Specifying the Demand Cap for Rail

A Report to the Department for Transport

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0. EXECUTIVE SUMMARY

Introduction

0.1.1 The aim of this project was to provide "expert technical advice to consider the rationale, theory, evidence, practice and options for representing market saturation within rail demand forecasts." It is intended to inform future updates to the Rail section of WebTAG guidance (Unit 3.13) based on an exhaustive view of all evidence relating to the necessity, specification and practicality of different methods for representing market saturation.

0.1.2 The layout of the report is as follows: Chapter 1 describes the objectives of the project. Chapter 2 sets out the general principles and practice of Cost-Benefit Analysis (CBA) as used for the appraisal of transport schemes. Chapter 3 reviews both the principles and the empirical evidence for "market saturation", an approach which potentially offers an intellectually satisfying resolution. Chapter 4 briefly reports on European practice. Finally, Chapter 5 describes the problem a 'demand cap' is intended to address and discusses the features of potential methods for capping demand.

0.1.3 To inform the project various meetings have been held with DfT officials, HM Treasury, HS2 Ltd and other consultants involved in rail forecasting.

Key Issues

0.1.4 Primarily to reflect the uncertainty as to whether demand for transport will continue to grow indefinitely, a practice has arisen – both for rail and road schemes – whereby demand is "capped" at some time in the future. This capping is currently done in different ways according to the transport mode in question and in certain cases differs according to the scale and lead time of the project.

0.1.5 In implementing a 'demand cap' a number of issues are raised in terms of:

- *Consistency* – whether it is necessary to have a consistent approach in order to compare schemes relating to different modes and of different scales;
- *Benefit Estimation* - unless it is believed that demand will not rise after the cap year, the benefits of schemes are being underestimated;
- *Appropriate Modelling of Saturation* – if evidence of saturation in transport demand exists, this would provide an empirical basis for the specification of the demand cap;
- *Dealing with Uncertainty* – Is a 'Demand Cap' the appropriate manner to deal with uncertainty in demand forecasts?

Study Findings

0.1.6 Forecasting procedures are generally grounded in observations of current or recent behaviour. Models for car demand do incorporate some saturation effects in their long-term demand forecasts, and those for air travel demand have imposed some reduction in growth despite the lack of empirical evidence. There are however, no such restraints on modelling rail demand and there is little evidence of rail demand saturation effects.

0.1.7 This lack of empirical evidence suggests there is little or no theory to support an abrupt halt in demand growth as implied by a 'demand cap'. It is however, true that current rates of growth in rail (and air) travel seem unlikely to continue so a capping approach might be prudent.

0.1.8 The HM Treasury Green Book recommends using a discount rate of 3.5% in policy appraisal and this recommendation is adopted in the DfT appraisal guidance WebTAG. Persistent growth in the drivers of transport demand such as population and GDP may lead to forecast transport demand growing at a rate faster than the 3.5% discount rate; employing a 'demand cap' would ensure a finite estimate of the present value of benefits if the appraisal period was assumed infinite.

0.1.9 There are varying practices in relation to the modelling time horizon in other European countries. The evidence gathered indicated that, of the countries investigated, France did apply some form of cap on demand forecasts. However, in this case the process was not consistent between modes, having been developed separately by the rail and road authorities, and there did not appear to be any clear rationale for it.

0.1.10 Should it be accepted that a 'demand cap' is necessary, then in the shorter term, it might be reasonable to concentrate on comparability between projects **within** the transport sector. This allows us to consider practical modifications which at least give a reasonable account of the priorities between alternative transport investments, particularly for cases where the budget is larger than the average 'scheme' and a portfolio of similarly sized interventions. The aim would be to create a level playing field where this is practical and desirable; this is already achieved across rail schemes by the current rail demand cap outlined in WebTAG 3.13.

0.1.11 In discussing possible solutions, there are a number of possible criteria: practicality, simplicity, transparency, comparability (across modes), stability and interpretability of output.

0.1.12 With this in mind the study considered a number of options to be assessed against these criteria:

- Whether the cap should relate to a level of demand or to a specified year?
- And, if the latter, how should that year be specified?
- Beyond the cap year, should the benefits be allowed to grow:
    - In line with population?
    - In line with predicted increases in value (eg fares, values of time)?

- Not at all?

- alternatively, could we proceed without any "capping", but either incorporate saturation within the demand growth procedures, or rely on supply side constraints to moderate demand growth (or both)?

0.1.13 The merits of the different options depend to some extent on the context of the appraisal. A rule specified consistently across DfT schemes would enable comparison across DfT schemes which are competing for funds. However, this might not provide HM Treasury with a view of the merits of a major transport scheme which is competing for funding with other government priorities rather than purely transport schemes.

0.1.14 We were not asked to produce a firm recommendation. Nonetheless, in the short term it appears necessary to continue with some kind of capping process. Where appropriate we see some merit in proposing that:

- for most schemes, outcomes should be modelled in detail for two years – opening year and "design year" (15-20 years later);

- Results for intervening years should be interpolated using standard methods e.g. TUBA;

- For subsequent years, following current conventions, no further growth should be assumed;

- In addition, beyond the design year, all prices should be frozen in real terms (fuel, fares etc), so that benefits would only increase in line with Values of Time (VoT) and, possibly, population.

0.1.15 In the longer term, we suggest further attention to the process of interpolation and extrapolation, and development of the notion of saturation, in line with the methodology developed for aviation. Nonetheless, we note that this is only likely to play a role in the relatively long term. It is noted that many of the inherent uncertainties – both of inputs and responses – could be captured within a more general risk analysis as advised by HM Treasury.

1. INTRODUCTION

1.1.1 The Institute for Transport Studies (ITS) at the University of Leeds was invited, in a letter dated August 15 2012, to submit a proposal whose main objectives were to provide "expert technical advice to consider the rationale, theory, evidence, practice and options for representing market saturation within rail demand forecasts." It was decided that the project would be headed by John Bates, and the proposal was prepared by him, with assistance from Mark Wardman. Other members of the team were Tom Worsley, Chris Nash and John Preston. The contract was awarded on August 29.

1.1.2 The project is intended to inform future updates to the Rail section of WebTAG guidance (Unit 3.13) based on a complete view of all evidence relating to the necessity, specification and practicality of different methods for representing market saturation. A number of specific questions were raised in the Brief. In order to deal with them, it was proposed that they should be roughly grouped into four topics as follows:

- *Uncertainty* Are there any theoretical arguments for use of demand capping in appraisal? What role does a demand cap play in the presence of social time preference discounting and techniques to treat uncertainty? What evidence is there about the distribution of uncertainty around future rates of demand growth?
- *Saturation* What evidence is there for saturation in the GB market for rail travel? What evidence exists of the extent to which long distance rail demand is driven by its disaggregate drivers and how does this evidence affect treatment of market saturation? What characteristics should an approach to representing market saturation demonstrate? Does the size of project or the year of opening have a bearing on the appropriate approach for representing market saturation? What do the options for the demand cap imply about the shape of the demand curve and the nature of the relationships between demand and key drivers such as GDP, population etc. as market saturation approaches? What techniques are available to ensure market saturation is handled consistently in a multi-modal model?
- *Practice Elsewhere* How does a demand cap for rail compare with the approach used for other modes and by other Departments? What practice is employed in comparable contexts abroad?
- *Other Issues* Would the approach to capping demand growth differ according to forecasting model forms e.g. the presence of supply constraints (crowding/ congestion), journey purpose splits etc? What are the implications of linking (or not linking) the demand and fare caps and what other assumptions could one make? Do the same considerations apply to linking cost growth (inflation) and the demand cap?

1.1.3 To inform the study, various meetings have been held with DfT officials, HM Treasury, HS2 Ltd and other consultants involved in rail forecasting. This is the Final Report of the Project.

2. BACKGROUND

2.1 Principles of Cost Benefit Analysis

2.1.1 Cost-Benefit Analysis (CBA) is the mainstay of project appraisal for the Department for Transport (DfT) and other Government departments and agencies. An essential component of this is discounted cost flow (DCF) analysis, which calculates a "Present Value" of both Benefits and Costs, using an agreed Discount Rate, in order to obtain a Net Present Value, as well as other indicators such as "benefit-cost ratios".

2.1.2 The focus of the work here is on the benefit calculation although some of the arguments apply to the costs as well.

2.1.3 If the benefits in year Y are written as B^Y, then the present value of benefits (PVB) is given as

$$PVB = \sum_{Y} \frac{B_Y}{(1+r)^{Y-W}} \qquad (1)$$

where r is the discount rate, and W is the base year.

2.1.4 While in theory the calculation could be summed over an infinite number of years into the future, in practice this is limited to a finite "appraisal period". This raises the question as to whether any unaccounted benefits at the end of the appraisal period (technically referred to as the "residual value") need to be taken into account. WebTAG also provides guidance on this.

2.1.5 The standard way in which the benefits are calculated is by means of a transport model, as we discuss below. While ideally the model would be run for every year Y of the benefit stream, in practice it is not generally feasible to run the transport model for all years. For this reason assumptions are required about the path of benefits for those years when explicit model runs are not carried out.

2.1.6 The DfT CBA procedures were originally grounded in the appraisal of road schemes. Historically the model was run only for the "design year" of the scheme (15 years after opening) and centrally recommended growth rates were applied to the benefits in that year to populate the other years required for the appraisal. However, following developments in the 1990s, substantial changes in procedure were made. Practice is generally standardised according to the rules set out in WebTAG Unit 3.5.4, the tabular presentation of the "Transport Economic Efficiency" results (TEE table), and the TUBA Manual[1]. These specify that the model be run for the

[1] TUBA is the DfT's software for Transport User Benefit Appraisal calculations

opening year (A) and the "forecast year" (B) ("typically 10 to 15 years after the opening year"[2]).

2.1.7 We focus on the main elements in the TEE table of relevance for modelling – User Benefits [S] and Revenues [R]. We ignore distinctions of purpose and other possible "segmentations", but in practice they will need to be made.

2.1.8 In terms of user benefit there are a number of generalised cost components that need to be distinguished. In particular the TEE table identifies the following items: travel time, vehicle operating costs, user charges (including fares) and operator revenues: we denote these as k. The contribution of component k to the overall benefit in year Y is given as

$$S_k^Y = -\tfrac{1}{2}\sum_{\mathrm{ij}}\left(T_{ij}'^Y + T_{ij}^Y\right)\left(C_{ij}'^Y - C_{ij}^Y\right) \qquad (2)$$

where T is demand, C is (generalised) cost in money terms, and the prime (′) denotes the "after" (with scheme) case. i and j are zones (in practice the summation can be extended over modes and time periods).

