Final Report

Impact of Induced Demand on Benefits

A ‘Think-Piece’ for the Department for Transport

Transport Appraisal and Strategic Modelling Division

Phil Goodwin

Emeritus Professor of Transport Policy
University College London and University of the West of England

philinelh@yahoo.com

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Preface

This is a technical report, but it has very strong policy implications. In a sentence, I confirm that the core problem established by SACTRA over 30 years ago still exists: building extra road capacity to solve congestion from increasing traffic is likely to induce extra road traffic, which receives benefits itself but causes additional delays and environmental costs to others.

The most interesting recent research has extended this to other transport interventions, including those intended to reduce traffic, and impacts not only on vehicle traffic but also on walking, cycling and public transport. Taken together, there is a complex pattern of the costs and benefits of the interaction of transport and planning policies: some of these strengthen, rather than offset, the intended benefits, especially in relation to sustainable and public transport, demand management, and multi-modal transport planning. There are therefore very important consequences not only on congestion, but also on environmental costs, and the effects are as important for the objectives of the Committee on Climate Change, Active Travel England, and local government planning departments, for example, as for highways agencies.

I am very grateful to Iven Stead, Head of Integrated Transport Economics and Appraisal at the DfT, who has been a supportive, thoughtful and well-informed project officer, and the contact group of DfT officials and related experts and professionals who have commented on my drafts at a technical workshop and online. I list them with gratitude in the Appendix. Their advice has been invaluable.

It may be helpful for readers to know that there was some controversy in the contact group on the questions of assignment modelling (now mostly or potentially resolved), and on a suggestion to abandon the word ‘induced’ and replace it by a phrase like ‘variable demand modelling’, which I have not followed. There was no particular controversy or objection in principle to my recommendations for two major changes in practice: I argue that the assumption of zero induced traffic for goods vehicles is theoretically and empirically untenable; and that the POPE retrospective evaluations of induced traffic outcomes need to be comprehensively recalculated. There is interest, but not yet convergence, I would say, about dynamic effects over time, and how to assess them, and some proposed new econometric analysis should help this.

Of course, I must make the caveat that the text of this report, the conclusions and advice, are solely my responsibility and do not necessarily reflect the policy of the Department for Transport or any other organisations and individuals. I am also in awe of the breadth of new work – I hope fairly reflected in the list of references – which I have relied on. Apologies to the authors of other relevant references which I have not cited, and I hope this will emerge in responses to publication of this work.

Phil Goodwin
Emeritus Professor of Transport Policy
University College London and the University of the West of England May 2026

Summary of Main Conclusions

1. Transport demand varies in response to many different external influences. Where these are expected to cause road traffic growth, there are often plans to provide extra road capacity to cope with it. For a period this extra capacity will reduce costs, in time and money, which will itself trigger more traffic growth, called 'induced traffic', The travel which makes up this induced traffic is there because it receives benefits. There is generally the potential for similar induced demand for all modes and contexts. The process also applies in reverse, when road capacity is reduced, or reallocated to public transport, active travel or other functions.

2. In the case of appraisal of expansion of highway capacity, the induced traffic can cause additional costs to other road users, and indeed other non-road users also, particularly congestion, environmental, social and other costs. These extra costs can be greater than the benefit to the induced traffic. But in other circumstances there can be induced demand without imposing such additional costs, indeed sometimes bringing extra economic, health, environmental other benefits. There is a good evidence base with qualitative and quantified results from many countries and contexts.

3. **Models.** The analytical traditions demonstrating and measuring these effects include two 'classic' models. They are

    - A simplified economic model of the relationship between demand, often defined as traffic volume, and cost, in terms of time and money. Lower cost increases traffic, but more traffic causes congestion and increases cost.

    - A very detailed suite of models intended (a) to forecast demand for travel across the network as a whole, and (b) traffic and network conditions (speed, delay) on every separate link and through every junction in a network, resulting from external trends including prices, incomes, demographics, land use and other changes, for around 35 years into the future, extended to 60 or sometimes 100 years. Such a model can then be used to estimate how much this traffic will be increased further by provision of additional road capacity, and from which other alternatives (modes, other activities, destinations, time periods) this traffic is attracted. Even when there are no effects on the total volume of traffic, there can be similar significant impacts of changes in its structure, eg as between different times of day.

4. Induced demand matters because it affects **forecasts** (including expectations about policy issues and suitable options), **appraisal** (ie the modelled calculation of costs and benefits of projects) and retrospective **evaluation** (what actually happened, compared with what has been forecast). It can make a difference to whether schemes or policies should be approved, rejected, or changed. If no account is taken of induced traffic effects, the tendency will be to *overestimate how bad* the conditions will be without

the project, and to *overestimate how good* they will be with the project, both therefore exaggerating the benefit. Therefore it is also essential to calculate the effects of variable demand on the do-minimum or baseline case.

5. **Hypercongestion.** There have been concerns that some classic demand models used in transport assume that some roads can accommodate more traffic than is realistic. There have been DfT warnings in the past that this could be a source of bias, but no clear evidence has been collected about the incidence or effects of this bias. Most modellers report that with care there need be no problem of bias, but there are still problems especially about the time scale of effects. I suggest a small research project.

6. **Limiting Cases**. Normal demand curves are in a range of different sensitivities or elasticities – the more elastic, the more induced traffic. The advisory committee SACTRA in 1994 considered two so-called 'limiting cases' of vertical and horizontal demand curves, and their effects on the benefits and costs of induced traffic. I suggest that the arguments reported about them by SACTRA are questionable, and do not now support some of the conclusions stated:

   - **Vertical demand curves and goods traffic.** At times in the past it was assumed that there was no induced traffic, and this was represented by a vertical (fixed) demand curve. Although this is now normally rejected for personal travel, long established freight modelling practice is still to assert that there is fixed demand, with no induced traffic, for LGVs or HGVs. This is not supported by the substantial body of evidence now available, and is not tenable in terms of commercial and operating practices. There should be a high priority for further work on serious long-term change in freight modelling, and also urgent practical development of short term approximate adjustments meanwhile. Similar assumptions of fixed demand for personal travel are also sometimes applied to 'small projects' on the argument that such effects will be too small to be important, but this can cause problems of scaling, consistency, and potential for bias. Calculation of measures of benefit based on consumer surplus do not work in the theoretical case of vertical demand.
   - **Horizontal demand curve**. This was thought to be of interest in the case where there is so much induced traffic that there might be no benefits at all, new road capacity instantly filling up and returning to the previous conditions. This approach does not produce a realistic or useful result, and does not offer a sensible way of defining conditions of zero benefit. It is more useful to consider this in the context of mode interaction.
   - **Interaction of modes**. However, other more useful developments in induced demand theory and practice (multi-modal programmes, positive feedbacks sometimes called 'vicious circles', reallocation of capacity, traffic reducing policies, dynamic demand) do more convincingly produce conditions where either additional benefits can be produced without extra costs or alternatively

zero or even negative benefits can be produced by feedback effects. These can substantially change the relative balance of benefits from increasing road capacity compared with other types of expenditure, and therefore are of particular importance to the need to 'make a robust and balanced case for road investment, relative to other forms of investment'.

7. **Conditions for benefit**. This does not completely resolve the questions of precisely determining 'the circumstances where induced demand can raise benefits' or 'whether there are advantages of providing extra capacity even if generalised costs do not fall'. It is already known that the benefits to the induced travellers themselves will always exist, and that therefore one of the conditions for an overall benefit will be the absence of significant congestion (and, by extension, environmental or other similar costs). Estimates of the size of this congestion effect have been made in earlier comparison of sensitivity tests in established models, and environmental effects are usually now included: they are substantial and, I think, expected to increase. Evidence is also sought of external benefits, often called 'wider economic effects', where specific road construction and its extra traffic may increase economic growth by more than its own value. (I understand DfT has commissioned another, larger, 'think piece' to clarify those effects. It will need to tackle the same evidence problems of additionality, separability, causal association, conditionality and quantification as have preoccupied research on induced demand in general, and on specific projects).

   Since measures of all costs and benefits attributable to a specific project or intervention are normally based on a modelled difference between conditions 'with' and 'without' the intervention, the accuracy of the do-minimum conditions are as important as the do-something conditions, and in particular that will require calculation of any damping effect on demand in response to rising congestion.

