more advanced modelling methods than the previous one, so represents a significant improvement in the evidence base for valuing reliability. Furthermore, as a number of respondents noted, the new results are consistent with the recent study into the value of time and reliability in the Netherlands.[16]

5.4 On the basis of the above the new guidance will update the reliability ratio to 0.4.

[14] RAND Europe (2005) 'The Value of Reliability in Transport: Provisional values for the Netherlands based on expert opinion'. Report TR-240-AVV. Leiden: Rand Europe.
[15] Black, I G & Trowiss, J G (1993) 'Demand Effects of Travel Time Reliability'. London: Department for Transport.
[16] Kouwenhoven et al (2014) 'New values of time and reliability in passenger and freight transport in The Netherlands' [pdf], available at: http://eprints.whiterose.ac.uk/84748/7/VOTVORpassengerpaper_v1_3.pdf

5.5 Respondents were supportive of conducting further research into the value of reliability for freight traffic, and offered to collaborate in this area. We will continue to work with our stakeholders to ensure the evidence base for appraising reliability impacts remains robust and up-to-date.

## Consultation questions: service frequency multipliers and the value of wait time

5.6 The following consultation question covered service frequency multipliers and the value of late time:

> 18. On the basis of the evidence presented here, do you agree with our planned changes to guidance on wait time and service frequency multipliers?

## Response

5.7 There were relatively few responses to this question and all those who did directly respond were supportive of our proposals. Therefore, in the new guidance, the wait time multiplier has been revised down from 2.5 to 2.0 in line with the meta-analysis presented in the consultation document. We have also clarified in guidance that PDFH service frequency multipliers, where they have been used for modelling forecasts, are also recommended for use in appraisal.

5.8 Some respondents noted from the Phase 2 research report that there was some evidence of different service frequency multipliers by mode, and recommended we undertake further research to see if these results could be implemented in guidance. As part of our plans for future research, we will consider this topic and explore the possibility of including service frequency multipliers by mode in WebTAG.

## Consultation questions: reliability for public transport

5.9 The following consultation question covered the valuation of reliability impacts for public transport:

> 13. On the basis of the evidence presented here, do you agree with our planned implementation of changes to the average lateness multipliers for public transport?

## Response

5.10 There was a broad spectrum of responses to this question. While some supported the proposed changes, others raised some more general challenges to the methods of valuing public transport reliability in WebTAG. The main issue stakeholders raised was that that the current methods for assessing

public transport reliability (i.e. using late time multipliers) do not necessarily capture the most relevant reliability impacts for high frequency public transport in urban areas. It is contended that in these cases, passengers do not perceive a timetable, and are more interested in the variability of journey times instead. In such instances, valuing reliability by applying the reliability ratio to changes in the standard deviation of travel time would be a more appropriate measure of benefits.

5.11 We accept this challenge, and note that at the extreme (for example many London Underground services) there is essentially no timetable from the passengers perspective, rendering the notion of average lateness less relevant for appraisal. WebTAG already provides a reliability ratio for public transport, although we recognise there is no comprehensive guidance on how this may be applied in practice and note that is currently very rarely used in scheme appraisals.

5.12 Some stakeholders were also not convinced of the rationale for the current link between the values of late and wait time set out in TAG unit A1.3, which underpins our changes to the lateness multiplier for non-rail public transport. As set out in the consultation document, the rationale for the change is that within the Passenger Demand Forecasting Handbook (PDFH) the multipliers for wait and late time for rail are similar. Therefore, in line with the approach currently in guidance, updating the wait time multiplier implies changing the late time multiplier also. We recognise that there is no clear-cut theoretical rationale for this approach, as in principle late and wait time are different things, but there is insufficient evidence for us to justify moving away from our current approach. Furthermore, as figure 15 in the consultation document shows, the resulting multiplier of 2.4 is within the range of directly estimated lateness multipliers from the new research.

5.13 Finally, a small number of stakeholders also felt there was a strong case for placing different late time multipliers on bus compared to other (non-rail) public transport, on the basis of the new research results. While we recognise there is some evidence to support this, the differences are not highly significant. Therefore, for consistency, guidance now recommends a lateness multiplier of 2.4 for all non-rail public transport.

5.14 As part of the ongoing programme of research into the VTTS we aim to revisit our current assumptions regarding lateness multipliers, to ensure they remain up-to-date and reflect the best available evidence.

# 6. Crowding

## Consultation questions

6.1 The following consultation questions covered crowding:

> 14. On the basis of the evidence presented here, do you agree with our plan to continue applying PDFH rail crowding multipliers?
>
> 15. Should it be a priority to provide guidance on valuing crowding reduction benefits for bus and other (non-rail) public transport modes in WebTAG?
>
> 16. Do the crowding levels described in this study offer a suitable basis for that guidance? If not, what metrics to describe crowding levels should be used? And can these be translated or mapped to the levels used in this study?
>
> 17. Are there are other sources of information or research that we should be aware of when preparing guidance in this area?

## Response

6.2 All responses to this question supported our proposals for continuing to recommend the use of PDFH crowding multipliers for rail. Therefore there is no change to guidance on crowding multipliers for rail.

6.3 A number of respondents were also supportive of providing crowding multipliers for non-rail PT, and there is a clear interest from our stakeholders in applying such values when developing business cases. These respondents also felt that the crowding metrics set out in figure 17 were a reasonable starting point for guidance, as many local authorities undertake bus occupancy surveys at this level of precision.

6.4 However, it was also felt that there would be significant value in undertaking further research to map the descriptions used in the survey to vehicle occupancies expressed in quantified metrics, such as passengers per number of seats. One respondent offered to collaborate on research into non-rail PT crowding multipliers and we look forward to continuing to work with all of our stakeholders to develop robust guidance in this area.

# 7. Walking and cycling

## Consultation question

7.1 The following consultation question covered walking and cycling:

> 19. On the basis of the evidence presented here, and in the research reports, do you agree with our proposal to apply values from the motorised modes to walking and cycling?