2.1.9 Slightly different formulae apply to the revenue components:

$$R_k^Y = \sum_{\mathrm{ij}}\left(T_{ij}'^Y . C_{ij}'^Y - T_{ij}^Y . C_{ij}^Y\right) \qquad (3)$$

2.1.10 Summing over the various components yields the PVB as:

$$PVB = \sum_Y \frac{\sum_k \left(S_k^Y + R_k^Y\right)}{(1+r)^{Y-W}} \qquad (4)$$

2.1.11 Of course, benefits cannot be generated before the opening year of the scheme. According to WebTAG 3.5.4, Y should range over 60 years[3] starting with the scheme opening year. The discount rate is also specified in WebTAG 3.5.4, as explained in para 4.1.4:

"The Green Book provides the discount rate which should be applied over different periods. The discount rate is assumed to fall for very long periods because of uncertainty about the future."

Table 1 Green Book Discount Rates	
Years from current year	Discount rate
0-30	3.5%
31-75	3.0%
76-125	2.5%
126-200	2.0%
201-300	1.5%
301 and over	1.0%

2.1.12 Running the transport model in years A and B allows the calculation of the quantities S_k^Y and R_k^Y. It is clear from the definition of these quantities in Eqq (2) and (3) that they require both demand estimates (T) and

[2] WebTAG module 3.5.4, para 4.2.4

[3] Note that prior to 2002, the appraisal period was 30, rather than 60 years.

(generalised) cost estimates (C). The demand estimates are partly exogenous to the transport model (through population changes and income changes, the latter also affecting car ownership), and partly endogenous, due to supply-side effects. The cost estimates are also partly exogenous (eg fuel prices/efficiency, fares as well as changes in VoT), and partly endogenous (supply-side effects such as congestion and crowding). Thus in the absence of a model run some of the changes are predictable and others are not.

2.1.13 One possible approach to forecasting is as follows (illustrated in Figure 1). In the base year 0 we have an observed demand T_0 and cost C_0 represented by point X. The base year demand and supply curves are constructed to intersect at this point.

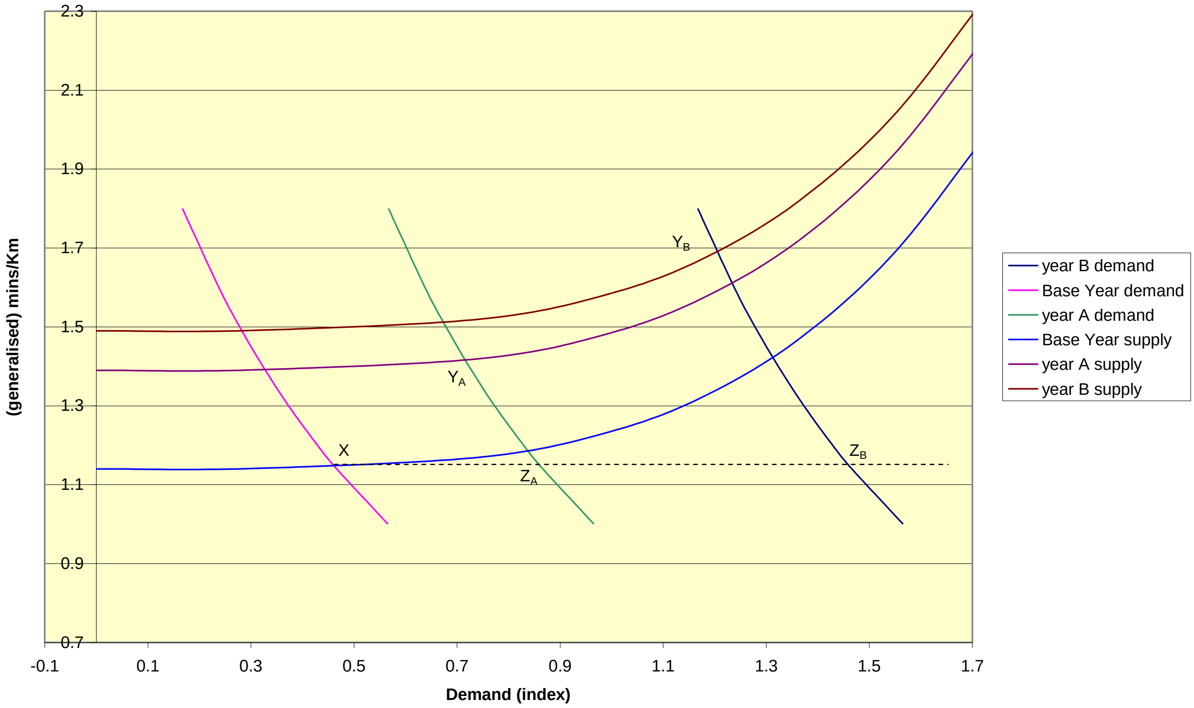

Figure 1 – Illustration of Supply-Demand equilibrium over time

2.1.14 The exogenous increase in demand to the modelled future years A and B is then predicted on the assumption that (generalised) costs remain at C_0 (as shown by the dashed line): this gives the points Z_A and Z_B in the figure, and allows us to locate the future demand curves. However, this is merely the "latent" growth in demand: to obtain the actual demand we have to find the point of equilibrium with the future supply curves. Even if there is no change in capacity, there is still the possibility of exogenous changes in (real) costs: these could be directly related to prices (eg fuel prices, fares) or to changes in the value of time. They are reflected in the shifts (parallel to the X-axis) in the supply curves for the future years, giving rise to the new points Y_A and Y_B.

2.1.15 Purely for the purposes of illustration, we have drawn the curves so that the growth in latent demand is greater between the two forecast years than between the base and first forecast year, while the converse is true for the growth in costs. The result is that the growth in demand from point X to point Y_A is less than the growth from Y_A to Y_B.

2.1.16 A comparable analysis is required to deal with the change in the supply curve resulting from the scheme. This then produces the quantities (T'^Y_{ij} , T^Y_{ij}, C'^Y_{ijk},.C^Y_{ijk}) and allows the benefit components S_k^Y and R_k^Y to be computed as in Eqq (2),(3).

2.2 Practice of Cost Benefit Analysis

2.2.1 The procedure just described refers to the two "modelled" years A and B. However, the quantities (T'^Y_{ij} , T^Y_{ij}, C'^Y_{ijk},.C^Y_{ijk}) are required for each year Y of the appraisal period. Note that it is by no means obvious how the change over time in these components will reflect the exogenous changes in the relevant variables, since the equilibrium process makes it clear that the changes are partly endogenous.

Interpolation

2.2.2 In the absence of such knowledge, the approach taken in TUBA is essentially as follows[4]. Between the years A and B, some of the change from S_k^A to S_k^B is due to the exogenous (generalised) cost changes. For example, the time benefits in year B may be higher partly due to the higher VoT assumed. Any such exogenous cost effects are first removed from S_k^B so that we can define

$$S_k'^B = S_k^B . \frac{p_k^A}{p_k^B} \qquad (5)$$

where p^Y_k is the relevant real value (eg fuel cost, fares, VoT) for component k in year Y (recall the discussion in 2.1.14).

2.2.3 Given this correction, for A < Y < B we linearly interpolate between S_k^A and S'^B_k to get an interim value of S'^Y_k

$$S_k'^Y = S_k^A + \frac{Y-A}{B-A}.(S_k'^B - S_k^A) \quad \text{(etc.)} \qquad (6)$$

and finally, we reinstate the exogenous (generalised) cost changes for the intermediate years:

$$S_k^Y = S_k'^Y . \frac{p_k^Y}{p_k^A} \qquad (7)$$

It can be verified that these formulae will also correctly reproduce S_k^B as the benefits for year B.

2.2.4 Overall, it would certainly be useful to have a better understanding of how the current assumptions – both for interpolation and extrapolation –

[4] Note that this is not intended as a description of the actual calculations in TUBA, but rather of the underlying principles

describe the benefits compared with what might be estimated by a greater number of "modelled years".

The Discount Rate

2.2.5 We now consider the impact of the discount rate. Historically, the discount rate has been well above its current value. In 1969 it was at 8% and at the time of the Leitch Report (1977) it was set at 10%[5].

2.2.6 In the late 1990s the discount rate was reduced to 6%. In the Treasury Green Book[6] in 2002, the risk component of the discount rate was "unbundled" from the social time preference rate (STPR). As a result the recommended discount rate was reduced to 3.5% (and this rate is progressively reduced beyond 30 years as shown in Table 1 above).

2.2.7 As noted in the Preface to the Green Book, this revised discount rate was "based on social time preference, while taking account of the other factors which were in practice often implicitly bundled up in the old 6% real figure. In particular, the new Green Book includes an explicit adjustment procedure to redress the systematic optimism ('optimism bias') that historically has afflicted the appraisal process."

2.2.8 Changing the Discount Rate has implications for the profile of discounted benefits over time. Assuming a discount rate of 10% and a benefit growth rate of 4% p.a., the benefits after 30 years are only worth 17% of current benefits, and the residual value adds another 21% to the total benefits calculated over the 30 year period. Obviously, the lower the discount rate the more likely it is that discounted benefits will increase over time resulting in the Present Value Benefits tending towards infinity: although this is somewhat addressed by finite appraisal periods, the residual value could form a very significant part of the appraisal.

2.2.9 In practice, this puts more weight on the longer term forecasts, which are subject to increased uncertainty on at least two counts: the difficulty of providing the required inputs (in terms of population, income etc) and the lack of knowledge as to how far relationships based on current evidence will continue in the longer term. The introduction of a "cap" on the growth of demand can be seen as a way of addressing this issue.

Extrapolation

2.2.10 In practice, benefits are not usually allowed to rise indefinitely. In the 1991 Report by MVA[7] into the DfT's National Road Traffic Forecasts (NRTF), it was noted that, at least in some cases, the official forecasts were being applied with cut-offs: "In and on the periphery of urban areas, DTp

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[5] There is some interesting commentary relating to growth in benefits and the discount rate in that report (paras 21.38-39):

[6] H M Treasury, The Green Book, Appraisal and Evaluation in Central Government (http://www.hm-treasury.gov.uk/data_greenbook_index.htm)

[7] MVA (1991), A Review of the Basis of the DTp Road Traffic Forecasts, Final Report

forecasts are applied but cut-off at a point representing the capacity of the road network.". The 1994 SACTRA Report notes (para 9.40): "attention has switched to the development of methods such as growth cut-offs, which mimic or proxy variable matrix methods within a fixed matrix framework.

2.2.11 In April 2004, WebTAG Unit 3.5.4 was updated to increase the appraisal period from 30 to 60 years and in respect of the appraisal period the text is essentially unchanged in the 2012 version. A key paragraph is the following:

> "5.4.7 Growth in the magnitude of benefits will largely be driven by growth in usage. In particular, it will generally be reasonable to assume that growth after the last forecast year is not higher than that implied by formal modelling up to the last forecast year. A sensitivity test assuming zero growth from the last forecast year is recommended for most schemes."