8. **Wider conditions for benefits to exceed costs.** It is unlikely that this issue can be usefully calculated as a question of highway capacity and traffic alone: the answer is likely to be much more dependent on the relationship between provision of road capacity for road traffic, policies on provision for other modes, and demand management including pricing: if transport prices do not reflect marginal social costs including congestion, safety, environmental costs and effects on local and national economic efficiency, (which is usually the case) there will be biases in the estimation of effects of increased capacity and other interventions. Existing models can be a useful research tool for investigating these issues by sensitivity testing, though the models are not always available, or sufficiently well documented, to enable independent testing and timely exploration of the effects of changing parameters or assumptions. Even the best available models do not consider a complete set of behavioural responses, and are uninformative about questions of how long it takes the dynamic effects to emerge.

9. **Evaluation, POPE, and effect of overestimated traffic forecasts.** In the entire period from the 1989 and subsequent official National Road Traffic Forecasts up to 2025,

national traffic growth has been systematically overestimated, usually with rather small errors in the early years of a new forecast, but increasing over time. Successive forecasts have been revised downwards. (The opposite had been true of some of the forecasts reviewed by SACTRA in 1994, using forecasts from earlier in the 1980s). This in turn tends to bias the calculation of the specific local forecasts with and without a highways project, and its benefits. From about 2002 until 2024, ex post evaluation of induced traffic from completed highways projects had been carried out by National Highways in their POPE programme, using mistaken methods which focussed on the difference between the original forecasts and the observed outcome: these tended to underestimate induced traffic, and overestimate traffic benefits, leading to controversies. Alternative methods, suggested by critics, had focussed on differences between the observed trends on improved roads and other comparable roads without improvement, and in those cases higher estimates of induced traffic have been found. National Highways in principle adopted this approach in 2024, but in practice effects have only started to be seen in some of the most recently published POPE reports, February 2026. Results suggest that, though incomplete, it is now in principle possible to recalculate the effects correctly. This would justify a significant new programme of transparent work, with systematic retrospective correction as well as application to later schemes. I recommend this. It could produce the most important improvements in the ex post measured evaluation of the characteristics and effects of induced demand.

10. **Econometric modelling**. There has been increasing interest in the possibility of developing different types of models which might be more reliable in calculating travel demand, distinguishing between that due to external trends and that due to specific interventions, and also explicitly identifying the time profile of dynamic changes over the years. Recent reviews carried out for DfT have recommended development of econometric modelling both for understanding and predicting traffic impacts. My recommendation is to support this. There are also other emerging developments in modelling which may be more effective in identifying specific aspects of induced demand.

2. Evolution of Treatment of Induced Demand

History

The historical origin of the discussion of induced demand in transport (and the reason why discussion often starts with 'induced traffic' rather than the more general 'induced demand') derived specifically from concerns that building roads to relieve growing congestion might be ineffective, or less effective, because the road building itself resulted in more traffic. This, previously named 'generated traffic', had been recognised by the Ministry of Transport from the 1930s, and possibly earlier. The earliest official example I know of was a Ministry of Transport study by Bressey and Lutyens (1938)[1], who reported that opening the Great West Road in 1925, more than a century ago,

> "as soon as opened, carried 41/2 times more vehicles than the old route was carrying: no diminution, however, occurred in the flow of traffic on the old route, and from that day to this, the number of vehicles on both roads has steadily increased…*These figures serve to exemplify the remarkable manner in which new roads create new traffic'*

Further decisive evidence was assembled by the Ministry's Road Research Laboratory in the 1950s and 1960s, and in research published by academics and consultants, and in the Department's own scientific work published by its Mathematical Advisory Unit (MAU) in the 1960s.

The Ministry of Transport (1968)[2] summarised its assessment of the results, reporting that:

> 'Generated traffic on large schemes has often amounted to between 5% and 25% over and above the normal forecast level',

(It also commented that allowance should also be made for the experience that 'the relief of an existing road may also attract generated traffic').

By 1971 such additional traffic was recognised as an essential part of the training of specialist staff working on road planning, for example in the pioneering influential text book by Lane et al (1971)[3] which gave detailed descriptions of how it should be allowed for in forecasting and appraisal, including the famous 'rule of a half' (see below) and its implications, very similar in principle to the much more detailed advice now contained in DfT's 'TAG' advisory notes. It was not at that time considered as a controversial matter.

However, at some point[4] in the late 1970s a decision was taken by the Ministry of Transport that such extra road capacity did **not** materially influence the volume of traffic except in a few very special circumstances, primarily new estuary crossings if they made very large changes in cost. This was connected with the development of the Ministry's formal cost-benefit appraisal system, COBA, though that itself did accept the possibility of such extra traffic. So in

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[1] Bressey C & Lutyens E (1938) Highway development survey 1937, Ministry of Transport, HMSO. My italics. Yes, that Lutyens. I note however that Webb, S&B (1913) The Story of the Kings Highway, wrote about 'the old issue, which had troubled the eighteenth century, whether the traffic was to be constrained to suit the road, or the road constructed to accommodate the traffic'.

[2] Ministry of Transport (1968) Advisory manual for traffic prediction for rural roads, London HMSO

[3] Lane R, Powell T J, and Prestwood Smith P (1971) Analytical Transport Planning, Duckworth

[4] I have not yet been able to discover exactly when this happened, or the reasons stated at the time. Two suggestions have been (a) for modelling simplicity and convenience, and (b) in order to make a more persuasive case in favour of some road projects thought essential.

practice, for a period, calculation of induced traffic was not carried out for specific scheme appraisals. I am not aware of any published work, in that period or since, with analytical or empirical evidence to justify this approach.

Traffic forecasts became a contested topic in a number of controversial road schemes. In one such controversy, a legal challenge was made: the case[5] was taken to the House of Lords in its capacity as the highest legal court, whose ruling supported the Secretary of State's position that traffic forecasts could not be challenged at road inquiries, in effect because the forecasts were policy. (That ruling does not currently apply, because the Department explicitly requires that the effects of uncertainty about the forecasts should be formally considered in road appraisal, but it still leaves a residue of disrespect for the legitimacy of objections on technical grounds).

In major road appraisals carried out during the 1980s and early 1990s, it was normal practice not to allow for any additional traffic that might be stimulated by additional road capacity. During this period there was a build-up of evidence that this was incorrect, including work in the Greater London Council by Purnell et al (1985-6)[6], but it was still assumed by the launch in 1989 of very much higher national road traffic forecasts, for the period 1989-2025, than had ever been made before, and the associated much greater road construction programme, 'Roads for Prosperity'[7].

SACTRA[8], the Standing Advisory Committee on Trunk Road Assessment, was asked to advise the Department on

> "the evidence on the circumstances, nature and magnitude of traffic redistribution, mode choice and generation, especially on inter-urban roads and trunk roads close to conurbations, and to recommend whether and how the Department's methods should be amended, and what if any research or studies could be undertaken".

[5] Bushell and Brunt v. Secretary of State for Transport and the Environment, 1980.

[6] Purnell, S, Jillian Beardwood and John Elliott (1999) The Effects of Strategic Network Changes on Traffic, published by GLC in 1985/6 and republished in World Transport Policy and Practice, 5, 2, 28-48 http://worldtransportjournal.com/wp-content/uploads/2015/02/wtpp05.2.pdf

[7] Department of Transport (1989) Roads for Prosperity, Cm 693, HMSO

[8] The Committee on Trunk Road Assessment (The Leitch Committee) was set up in 1975 and reported on into-urban road appraisal in 1977, and was then reconstituted as a 'Standing' Committee. There is no general archive of its activities in the early period, but in 1989 it was given new terms of reference and membership, and assigned the task of producing three reports, on the Environmental Impact of Road Schemes (1999), Trunk Roads and the Generation of Traffic (1994), and Transport and the Economy (1999), all published by HMSO. After that it was not asked to write any further reports, and ceased meeting, but was not formally wound up until the abolition of many Quangos in May 2010. In July 1999 the Commission for Integrated Transport was formed to give independent advice to the Government, and commissioned much research and many reports, now archived, some of which are referred to below. It was also abolished in 2010. DfT has adopted various other forms of seeking advice, including informal invited meetings, special commissions such as the Eddington Committee which reported in 2006. In 2015 DfT set up Joint Analysis Development Panel, JADP, which provides a focus of discussion on issues of appraisal and modelling, but does not produce reports. Other advisory bodies include the DfT Science Advisory Council, a College of Experts, various committees and Boards, consultancy contracts, and ad hoc 'thinkpieces' like this one.