7.2 The vast majority of respondents supported our proposal to apply the values from motorised modes to walking and cycling. Largely, it was seen as the most appropriate solution in practice, given the research results and some of the difficulties experienced in estimating the VTTS for cyclists. Therefore, the new guidance now sets the VTTS for walkers and cyclists at the same level as the 0-50 km band for business trips, and at the common all-modes, all-distance VTTS for non-work trips. A continuous function has not been recommended for walking and cycling VTTS because no significant distance effects were found in the study.[17]

7.3 Some respondents felt there was potentially a broader body of evidence on the VTTS for walking and cycling that could have been drawn upon, citing a considerable body of past evidence and academic literature that could be investigated. As part of our ongoing programme of research into the VTTS, we will consider reviewing this evidence.

7.4 However, as set out in the following section, respondents generally agreed that there was potentially more added value in diverting research resources to other areas as opposed to walking and cycling, given the relatively low impact of the VTTS on business cases for cycling and walking schemes compared to other impacts such as journey ambience and health benefits.

[17] DfT (2015) 'Provision of market research for value of travel time savings and reliability: Walk and Cycle Report', p.62 [pdf], available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470237/vtts-walk-and-cycle-report-issue-14-aug-2015.pdf

# 8. Other issues

8.1 A number of consultation respondents raised other issues in addition to the specific consultation questions. The key points are discussed in this section.

## Stated preference versus revealed preference

8.2 A number of respondents were concerned with what they perceived to be poor levels of revealed preference validation of the stated preference results from the research. Generally, we agree that validating the VTTS against observed behaviour is desirable as it provides increased assurance for the values. As set out in the consultation document, there was a reasonable degree of corroboration between revealed preference and stated preference results for employers' business VTTS, with the stated preference results lying within the confidence interval of the revealed preference results. Furthermore, as set out in table 5.9 of the Phase 2 report, the revealed preference and stated preference commute values are very close to another, although the revealed preference value is statistically insignificant. The revealed preference value for other non-work trips is also close to the value from the core stated preference games, but again has a low level of statistical significance. This underlies the extremely challenging nature of deriving useable values from revealed preference data.

8.3 As part of the on-going programme of research to ensure the VTTS remain up-to-date, we will explore and consider new methods for collecting revealed preference data to continue to build a strong validation dataset.

## Small time savings

8.4 A number of respondents were concerned with the assumption of a 'delta T' of 10 minutes that has been used to calculate the VTTS. This 'delta T' is the difference between the journey time in the stated preference experiment and the 'reference' journey time (i.e. from the trip the respondent had made). In the behavioural modelling of the stated preference data, this was found to have a positive effect on the estimated VTTS - the higher the 'delta T', the higher the VTTS. However, for the estimation of nationally representative values of time in the Implementation Tool, the values were normalised to a 'delta T' of 10 minutes. That is, they correspond to what the estimated value of time (£ per hour) would be on the basis of a 10 minute time saving.

8.5 The primary concern raised by these respondents was that this approach could misrepresent the VTTS for small and large time savings, which differ substantially from 10 minutes in magnitude. Some respondents cited table 7.9

of the report, which shows significant variations in the VTTS depending on the level of delta T for car, rail and other public transport, as evidence for this. These results reflect the delta T parameters given in table 7.3, which are significant for all modes except bus.

8.6 It is worth restating the rationale for choosing a delta T of 10 minutes, which was the recommendation of the study team:

- Transport appraisals are typically carried out 'at the margin' for an incremental scheme. Therefore, they need to obey the principle of 'adding up' across appraisals i.e. the incremental value of (A minus B) plus the incremental value of (B minus C) should equal the incremental value of (A minus C).
- The values need to be nationally representative, and therefore reflect the full spectrum of sizes of time saving attributable to different kinds of scheme and different modes. As noted in the Phase 2 report, Welch and Williams (1997) judged that although time savings for many road schemes can be small, for other schemes (such as high speed rail) they can be much greater.[18]
- A value of 10 minutes is consistent with recent Scandinavian studies. The Danish study[19] suggested different threshold values of delta T for different modes, though for most modes it was stable between 10-20 min. Based on this they decided that 10 minutes was 'reasonable' for all modes. The Swedish study[20] also found varying thresholds, especially between long and short distances: in the event they decided to use 15 minutes for regional trips and 20 minutes for long distance, though these were essentially arbitrary decisions based on what was felt to be 'reasonable'. In Norway the VTTS for short distance modes turned out to be rather stable at a delta T of 10 minutes, but not for long distance modes. They used the threshold 10 minutes for short distance travel and 15 minutes for all long distance modes, following the reasoning in the UK, Danish and Swedish studies.
- Good practice would suggest that the estimated behavioural models should only be applied within the range of covariate values over which they have been estimated. The range of delta T presented in the stated preference data tends to be on the low side (particularly for bus and 'other public transport', where more than 80% of the values are less than 10 minutes), but for car and rail a reasonable proportion (more than 15%) are above 20 minutes.

8.7 Our best judgement, based on all of the above, is that the arguments in favour of standardising the VTTS on the basis of a delta T of 10 minutes are robust. Therefore, the values now in guidance are based on an average time saving of

[18] Welch, M. and Williams, H.C. (1997) 'The Sensitivity of Transport Investment Benefits to the Evaluation of Small Time Savings'. Journal of Transport Economics and Policy vol. 31, pp231-254.

[19] Fosgerau, M., Hjorth, K. and Lyk-Jensen, S.V. (2007) 'The Danish Value of Time Study, Results for Experiment 1, Note 5'.

[20] Börjesson, M. and Eliasson, J. (2014) 'Experiences from the Swedish Value of Time study', Transportation Research Part A, 59, pp144-158.

10 minutes. It is worth noting that this is a clear improvement on the previous values, where the 'size' and 'sign' effects on the VTTS were not controlled for.

## Local values of time

8.8 Some respondents were keen to be able to derive appraisal values specific to their local area. They accepted that the values now being taken into guidance were appropriate for the UK as a whole, but were concerned these values obscure significant regional variations, which could have detrimental implications for some business cases.

8.9 WebTAG contains best practice guidance for carrying out an appraisal of social welfare, in line with Green Book principles, in a transport context. For non-work time savings, which typically make up a large proportion of the benefits of transport investment, national average values of time should be applied across the country. This is in order to control for variations in the VTTS attributable to income, which do not necessarily reflect true impacts on social welfare. If the values were related to income, investment would be concentrated into high-income areas or modes, and the interests of those on lower incomes, who may already suffer from relatively lower mobility and accessibility, will be given less weight.