2.2.12 Typically, for highway schemes, practitioners make forecasts for the opening year and for 15 years after opening (in line with DMRB[8] 12.2.1 para 2.8.4). Thereafter a zero growth assumption is made although of course the related time benefits continue to rise in line with GDP impacts on VoT, and discount rates are applied. Indeed, the default in TUBA is to assume that after year B, the benefit quantities only change to reflect changes in value. This could be interpreted as an assumption of no demand increase (and hence no supply-side increase in cost), while the costs continue to change in line with exogenous assumptions. Hence the implied formula is:

$$S_k^Y = S_k^B \cdot \frac{p_k^Y}{p_k^B} \qquad \text{for } Y > B \qquad (8)$$

2.2.13 Guidance permits practitioners to assume a further growth factor (the "user-defined change in the magnitude of benefits") although in practice this option is rarely used and the standard assumption for TUBA users is that there is no demand increase after the second modelled year (B).

2.2.14 Figure 2 shows the pattern of discounted benefits for an anonymised highway scheme. The discounted benefits continue to increase up to the design year, and then fall away as the discount rate "trumps" the increase in VoT etc.

2.2.15 The following two paragraphs from WebTAG Unit 3.5.4 are also of relevance[9]:

> "5.4.8 Decline in the magnitude of benefits will mainly be determined by reducing benefits (or increasing disbenefits) per unit of use. It is, therefore, scheme dependent. The approach may be expected to vary by mode. For a highway scheme, for example, time savings per trip may fall as congestion

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[8] Design Manual for Roads and Bridges: this document is now overseen by the Highways Agency. Section 12 relates to the "Traffic Appraisal of Road Schemes"

[9] Note that it is not in fact obvious that capacity problems will have the impact on benefits that is being suggested in these paragraphs

grows. For a public transport scheme, however, time savings may be preserved, but overcrowding may lead to disbenefits.
"5.4.9 Determining the transition from growth to decline (including any intermediate period between the two) will also be a scheme specific issue. In many cases, the growth in demand (which underlies growth in the magnitude of benefits) will lead to congestion or overcrowding and hence to decline in the magnitude of benefits."

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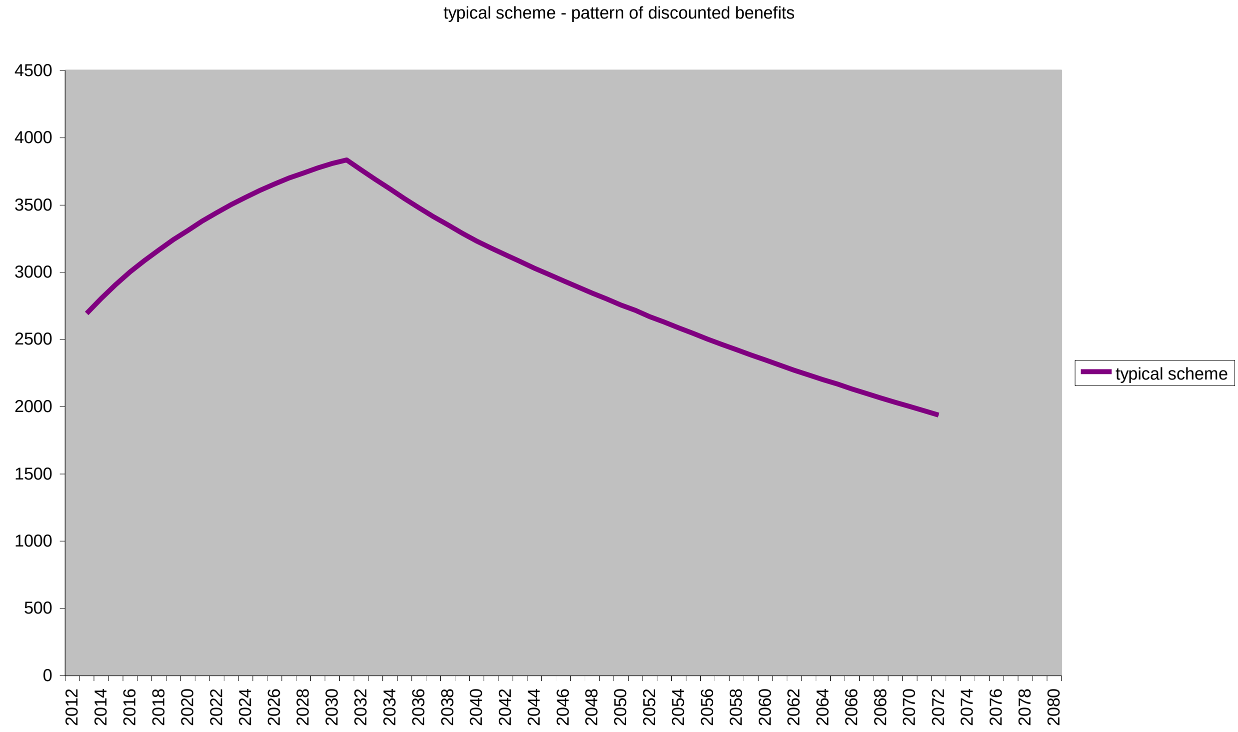

Figure 2 – Pattern of Discounted Benefits for a "typical" road scheme

2.2.16 From this we can see that, on the highway side, the problems of increasing benefits, and the associated possibility of the PVB tending towards infinity, have been addressed in practice by cutting off the growth in demand beyond the second forecast year and by limiting the length of the scheme appraisal to 60 years.

The practice for Rail Appraisal

2.2.17 The rail demand "CAP" was introduced in around 2005 in connection with the Guidance on Major Project Appraisal and was later transferred to the 2007 version of WebTAG Unit 3.13.1, where, as noted in the proposal, it is stated:

"Where demand forecasting in rail is necessary, it is important that in order to ensure consistency between appraisals, demand growth is capped in the year 2026 in the central case. Sensitivities may be presented with different demand caps."

2.2.18 The intention was mainly to create a "level playing field" in terms of assumptions about future demand profiles for the appraisal of rail schemes as well as some issues regarding comparability with other modes. An additional aim was to reflect the large uncertainty around future levels of rail demand.

2.2.19 The demand cap was specified as being twenty years (from 2006) and this seems reasonable, especially given that the majority of rail schemes at that time were projects which could be progressed in the relatively short term. In addition, this approach has the benefit of being simple to implement.

2.2.20 The rail demand cap year remained subsequently at 2026 until the most recent 2012 WebTAG update[10] which ensures that the 20 year period "rolls on" automatically. Paragraph 3.3.1 of the latest WebTAG Unit 3.13.1 states that:

Where demand forecasting in rail is necessary, the Department believes that it is not reasonable to expect that demand will grow indefinitely, and that there should be a final modelled year. For the purposes of appraisal, this means that the Department expects in the majority of cases that demand growth should be capped after a 20 year period from the year the appraisal is undertaken (e.g. an appraisal carried out in 2011/12 would be on the basis of demand capped in 2031/32). Sensitivities of 10 and 30 years of growth should be presented. Under exceptional circumstances, such as with long-term infrastructure projects or where the modelling approach allows, it may be appropriate to use a different demand cap. In these cases advice should be sought from DfT.

2.2.21 The cap is largely used by DfT in assessing rail proposals, though some of the schemes may be advanced by other agencies such as Network Rail (but still following WebTAG Guidance). It is also relevant that, as rail franchises concern periods shorter than 20 years, there is no direct impact of the cap on these. In this context, the emphasis is on uncertainty and simplicity of procedure. The proposed variation of the cap year (in addition to 20 years, 10 and 30 for "sensitivity") is potentially useful for indicating the level of demand necessary to justify the scheme.

2.2.22 The idea of a "demand cap" for rail schemes has some rationale in terms of compatibility with TUBA as practised. The particular difference is that rather than allowing the user as a default to ignore demand growth after the last modelled year, there is a prescription for a particular year, and this is regardless of the opening year. While this is not a problem for the majority of schemes assessed by DfT, substantial capital schemes, especially those where the opening year is a long way into the future, may justify the use of a different approach. The demand cap as currently defined has the potential to make comparisons of BCRs between modes more difficult[11].

2.2.23 It is important to note that neither in the standard TUBA case nor in the rail-specific case is there any implication that demand growth will cease in the assumed year: the practice aims at simplifying the modelling task and

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[10] The most recent guidance became definitive during August 2012

[11] of course the general problems associated with very long run forecasting apply to all modes, not just rail

making some allowance for uncertainty surrounding the pattern of demand a long way into the future.

2.2.24 One potential issue, in this context, is the 3.5% discount rate applied in the HMT Green Book. If one assumes a population increase of about 0.5% per annum, projected GDP/capita growth of 2% per annum and a GDP-elasticity of a little over 1, it is feasible for discounted benefits to continue to rise over time.

2.3 The Approach taken by HS2

2.3.1 The HS2 appraisal also makes the assumption that demand growth will not continue indefinitely, but implements the "cap" in a different way. This is set out, and justified, in the January 2012 document "Economic Case for HS2: Updated appraisal of transport user benefits and wider economic benefits"[12]. Essentially a cap has been implemented on the level of demand "as a proxy for the concept of saturation". In other words, the principle is to cap demand "at a specific level, rather than at a particular point in time".

2.3.2 Aside from some revision in the methodology "in the light of changes in patterns of demand resulting from the updated base year", this means that the year in which the cap is reached is sensitive both to observed changes in demand and to the input assumptions – in particular, forecasts of future economic growth.

2.3.3 Paragraph 10.2.3 of the January 2012 document acknowledges that the Business case is sensitive to the cap assumptions: this is based on a "risk analysis" exercise discussed in the "Risk and Uncertainty" section (§9) of the companion document "The Economic Case for HS2: Value for Money Statement." The more detailed risk analysis shows that the (level of the) cap is also a significant factor.

2.3.4 Moreover, while it might appear that simply putting the cap year further into the future would be unequivocally good for the BCR, this is not in fact the case. If rail fares are allowed to continue to rise, some rail demand will shift to other modes when using a multi-modal demand model. At the same time, however, the relative growth of the other modal markets can benefit HS2 by providing a larger market to capture. In general, the direction of the effect is not clear. This of course raises issues as to whether the cap should be applied to other modes as well.

2.3.5 There are also issues relating to the treatment of rail fares and operating costs: does it make sense, in the HS2 context, to cap demand but assume that real rail fares continue to rise (which potentially generates extra revenue, but strictly – as noted – would shift demand to other modes)? Currently HS2 is applying a "fares cap" in the same year as the "demand cap", so the issues noted above do not apply. In any case, while government currently has a stated policy for rail fares which can be

[12] http://www.dft.gov.uk/publications/hs2-economic-case-appraisal-update/

incorporated into the modelling, this relates largely to ticket types which are not used by Long Distance travellers.