Work on the study started in 1992 and reported in March 1994[9]. It reconsidered all the available evidence and commissioned some new studies. The report was long (241 pages) and detailed. Recommendations were broadly consistent with support of the Department's view quoted above from 1968, and the growing consensus in the early 1970s, but not in support of the practice of ignoring induced traffic which had become common since the early 1980s.

The Distinction between induced traffic and induced demand

All travel demand is variable, being influenced by many factors including prices and incomes, demography, area of residence, geography, social expectations, transport and planning policies, technical developments, and cultural norms. In the post-war period these had combined to produce a general trend to increased car ownership and use, and in other traffic including vans and lorries.

Within this context, induced traffic is the term used for the extra road vehicle traffic resulting specifically from a road improvement, usually measured in vehicle-km or pcu-km. It results from resulting from the combined effect of changes in trips, distribution and mode choice. All these effects are also considered in the wider term, induced travel demand. This includes not only road traffic but also other changes in the quantity or structure of demand, which results from transport improvements defined more widely. It may be measured in a wide variety of ways, including people, trips, passengers, vehicles, purposes, and locations. It also includes other impacts which affect costs and benefits, such as changes in the times of day of travel as between congested and less congested times, which have no effect on total volume of traffic but potentially large effects on travel times and congestion. The reason why discussions on this topic first developed on traffic and road improvements was because that was the highest profile, often controversial, focus of concerns about the effects of the strategic policy approach. This had been developed in the 1940s and 1950s, that more road space should be provided to accommodate forecast traffic growth, relieve congestion and facilitate movement. (This became known as the 'Predict and Provide' approach[10], ie predict a growth of traffic and provide sufficient road capacity to accommodate it, a phrase which is now generally rarely mentioned with approval). This had led to concerns that the provision of extra road capacity might itself increase the growth of traffic, reducing or overturning the improvement in travel conditions.

This idea that 'new roads create new traffic' had sometimes been called 'generated traffic', but this phrase had become confused with 'trip generation', an important element in demand modelling, and the phrase 'induced traffic', was proposed by SACTRA (1994) specifically to replace the phrase 'generated traffic'.

Therefore there is a need to distinguish the external influences from those which resultfrom the road provision intervention itself. SACTRA (1994) expressed this in the question:

> 'does improving the road system introduce extra traffic which, without the improvements, would not otherwise be there?'

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[9] SACTRA (1994) Trunk Roads and the Generation of Traffic, Department of Transport, HMSO, available online on multiple sites including at https://nsip-documents.planninginspectorate.gov.uk/published-documents/TR010044-001678-sactra-1994-trunk-roads-traffic-report-unlocked.pdf

[10] I am not sure who first coined this phrase, possibly Susan Owens (1995), in her important critique, Owens, S. (1995). *From "predict and provide" to "predict and prevent"?: Pricing and planning in transport policy.* Transport Policy**,** 2(1), 43–49. DOI: *10.1016/0967-070X(95)93245-T.*

Two classic models

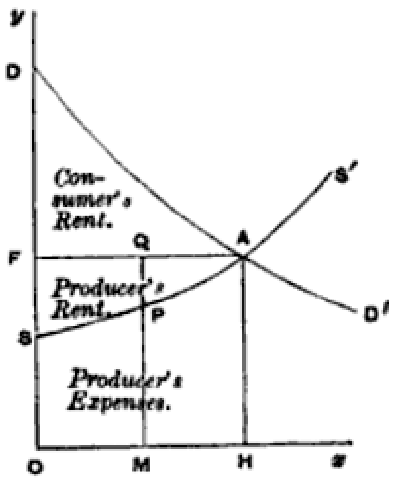
Investigating this question has been dominated by two 'Classic' models. These were (a) a relatively simple theoretical model derived from the economic interaction of demand and supply developed in 19th Century economic theory, amended to include the effects of congestion on costs; and (b) a very detailed official forecasting and appraisal model, developed as a branch of civil engineering, aiming to calculate the volume of traffic on every separate link in a road network, and its growth into the future over long periods of time, as a function of every important external influence and of the provision of transport infrastructure and services.

The main features of both these classic models were broadly complete by the late 1960s, though have continued to evolve incrementally since. There are sometimes practical problems of reconciling the two.

The classic economic model of equilibrium between demand, supply and cost

A fundamental tool of economic analysis, dating back into the 19th Century, eg Marshall (1890)[11], is a diagram relating demand and supply to goods produced and sold in a market. It has a downward sloping demand curve, labelled D in figure 1 below, and an upward sloping supply curve, labelled S. The lower the price, the more goods will be bought but the fewer will be supplied, and vice versa. There is one price where the two curves intersect, so demand equals supply, and this is termed equilibrium.

Fig 1 Why is the area under a demand curve considered as a measure of benefit?



What is labelled 'consumer rent' in the diagram above is now called consumer surplus. It is crucial to understanding why the demand curve slopes down, which is in effect the same reason why induced traffic exists. The argument was originally devised, by a French road and bridge engineer, Dupuit (1844)[12], half a century before Marshall, in demonstrating conditions under which charging tolls diminished the usefulness to the public of a road. It is the measure of the extra benefit that a consumer receives because the utility or satisfaction they get from

[11] Marshall A (1890) Principles of economics, MacMillan & Co, 8th edition 1938

[12] Dupuit J (1844) On the measurement of the utility of public works, Annales des Ponts et Chausees, Vol 8, translated by R H Barack for International Economic Papers (1952, and reprinted by Munby D (1968) Transport, Penguin Books. Munby adds further comments on the history.

consuming a product is always bigger than the price they have to pay for it. (Otherwise, they would not buy it). It is measured as an area underneath the demand curve.

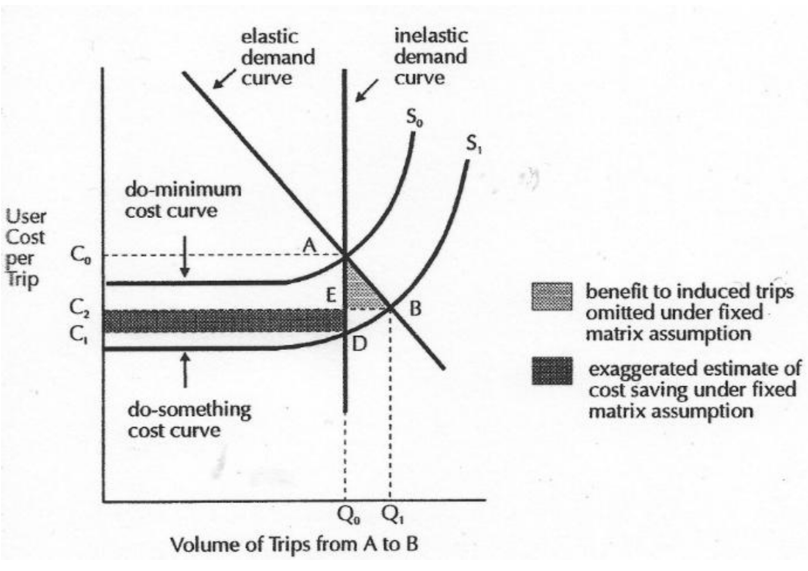
The conceptual underpinning of the idea of such a demand curve is to imagine all the potential consumers lined up in the order of the maximum amount of money that each would be prepared to pay for the commodity in question. Then the maximum price possible is determined by the one who would be prepared to pay most, and the curve is determined successively by new consumers joining the market at each level of price reduction. For each consumer, the surplus utility is the additional amount they would be willing and able to pay, over and above the actual price charged. It is an inevitable result of any variation in tastes or incomes among consumers, which is universal.

Therefore a model of equilibrium applies to the relationship between the volume of traffic and the cost it faces, very similar to the classic economic case of demand and supply. It has been common in UK practice since the 1950s, usually referring to Wardrop (1952)[13], and essentially applied in all discussion of the economics of traffic ever since.

Thus discussion starts with a textbook interaction of a downward sloping demandcurve and an upward sloping supply curve, but replacing the 'supply curve' by a cost curve initially based only or mainly on travel time, but now normally including time, money costs, and in principle any other costs related to the volume of traffic including environmental costs, accidents and other indirect impacts. (Sometimes these are listed separately, but any that are proportional to the volume of traffic or demand generally, should be included in appraisal).