8.10 However, for business trips this rationale does not hold and there is therefore in principle greater scope for local VTTS. This is because the VTTS for employers' business trips measures the change in total welfare as a result of quicker business journeys, which includes the economic surplus earned by firms, and potentially residual welfare impacts perceived by their employees Because it is not generally possible to identify the ultimate beneficiaries of this surplus (i.e. the beneficial owners of a firm) in a transport appraisal context, we treat this as a benefit to the overall economy without any distributional impacts. Therefore, segmentation of the employers' business VTTS by relevant covariates (including distance, income and geography) is in principle appropriate for appraisal. In part, the new VTTS, which vary with distance, will capture some of the regional variation in values to the extent they are correlated with distance. In order to compare results across different schemes it is important that the core appraisal a presented using a consistent set of values. For this reason, WebTAG will continue to recommends the use of the same employers' business VTTS (and associated segmentation) for all scheme appraisals.

8.11 WebTAG accommodates the use of local VTTS values for modelling purposes (using constant elasticities for income and distance),[21] but for appraisal the WebTAG values should always be used in the core appraisal.

8.12 In some cases it may be proportionate and material to the business cases to explore local VTTS in appraisal as a sensitivity on the core appraisal. We will continue to work with our stakeholders to explore the potential for spatially disaggregated values of time, but there are a number of challenges that would need to be overcome before regional values could be robustly grounded:

[21] See TAG unit M2, annex C, available at: https://www.gov.uk/government/publications/webtag-tag-unit-m2-variable-demand-modelling

- The behavioural choice modelling underpinning the new values is based on data from a broad spread of locations across the country. Therefore, in principle the estimated relationships between the VTTS and its determinants would need to be re-estimated on the basis of SP data from that region only.
- The implementation tool, in its current form, does not support the calculation of regional values of time. Even if it were modified to include this functionality, the point above about the behavioural modelling would need be addressed or there would be significant uncertainty in the results.
- Data requirements for producing the local values could be onerous. In order to be consistent with the level of detail in the modelling underpinning the new national values, primary data collection for the regions concerned would be required and SP surveys would need to be conducted.

# 9. Future research

## Consultation questions

9.1 The following consultation questions covered our plans for future research:

> 20. Of the options outlined here, where should our priorities lie for further value of time research?
>
> 21. Are there other areas not covered here that we should also be considering?

## Response

9.2 Respondents were interested in all of the proposed areas for future research with the following identified as priority areas by many respondents:

- having in place an on-going programme of research to ensure the VTTS remain robust and reflect the best available evidence;
- making the data available;
- development of estimates of VTTS in congested conditions;
- further research into the valuation of reliability and crowding on non-rail public transport, especially in dense urban areas; and
- further analysis of the non-work values of time, exploring the potential for further segmentation of these values as described in section 8 of the consultation.[22]

9.3 The complete SP and RP survey data that underpins this study is now available on request from TASM@dft.gsi.gov.uk. We hope that the provision of this data for research purposes will support the future development of our understanding of the valuation of travel time savings.

9.4 The VTTS study has resulted in the implementation of a comprehensive and consistent set of guidance changes across the modelling and appraisal units of WebTAG. This represents a significant step forward in our understanding of the valuation of travel time savings and one which has only been possible with the support and help from our stakeholders.

[22] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/470998/Understanding_and_Valuing_Impacts_of_Transport_Investment.pdf

9.5 Over the next 12-18 months we will be taking forward the areas of research set out above, and will report on progress in 2017. We will continue to collaborate and engage with our stakeholders as we progress this programme of work, to ensure that it provides a robust basis for potential future guidance changes and meets the needs of our users.

9.6 All enquires please email TASM@dft.gsi.gov.uk.

# Annex A: Detailed consideration of the derivation of trip distances for calculating VTTS

### Should the VTTS be based on 'network' or 'crow-flies' distance

A.1 The NTS trip distances used in the calculation of the VTTS elasticities represent actual trips, which occur on the network in real life. The 'network' measure of distance is most consistent with this. Crow-fly distances may distort the real distance travelled. Obvious examples are river or estuary crossings, where crow-fly distance can be much lower than actual distance to the nearest bridge. We are therefore recommending in guidance that the network distance should be used as the basis of calculating VTTS for appraisal in most circumstances.

A.2 We recognise that there may be specific circumstances where the architecture of the models prevents the use of the full network distance. These examples may include public transport models where access and egress are not modelled explicitly and only station-to-station distances are available. Others may have a multi-layered structure where access is modelled in a complex way and consistent definition of distance is not available. In such circumstances, guidance now recommends that the most proportionate method of deriving a stable distance matrix should be used. The guidance also makes it clear that if access/egress is not represented, an evidenced adjustment for access should be made (if it is proportionate to collect such evidence), so that distances used in deriving the VTTS reflect true O-D distances.

### Should the VTTS be based on base year distance, without-scheme distance or with-scheme distance?

A.3 When applying the distance relationship for applying VTTS, there is a question about which transport model run should be used to derive the average trip distances used to calculate the VTTS for a given origin-destination pair. In principle, there are a number of feasible options that model year distances could be skimmed from:

- the base year model;
- a modelled forecast year, which could be the without-scheme or the with-scheme case; or
- an uncongested network (representing 'free-flow' conditions).

A.4 The underpinning theoretical rationale for how the VTTS should choose between the base, without-scheme and with-scheme cases depends on the

balance between the extent to which the distance relationship observed in the data reflects:

a. people's individual preferences for VTTS over different distances; and
b. the changing sample composition across different distance profiles.

A.5 The theoretical position is therefore ambiguous, but our best judgement om the basis of the research is that a significant proportion of the variation in the VTTS reflects the latter (the sample composition), so there would be a lack of assurance around the results if allowing the VTTS to vary according to differences in distance between the without-scheme and with-scheme cases.

A.6 Furthermore, derivation of the VTTS in the study was premised on the state of the network as it currently is. Therefore there is a significant degree of uncertainty around the extent to which the relationship between VTTS and distance could change in response to the specific network improvements and indeed many years into the future. For this reason, our best judgement is that the VTTS should also not vary according to differences in distance between forecast years.