2.3.6 Thus it appears that there are a number of differences between the way the cap has been implemented for HS2 compared with the standard treatment of rail schemes. The use of a defined level of demand, rather than a particular year, means that the cap year alters when the levels of input forecasts (GDP etc) change. There are related questions as to how other modes should be treated and what "background" assumptions regarding changes in benefits (as opposed to demand) should be made over time.

2.4 Summary

2.4.1 The main issues which this all seems to raise are as follows:

- consistency
- benefit estimation
- appropriate modelling of saturation
- dealing with uncertainty

2.4.2 Consistency arises on two fronts – the comparison of schemes relating to different modes, and also the avoidance of counter-intuitive results when using a multi-modal model. For example, if we were to cap rail demand but allow car demand to carry on rising, we would create a rising pool of non-rail demand from which a rail scheme could then extract more benefit.

2.4.3 Unless we believe that demand will not rise after the cap year, it would seem that we are underestimating the potential benefits of the scheme. This becomes more important with a low discount rate. Note that although it is argued that capacity constraints (e.g. crowding) will eventually choke off benefits, this is not self-evidently true. Even if both Do Minimum and Do-Something scenarios become highly constrained, the benefits in terms of cost saving could still be maintained.

2.4.4 An intellectually satisfying approach would seem to be to try and develop the arguments for "saturation" and incorporate these explicitly into the forecasting procedure. Nevertheless, there remains the issue as to how to deal with uncertainty. On this matter, the position of HM Treasury is clear, that the discount rate should be unbundled of any uncertainty elements. The demand cap may then be thought of as a means of reflecting the inherent uncertainty in demand forecasts.

2.4.5 In the next Chapter we review the concept of saturation and assess the evidence relating to it.

3. SATURATION

3.1 Theoretical aspects

3.1.1 Demand for many products is reasonably expected to saturate, and forecasting models often make use of an S-shaped curve (e.g. for consumer durables). There are a number of possible reasons: satiety (law of diminishing marginal utility); insufficient time for consumption; or, supply-side constraints (which might also be reflected in higher prices).

3.1.2 Intuitively this seems likely to be true of demand for travel as well. A saturation level for car ownership – a major driver of travel – has long been included in national forecasting procedures, using an S-shaped curve. This is an example of “demand saturation”, typically associated with a zero income elasticity of demand.

3.1.3 In addition, capacity constraints (congestion) exercise a damping process on the growth of highway-Km driven. Although in principle crowding on the rail system could play a similar role, in practice this kind of capacity constraint is not significant in current rail forecasting procedures, partly because policies of increases in real fares and of supply changes are often assumed (in both the base and the do-something case). On the aviation side, the “unconstrained” demand forecasts are kept in check by capacity constraints on runways and terminals. But these supply side constraints are insufficient to reduce the rate of growth to what would appear to be a plausible increase and so judgement is used to reach an assumption about the rate at which the market matures.

3.1.4 In an ideal world, travel demand forecasts would operate across all modes on a consistent basis, allowing for appropriate drivers of travel demand growth and modal allocation based on differential developments of generalised cost, including capacity effects. Unfortunately, such multi-modal forecasting procedures can fail to reproduce the observed growth in rail travel[13]. This has led to a widespread practice of using separate demand growth procedures for highway, rail and air.

3.1.5 Road forecasts are essentially those of vehicle-km, and conceptually can be decomposed to trips per vehicle (constant, perhaps falling), and distance per trip (which has displayed relatively low sensitivity to factors such as income, fuel prices etc.) Taken together with the car ownership effect these lead to declining rates of growth in vehicle-km. By contrast the forecasting procedures for rail and air are essentially elasticity-driven, based on available time-series evidence, and primarily related to GDP and fares.

3.1.6 Despite various investigations, such as that by Arup/OXERA (2012), no empirical evidence has been found for a decline in income elasticity over time for rail. The currently recommended Passenger Demand Forecasting

[13] See the discussion in §2.2 of WebTAG Unit 3.15.4

Handbook (PDFH) GDP elasticities, all conditional upon the constraints on car time and fuel cross elasticities, population elasticities and car ownership effects, are 1.9 and 0.9 for long distance trips to and from London respectively, 1.1 and 0.5 for long distance and suburban Non London trips respectively, and 1.2 for trips between the South East and London. Given incomes are higher in London than elsewhere, this could be indicative of a saturation effect. However, the greater focus of economic activity on London might actually have driven larger income elasticities of business trips to London. In terms of leisure trips, it is generally felt that increasing discretionary income will serve as a stronger incentive to short stay visits to London by rail than from London, not least because Londoners are more likely to use their cars for trips elsewhere whereas using a car for a trip to London is an unattractive proposition.

3.1.7 There have been variations in the recommended GDP elasticities over time. Comparison with those prior to 2002 are not possible given the different formulation. In PDFH3 and before, a GDP elasticity and time trend were used to forecast demand and in estimation. These GDP elasticities are not comparable with current ones.

3.1.8 The same conclusion has been reached for air (see paragraphs 2.19-22 of DfT (2013)[14]). Of course, supply-side effects can still play a role (crowding, airport capacity), and these are gradually being introduced into forecasting procedures. But aside from these, demand per se is assumed to continue to rise, albeit at a decreasing rate in the case of aviation where an assumption is made about market maturity.

3.1.9 From a theoretical point of view, it seems important to separate supply-side constraints from the demand elements of saturation, though in practice this may not always be easy. For this reason, the concept of saturation is often associated with an income elasticity of zero. The example of car ownership is instructive in this respect.

3.1.10 The NATCOP model[15] consists of separate models for the probabilities of owning at least one car, the conditional probability of owning at least two cars given at least one, and the conditional probability of owning at least three cars given at least two, with the models varying by eight household types (combinations of the number of adults, whether retired or not, and the presence of children) and five area types (largely based on population density). If we use the model parameters, we can construct the implied graph of cars per household against income[16]:

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[14] UK Aviation Forecasts, January 2013. In particular, para 2.21: "In 2010 the Department commissioned a detailed review of the available evidence on market maturity and other factors potentially affecting the relationship between air travel demand and its key drivers from the University of Westminster. Although it was not possible to uncover quantified evidence of how the response to key drivers changes over time, the review did recommend that a set of judgments about the date from which market maturity will take effect and the scale of the impact on the way passenger demand responds to changes in its key drivers be included in the forecast."

[15] MVA Consultancy, Updating National Car Ownership Model, Report for Department for Transport, October 2007

[16] The graph displayed relates to households of type 8 (Three or more adults, with children) in area type 5 (Population density less than or equal to two people per hectare), with appropriate assumptions being made for other background variables

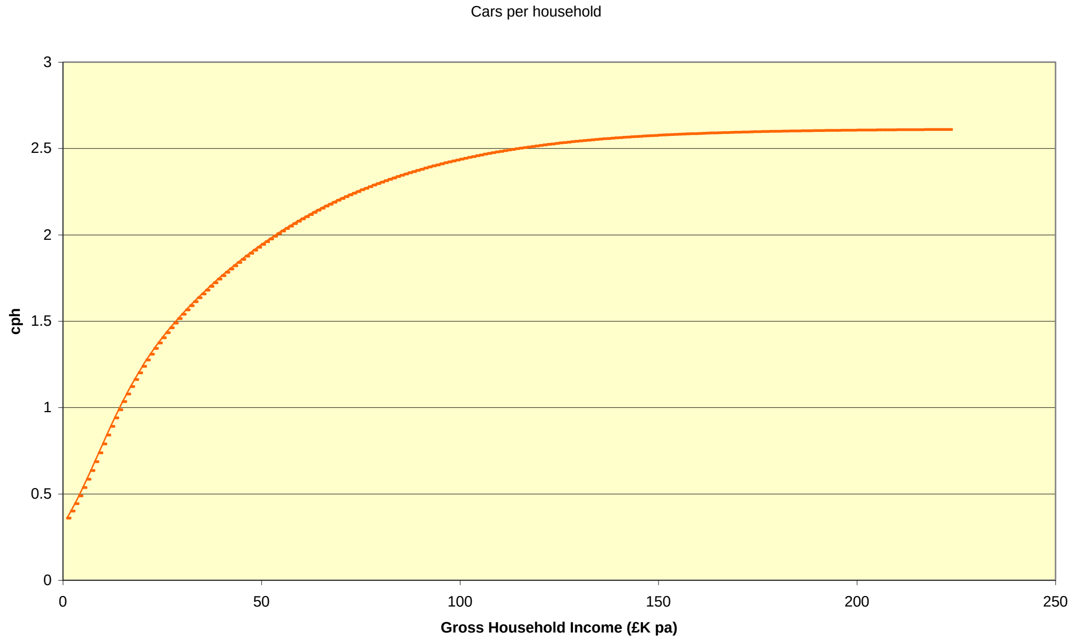

Figure 3 – Illustrative Graph of cars per household against income, from NATCOP Model

3.1.11 The "saturation" effect is very clear, suggesting (for the household and area type illustrated) a maximum level of cars per household of around 2.61, with an income elasticity of zero. Within the model structure, the implications for national car ownership still depend on total population, household structure, and distribution between different types of urban area. These effects are incorporated into the official forecasts[17], where it is noted (3.9):

"There may be a saturation point in car ownership, where rising incomes fail to result in demand for additional cars. However, even if some sections of the market are nearing saturation, there currently appears to be scope for further growth amongst other sections of the population."

3.1.12 In practice, supply side constraints may prevent the saturation level, with its related zero income elasticity, being reached. As noted, these could be related to price effects, but – particularly in relation to travel – they could also be related to capacity constraints and other "technological" constraints, such as the time required for "consumption". This presents the usual econometric problems of simultaneity (or endogeneity) in estimating the demand curve based on time series data. In spite of this, the definition of saturation in terms of the level at which the income elasticity becomes zero has some theoretical value.

3.1.13 In the following sections, we discuss the empirical evidence for saturation for the different modes.

[17] DfT January 2012a, Road Transport Forecasts 2011, Results from the Department for Transport's National Transport Model

3.2 Rail Studies

3.2.1 A vast amount of analysis of rail ticket sales data has been conducted over the past 40 years. The models almost always enter the independent variables with constant elasticities, thus in the form

$$ln(Y_{ftp} / Y_{fTp}) = \sum_k \beta_k \, ln(X^k_{ftp} / X^k_{fTp}) + \gamma(t - T)$$

where Y is the demand, the X variables are possible explanatory variables such as fares or income, f = flow, t = year, p = 4-week period and T is an appropriate reference year

though a feature of the analysis has been the examination of how these elasticities vary across different states. However, the key point to note is that these different states are usually cross-sectional in nature, such as different routes, distances, competitive situations, areas and urban hierarchies[18], and the time series dimension which could, with appropriate model specification, provide insights into possible demand saturation effects on elasticities is often absent.