SACTRA's presentation is shown in Figure 2 (from figure 8.6, p 119).

Figure 2 The 'Classic Model' of Erosion of User Benefits due to Induced Traffic



This is essentially the same diagram that is given most recently by DfT (2026)[14], where it is explained, in simplified terms, that

> 'As demand increases, congestion will lead to increasing costs of travel. Therefore, the costs of travel can be represented with a traditional, upward sloping supply curve

[13] Wardrop J G (1952) Some theoretical aspects of road traffic research Proc.Instn Civ Engrs Part II, 325-62

[14] DfT (2026) TAG Unit A1.3 User and Provider Impacts, Fig 1

and the impact of a scheme can be considered as shifting the supply curve, changing the cost of travel' (para 2.1.5).

There are two quantities of interest.

One is the small triangle which represents the additional benefit experienced by the additional traffic. This is derived from the economic theory of a *consumer surplus*, the area under the demand curve, which is equivalent to the amount that in principle consumers would be willing to pay, over and above what they are actually charged, in time or money.

This is the origin of the practice of applying a measure of benefit to the induced traffic of half the difference, on average, between the rejected old cost and the accepted new cost, called the 'rule of a half'[15]. It is not an arbitrary downgrading of the importance of induced travel.

The other is the larger rectangle, representing the extra costs to all road users, due to the additional congestion caused by the induced traffic itself. This will be greater in more congested conditions, and will be zero if there is no congestion, now or in the appraisal lifetime of the scheme, on the scheme itself or the surrounding network. This is rare.

Nowadays we should always include the extra costs of any environmental impacts,health and neighbourhood effects which can also arise from more traffic: it is sometimes convenient in cost-benefit calculations to add them separately rather than incorporating in the cost curve, but where they are proportional to demand, it is important that they should be valued as part of the induced demand calculations. In principle there can also be indirect external benefits of induced traffic which are important if they are big enough to offset the congestion and environmental costs. Generally potential external benefits, over and above what the traveller pays for, are more elusive, controversial and difficult to measure than external costs, especially of congestion, which are immediately apparent. I think DfT has also commissioned another 'think-piece', with a larger team of experts, to take this further, and their report is eagerly awaited.

Analysis reported by SACTRA indicated that the usual case was for the rectangle of extra costs to be much greater than the triangle of benefits, hence the view that 'taking induced traffic into account reduces the value for money of a scheme'. This does not mean that the induced travel itself has no benefits, but that its effect on the rest of the traffic is negative.

The effects of induced traffic depend on the slope of the speed/flow curve, but also on the elasticity of the demand curve. In the SACTRA report, a vertical 'fixed demand' line was

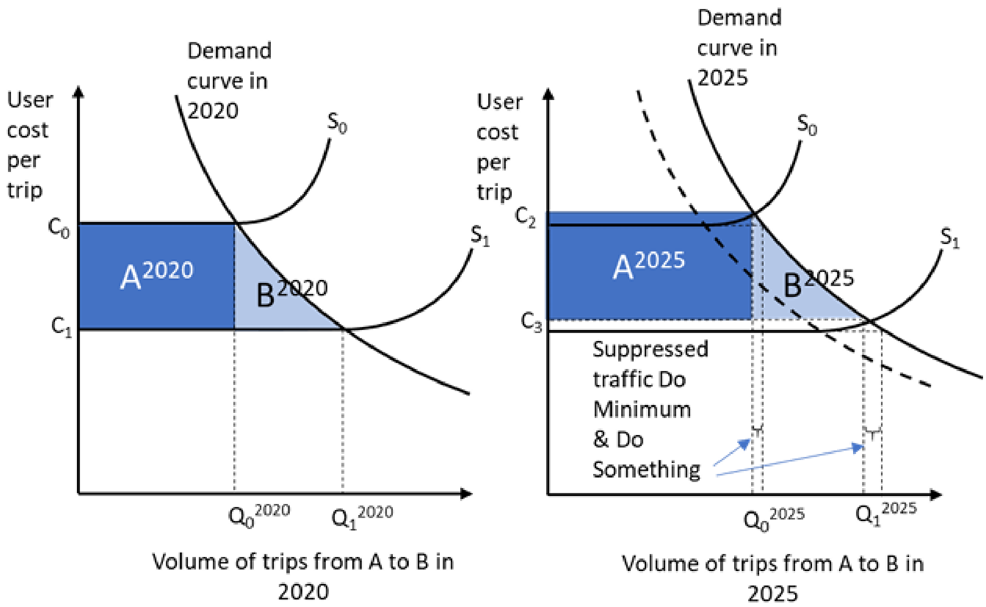
[15] If the demand curve is a straight line this factor of a half will be arithmetically correct. If it is curved it will be approximately correct if the difference in costs is small, but can be replaced by a more precise estimate if the demand curve is known not to be straight, and the cost difference is large. Mostly this is only of use in theoretical discussions, and is rarely applied in practice. A major caveat is that 'willingness to pay' is not a perfect or value-free measure of benefit, especially in the context of social pressures and needs, but it has a deep effect in most public sector appraisal. Manifestly, money costs will have a higher importance to people who have less money, and time costs will be more important to people who have less time. The use of a national average value of time (rather than income-related values) has the effect of reducing the value of time savings to more affluent users, and increasing the benefits to less affluent ones, compared with their own willingness (ability) to pay. Both DfT and Treasury support the principle of adjusting for this when it is important, but such adjustments – which are important – are usually only discussed in the context of the fairness of distributional impacts and unfortunately become footnotes (like this one) rather than the main text. I have suggested the need to make corresponding adjustments related to the constraints and pressures on time, but so far without result.

presented as the 'limiting case' of a demand curve, which had seemed to be intuitively sensible – as the demand curve gets less and less elastic, it becomes steeper and steeper until it is vertical. This may be seen by rotating the elastic demand curve clockwise, until geometrically it clearly becomes vertical. The other limiting case was seen as a horizontal demand curve, as the elasticity gets greater and greater. There are fundamentally implausible consequences of both, in terms of willingness to pay for improvements. The real world will in nearly all cases be in a range from low to high demand elasticity. I now consider that this framing was a theoretical error[16]. For economic analysis, vertical and horizontal demand curves cannot be the effective limiting cases. The reasons are discussed in section 7.

Distinguishing traffic growth due to external trends, from that due to induced traffic

This analysis needs to be extended to the usual situation, where changes in demand are due both to external effects (eg incomes and other social trends), considered as exogenous to the project being assessed, and also to the effects induced by the project. SACTRA considered this, and an important recent review commissioned by DfT, by Dunkerley et al (2018)[17], usefully provided a clearer version of the SACTRA diagrams, which I copy here.

Fig 3 Appraisal of Induced Traffic with Exogenous Traffic Growth



This shows that potential errors in appraisal are distinctly different in the cases of changes in demand due to external effects, and those due to induced effects. This is discussed further in section 10 below, in connection with the large overestimates of national traffic forecasts in the whole period 1989-2025, and a simultaneous tendency to underestimate induced traffic

[16] I recognise that as an author of the 1994 SACTRA report, I accepted this framing for the vertical and horizontal demand curve, and I am now saying that I was wrong, and apologise. I have raised this with my surviving co-authors who are, alas, few in number or not easily accessible.

[17] Dunkerley F, Whittaker W, Laird J, & Daly A (2018) Latest evidence on induced travel demand: an evidence review, Department for Transport https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762976/latest-evidence-on-induced-travel-demand-an-evidence-review.pdf. I think the diagrams are by Laird, developed in work he had done in New Zealand.

effects. The main practical conclusion is that induced traffic effects must be distinguished from external traffic growth effects, and calculated differently. It is the reason why it is useful to have a separate label for induced traffic, not to combine it with exogenous influences in the general term 'variable demand'.

The classic transport demand model

In practical modelling practice, we do not directly see either of the simplified curves which underpin appraisal economics shown above, though they remain crucial to analysis. What we see is much more complicated because both demand and cost are modelled separately in many different mathematical forms and practical segments. The dominant form of model used to predict future traffic increases and test the effect of road construction (or other initiatives) is sometimes called the 'four stage' (or five) model, or 'the Classic Model', or indeed sometimes just 'the model'.