A.7 A further practical consideration is that TUBA, a software package commonly used for appraisal,[23] linearly interpolates distance between modelled years. This could lead to un-transparent and counter-intuitive results if the VTTS were allowed to vary in line with these interpolated distances. Therefore, for the purpose of calculating employers' business VTTS, it would seem desirable to maintain a consistent measure of distance across all modelled years and scenarios. This is satisfied by the use of distances skimmed from the base year model. An additional advantage of using the base year distance is that it can be expected to be the most reliable representation of actual behaviour as it is calibrated and validated against real data.

A.8 For the above reasons, in guidance we are recommending that the employers' business VTTS (for car and rail trips) is calculated on the basis of base year distance across all modelled forecast years and scenarios. We recognise that there may be cases where, due to committed schemes coming on-line in a forecast year, the base year distance matrix is significantly different to forecast year distance matrices. For example a bridge to be built in the future could be a committed scheme, which will alter the network structure significantly, but only feature in forecast year networks and not the base year network. In these cases the new guidance will recognise that it may be reasonable to use forecast year without-scheme distance skims instead. However, this approach must be justified and the evidence supporting presented in the forecasting report.

### How should network distance be derived?

A.9 Given the decision to recommend in guidance that the base year matrix is the default source of distances for the purposes of deriving VTTS, there are then a number of further options to consider for how exactly the network distances from the base year matrix are derived for any given O-D pair. These options include:

[23] https://www.gov.uk/government/publications/tuba-downloads-and-user-manuals

1 shortest network distance;

2 trip-weighted (assigned) distance; or

3 distance along the minimum generalised cost route, which could be on a congested or an uncongested network (representing 'free-flow' conditions).

A.10 At this point it is important to consider the practical implications of deriving distance matrices from existing models, the consistency of the application of distance between scenarios and periods, and the consistency with the underlying evidence from the new VTTS study.

A.11 For most highway modelling applications, it is necessary to define a time slice for the base year matrix, and even on an uncongested network there may still be differences between different time slices (different settings of traffic signals, road, lane or turn closures by period). This would yield different VTTS in different time slices, which would mean that the same O-D could have a different VTTS assigned to it in different time periods. This again could lead to un-transparent and counter-intuitive results with no clear link to the underlying evidence on the VTTS. Furthermore, the option of skimming distances from an uncongested network may not be readily available from existing models (currently, common practice is to derive a trip-weighted distance from assigned networks for use in TUBA) or may not be supported by software packages used for modelling.

A.12 Importantly, distances skimmed from an uncongested network would appear inconsistent with the way trips are made in real life (where the network is subject to congestion). As described in para A1.1 above, the NTS trip distances used to calculate the continuous function represent actual trips which occur on the network in real life, and a validated model should generally be the most accurate representation of this.[24] In principle, therefore, the distance used to calculate the VTTS should be based on the average network distances from a converged assignment process. The assignment model will use VTTS to inform the relative sensitivity of time and cost in the assignment, so the average distance depends on the VTTS used for assignment.[25] However, given that the guidance now sets out that the preferred method of reflecting the new VTTS in assignment is to use the average rather than distance-varied value (see paragraphs 1.25-1.26 in the main body of this document), this circularity issue appears to be mitigated.

A.13 Like distances from an uncongested network, average assigned distances from a congested network will also differ by time slice. If implemented by time slice, the distance-varied VTTS would then change for the same origin-destination due to different network definitions and re-routeing which will affect trip distances. As discussed in paragraphs A4 to A6 above, this is problematic because a large proportion of the variation in the VTTS with distance is due to differences between the sorts of travellers travelling different distances, as opposed to people's individual preferences.

A.14 Therefore, we judge it is necessary to have the same VTTS assumptions (in relation to distance) across all time slices, and to achieve this, it is necessary to

[24] See TAG units M2 and M3 for detail on validation standards for assignment and demand models
[25] See TAG unit M3 for detailed guidance on assignment modelling

select a single distance matrix for calculating VTTS. Implicitly, the VTTS from the SP1 results in the new research reflect average levels of congestion across all trips at all times of day (as they are enumerated using a nationally representative NTS sample). Consequently, the 'ideal' distance matrix for this purpose would reflect 'average conditions'. Given that most highway models relate to time periods, a demand-weighted average daily matrix would need to be calculated from time period outputs and this should be necessary only once. Guidance also recommend that it may be desirable, for internal consistency, to symmetrise the matrix by taking the average of both directions, unless there are reasons why distance in one direction should be significantly different.

A.15 In cases where it is not feasible or proportionate to calculate the average 'daily' distance, the most practical way to achieve a stable distance matrix could be to base it on a particular time slice. The inter-peak will typically be subject to fewer model convergence issues due to lower levels of congestion, and is also more likely to offer a more symmetrical measure of distance (not affected by differences between peak and counter-peak direction). However, we recognise that in a number of cases only one or two peak periods will be modelled. In these cases, where proportionate, an average distance across all modelled time slices would be the best approximation to the true average daily distance.

# Annex B: Quality assurance of revised value of time proposals

**Institute for Transport Studies (ITS), University of Leeds**

**28th June 2016**

## Introduction

The Department has commissioned ITS Leeds to undertake quality assurance (QA) of their revised proposals for representing variations in appraisal values of travel time savings (VTTS) by distance. This rapid review has been undertaken by Richard Batley, Andrew Daly, John Bates, Peter Mackie and Thijs Dekker.

## Summary of revised proposals

In their invitation to ITS Leeds to undertake this QA, the Department summarised the revised proposals as follows:

*'The Department is proposing to change the number of employers' business VTTS bands from 3 to 4, as well as introducing a continuous function for varying VTTS with distance as the preferred method. The resulting new distance bands are 0-50km, 50-100km, 100-200km and 200km+, and have been estimated using the Implementation Tool provided to the Department by Leeds ITS in 2015. The continuous function has been estimated in 'R' using the outputs from the Implementation Tool'.*

## Scope of the QA

This QA exercise covers three specific points.