3.2.2 In contrast to the case for price and time elasticities, there have been no large scale and detailed reviews of GDP elasticities. In any event, though, there are significant difficulties in comparing GDP elasticities from different periods to determine whether there is some trend evident.

3.2.3 Firstly, the models are not comparable. The earlier models, estimated when rail demand is less saturated (if such an effect exists), were based on a GDP elasticity and time trend, whilst more recent models do not contain time trends but sometimes contain various cross-elasticity effects. Given that time trends are not independent of GDP, the GDP elasticities estimated without trends are not comparable with those estimated with trends.

3.2.4 Secondly, even when the more recent models did contain time trends for comparability, or where models with identical specifications can be identified for different time periods, the GDP elasticities would not be comparable unless the effect of non-GDP external factors had been appropriately isolated. This is because the trend effects were generally working against rail in earlier models, due to reducing car running costs, new infrastructure and increasing car ownership, whereas in more recent times the growth in car ownership has slowed down, fuel prices have increased significantly and congestion is much more of an issue.

3.2.5 In PDFH[19], the effect of non-car ownership falls over time as car ownership reaches saturation. Although this is entirely reasonable, it was

[18] We return below to a cross-sectional analysis that we believe could provide useful insights. A good example of analysis of cross-sectional variations in rail elasticities is provided in MVA (2009)
[19] Association of Train Operating Companies [ATOC], Passenger Demand Forecasting Handbook

not directly estimated. Instead it stems from analysis of trip rate data and the relationship between rail demand and whether there was a car in the household.

3.2.6 The few studies of which we are aware that have explicitly examined whether the GDP elasticity is varying in ticket sales models are summarised below.

3.2.7 Wardman and Dargay (2007) conducted analysis of very large data sets of non-season ticket flows. Prior research, which had been incorporated in PDFH recommendations, covered the years 1990 to 1998. To this was added data up to 2005, with one of the aims of the study being to examine inter-temporal variations in demand parameters, particularly in relation to GDP.

3.2.8 In order to isolate effects that might otherwise be attributed to the GDP elasticity, parameters representing the effects on rail demand of car journey time, fuel costs, the level of household non-car ownership and population were constrained to equal best evidence values. Separate models were estimated for long distance London flows, long distance Non-London flows, South East flows and suburban Non-London flows. There was some evidence that the GVA elasticity varied between the initial (1990-98) and new (1999-2005) periods when separate models were estimated to each period.

3.2.9 The study tested whether the GVA elasticity varied over time by pooling the data across the two time periods and allowing the GVA elasticity to vary with time (T) or the logarithm of time. The former allows an elasticity relationship of:

$$\eta = \alpha + \beta T \qquad (9a)$$

which was preferred for long distance London flows. The logarithmic formulation implies an elasticity of:

$$\eta = \alpha + \beta lnT \qquad (9b)$$

which was preferred for all other flows. Significant coefficients for β were obtained in all cases, indicating a time trend to the elasticity.

3.2.10 The implied (absolute) changes in the GDP elasticity over time for the four sets of flows are set out in table 2.

Table 2 – Estimated changes in GDP Elasticities

Year	Long Distance London	Long Distance Non London	South East	Suburban Non London
1990	0	0	0	0
1995	-0.015	-0.013	0.071	-0.114
2000	-0.030	-0.018	0.101	-0.163
2005	-0.045	-0.022	0.119	-0.192

3.2.11 These are small changes relative to the overall elasticities, and at face value imply that with a current GDP elasticity of 1.6, it would take more than 500 years to decline to zero. The results are based on a model which was specified in changes in demand and used weighted estimation according to the size of the flow, as had been done in previous analysis of earlier data. Although the effects appear statistically significant (though note that for the South East the elasticities actually tend to increase), the effects for the two sets of long distance flows became insignificant when the weights were removed. Moreover, in the more traditional fixed effects model[20], the β terms were statistically insignificant for all four sets of flows.

3.2.12 Thus our interpretation is that even under the most 'favourable' set of results, with large data sets and a length of time series that exceeds that for most rail demand models, there was no convincing evidence in this study to support the GDP elasticity falling by a significant amount over time.

3.2.13 MVA (2008) examined a long time-series of ticket sales data from 1980 quarter 1 to 2007 quarter 1. One of the objectives was "to consider the constraints to passenger demand growth brought about by demand (market saturation) and supply (capacity restriction) side factors". The study states that "following exploration of the range of potential explanatory variables using the constant elasticity specification it will be important to explore variation in elasticity over time and across different levels of the variable". Separate models were estimated for long distance, South East and regional flows for seasons, and more importantly from a demand cap perspective, for non-seasons. The study concluded, "From a methodological perspective, the analysis suggests that a constant elasticity functional form is appropriate and there are no substantial structure breaks/ time varying parameters".

3.2.14 However, an emphasis was on whether elasticities (of any type) varied before and after privatisation. Whilst the variable elasticity specification could have indicated the GDP elasticity varying with the level of GDP, it is not clear whether this was in fact tested. Nonetheless, we take this study as indicating that there were no trend variations in GDP elasticities over

[20] A fixed effects model regresses demand (invariably in logarithmic form) on a range of independent variables, also invariably in logarithmic form where they are continuous in nature, and also specifies a series of dummy variables for each flow. These fixed effects serve as separate intercept terms for each flow to account for underlying differences in the magnitude of rail demand across flows due to factors not explicitly included in the model such as the population levels in origin and destination catchments.

time, given the stated objectives of the study and the methods used, since otherwise one would expect such a finding to have been reported.

3.2.15 Most recently a major study into the elasticity based influences on rail demand was undertaken by ARUP and OXERA (2011). From the documents that we have been able to review within the time available, we are not aware of the exact econometric tests conducted that might cast light on how elasticities might vary over time. Nonetheless, their summary concluded:

> *"There is no evidence of market saturation. Assuming that the economy will grow according to trend in the long term, rail demand will continue to increase, and plans will have to be drawn up to cater for this growth"*

They recommend:

> "investigation of market saturation using more disaggregate data—ie, examine the dataset to see whether there are (local) areas or flows where there is evidence of market saturation"

3.2.16 We would support this recommendation. One option to represent this would be to follow the approach set out for air travel demand by the Department for Transport (2011b) by segmenting the GDP elasticity according to local levels of income. If saturation is occurring, we might expect the GDP elasticities to be higher in an area with low average income levels.

3.2.17 All in all, there appears to be little evidence to support the GDP elasticity falling as demand reaches saturation. However, it could well be that any analysis of how the GDP elasticity varies over time has faced a number of limitations that seriously impact on its ability to detect any demand saturation effects (and which make the suggested cross-sectional approach attractive). These limitations are:

- Unmodelled trend effects, such as cohort effects, structural change (including falling values of time on rail due to increased technological possibilities for using travel time for productive or recreational purposes) and environmental concerns
- The failure to accurately isolate other external factors even when they are entered into models
- The use of regional GDP/GVA variables, which could explain why large regional **centres** (eg Leeds) appear to have much larger GDP elasticities.

3.2.18 Note that it is not inconceivable that the GDP elasticity could increase over time. This will occur if rail takes an increasingly large share of new rather than existing traffic and the reasons for it are not accurately modelled. Given that we cannot distinguish between business and leisure trips in ticket sales models, the overall GDP elasticity will increase if the GDP elasticity for the dominant leisure market exceeds the GDP elasticity for the business market. Cohort effects, such as existing generations having a higher propensity to travel than previous ones, could also lead to an upward tendency.

3.2.19 An alternative approach would be to examine trip rates from survey based evidence, such as the National Travel Survey (NTS), to determine variations in the propensity to make rail trips across different income groups and, where there is a repeated nature of the surveys, to examine variations over time. If trip rates do not increase in line with income across different income groups, then we might expect the GDP elasticity to decline over time.

3.2.20 According to Daly (2011), detailed analyses in the context of the work for the DfT's Long Distance Model [LDM] showed no evidence of saturation in the long-distance travel market. While the incidence of such trips is low, there is evidence of significant income effects.

3.2.21 Dargay and Clark (2010) also provide an analysis of NTS for long distance trips. They cover NTS data for 1995 through to 2006 and include both income and trend effects. This work is not so revealing for our present purposes since the linear-additive functional form adopted forces the income elasticity to increase with income levels. The dependent variable was total distance travelled in miles for long distance journeys: a range of variables from variables were used, including real average household income as the measure of income.

3.2.22 The authors state, "Given the linear function used, the elasticities are not constant but are dependent on distance and the level of income. Those reported in this paper are calculated at the mean values of these variables, so the income elasticity is = $\beta Y/D$ where β is the coefficient of income, (Y) and D is distance travelled[21]"

3.2.23 What would have been useful is to tabulate how the propensity to make rail trip rates varies with income, after allowing for other factors, rather than forcing the income elasticity to increase with income which is contrary to the saturation effect. Alternatively different functions could have been used which permitted different income elasticity relationships.

3.2.24 We might expect the sensitivity to fare increases to fall as saturation is approached, since with no response to income we would not expect a response to price either. However, the meta-analysis of fare elasticities reported by Wardman (2011) could not detect any variation in the price elasticity over time, although it did detect a small effect on the price elasticity from the price index for long distance non-season tickets.

3.2.25 In summary, current evidence relating to both the analysis of time-series rail ticket sales data and cross-sectional trip rate data does not provide any support for the GDP elasticity falling as one might expect as rail demand approaches saturation. As has been pointed out, the rail market does not appear to be nearing saturation.

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[21] Y and D are here the mean values of these variables

3.2.26 There might be some possibilities of investigating data from a particularly "mature" market such as Eurostar London-Paris, where demand has been relatively stable over a reasonable period.

3.3 Aviation

3.3.1 As part of their forecasting methodology the DfT issued a useful document "Reflecting changes in the relationship between UK air travel and its key drivers in the National Passenger Demand Model"[22]. The report noted that the term "market maturity" is often used "to refer to the process by which the demand for a product becomes less responsive to its key drivers over time. In the literature, income elasticity of demand (YED) is often used as an indicator of the maturity of a market."

3.3.2 In earlier work a "damping" method had been applied to the unconstrained (constant elasticity) forecasts. From a specified future year onwards, the implied growth rate relative to that year was raised to a power less than 1.

3.3.3 If '0' is the specified future year, t is some later year, then the formula is specified as:

$$P_t^* = \left(\frac{P_t}{P_0}\right)^{-\alpha} . P_t ,$$

where P_t is the unconstrained forecast and P_t^* is the constrained forecast, with α varying by market in the range 0.1 to 0.7. By re-arranging the equation, we can see that the constrained growth between year 0 and year t has the formula: $\frac{P_t^*}{P_0} = \left(\frac{P_t}{P_0}\right)^{1-\alpha}$. However, in subsequent work, the University of Westminster (UoW) recommended against this formulation, preferring "an approach that involves direct adjustments to the income elasticities estimated for each market segment". The work also makes some effort to define the concept of saturation. However, as noted earlier for both rail and air, no empirical evidence has been found for a decline in income elasticity over time.