This proposed that travel demand was the result of four distinct, clearly defined, separate processes: trip **generation** which determined the number of trips; **distribution** which determined their location in space by matching origins and destinations; **mode split** which determined the relative use of cars and public transport; and **assignment** which determined the route chosen. Initially these were sometimes thought to represent, by definition, the complete total amount and location of movement, but a fifth choice, **time of day**, was added in principle quite early though not always in practice, and a longer list of demand responses has emerged since, discussed below. Modelling consisted of forecasting the volume of traffic on every separate link in a road network, for up to around 30 years into the future, with some extrapolation up to 60 or even 100 years. Feedback loops are essential to reflect the interaction among the responses. The outcomes in each stage are, or can be, sensitive to travel times and costs, usually modelled as a generalised cost combining the two, as the main mechanism by which new road provision can affect demand.

The separate sub-models each have their own history, and operate in different ways. Generation initially was based on cross-section surveys, with the number of trips determined by forms of rather static category analysis dominated by variables like car ownership (itself derived mainly from income), area of residence, income, household structure, employment status. Initially it was assumed insensitive to cost, speed or transport quality. Distribution was derived from a most likely statistical matching of the number of origins and the number of destinations in each zone, with a distance decay function operating as a sort of demand curve. Mode split was the most explicit reference to economic choices, from the costs and speeds of the different modes, with an individual logic but often rather aggregate application. Assignment was an iterative process seeking to fulfil the definitions of an equilibrium driven by cost-flow relationships somewhat similar in form to those described above, but different for each type of road, type of vehicle, and in principle weather, accidents, road works and so on. They are subject to caveats related to road capacity discussed in section 5 below. They provided the main (and sometimes only) feedback effect which would change each of the above modelled processes.

These classic models, in practice, have very large and complicated existing software, not necessarily well documented, and often not with open access, either for reasons of commercial confidentiality or as a policy decision. They tend to be operated by highly skilled consultants, mostly employed by promotors or developers of schemes, and the arrangements for scrutiny, where they exist, are not always transparent. They are mostly based on the assumption of an achieved equilibrium. The models themselves impose constraints in what information they need (or can handle), and how well they reflect reality.

Two practical problems for the analysis of induced demand are

> (a) the relationships were based on statistical data, but by different processes in each case, aimed at producing something like the ‘average’ or ‘representative’ traffic flow for each link, but it was not an average which could be described with statistical measures like standard errors. Forecast traffic flows are never described with statistical error bands. Rather, uncertainty about the size of the forecasts was handled by varying the input assumptions, like income or prices, not by the inherent statistical variation in the data which must always exist.
>
> (b) the whole model structure was intended to produce an equilibrium, not a process, and there are therefore no dynamic outputs addressing questions like how long it will take to reach the equilibrium, even though it is a common experience from ex post studies that induced demand is different (and usually greater) after 5 or 10 years than after 1.

Eclectic other models

Although the conceptual model and the detailed traffic models described above aredominant in the appraisal of road projects and traffic benefits, they are not nearly so extensive in the appraisal of public transport projects (which are often driven by models based on demand elasticities). Initiatives for traffic reduction by reallocation of capacity are often assessed by local ad hoc judgement of layout and restrictions, and application of experience from ex post evaluation of schemes in other areas. Even though traffic reduction is often among the declared objectives, there is less formal focus on forecasting this in advance, but a greater emphasis on measuring it retrospectively. Some further information about these is given in the Literature Review in Appendix 1.

‘Unlocking’ and ‘’Enabling’

Overall, it is now fairly clear that identifying and appraising the effects of an interventionrequires identifying both its intended and unintended consequences, and explicitly distinguishing these from the effects which are due to other causes, such as trends in prices and incomes, tastes, demography and technology. However there is a grey area of which the warning signs are often claims that a project will ‘unlock’ or ‘enable’ other intended developments, such as on housing or economic prosperity, but do not guarantee them. Thus it is obvious that a large housing development will generate more traffic, but that may not be classed as induced in appraisal of the additional roads provided, because the local plan had already specified that the housing is needed, so it is attributed to the plan not the road. Similar logic is sometimes applied to claims of ‘wider economic benefits’ but without attributing any resulting traffic growth to the project. My own view is that this is an inconsistency which can lead to biassed appraisal, and it would be timely to review this whole class of exceptions.

3. Evidence about Effects

Reversibility of induced demand effects

SACTRA noted that

> ‘induced traffic implies an *increase* in trips and/or traffic through these mechanisms. The converse of the above mechanisms implies a *reduction* in trips and/or traffic, and is often termed ‘traffic or trip suppression’. In what follows, the terms ‘induced traffic’ and ‘suppressed traffic’ are used for simplicity to describe all or any combination of the above factors. Both induced traffic and suppressed[18] traffic are of interest to SACTRA”. (p217)

In equilibrium models the difference between ‘with’ and ‘without’ an improvement is exactly symmetrical and reversible, with no friction or delays. However, the language of comparison often encourages the assumption that ‘before and after’ is equivalent to ‘with and without’, with informal assertions that (for example) reassignment is a short term effect, and changes in distribution and mode choice are longer term effects. These assumptions make sense in terms of how we understand the real life experience of speedy changes in route and slower changes in workplaces and homes, for example, but there is no empirical or analytical justification for deriving these time scales from equilibrium modelling based on cross section data. The comparison in practice is between a calculation of the demand effects ‘with’ and ‘without’ a scheme, sometimes called ‘counterfactual’ or ‘baseline’. (In before-and-monitoring studies with a specified time scale, the true pace of change can be revealed). The ‘without’ or baseline case can also be affected by the opposite of induced traffic: for example, if general traffic growth would cause higher congestion, then this would itself dampen or suppress some of that growth.

So if no account is taken of induced traffic effects, the tendency will be to o*verestimate how bad* the conditions there will be without the project, and to *overestimate how good* they will be with the project, both therefore exaggerating the benefit. This is why it is necessary to calculate the effects of variable demand on the do-minimum or baseline case, as well as the do-something case. National Highways affirm that that this is now always their practice, but it is uncertain whether it is breached in some local authority schemes.

Induced demand for public transport

There is a very large body of research about the demand for public transport. For example, the state of the art literature review by Balcombe et al (2004)[19] listed and summarised around 600 references, many in the form of empirical elasticities of demand with respect to fares and many different aspects of the quality of service. These have continued to be updated, notably

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[18] I signed up to this point as an author. My own feeling now is that while ‘induced’ neither implies good or bad, ‘suppressed’ has an unavoidably negative connotation, and I prefer ‘reduced’.

[19] Balcombe R, Mackett R, Paulley N, Preston J, Shires J, Titheridge H, Wardman M, White P (2004) The demand for public transport: a practical guide, Report TRL593, Transport Research Laboratory ISSN 0968-4107 https://www.trl.co.uk/uploads/trl/documents/TRL593%20-%20The%20Demand%20for%20Public%20Transport.pdf

in the periodic review articles by Wardman et al (2018)[20] (2022)[21]. Rail demand forecasting has its own set of recommended procedures for forecasting demand, the Passenger Demand Forecasting Handbook, not itself issued in published form, though see, for example, the review by ITS et al (2016)[22], and Worsley (2012)[23].

It is striking that there has been little or no concern in the public transport industries about 'the problem' of induced traffic and its effects – mostly, the demand estimation, based on empirical elasticities, implies that there is additional demand when improvements are made, and this is to be welcomed. There will be some cases, for example with crowded rail services, or with concessionary bus passengers during busy periods, when additional demand can be seen as causing crowding, but these are usually resolved in relation to the social case for price support, not generic features of demand. On average, the effects of public transport improvements on reducing car use are expected to be small, because the overall market shares are very unequal, but when it applies this is also welcomed as a contribution to transport generally, and is in some cases crucial, especially in urban areas where it is possible to implement a combination of several different levers. Reallocation of road capacity from general road traffic to public transport is the key example, discussed below.

So with some exceptions, it is the case that the existence of induced demand in public transport is not doubted, but it is mostly welcomed.