1. Assurance that the proposed use of the function is:
    a. A robust representation of VTTS across distance, in terms of standard of statistical inference and economic theory
    b. Consistent with the Phase 2 research report and recommendations made by the study team
    c. A reasonable, unbiased approach for individual scheme appraisal
2. Quality assurance of the estimation of the continuous function in 'R', covering:
    a. Checking of the 'R' script
    b. Correct use of the *nls* command in 'R' to estimate the function parameters
    c. Appropriate application of econometric diagnostic tests (residual plots) to validate the model's outputs
    d. Correct outputting of the model estimates and application in MS Excel for deriving VTTS for a given distance
    e. Whether the method used for deriving the confidence interval around the continuous function is robust

3. Quality assurance of the calculation of the fourth band (and associated 95% confidence interval) using the Implementation Tool, covering:
    a. Specification of input files
    b. Copying across of appropriate outputs (car and rail EB VTTS) and converting to a 2010 price and value base year

The QA exercise is based upon the following items provided by the Department:

- A draft copy of the updated WebTAG unit (A1.3) on valuing travel time savings.
- A note prepared by the Department's TASM division setting out the detailed rationale for four proposed distance bands and a continuous function.
- 'R' scripts for estimation of the continuous function, alongside the required input files.
- Implementation Tool input and output files for the proposed 4 discrete distance bands.

## Response to point 1 of QA

In responding to point 1 of the QA, we have annotated the TASM note and draft WebTAG with various technical and presentational comments, and also supplied a technical note written by Andrew Daly. Here we summarise the key issues arising from point 1.

### 1a. A robust representation of VTTS across distance, in terms of standard of statistical inference and economic theory

In terms of *statistical method*, we agree with the broad approach employed by TASM for fitting a continuous function to the VTTS generated by the Implementation Tool. We support the choice of logistic functional form over constant elasticity, because of the preferable manner in which it deals with the top and bottom ends of the range.

Whilst supporting the broad approach, our preliminary QA documented several points of detail which warranted further consideration by the Department. Key among these points of detail, we recommended that, having chosen the logistic function, the Department should analyse how well the function fitted the data at the top and bottom ends. For example, if it were shown that the logistic function went importantly below the band average for (say) 0-10 km, then a lower bound could be estimated to constrain the function (which is naturally bounded below at 0). The Department undertook this additional analysis, and it was found that the introduction of a positive lower bound offered inferior fit to the data; therefore the logistic function as initially proposed by the Department was retained. Moreover, we are satisfied that the points of detail identified by our preliminary QA have been adequately dealt with in the final proposals.

With regards to the four proposed distance bands, we feel that these give a reasonable representation of band averages. We note that the significance of the *increase* (i.e. using a one tail test) in VTTS of the 4th band over the 3rd is marginal (92.5%) for car, but significant at 99% for rail. This lends qualified support to the argument that there is sufficient data (i.e. trips of 100-200km and 200km+) to justify these four bands vis-à-vis three. On the other hand, we are mindful that the longest distance band contains only a small *proportion* of the overall trips. The proposed distance bands might thus be seen as balancing these competing arguments.

In terms of *economic theory*, our attention is drawn to the differences between the functions for rail and car, especially in terms of their respective asymptotes. Whilst modal differences per se could be justified, further exploration of the likely underlying reasons for these differences at longer distances (income, employment, etc.) would be useful in building a narrative for the revised proposals.

### 1b. Consistent with the Phase 2 research report and recommendations made by the study team

The Phase 2 report recommended that:

*'the Department should disaggregate VTT by distance or some geography typology (e.g. urban/inter-urban) that reflects differences in distance. This will require further work to identify appropriate distance disaggregations. Such work would involve the use of distance profiles from real scheme appraisals, to explore the full implications of the approximations to the 'real' VTT of the distance-weighted VTT under different distance disaggregations'.*

Reflecting back upon this recommendation, we make a number of observations, as follows.

First, this recommendation covered all purposes, but the Department has ultimately decided to adopt distance variation only for business. We understand that this constitutes a preliminary position, and is subject to change in the event of new insights being extracted from further analysis of the non-work dataset. Whilst it would have been preferable to undertake such analysis before proceeding with a continuous function for business, we support the intention to explore the feasibility of a similar method for non-work.

Second, and following from the previous point, we are struck by the relative attention devoted to business and non-work values within the draft WebTAG guidance, especially given the large changes to the commuting vs. other non-work ratio which are proposed.

Third, we have not been privy to the Department's testing of alternative bandings/continuous functions on real scheme appraisals, and such testing does not therefore inform this QA. Our presumption is that rigorous testing has been conducted by the Department. We recommend that, in the course of responding to the recent consultation, the Department should publish details of this testing process.

### 1c. A reasonable, unbiased approach for individual scheme appraisal

In terms of implementation within practical scheme appraisal, we feel that a key issue is how 'distance' is defined, and in particular how closely this corresponds to the NTS definition of 'reported distance'. This is important whether using distance bands or the continuous function, but arguably becomes more pertinent in the case of the latter. Moreover, it is especially important that, however defined, 'distance' does not change between the base and scheme scenarios – it is this which is most likely to produce worrying results.

Whilst the draft WebTAG recommends the continuous function as the preferred approach, we note that the guidance also allows practitioners to make a case for distance-banded values. We are concerned that this two-pronged approach could invite game-playing.

All of the above points assume that, in practical appraisal, journey purpose data of reasonable quality can be assembled and that definitional distinctions such as those between EB car and OGV are clear to all concerned.

**Response to points 2 and 3 of the QA**

**2a. Checking of the R script**

In essence, the R script works correctly. Our preliminary QA identified a small number of areas where the 'cleanliness' and efficiency of the script might be improved, and these improvements were implemented by the Department.

**2b. Checking the nls command**

The nls command refers to fitting the non-linear regression model specified in equation (2) of the TASM note, which needs an error term like equation (1). The estimated parameters *a*, *b* and *c* correspond respectively to the parameters *L*, $x_{mid}$ and *k* in equation (2). The nls command is correctly implemented, including the respective distance and trip weights.