3.3.4 The current method has moved away to some extent from the UoW approach. They note that "given our expectation that market maturity will cause demand to become less responsive to all of its key drivers through time, not just to income, we propose to reduce the elasticities of demand to its other drivers (e.g. fare) at the same proportionate rate as we reduce the income elasticity." This is not necessarily consistent with the "pure" theory of saturation set out earlier.

3.3.5 Based on an assessment of the different markets, different "start years" ("0") are defined representing the year in which adjustments to the constant elasticities begin. Then the elasticities are assumed to decay

[22] DfT (2011), August 2011, http://assets.dft.gov.uk/publications/uk-aviation-forecasts-2011/key-drivers-npdm.pdf

linearly at a uniform rate over 70 years to a specified end value, which need not be the zero value associated with saturation[23]. For the "central" assumptions, the end value is specified as 0.60.

3.4 Car

3.4.1 We have already discussed the saturation of car ownership. In practice, the NTM (national transport model) does suggest a declining rate of traffic growth post 2020 and more severely after 2025 (see figure 4, based on DfT(2012a)), largely due to this effect, but also due to the demand impacts of congestion.

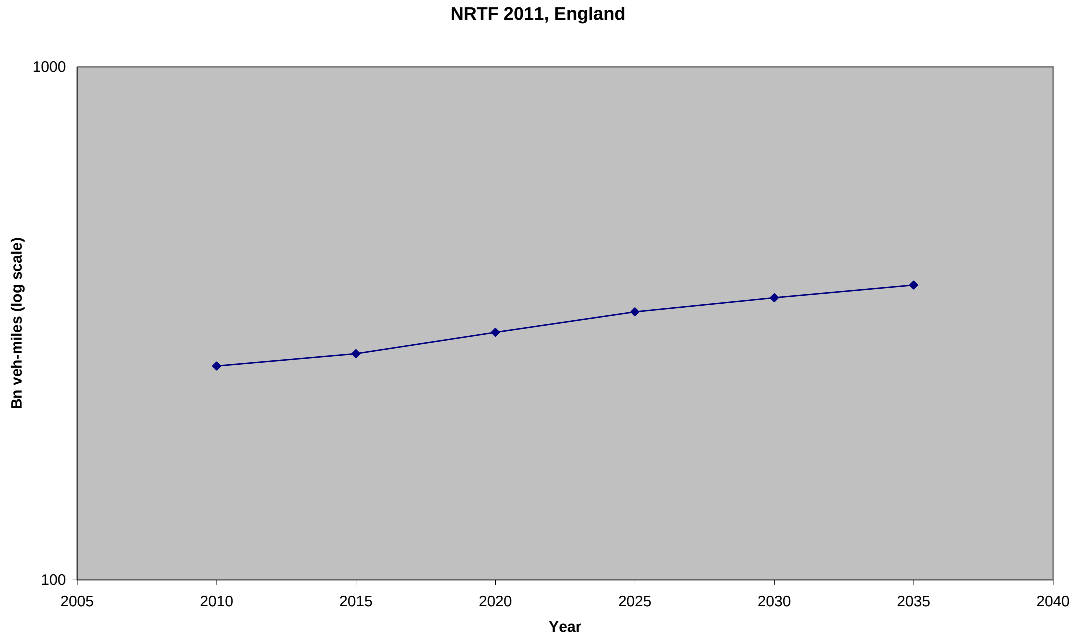

Figure 4 – Official DfT Forecasts for Traffic Growth (all vehicles)

3.4.2 Note that assuming zero demand growth beyond the *de facto* cap year has two countervailing effects: (undiscounted) benefits associated with the additional demand that might in fact arise are ignored, but so also is the possible erosion of time savings caused by the increasing congestion associated with this increase in demand. The net impact on the future stream of benefits is not clear *a priori*.

[23] For various reasons, the models make use of total income (GDP etc) rather than *per capita* income, so that some of the effect can be due to population growth. On this basis it is argued that saturation would be reached when "when the YED is equal to the proportion of income growth that is expected to be related to population growth."

4. FOREIGN PRACTICE (ESSENTIALLY EUROPE)

4.1.1 Within the timeframe available for this project, we have not been able to investigate the different approaches taken by other countries to the issue of demand capping in significant depth. We have therefore drawn on information provided by our academic and industry colleagues in a number of European countries largely within the rail industry. Responses have been received from Germany, France, Switzerland, Sweden and the Netherlands.

4.1.2 It is found that there is generally concern that rail traffic cannot grow indefinitely at projected rates and a slowing down in growth is often predicted (although in Sweden past traffic growth has been under estimated, leading to current capacity problems). In some cases there is concern that models essentially designed for short run forecasting are being projected far into the future. Amongst the reasons given for a slowing down in growth of demand are lack of rail capacity and rising track access charges designed to relieve government budgets.

4.1.3 It is noteworthy that of the five countries responding, only France appears to have some kind of cap on demand forecasts. For rail, RFF assumes that the growth of traffic is halved after 30 years and the appraisal horizon is 50 years, which means that between the 31st year and the 50th year, demand growth is lower in a rather arbitrary manner. The residual value is the book value. For road, it is assumed that traffic growth is constant up to year 50, and afterwards that traffic ceases to grow. The residual value is the discounted value of the future net benefits (which are the same for each year) up to infinity. So the process is not consistent between modes, having been developed separately by the rail and road authorities. So far as we can discover, there is no very clear rationale for it.

4.1.4 Ideally, any differences between countries should be viewed in the more general context of their appraisal procedures, particularly in relation to discount rates and time horizons, and also the growth in the real value of benefits. Such an investigation is well beyond our remit, but the EC HEATCO Project [24] contains some useful information. It is stated in section 3.3.5 of Deliverable 1 of the study[25] that "Nine of the 25 surveyed countries use a discount rate which includes a risk premium, whereas 13 countries (of which four also include a risk premium in the discount rate) use scenario analyses." Given the date of publication, not all the information is necessarily up to date: it may be noted that the UK appraisal period is still described as 30 years rather than the 60 years as currently specified in WebTAG.

4.1.5 The final deliverable of the HEATCO project[26] makes the following observations with regard to the discount rate:

> "there is no convergence on which discount rate and appraisal period to use."

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[24] http://heatco.ier.uni-stuttgart.de/

[25] HEATCO Work Package 3: Current practice in project appraisal in Europe, Jan 2005

[26] HEATCO Deliverable 7: Final Technical Report, submission date: 15 December 2006

and, from a list of 15 "general principles" for CBA, the following three are of interest:

"3. **The project appraisal evaluation period**. We recommend the use of a 40 year appraisal period, with residual effects being included, as a default evaluation period. Projects with a shorter lifetime should, however, use their actual length. For the comparison of potential future projects, a common final year should be determined by adding 40 years to the opening year of the last project.
"4. **Treatment of future risk and uncertainty**. For the assessment of (non-probabilistic) uncertainty, we consider a sensitivity analysis or scenario technique as appropriate. If resources and data are available for probabilistic analysis, Monte Carlo simulation analysis can be undertaken.
"5. **Discounting**. It is recommended to adopt the risk premium-free rate or weighted average of the rates currently used in national transport project appraisals in the countries in which the TEN-T[27] project is to be located. The rates should be weighted with the proportion of total project finance contributed by the country concerned. In lower-bound sensitivity analyses, in order to reflect current estimates of the social time preference rate, a common discount rate of 3% should be utilised. For damage occurring beyond the 40 year appraisal period (intergenerational impacts), e.g. for climate change impacts, a declining discount rate system is recommended."

4.1.6 These general principles are in line with UK practice. However, it would require considerable effort to verify that the numbers and conclusions presented are still valid. The citations from the HEATCO project are merely provided to give some context to the information from the five countries who responded to our enquiries.

[27] This refers to the Trans-European Transport Networks, a planned set of road, rail, air and water transport networks in Europe

5. POSSIBLE SOLUTIONS

5.1 Preliminary Discussion

5.1.1 As we have seen, we are operating in a context where it is not normally possible to conduct transport modelling for a large number of years, and in general we expect to be confined to a maximum of two modelled years, though with the elasticity models typically used for rail studies the problem is less severe. Moreover, each modelled year requires a reasonable amount of input data, relating (at least) to population (at a relatively local level), car ownership (similarly) and income growth (usually at a national level). Official forecasts are available in principle, but they become increasingly uncertain and ultimately unavailable as we move further into the future. In addition, there are requirements to provide supply-side inputs, which also become increasingly onerous.

5.1.2 At the same time, the procedures for forecasting the response to the input variables are generally grounded in observations of current or recent behaviour. As we have seen, the models for car demand incorporate some saturation effects, and those for air have imposed some reduction in growth despite the lack of empirical evidence. There are, however, no such restraints on rail demand forecasts (nor is there any empirical evidence supporting such restraints): growth is forecast to continue at a fixed proportion of predicted income growth (i.e. using constant elasticities).

5.1.3 As we have noted, it is generally considered reasonable that travel demand growth will not continue inexorably, and there is some concern, therefore, that the current methodology may exaggerate the level of future demand, especially in the longer term, where both the inputs and the methodology are more uncertain. This is obviously of particular relevance in cases where the modelled growth in benefits exceeds the discount rate.

5.1.4 Thus, the problems arise from two sources. The first is that it is uncertain that current rates of growth in rail (and air) travel will continue, and yet despite a number of studies looking into this issue there is no empirical evidence of declining growth rates, in particular of a declining income elasticity, which would be reflective of the idea of saturation. The second is that, in the absence of saturation, future benefits may – at least for some components – increase faster than the discount rate, so that there is no prospect of convergence, or of an appropriate treatment of residual value, over any finite appraisal period.

5.1.5 The first issue would ideally be addressed by developing the notion of saturation for rail patronage along the lines of what has been done for aviation forecasts, perhaps by analysing the scope for a reduction in the forecast rate of growth in each of the separate markets identified in PDFH. As far as road traffic is concerned, the existing methodology for car travel is probably sufficient. Nonetheless, even with zero growth in either car ownership or Km per car, increases in population and value of time could contribute to a growth in benefits for highway schemes of the same order as the discount rate (especially as this is scheduled to decline in steps over time).

5.1.6 It is implicit that the problem of calculating a finite project value in the face of discounted benefits that rise over time has been present ever since the change in the discount rate, and in this respect the change of the appraisal period from 30 to 60 years has had no material effect.

5.1.7 Both the rail demand cap and the "default" application of TUBA for highway schemes need to be seen in this context. They can be seen as devices for restricting the rise in discounted benefits over the appraisal period. As such, they can probably be viewed as conservative estimates, but the arbitrary nature of the cap makes it difficult to assess to what extent this is the case.