Effects on demand of policies other than road building

The SACTRA discussion was focussed on the effects of highway improvements. Four important extensions to the SACTRA focus have become more prominent, in theory and practice, since then:

a) The same thinking has been applied to schemes for improvements of walking, cycling or public transport improvements, and to interventions reallocating capacity or resources among different claimants, when one would need to take account of simultaneous induced demand for some affected parties, and reduced demand for others. The Literature Review in Appendix 1 gives more detailed summaries of results from multi-modal studies; road capacity reductions for reasons of pedestrianisation, bus lanes, and some accidents, repairs and disasters; 'Smarter Choices' initiatives (formerly called 'soft measures'); and low traffic neighbourhoods. There is a great variation in results but all tend to show some similar features to the results for road capacity increases, and where well designed the traffic reductions do not suffer from

[20] Wardman M, Toner J, Fearnley N, Flugel S, Killi M (2018) Review and Meta-analysis on inter-modal cross-elasticity evidence, Transportation Research Part A, 118 662-530 Review and meta-analysis of inter-modal cross-elasticity evidence - ScienceDirect

[21] Wardman M(2022) Meta-analysis of British time-related demand elasticity evidence: an update, Transportation Research A: Policy and Practice 157 198-214 Meta-analysis of British time-related demand elasticity evidence: An update

[22] ITS, Leigh Fisher, Rand Europe, Systra (2016) Rail demand forecasting estimation, redacted, phase2-rail-demand-forecasting-estimation-study.pdf

[23] Worsley T (2012) Rail Demand Forecasting Using the Passenger Demand Forecasting Handbook, RAC Foundation otm-rail-demand-forecasting.pdf

increased congestion for other road users. Where there is, this tends to get less over time rather than growing.

b) The interventions are not solely construction of capacity, but also its management, regulation and pricing. I note that capacity 'reallocation' has a broad mix of intended and unintended measures, so in addition to simple policy choices such as bus lanes, there are also cases of reallocation of capacity between moving traffic and parked cars, and between parking and pedestrians (eg pavement parking and similar), from emergency rescue lanes to traffic use, interaction at bus stops with cycle lanes. Induced demand for one class of transport user and reduced demand for another will be a common feature, and the costs and benefits involved for each cannot be ignored or assumed to cancel out.

c) The costs and benefits of intervention have not only related to congestion, but also to environmental effects, health, safety and any other social or economic effects judged to be important. These can in principle include potential external economic benefits over and above those that are paid for by the recipients.

d) Observation that estimates of induced traffic evolved over time, in such a way that estimates after 5 years, say, were larger than those observed after one year. These are impossible to estimate in advance with equilibrium models, so there is increased interest in dynamic models with an explicit time frame, implemented in some econometric estimation of elasticities but rarely if ever applied in project appraisal[24]. Identification of whether assumed elasticities are short term or long term, and how long it takes to progress from one to the other, has to be done by reference to the data and model forms used to derive the elasticities; usually, this will require time series data and a lagged specification.

The key common factor is the need to distinguish those effects on demand which are autonomous and external, separately from those effects which arise from the intervention itself. Therefore the key property of induced travel is that its benefits and costs must be identified separately from the similar range of responses that are due only to external influences.

Induced demand is a common, (nearly) universal economic response to lower costs,and can apply in principle to all modes of transport, and to all instruments of reducing time, money or other costs. Whether this is favourable or unfavourable depends on the policy context, and its size is an empirical question to be judged by experience, modelling, and evaluation.

Mechanisms of changes in travel demand

The *mechanisms* by which the total and structure of demand could change are crucial. The original DoT brief given to SACTRA related to three mechanisms, central to the classic transport model described above:

> 'evidence on the circumstances, nature and magnitude of **traffic redistribution, mode choice** and **generation** resulting from new road schemes'.

[24] An exception would be the calculation of cash flow in cases where funding is contractually important. Such calculations are rarely published in public, but the idea that the cash flow of revenues can be calculated with no dynamic build up of demand effects is, to my view, bizarre.

It will be seen that the mechanisms corresponded with those already used in the classic transport demand model. Assignment or route choice was assumed not to constitute a 'change in demand', though this may not always be the case as discussed below.

In the first few months of the inquiry, SACTRA widened this question to admit the possibility of other potential mechanisms[25], and review of the published literature since then, summarised in Appendix 1, has included further dimensions of changes in travel choices, especially connected with the balance between car use and other modes, activities and policy instruments. This has been extended recently in consideration of some effects of Covid, especially about the substitution of travel for online and other activities, and in freight by logistic practices, travelling salesman, warehouse and depot location, and competition between personal shopping and home delivery.

So induced and reduced traffic and demand may include a wide range of different responses is used to embrace a number of possible responses to new roads, not all easily treated in the classic definitions of trip generation, distribution, mode choice and assignment. This list is continually evolving, as discussed in Appendix 1, but Table 1 shows my summary of the state of play of traditional and new responses.

[25] SACTRA (1994), pages 217-218

Table 1 Potential mechanisms for induced/reduced demand responses

Rescheduling of vehicle trips to take advantage of changed conditions in peak periods;

Changing the frequency of vehicle trips between any given origin, destination and purpose;

Decreases/increases in vehicle occupancy for personal travel and loads for freight;

Switching between conventionally owned household cars, car clubs, taxis, hire cars, (and potentially autonomous cars), with different conditions of use, access, and prices;

Switching between public transport, cycling, walking and private vehicle for existing trips;

Changes in forms and level of private vehicle ownership and consequential use;

Vehicle type – differences between energy sources, also weight, size, engine power;

Travelling to new destinations for the same purpose as existing trips; and entirely new trips;

Rescheduling allocation of responsibilities within households, chaining, and combining trips for different functions;

A shifting balance between shopping locally and to more distant destinations, in fewer large purchases or more smaller ones, by own vehicles or home delivery;

Shifts in social, work and leisure activities between travel and internet-based activities (work or family meetings by Zoom or Teams; streaming instead of theatre and cinema, delivery of cooked food to eat at home instead of in restaurants);

Changes in the pattern of land use, leading to changes in the pattern of trips and traffic.

Shifts in logistics affecting suppliers of services or goods, changing location and size of warehouses or organisational hubs, and arrangements for contract distribution.

Vehicles-as-workplace, stations as location for meetings, shopping and leisure

Note that changes in routes or times of day of travel, not usually defined as 'induced traffic' nevertheless can have effects on congestion, environmental effects etc, and then require similar appraisal to increased or reduced travel.

The key implication of this list is that some of these responses cannot easily be dealt with in the classic demand model, or at all in the classic economic model. But whether modelled or not they will be present in any retrospective evaluation, which probably explains why there has been much more success in identifying the broad quantitative change in traffic than in identifying how much is due to each of the mechanisms modelled. In general, the more different unmodelled responses are possible, the more likely it is that forecasts will underestimate induced traffic.

Research methods

Partly because of the wide range of mechanisms that could produce induced demand, the SACTRA investigation deliberately used a wide range of different methods of enquiry. The core evidence base sought consisted of detailed shorter and longer term data on traffic growth following specific road improvements, including treated roads and the effects on other neighboring roads and alternative routes. But this was also compared with a wide range of different analytical approaches, including

- the differential traffic growth rates on roads subject to different levels of congestion;
- econometric and survey studies of travel demand, especially related to demand elasticities, the effects of money costs on car use, motorway capacity, and the value of time;
- empirical analyses of the total amount of time spent travelling, and its stability over time;
- comparison of forecast and observed traffic growth from road improvement schemes;
- data on peak spreading in London;
- debates using ‘common sense’ arguments and local controversies;
- surveys of the opinions and expectations of transport professionals;
- attitude surveys of road users;
- empirical analysis of the effects of public transport service levels on car ownership and use;
- reviews of freight operators’ responses to improved infrastructure;
- analysis of the interactions of transport and land use;
- development effects;
- sensitivity tests using available models.

This wide range of methods also produced – or explained - some variation in results, as one would expect. Overall this increased rather than reduced confidence in the core findings, as it was possible to triangulate and compare sources of inconsistency. While any one method had problems, it was mostly possible to narrow down the results to a useful range.

Most other studies since have not used the same multi-method approach. It is not clear why.

Evidence from modelling

The SACTRA report, in its chapter 10, and Coombe (1996)[26] reviewed evidence from models which had used fixed demand or variable demand assumptions to calculate how much difference it would make if the true demand was variable but had been calculated assuming it were fixed. The key results were derived from models of road schemes in Cardiff, Belfast, West London, Norwich, Bristol, and Leeds, and also Dortmund and Bilbao, with special reference to seven studies by H C W L Williams[27] and collaborators listed in the SACTRA report (page 162).

The following extract summarises the overall conclusions of this analysis.