**2c. Goodness of fit and residual plots**

The R script provides a number of goodness of fit procedures:

- The observed (unweighted) VTTS measures are correlated with the predicted (at the mean) VTTS values from the logistic functions. This is correctly implemented.
- Then a regression is run, where the fitted values are a function of the predicted values. We do not immediately see the added value of this step, but it appears not to be implemented in the TASM note.
- Appendix A of the TASM note produces plots of the fitted logistic values versus their residuals. Due to the non-linear transformation in equation (2) of the note, this plot makes more sense than generating plots of the distance values against their residuals.
- In response to our provisional QA of points 2 and 3, the Department tested for normality and homoscedasticity of the residuals, finding that in both cases the null hypothesis was rejected, i.e. the residuals were found to be non-normal and heteroscedastic. We note that re-estimation of the model with heteroscedasticity-robust standard errors did not however affect inferences regarding statistical significance. We also note that whilst non-normality invalidates the t-statistics associated with parameter estimates, it is unlikely to introduce significant bias into those parameter estimates.

**2d. Correct implementation into MS Excel**

The MS Excel file '*3 - new bands and function.xlsx*' contains various tabs. 'IT output – car' and 'IT output – rail' cover the (unweighted) VTTS values for business trips from the NTS sample for the respective modes. The corresponding distances are reported in miles and kilometres alongside the trip weights. We found no errors in this tab.

The 'IT outputs' tab then summarises the VTTS output for various runs of the Implementation Tool. The runs vary in terms of their inclusion of different distance bands and modes of transport. We were able to replicate all of the included mean values and most of the associated standard errors. For the 0-50km and 50-100km distance bands, the standard errors are not direct outputs of the Implementation Tool, but these appear to be in the right 'ballpark'. We further note that the values in column P rows 10 and 11 appear to come from outside of the Tool, and to be set at an arbitrary level.

The Tab 'Function parameters' correctly copies the parameters from the logistic models. Equation (2) is then inverted to give Dmax=xmid-k*ln(L/VTTSmax -1) and Dmin. The Excel formulae correctly implement these operations. The elasticity parameters and average distances are also correctly implemented. The number of digits used in copying across from R could however have been more consistent in this tab.

The Tab 'Chart calcs' then correctly implements the logistic function, but only provides an unrestricted (i.e. no lower and upper bound) values for the trip weights. The distance-weighted VTTS functions (and figures) are all bounded at 50km and 200km. The remaining columns are not part of this audit.

**2e. Confidence intervals**

The confidence intervals for the continuous function are linearly interpolated from the four distance bands. That is, for trips up to 50km the 27% deviation from the mean is used for both car and rail. For trips over 200km this value reduces to 24% and 22% respectively. The confidence intervals decrease in a linear fashion between these distance bounds.

Judging by the percentage values for the confidence intervals at intermediate ranges, this linear approximation is somewhat crude. An alternative approach might be more appropriate, but would require additional time to be developed.

| | **car** | **rail** |
|---|---|---|
| 0-50km (average across modes) | -27% | -27% |
| 50-100km (average across modes) | -21% | -21% |
| 100-200km | -24% | -19% |
| 200km+ | -24% | -22% |

**3a. Specification of input files**

In replicating the 'IT outputs' tab in QA 2d, we have replicated the relevant input files for the fourth band and retrieved the same results.

**3b. Copying across of appropriate outputs**

Within the Implementation Tool, the NTS data covered a number of years for which the following GDP deflator index was used to uplift the values to 2014 perceived prices. This process can be reversed to get back to 2010 values.

| Year | Factor |
|---|---|
| 2014 | 1 |
| 2013 | 1.017056 |
| 2012 | 1.035261 |
| 2011 | 1.052454 |
| 2010 | 1.074818 |

Source: https://www.gov.uk/government/statistics/gdp-deflators-at-market-prices-and-money-gdp-march-2015-quarterly-national-accounts

However, when contrasting the values from the 'IT outputs' tab (reported in 2014 perceived prices) with the table reported in the TASM note, we observe that all values are also scaled by a factor of 0.953. On querying this with the Department, we understand that an additional conversion has been applied based on the GDP per capita index.

## Conclusion

Returning to the two main points, we confirm that:

- We agree with the Department that there is clear evidence from our work that the VTTS for EB purpose car and rail trips varies with journey length and that this should be represented in appraisal.
- We agree that this variation is best represented by a suitably defined logistic curve; we would prefer to see this continuous function used for all appraisal applications if practically feasible and cost-effective with the values at different distance bands appearing in the WebTAG text as descriptive material.

# Annex C: Incorporating new values of time into modelling

**1. Introduction**

1.1 In response to the publication of research deriving new values of time in October 2015: https://www.gov.uk/government/publications/values-of-travel-time-savings-and-reliability-final-reports, the Department for Transport requires a short 'think piece' on the impact that new values of time savings (VTTS) will have on existing and new transport modelling practice.

1.2 The new values of time have changed from those currently provided in WebTAG. In particular, a key change is the evidence that the VTTS of employer's business trips increases with distance, with values indicated through segmentation of distance bands of < 50km, 50-100km and 100+kms. The VTTS is significantly different by distance banding for this particular purpose. All other purposes have seen changes in values, and there are also some notable changes by mode in the employer's business purpose. In those instances where value of time has decreased for any particular segment, users will tend to be more responsive to cost whilst for any segment that has an increase in value of time, users will be less responsive to cost.

1.3 The value of time for employers' business for short journeys has been reduced from existing guidance, and as a consequence, these travellers will be more likely to choose short routes and be less affected by 'bypass' schemes for example that introduce longer/faster alternative routes.

At the same time the value of time for other non-business travel has also be reduced, whilst the value of time has increased for commute travel. Therefore the net effect will be a combination of plus and minus from different segments by purpose and distance mix for any intervention.

1.4 Clearly, the new values of time will lead to an immediate impact on economic appraisal. The subject of this 'think piece' is limited to issues around modelling which falls into two considerations summarised as follows:

- what to do with existing models that have been calibrated to the existing values of time; and
- how they should be incorporated into models and what opportunities they might present to better reflect travel behaviour when designing a new model.

**2. Interpretation of the VTTS evidence**

2.1 While there are changes to the absolute VTTS, the key methodological change in the new evidence is the statistically significant variation in VTTS for business travel with distance.

2.2 The new research indicates that VTTS increases with distance for all purposes (after allowing for income related effects). This increase is demonstrated to be statistically significant (at 95% confidence level) for business travel. For other purposes the statistical confidence in the research findings is lower. Nevertheless a relationship between VTTS and distance has been reported in previous research evidence. Indeed the previous UK national VTTS research demonstrated a statistically significant relationship which is referred to in WebTAG M2 Appendix C.