5.1.8 In the shorter term, this may turn our attention towards concentrating on comparability between projects within the transport sector. Once we acknowledge that this is an important aim, it becomes possible to consider practical modifications which at least give a reasonable account of the priorities between alternative transport investments, particularly for the case with a budget considerably larger than the average 'scheme' and a portfolio of similarly sized interventions[28]. The key requirement is to create a level playing field. Most of the options that we present below can be considered with this in mind.

5.1.9 An alternative might be to assume that downside risks dominate upside ones, especially since, as noted above, the change in the discount rate from 6% to 3.5%/3.0% was made to unbundle risk[29]. An implicit outcome of the approach adopted in the Green Book would seem to be an assumption that the risk of longer term benefits failing to materialise were greater than the risk of underestimating them.

5.1.10 In relation to "standard" highway schemes, we are not aware of any evidence – eg from the Highways Agency POPE database – to indicate a tendency to overestimate traffic volumes - at least in the shorter term. In addition, there is recent evidence regarding forecasting for new rail stations[30], where the study found that in general demand is slightly under-forecast, but not by a consistent factor. There was no evidence of demand forecasting inconsistencies by category of station. On the other hand, there are well documented cases of schemes (eg the work by Booz & Co on HS1[31], and the general evidence adduced by Flyvbjerg[32]) where demand has been over estimated.

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[28] We have had further discussions within the team about the **timing** of options. If there are more projects with good BCRs than can be accommodated within the budget, then an important question for appraisal is which do we do now and which do we postpone? Answering this question requires much less emphasis on long run forecasts, but would require an allowance for the costs of option generation (in particular, property blight), as well as the preparation of a rather larger "pool" of projects than is currently the case.

[29] It does not seem that the risks are fully covered by the adjustment to project costs to account for optimism bias.

[30] see http://www.dft.gov.uk/publications/new-stations-study/ para 11.14

[31] Review of HS1 Demand Forecasts, prepared for:HS2 Limited, London, February 2012.

5.1.11 The available evidence needs to be carefully sifted. For example, in the case of HS1 it appears that the problems were more an issue with inputs (e.g. assumptions around competition) than problems with the methodology itself.

5.1.12 If we ignore the issues relating to discounted benefits that increase over time, then the forecasting requirements can be limited to the issues of extrapolation and uncertainty. In discussing possible solutions, there are a number of criteria: practicality, simplicity, transparency, comparability (across modes), stability and interpretability of output. In what follows, we set out a number of proposals and assess them in general terms against these criteria. In all cases, the discussion relates to undiscounted forecasts of benefit: it is assumed that the existing guidance on the application of discount rates would continue to apply.

5.1.13 While the generation of options for the demand cap is a separate consideration from accounting for uncertainty, the implications of the various options for uncertainty differ and some options would appear to put less weight on the risks of under-provision than others. We discuss the treatment of uncertainty in a later section.

5.2 Options for a Demand Cap

5.2.1 In developing the revision to the earlier WebTAG 3.13.1 Guidance, DfT Rail considered a number of options relating to the Cap. The earlier approach, which might be described as "Periodic adjustment of the demand cap year" was rejected in favour of the use of a rolling demand cap based on a fixed number of years from the appraisal year. We understand that this was justified on the grounds that it removed the need for regularly adjusting the guidance, and coming to a view on saturation when the models were unable to inform this. It also, when used with ranges, provides valuable evidence on the robustness of a scheme's VfM to different lifespans of the current trend of demand growth.

5.2.2 We have expanded the set of options. They are in most cases compatible with the discussion in Sections 2.1 and 2.2, in terms of two forecast years A (base year, usually taken as "opening year") and B ("second modelled year"), and the rules for calculating the relevant benefits in each year within the appraisal period. Note that there is a general assumption that the methods would apply equally to all modes: this is particularly important for appraisals which make use of multi-modal demand models. In addition, the approaches would generally be applied separately for each demand segment – e.g. by purpose, or ticket type, though this is less straightforward for options (such as Option 2 below) where a total level of rail demand is specified.

[32] see references at end

1. Specify a year (the “cap year” **C**), beyond which the forecasting model does not apply:

    a. As a specific year (eg 2027), which is rolled forward from time to time – eg every five years;
    [this corresponds with the earlier rail guidance]

    b. In terms of a given number of years N (e.g.15 or 20) from a base year D, so that C = D + N:

        i. Taking the base D as the year in which the appraisal is carried out [this corresponds with current rail guidance]

        ii. Taking the base D as the year of opening [this is in line with C = D + 15 as the “design year” in the case of road schemes]

        iii. Taking the base D as the year in which the powers are granted to proceed with the scheme – the ‘powers year’

2. Specify a level of demand beyond which no further growth in traffic/travel volumes is assumed: in principle this would need to be done for each mode.
[at least for rail demand, this corresponds with the HS2 approach]

3. Reduce the length of the appraisal period to 5 or 10 years to reduce the risk of uncertainty about future growth having an impact on the BCR and accept that all schemes will show lower BCRs.

5.2.3 For options 1-3 above, there are further sub-options to assume that, after the cap year:

i. The quantity and value of benefits is fixed for all subsequent years, or; $[S_k^Y = S_k^C, Y > C]$

ii. The quantity of benefits is fixed but their value increases in line with the pre-cap relationship – eg the value of non-working time savings increases at a rate of 0.8 * GDP *per capita* growth, as well as increasing fuel prices and fares etc., and/or;
$[S_k^Y = S_k^C.(p_k^Y/p_k^C), Y > C]$

iii. That changes in generalised cost (or GJT) which are part of the overall scheme but implemented after the year of the cap are included in the benefits .
[applies to HS2 under some of the above options]

For each of these sub-options, it would also be possible to assume that benefits would continue to grow pro rata with population: in other words, the cap would be related to *per capita* benefits rather than total benefits. This involves a further multiplier Pop^Y/Pop^C

4. Impose a judgement-based reduction in the rate of growth with the aim of representing saturation (or more generally, with a specific "target" in a specified year):

    a. On the overall growth in demand; [former DfT aviation approach]

    b. On the income elasticity either

    [variants on new DfT aviation approach]

        i. Leaving other elasticity values (eg on population growth) unchanged, or;

        ii. Reducing the values of all exogenous values in the forecasting model, or;

        iii. Reducing all exogenous and endogenous elasticity values.

5. In the case of rail forecasts, assume that demand will revert from now onwards to the long term trend in patronage which, since 1946, has averaged 0.21% pa and assume that this growth rate continues over the 60 year appraisal period.

6. Set no cap and let congestion and crowding moderate the first round forecast of demand growth, separately for the Do Minimum and the Scheme Option.

5.2.4 A final possibility is to acquire sufficient evidence to construct a methodology which leads, with appropriate market segmentation, to a well-based approach to saturation. This could involve effectively estimating the saturation level of the demand cap based on the trends in trip rates of different income groups. As we discuss in the next sections, we do not see this as practical in the shorter term.

5.2.5 The options are not all mutually exclusive, and some of them could be combined. The merits of each option depend in part on the context for which the appraisal is carried out. A rule which provides for an unbiased allocation of the DfT's budget between options and modes and for the prioritisation of these projects might not provide Treasury with a rounded view of the merits of a major transport scheme which is competing for funding with other government departments' projects.

5.3 Discussion

5.3.1 The specification of any particular year as the cap year (Option 1 variants) has the merit of transparency and simplicity although it lacks any theoretical basis. Option (1a), where the year is rolled forward from time to time, could risk incentivising scheme promoters to adopt a game-playing strategy and delay carrying out the appraisal until shortly after the cap has been rolled forward: it would also make it difficult to compare options between years. Adding an additional 5 years to a 15 year appraisal period is likely to have a significant impact on the BCR. This option would seem to score badly in terms of the consistency objective.

5.3.2 Option 1bii, where the cap year is based on the scheme opening year, is consistent with the approach taken for highway schemes, which generally assumes no further traffic growth after the 'design year', usually defined as 15 years after opening. . In those cases where the opening year or the year in which powers are granted (option 1biii) is much later than for the typical project, practical problems of forecasting longer term demand and the supply side changes in the 'without scheme' comparator present certain difficulties, although these can be mitigated by making assumptions about future year generalised costs or GJT on the rest of the network, as we understand is done at present for highway schemes. Further, the 'with scheme' forecasts themselves are also less certain, and thus these options require more attention being paid to the treatment of uncertainty.

5.3.3 Taking the base as the year in which the appraisal is carried out (option 1bi) reduces the period over which forecasts need to be made. But this cannot necessarily be taken to imply a more accurate estimate of the stream of benefits than in adopting an option that caps growth in a later year, even if the latter is the less certain projection.

5.3.4 It seems likely that the year in which the appraisal is carried out will change more frequently than the year of opening or the year in which powers are expected to be obtained: many projects go through several appraisals. Although this is not an insurmountable problem, adopting option (1bi), where the base D is the appraisal year, will in such cases (when the appraisal year changes) require a new appraisal to be carried out with the forecasts extended to cover a further future year. We note that revisions to appraisals are often conducted in respond to changing circumstances such as revisions to GDP and fuel price forecasts or alterations to scheme deliverables and costs.

5.3.5 In arriving at the current (August 2012) position in respect of the rail demand cap, there was some discussion of the relative (dis)advantages of setting the cap year with respect to the opening year (1bii) rather than the appraisal year (1bi). It was felt that (1bii) would tend to favour schemes with later opening dates, typically the larger schemes, by giving them access to greater benefits than smaller schemes due for earlier implementation could claim. This could also create perverse incentives to delay schemes which should be taken forward earlier.

5.3.6 Certainly, the opening year should represent the earliest realistic opening year, and should not be allowed to be varied with the aim of achieving a higher BCR. Ranking the schemes which are to be approved according to their BCRs against a given budget should discourage such behaviour.

5.3.7 Option 2 (specifying the cap in terms of the demand level) is as transparent as the set of options which cap demand in a specific year, and has a better theoretical foundation, because it serves as a proxy for saturation. However, this option might be interpreted as assuming greater knowledge about demand projections, and hence the level beyond which demand will not increase, than the former set. The analysis for HS2 has demonstrated some difficulty in defining which particular demand flows are to be considered for the cap in the context of the scheme. This option provides for consistency with the analysis done to date on HS2, but not with other applications. Moreover, as noted in §2.3, the variable nature of the cap year and the unpredictable impact on benefits can lead to counter-intuitive results.