> "10.68 We consider this to be the nub of what these model tests are telling us about the effects of induced traffic: namely, that small changes in traffic, in congested urban areas, will result in large changes in economic benefit, and that this is an inescapable result of the nature of the mathematics involved, which confirms the conclusions of the qualitative analysis presented in Chapter 9.
>
> If we regard the percentage reduction in economic benefits as substantial, then we must recognise that the percentage reduction in Net Present Value, which is the crucial indicator of scheme worth used by the Department, will be much greater. The absolute reduction in the Present Value of Benefits is the same as the absolute reduction of the Net Present Value, but as the latter is always smaller than the former, the percentage reduction of the latter is always larger than the former.
>
> 10.69. As far as the effects of road system improvements on freight movements are concerned, there is some evidence that the actual benefits exceed the direct travel cost savings normally included in the economic evaluations.
>
> 10.70 Williams et al (1991) came to the conclusion that, insofar as currentprocedures for the appraisal of highway schemes in urban areas do not allow for the full range of trip response, they can be said to be flawed. Of more interest is the degree of error introduced by weaknesses in procedures. The circumstances where errors are likely to be greater will be:
>
> - when congestion is greater - as is usually the case in urban areas compared with rural areas;

[26] Coombe D (1996) Induced Traffic: What do Transportation Models tell us? Transportation 23 (1) 83-101

[27] Williams H C W L and Moore L A R (1990). The Appraisal of Highway Investments Under Fixed and Variable Demand. Journal of Transport Economics and Policy 24: 61-81.
Williams H C W L and Lam W M (1991). Transport Policy Appraisal With Equilibrium Models I : Generated Traffic and Highway Investment Benefits. Transportation Research 25B(5): 253-279.
Williams H C W L and Lai H S (1991). Transport Policy Appraisal With Equilibrium Models II : Model Dependence of Highway Investment Benefits. Transportation Research 25B(5): 281-292.
Williams H C W L, Lam W M, Austin J and Kim K S (1991). Transport Policy Appraisal With Equilibrium Models III Investment Benefits in Multi-Modal Systems. Transportation Research 25B(5): 293-316.
Williams H C W L and Yamashita Y (1992). Equilibrium Forecasts of Travel Demand and Investment Benefit Measures for Congested Transport Networks. Proceedings of PTRC Summer Annual Meeting.
Williams H C W L and Yamashita Y (1992). Travel Demand Forecasts and the Evaluation of Highway Schemes Under Congested Conditions. Journal of Transport Economics and Policy XXVI(3): 261-282

• for those trip purposes, and in conditions where user behaviour is more responsive to changes in travel costs - again, this is usually the case in urban areas compared with rural ones;

• if traffic growth over time were assumed to be solely a function of exogenous factors and independent of travel costs;

• where a significant proportion of the response is new traffic, whether due to trip generation or mode transfer or induced land-use changes.

(The analysis in the report gave numerical measurements of these effects, which are very sensitive to the precise definitions of elasticities, the level of congestion, and the peed-flow curves assumed, in a way which seems logical but the quantification does not add to the qualitative results summarised, so I have not repeated the results here. It is simpler to refer directly to the summaries given in the SACTRA report).

It would be useful for develop guidelines for how models developed with public funds by public agencies, can make these available to researchers and other interested parties, including learning how to use them, publicly available manuals, and any necessary training.

4. **Retrospective Evaluations of Induced Traffic in Newly Opened Road Schemes (POPE)**

In DfT terminology, evaluation refers to the ex-post examination of evidence after a project or policy is implemented, to compare the forecasts and ex ante appraisal with the observed outcomes. It is essential that the comparison is on the basis of a counterfactual aimed at assessing 'what would have happened without the intervention'.

This issue was much discussed in the SACTRA report, and there were disagreements between the Committee and those in DfT responsible for the appraisal of earlier schemes, who had suggested that 'if induced traffic exists, then evidence for it would be seen in a tendency for forecasts to underestimate traffic flows after the scheme is opened'. Such a tendency did indeed exist. The Department suggested it was not due to induced traffic, but to a recent separate underestimation of general traffic growth in the 1984 National Road Traffic forecasts (and, temporarily, the 1989 forecasts), for which an adjustment could be made.

The Committee queried the adjustment suggested, but this was left unresolved due to the quality and suitability of the available data. It recommended starting a new monitoring programme, designed to be able to produce more reliable data on induced traffic.

After some interim arrangements, National Highways started a new monitoring programme called POPE, Post-Opening Project Evaluation, covering all major schemes opening since 2002, all or nearly all of which had been appraised during the periods of the 1989 and subsequent National Road Traffic Forecasts, and their corresponding local traffic models. The earlier forecasts had assumed there would be no induced traffic, but increasingly variable demand models were used which in principle could allow for induced traffic, due to changes in some or all of trip generation, distribution and mode split, including all schemes opening after about 2015.

No retrospective evaluations of induced traffic were published for any specific named schemes, but every two years or so National Highways published a 'meta-report' given in anonymised, cumulative form for all schemes. The size of any induced traffic effect was not reported, but the analysis did claim to distinguish between those schemes which 'showed signs of induced traffic', and those which showed no such signs. A substantial (and increasing) majority were reported as not showing signs of induced traffic. This was during a period in which every national forecast had been an overestimate[28], discussed in Appendix 1. There was no application of an adjustment corresponding with that which had been suggested earlier by the DfT when the national forecasts had been underestimates.

CPRE and the Countryside Agency published highly critical analyses of these results by Matson et al (2006)[29], extended by Sloman et al (2017)[30]. They said, in summary, that the calculations had not made any attempt to design a counterfactual, but had simply compared traffic flows after opening with the forecasts made in the appraisal, and this did not measure induced traffic. They proposed an adjustment similar to that which had been suggested by the DfT to SACTRA, though not based on errors in the national forecasts, but an actual traffic flows on comparable but unimproved roads in the same region. Applying this to a sample of actual (identified) schemes, Sloman et al calculated induced traffic at broadly similar levels to those which had been calculated by SACTRA, or higher.

National Highways did not respond to these criticisms, but after 2019 ceased publishing meta-analyses which stated that most schemes did not show signs of induced traffic, and in 2024 issued a revised evaluation manual[31] which in effect adopted the same form of appraisal as that recommended and used by Sloman et al, and criticised its own earlier method.

There was then a substantial delay in publishing reports for many schemes for which POPE reports had been completed from 2022 onwards (connected with continuing discussions with the DFT about the effects of the 'smart motorway' schemes), but in February 2026 the delayed reports were published in a single combined list, National Highways (2026)[32]. Nearly all of them referred still to the earlier (pre-2024) evaluation method, which was not able to provide a reliable calculation of induced traffic. However at least one of the most recent reports was an evaluation based on the 2024 evaluation manual, namely the POPE report on all lane running for some M1 junctions, National Highways (2025)[33]. Its summary reports (p14)

> 'To assess the impact of the project on traffic levels, it is useful to understand the changes within the context of national and regional traffic. To do this, we use the Department for Transport (DfT) annual statistics. The data is reported by local authority and road type, recording the total number of million vehicle kilometres travelled. This data is used as a baseline, and *we attribute any growth observed on roads in the project area which is above national and regional trends to the project*'.

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[28] Goodwin P (2025) National Road Traffic Forecasts 1965-2025 https://tapas.network/93/goodwin.php

[29] Matson L, Taylor I, Sloman L and Elliott J (2006) Beyond Transport Infrastructure: Lessons for the future from recent road projects, CPRE and the Countryside Agency beyond-transport-infrastructure.PDF

[30] Sloman L, Hopkinson L and Taylor I (2017) The Impact of Road Projects in England, Report for CPRE, Transport for Quality of Life. https://www.cpre.org.uk/wp-content/uploads/2019/11/TfQLZ-ZTheZImpactZofZRoadZProjectsZinZEnglandZ2017.pdf

[31] National Highways (2024) POPE Methodology Manual. https://nationalhighways.co.uk/media/pq2jb142/pope-methodology-note-2024-v2.pdf
The earlier manual is no longer available on the NH website.

[32] Post Opening Project Evaluation (POPE) of major schemes - National Highways

[33] M1 junctions 28 to 31 and junctions 32 to 35a all lane running - 5-year post opening project evaluation, report dated 2025 and published February 2026, covering the period to 2022.