2.3 In considering the current research evidence therefore it may be more appropriate to ask

whether the evidence demonstrates that VTTS should not vary with distance. Expressed in this way the conclusion would be identical for all purposes; **there is no evidence to justify adopting a flat function that does not vary with distance for any purposes.**

2.4 While it is not within the scope of this note to review the available literature with rigour, our view is that the balance of evidence is that VTTS increases with distance for all purposes, and that our models should represent this (or that we should justify simplifications). It would, furthermore, unjustifiably add complexity to our models if we sought to make different behavioural assumptions for different purposes where there is no compelling evidence to do so.

**3. Consideration of the new values of time in current models.**

**3.1** The simplest view to take here is that if a current model has been developed past the calibration and validation stage, then that should suffice for use in current modelling work. It may not be appropriate immediately to adjust an existing model to new values of time and carry out a full recalibration of the model, but to incorporate the new values where justified in line with the principles of proportionality at a suitable stage in the study programme. It would be sensible to carry out a sensitivity test on a scheme by scheme basis to understand any possible effect, but not to undertake a full recalibration until a more appropriate stage in the development process where the sensitivity test demonstrates that there are material implications for the scheme. Such a sensitivity test is likely to be delivered at a lower time/resource cost, whilst also helping to mitigate some of the risks from not fully updating the model.

**3.2** Proportionality and the decision to update is a matter of judgement and is inevitably a balance or trade-off between resources and the improvements in accuracy and update would bring about together with the implication of the of the improvements for the interpretation of the interventions tested. Whilst there is no overarching principle on what the balance or trade-off should be for different types of projects and decision points, it would be reasonable to presume that the case for not adopting the latest values of time would be stronger the more it can be shown in general:

● a low risk of a successful challenge to the omission – i.e. low importance of model outputs to affected stakeholders;

● any changes that may be brought about are not material to the decision to be made; and

●the additional time and cost do not offset the risk that decisions are made incorrectly, the risks being presented to the decision maker.

**3.3 We assume that the new values of VTTS will be considered for economic appraisal.** In summary, therefore, there are three potential levels of actions in how the new values of time may be considered in the modelling:

● the current model is sufficient for the stage and decision making required from it; in which case the modeller will need to explain their judgement to decision makers, but no further action would be required beyond considering/using new values of time for appraisal only;

● sensitivity testing adopting the new central values for demand and/or assignment models to better articulate nature and scale of implications; **if the proportion of benefits is small for**

**employers' business, then the errors associated with the existing modelling method are less likely to be material;** the sensitivity testing provides the modeller with evidence to quantify the materiality of changes in VTTS for the model outputs and advise whether model development and recalibration would be justified for a particular intervention;

● if any of the purpose and distance segmentations comprise a large proportion of demand or benefits and or where redistribution effects are particularly important across a range of travel distances, then consideration should be given to developing and recalibrating the model, as next discussed.

**4. How may the new VTTS evidence be considered in developing new models?**

4.1 The purpose of transport models is to provide the information we need to reach informed decisions on whether and how to intervene in our transport systems. Achieving this objective involves striking a balance between:

● the sophistication with which we represent travel behaviour (and transport system performance),

● the cost and time required to develop and apply the models,

● the sensitivity of the decisions to the outcomes,

● the assumptions we need to make, and

● the ability to accommodate forecasting uncertainty in making decisions.

4.2 In discussing the implications of new VTTS evidence we start from a perspective of how this can help us better represent human behaviour. We then reflect on the costs and value of additional sophistication in our models.

**5. What is cost dampening?**

5.1 Our modelling and guidance have evolved over time. For numerous reasons reflecting the knowledge of our industry, the type of interventions we develop models for, the capability of our software, and the type of information we provide to decision makers, we have tended to adopt a simple concept of generalised cost as a linear combination of travel time and cost.

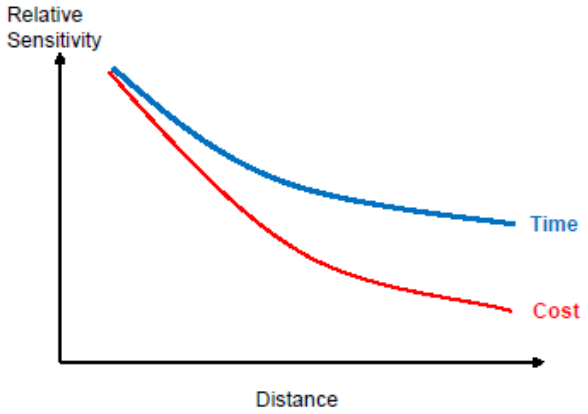
5.2 A typical thought experiment is to consider how a traveller would respond to a one minute or£1 increase in their journey time or cost. It is reasonable to expect that there would be a much larger response for a short 20 minute journey that costs £3 than for a much longer 6 hour journey that costs £100.

5.3 Our models generally apply random utility maximisation theory.[1] This theory states that travellers choose the alternative that they perceive to be best. There is no requirement for the linear formulation. Indeed the 'cost dampening' language in WebTAG M2 recognises the limitations of assuming a linear formulation and describes methods that have been applied to

[1] There are wider considerations of adequacy to represent decision making, and the use of particular model forms, which we are not directly affected by the new VTTS evidence that is the subject of this note

mitigate the inherent deficiencies that are unacceptable in some contexts. Considered in this context, the VTTS evidence can be interpreted, as illustrated, as indicating that travellers' sensitivity to cost declines more rapidly with distance than their sensitivity to time. We conclude therefore that we should express utility functions in our models that:

- imply that sensitivity cost and time declines with travel distance
- that the value of travel time savings increases with travel distance




5.4 That is not to say that we advocate a particular explicit form of function; simply that the models should represent variations in sensitivity cost and time with distance. There appears to be limited understanding in the appropriate form, as evidenced by the range of cost dampening relationships set out in WebTAG M2 and we would **welcome research and guidance looking better to formulate a functional form that better represents the relationship**. This may for example draw on analysis of distribution functions, such as the improved fit offered by the lognormal than a combination of log and linear (tanner) functional form, or on other empirical analysis of the variation in travel behaviour with distance.