5.3.8 Option 3, which would take the annuitized project costs and show the present value of the flow of benefits only over the first 5 or 10 years after opening (or after the appraisal year or the year in which powers are granted) avoids the requirement to make longer term forecasts. Given that the current approach invariably shows benefits rising beyond this period, a consequence of this option would be to reduce the BCRs of all transport schemes (thereby risking the benefits of transport investment being underestimated if compared with other programmes). In addition, within the transport sector, this Option is likely to reduce the relative attractiveness of what are generally the larger schemes which provide for anticipated longer term growth and which, because of economies of scale, cannot be delivered on an incremental basis. Nonetheless, by the use of different "lives" in calculating the amortisation for projects with different kinds of infrastructure, this can allow for the longer term effects[33] in a more transparent way than attempting to make long term forecasts of demand.

5.3.9 With regard to the sub-options relating to the assumptions about the calculation of benefits beyond the cap year, Sub-option (i) above has the merit of extreme simplicity, and, as with sub-option (ii), of transparency. The latter is consistent with existing WebTAG guidance for all transport schemes and has advantage of giving some recognition to the increasing real value future generations will put on the benefits of the scheme. Sub-option (iii) requires forecasts to be made for the years after the cap if parts of the project are completed after the cap year. There is a risk that such an approach might be perceived as resulting in a source of inconsistency between projects which are implemented in stages over a long period and the more conventional schemes.

[33] Note that while this alternative would deal with the **costs** relating to projects with different lives, it might not always provide consistency between schemes where the rate of growth of the benefits differs (e.g. one benefitting commuters, with relatively slow growth and another benefitting long distance flows to London, with higher growth)

5.3.10 An assumption that benefits after the cap rise in line with population growth is not necessarily consistent with the forecasting models used for road, rail and public transport schemes. The conventional 4 stage transport model[34] projects growth rates which are influenced by changes in the composition of the population, while the population growth variable for most rail commuting flows relates to the growth in population in the area served by the route in question relative to the growth in the rest of the region. So the inclusion of a simple population growth related increase in benefits after the cap year would be inconsistent with current practice and with the projections of demand up to the cap year. Nonetheless, in as far as some of the growth between years A and B is associated with population change, there is a case for attempting to project this forward, provided that some procedure which better reflects the relationship between population growth and demand during the period prior to the cap is used for this purpose.

5.3.11 With regard to the variants of Option 4, variant (a) certainly has the merit of simplicity when compared with the alternatives under (b). Nevertheless, adopting this simple approach in place of option (b) would be inconsistent with the Department's approach to aviation forecasting and would run counter to the arguments published by the Department in support of the approach..

5.3.12 The Option 4 variants are an attempt to replicate a declining growth in demand on the basis of judgment-based "rules". As we have indicated, the approach which is by far preferable on theoretical grounds would be one of replicating saturation or a continuing reduction in the rate of growth through expert judgement based on cross sectional and other disaggregate analysis. Unfortunately, while this is certainly an option worth examining in the longer term, it is not one that could be delivered within the timescale of this project. Indeed, existing evidence does not suggest any saturation effects and it might be the case that even more extensive analysis might not uncover anything to support expert judgement. In addition it is unlikely to lead to practical outcomes as long as the discount rate remains low.

5.3.13 While Option 5 could be seen as an ultra-conservative approach to rail demand forecasting, there would seem to be no justification for departing from recent evidence on the elasticities estimated for rail patronage and reverting to a long term time trend which incorporates the circumstances and behaviour of past generations. There are also potential problems of consistency with other modes.

5.3.14 Finally, Option 6 by its nature will not address the (short term) problem that the present value of the benefits is likely to increase in each successive year and become very large prior to the 60th year as the growth in demand and in the value of the benefits rises considerably more rapidly than the discount rate. In addition, it is likely to cause difficulties for model convergence.

5.3.15 Although from a theoretical point of view the idea of a cap related to the level of demand could be considered the most appealing (in line with the

[34] that is: trip generation, trip distribution, modal split and assignment

concept of saturation), it is clear that in practice this causes issues of presentation due to the discontinuous impact on the benefit calculations as the implied cap year changes with modifications to input forecasts of GDP, changes to base year demand etc. On this basis, Option 2 has some shortcomings.

5.3.16 In the short term it appears necessary to continue with some kind of capping process (given that this is essentially embedded in current appraisal procedures) and it would help to say:

- for most schemes, outcomes should be modelled for two years – opening year and "design year".

- Results for intervening years should be interpolated using current TUBA methodology

- For subsequent years, following current conventions, no further growth should be assumed (again, in line with TUBA default methodology).

- In addition, beyond the second modelled year, prices should be frozen (fuel, fares etc), so that benefits would only increase in line with VoT (and, possibly, population). Note that the rise with VoT allows for an expected rise in income for future generations: however, as a sensitivity test this could be turned off.

5.3.17 This type of process could be applied to all schemes, by all modes, thus ensuring consistency and avoiding special cases. Where the modelling requires multi-modal forecasts, the "cap" should be applied to all modes. Practical modelling difficulties may however, ensue for schemes with long lead times which therefore involve a demand cap applied long into the future.

5.3.18 However, this would not be regarded as a satisfactory position, merely a holding one. It does nothing to solve the anomalous pattern of benefits (though, of course, this pattern could be "suppressed" by confining the appraisal period to the interval between opening and "design" year).

5.4 Dealing with Uncertainty

5.4.1 In relation to uncertainty, there is a very strong steer from HM Treasury to make use of risk analysis approaches. Given the increased popularity of "fan charts" and the acceptance of the existing DfT risk analysis work on HS2 reported in the document "The Economic Case for HS2: Value for Money Statement.", it can be considered that it has come of age.

5.4.2 A brief review of this work suggests that the risk analysis had correctly identified the two most important input variables that will influence future rail demand – GDP and fares, so that with the proviso that appropriate assumptions are made for the variation in the input variables, the procedure should deliver useful results. It is noted that the key assumption in the overall process was the alignment of future years with the particular levels of rail demand forecast in the two modelled PLANET years. While this seems unproblematic in relation to alternative assumptions related to GDP and/or population growth, it might be less appropriate for alternative rail fare assumptions. Hence, it may be recommended that "the existing procedures be buttressed by the addition of a further PLANET run for the 'first modelled year' in which an alternative (but not unrealistic) assumption about fares post 2015 is made, together with a compensating adjustment in GDP per capita, with the aim of producing approximately the same level of demand."

5.4.3 In regard to the treatment of the Cap, this analysis was based on the existing HS2 approach (corresponding with Option 2 given earlier), and the findings revealed that the outcomes were highly sensitive to the level of demand assumed by HS2 for this purpose. A possible alternative could involve attempting to reflect the uncertainty about the future profile of demand, and specifically the income elasticity.

5.4.4 In line with this, it might be appropriate to follow the general lines of the aviation approach, by which the income elasticity of demand (YED) is successively reduced over time. This requires a) an assumption as to when the reduction is to commence, potentially allowing for different levels of "maturity" among the component markets, b) a target ultimate value for YED (ideally zero, implying "saturation"), and c) the speed of decline (alternatively, the time at which the ultimate level is reached).

5.4.5 A range of values could be elicited (possibly from a panel of "experts") for these assumptions, which could then be combined with the other assumptions relating to inputs (GDP etc). Allowance could also be made for the uncertainty of the base elasticities for income, fares etc. Incorporating all this into a Monte-Carlo based risk analysis procedure would generate an output fan chart.

5.4.6 Nonetheless, it should be noted that unless the 'fan' is skewed well below the 'central' uncapped forecast, the expected real value of the benefits will increase in each successive year (until saturation). Indeed, it would be instructive to examine the allowance that would need to be made for downside risk if, to take an example, the net benefits in year 60 were to be no more than those in year 30, and on a declining path.

5.5 Potential Longer term Research

5.5.1 Essentially the growth in benefits can be viewed along the following lines:

$$\text{Growth in Benefits} \approx \text{Growth in per capita Benefits} * \text{Growth in Population}$$

$$\text{Growth in per capita Benefits} \approx \text{Growth in per capita Demand} * \text{Growth in Value}$$

$$\text{Growth in per capita Demand} \approx (\text{Growth in per capita Income})^{YED}$$

Growth in Value (of time) ≈ (Growth in per capita Income)$^{\eta}$

where η is the elasticity of the value of time with respect to income, conventionally taken as 1.0 for business travel and 0.8 for leisure. Putting this all together, we have something like

Growth in Benefits ≈ population growth * income growth to the power of (YED +η)

YED (elasticity of demand with respect to income) is less than 1 for car travel, but it is greater than 1 for most rail travel. Hence the sum of (YED +η) is certainly more than 1 and could approach 2 in several markets for rail and air.

5.5.2 Hence, a key issue is that even for highways, growth in benefits is expected to continue beyond the design year at a rate greater than the discount rate, which in any case is required to fall over the longer term. Note that the residual value at the end of the 60 year appraisal period is likely to amount to a significant (and in some cases an infinite) sum, which would seem to be at odds with the current recommendation to ignore residual value (see paras 5.2.3, 5.3.4 of Unit 3.5.4).

5.5.3 While an intellectual case can probably be made for the notion of saturation (though proper definition is needed) this is only likely to play a role in the relatively long term – ie well beyond the "design" year. For example, the aviation approach is essentially to define the onset of "market maturity" in terms of when the income elasticity of demand has the value of 1, and to define the year in which this value is reached. Then the saturation value (of income elasticity) is assumed (not necessarily 0) together with the year in which this value is attained (in all cases, this is assumed as 70 years beyond the market maturity date). In practice, the rate of reduction of the income elasticity is applied to the elasticities of all other drivers as well (eg fares) – though the theoretical rationale for doing so is not clear[35]. With time it should be possible to devise something along similar lines for other modes.

5.5.4 In addition, further (modelling) work is required to investigate the appropriateness of the TUBA approach to interpolation. The process of linear interpolation could be challenged – in principle it would be better to use a form of interpolation that reflects the demand growth profile. Implicitly, the current assumption is that, after removing changes in value, benefits rise with demand. This may be a satisfactory approximation, but it is not self-evident. This could be investigated by modelling an intermediate year (between years "A" and "B") and tested in different circumstances (both between modes and between schemes, and above all in cases where significant modal transfer is envisaged): the investigation

[35] In the DfT Aviation note [DfT (2011b)], the justification offered is "given our expectation that market maturity will cause demand to become less responsive to all of its key drivers through time, not just to income" (para 4.2)

could involve both empirical work using existing models and some theoretical work using simple examples.

5.5.5 Any conclusions on possible modifications to the interpolation process should then be extended to extrapolation, whether or not a cap on the growth in demand is being applied at year “B”. There is also scope for investigating the sensitivity of PVB to alternative approaches to extrapolation (e.g. along the lines of the sub-options in paragraph 5.2.3).

5.5.6 This would help to give a more robust and realistic impression of the profile of benefits which could be applied to the standard two modelled years. In the course of doing so, it would indicate whether the current cap assumptions are indeed likely to underestimate the level of benefits.

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