5.5 There are some contexts, where the range of travel distances that need to be to be represented in a transport model are limited. This might, for example, apply to some smaller interventions. A modest exercise could be to review the range of travel distances that need to be modelled for particular interventions and justify the use of simpler functional forms (ie with no variation in VTTS with distance).

5.6 While tangential to the discussion here, the research evidence also demonstrates a relationship between income and VTTS; some but not the majority of the variation in VTTS with distance relates to the correlation of travellers' income with travel distance. In expressing the appropriate functional form, care will be required to align the variation with the segmentation represented in the transport model. If a model is segmented by income there will be a smaller increase in VTTS with distance than for a model where demand is not segmented by income.

**6. What do we mean by distance?**

6.1 The next question which will have important practical implications is what we mean by travel distance. The VTTS evidence is based on the length of the trip made. Consider for example introducing a new estuary crossing where there would be a substantial reduction in travel time and distance and there may be new tolls. Which measure of separation is it appropriate to consider: the original route, the new route, or both (with different values of time for the two routes)? Clearly these options would have significant implications for the forecasts, especially

when tolls are considered.[2] **It does not appear that the 2015 research evidence can answer this question and further research may be needed**, there are significant implications both for the modelling and the appraisal.

6.2 It may be necessary to make an interim recommendation. We would not recommend direct use of crow fly distance metrics as this would be inconsistent with the VTTS research. Changes in transport networks, values of time and travel costs would all affect travel distances identified from network models. Further research as indicated above would be needed to form a view of how these changes would affect behaviour. It would seem reasonable to conclude that if we are applying a function that includes travel distance we should reflect the implications for forecasts; that is, if travel distances are forecast to reduce VTTS would also reduce.

**7. Representing VTTS in Demand Models**

7.1 Most UK demand models are implemented using the nested logit approach set out in WebTAG M2.[3] This approach already embraces 'cost damping' as a way of compensating for a linear expression of generalised cost in the logit formulation. A number of 'cost damping' functions are recognised, including the option of varying the non-working value of time by distance. Currently guidance is that employers' business value of time should not vary with distance and this is the critical change evidenced by the new VTTS evidence. We would advocate **that the default recommendations should be for a non-linear utility function** and that the current requirement to justify the use of cost dampening should be withdrawn (WebTAG Unit M2 para 6.4.9). This should represent no fundamental change in practice typically applied for the larger scale models. Provided guidance on the functional form and recommended parameter ranges is prepared, there should also be no change to the model implementation effort required; calibration and realism testing tasks would remain.

7.2 Implementation of this recommendation would involve

- considering options on how best to represent utility functions (i.e. better expressing acceptable functional forms that encapsulate variations in sensitivity and VTTS with distance;
- developing recommended default parameter values for these functional forms, in the short term these could be derived from existing lambda, theta and VTTS parameter recommendations reflecting the changed function form;
- updating the relevant WebTAG unit M2; and
- introducing the revised function and parameters as needed into DIADEM.

7.3 Some demand modelling, particularly for the air and rail industry and in consideration of public transport fares, is undertaken using elasticity models. These are generally applied to reflect modest changes and, if so, should be within the range for which the elasticity is appropriate. There should in principle be no need to change this type of modelling in the light of the new VTTS evidence, although it may be that the evidence can be interpreted to refine the models, allowing them to be applied for a wider change in input assumptions. **We would not recommend the implementation of VTTS variation using discrete distance bands rather than some continuous function in demand models.**

[2] It would also be appropriate, in considering tolled options, to model the distribution in value of time. This does not however affect the question here as there could be different distributions based on the interpretation of travel distance.
[3] TfL's consideration of cross-nested functions would fit within this general discussion.

## 8. Representing VTTS in Assignment models

8.1 In contrast to demand models where there is (generally) considerable flexibility in the formulation of utility functions, assignment models predominantly assume a simple linear function. This may also be an inherent constraint of some, but we believe not all, of the route finding algorithms. There are therefore significant practical challenges in how the new VTTS evidence may be best represented. It would, in principle, seem most appropriate to seek to adopt the same approach and adopt model forms that represent how routeing behaviour varies with travel distance. This will however require **the DfT to encourage software suppliers to develop their products**, and may best be viewed as a medium term aspiration. An interim position is required.

8.2 Many assignment models adopt gross simplifications in the representation of travel costs. Even where fares are represented in public transport assignment models (rather than the associated demand model), few urban public transport models distinguish between concession and standard fares, let alone season and the variety of fare types available. Most area wide highway assignment models assume a typical average speed and vehicle type to estimate an average car cost per Km. In the context where there are significant variations in travel costs between individuals that are not represented in our models, the consequences of more approximate methods to represent the variation of VTTS with distance are uncertain.

8.3 In the interim, feasible options would appear to be the use of a single VTTS for each purpose or to segment the purpose matrices into VTTS bands (related to distance and ideally income variations). One consideration here for larger models will be the model run time implications, which increase approximately linearly with the number of user classes, and whether there are software limitations on the total number of distinct user classes.

8.4 If this approach is adopted, there is a need to consider consistency with the demand modelling. It may be that a weighted average VTTS, reflecting the distribution of demand by trip length (and income where represented explicitly), provides for adequate consistency between assignment and demand models. This is implicitly assumed in current guidance.

8.5 A further challenge is the definition of distance. While it is a straight forward exercise to segment demand matrices based on fixed distance assumptions, if the definition of distance is defined by the model outputs, there would be need for relatively complex matrix manipulation procedures. There would be further complexity introducing methods to segment demand based on route options should there be significant differences in distance between alternative routes. It is questionable whether complex and costly implementation of such capabilities would be warranted in most circumstances. It may be that in advance of additional research indicated above to understand better how distance affects behaviour, it is premature to introduce any form of distance banding. Pending better understanding, **we would not recommend incorporating distance banding to represent VTTS variation in assignment models**. There may be specific instances where such segmentation can be justified, however if so, careful consideration would also need to be given also to the interpretation made to VTTS evidence and to the accuracy with which cost is represented.

8.6 As noted above, given software improvement, we would wish to see the use of continuous functions of VTTS adopted. In the medium term this will address the degree of inconsistency implied in the interim position we propose with different interpretations of VTTS in demand and assignment models. That said the interim position has the same degree of inconsistency as apparent in many models developed under current guidance where ‘cost dampening’ is applied.

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21 March 2016