The phrase 'induced traffic' is not used anywhere in the new POPE evaluations, but I interpret the sentence I have put in italics as being their assessment, using the new evaluation method, of induced traffic.

The evaluation then continues to make an assessment of the outturn figures on the overall value for money and performance of the scheme, with a summary as follows:

> 'The forecast value for money for M1 junctions 28 to 31 was 'high', with a low growth to high growth scenario range of 'high' to 'very high' value for money. The project has been re-forecast to be 'low' value for money. The forecast value for money for M1 junctions 32 to 35a was 'high', with a low growth to high growth scenario range of 'high to 'very high' value for money. The project has been re-forecast to be 'medium' value for money. The main reason for the overall reduced level of benefits from this project is the lack of journey time savings. The appraisal forecast significant traffic growth, but with better journey times with the implementation of the scheme compared to the counterfactual (i.e. if the scheme was not delivered). The observed data suggested more modest traffic growth likely as a result of the COVID-19 pandemic and associated lockdowns. This has affected the project's value for money'. (page 66)

Again, there is no explicit mention of induced traffic, but in this case I interpret the commentary as a recalculation which does allow for the reduced value for money arising from the revised lower traffic growth figures, and their consequence, but *not* including a revision due to recalculation of induced traffic, ie a revised quantum of the effects of induced traffic on congestion (or indeed its environmental or other impacts) or calculation of applying the 'rule of a half' to the induced traffic component.

Thus none of the newly available POPE assessments, even the new ones, seem to calculate the effects of induced traffic on appraisal, but at least one[34] uses a sensible method of estimating the quantity of induced traffic which could in principle then be used to assess what the effects on appraisal would be.

The point of this discussion is that I count it as a very important 'proof of concept' of the ability of the National Highways revised evaluation manual to deliver helpful conclusions. In this particular case the period of the evaluation ended in 2022, so of course the biggest impacts observed were influenced by Covid, for which there was still considerable uncertainty about whether its impacts had yet been completed, so I do not think that the effects as recorded count as a model for an evaluation of the effects of induced traffic. But updated data will be capable of doing so, as well as allowing for the continuing changes in behaviour which appear to be long lasting and may be permanent.

With that in mind I consider that the new POPE approach has the potential for supporting the best and most informative evaluation of induced traffic from completed road projects, but only if reanalysed for all of the backlist of projects.

This is an extremely important evidence base on an extremely important problem, and my recommendation is that there should be a programme of retrospective recalculation and publication of the induced traffic in every case, without anonymising the schemes, and with careful exploration of the out-turn induced traffic, and explanations of the sources of

[34] There may be more, but I have not read in detail every one of the newly released list.

variation, for example class of road, are of the country, and size of scheme, and consideration of the form of model and data used in the original appraisals. This evaluation ought to be done identifying cars, LGVs and HGVs separately, and in total, thereby closing the gap in evidence on freight induced traffic.

This is new territory, requiring new and creative thinking. My advice, in the section of recommendations in Section 9, is that the work should be supported collaboratively by DfT and NH, with transparent scrutiny and involvement by independent specialist academics and consultants. It could produce the most important new evidence on induced traffic in a generation.

5. Speed-flow, Assignment, and Hyper-congestion

Relevance to induced traffic

Assignment models have a particular importance in calculating the total amount and costs of induced traffic, not mainly because the choice of one route or another makes much direct difference to the total volume of traffic[35], but because the calculated changing levels of congestion provide important information which feeds into changes in trip-making, mode use, destination choice and all the other changes in demand. If the level of congestion is wrongly estimated, so will be the positive or negative changes in induced demand.

The word 'hypercongestion' refers to the suggestion that there may be assumptions in modelling of greater levels of congestion than would actually occur, or indeed greater than would be possible. This has caused concern – including, in earlier periods, by DfT. I should say that there is a strong and firmly-based view among modellers that this concern is exaggerated. If so, this section of my report (and its inclusion in my terms of reference), may not be very important. Hopefully, it may even so clarify why the arguments have taken place.

Nature of the problem

Defining the relationships.

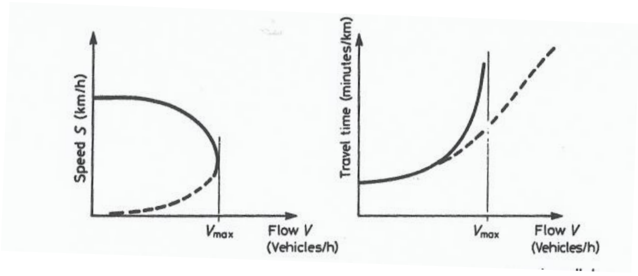
I think the following description correctly describes the preferred modelling approach for use in assignment, using a convenient summary of the classic analysis given by Ortuzar and Willumsen (1990)[36], which I copy in Figure 4 below. It shows that if more and more traffic seeks to travel on a road link, it will eventually cause congestion to increase and the speed to decline, until it exceeds the road capacity, when (until it recovers) speed drops to, or close to,

[35] There are other circumstances when route choice is also a demand response, travellers actually preferring one route to another for reasons other than speed, for example between lit and unlit roads, or motorways and non-motorways, or the scenic or other quality. For example in work by Nicolson which suggested that congestion on the A303 near Stonehenge is significantly caused by "rubbernecking" — drivers slowing down to look at the monument — and that a much cheaper solution than building a tunnel would be to use sight screen so drivers would not be distracted. Such matters are an example of real life complexity which does not easily fit into modelling. Nicolson A (2021) 'Highways England has its head in the sand about rubbernecking at Stonehenge', Local Transport Today 935, 5.2.2021

[36] Ortuzar J de D and Willumsen L G (1990) Modelling Transport, Second Edition, Wiley p289

zero, and travel time increases. Travel time will be a large component of the cost of travel, and is sometimes assumed to be the only one that matters.

Fig 4 Speed-flow and travel time



Ortuzar and Willumsen explain that "the cost-flow function should allow the existence of an overload region, i.e. it should not generate infinite travel time, even when flow is equal or greater than capacity…. Moreover, short-term overload can certainly happen in practice without generating anything approaching infinite delay! The dotted line in the cost-flow in Figure [4] simulates this".

Bates (2008)[37] pointed out that

> "The classical approach defines the supply curve as giving the quantity *T* which would be produced, given a market price *C*. However, while certain aspects of the supply function do, of course, relate to the cost of providing services (whether it be the cost of highway infrastructure or a public transport service with a specified schedule), the focus of supply relationships in transport has very often been on the non-monetary items, and on time in particular. This is because many of the issues of demand with which transport analysts are concerned impinge on the performance of the transport system rather than on the monetary costs.
>
> Hence, it is more straightforward to conceive of the inverse relationship, whereby *C* is the unit (generalized) cost associated with meeting a demand *T*. Since this is generally what is required for the transport problem, we adopt this interpretation. In this sense, the supply function encapsulates both the response of supplying "agencies" and the performance of the system. Note therefore the different "directionality" of the two functions: for demand, the direction is from cost to quantity, whereas for supply the direction is from quantity to cost".

Thus the X-axes in Fig 4, both labelled 'flow' are different, the left hand representing vehicles getting through per hour, and the right hand representing the demand seeking to get through. May et al (2000)[38] argue that

> "However, what is needed for an analysis of the costs associated with a given demand is the time spent by all the demand flow up to the time that it exits the link. This requires that vehicles be "tracked" until they leave the link. In turn this means that the

[37] Bates J (2008) History of Demand Modelling Chapter 2 in Hensher and Button (2008) Handbook of Transport Modelling, Elsevier ISBN 978-0-08-045376-7

[38] A. D. May, S. P. Shepherd, and J. J. Bates (2000) Supply Curves for Urban Road Networks. Journal of Transport Economics and Policy, 34(3) 261-290

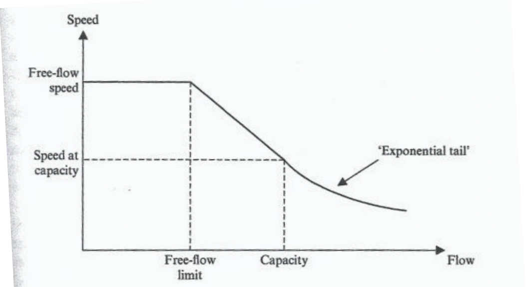
period over which this travel time is measured may well be longer than that over which the demand occurs, and over which performance associated with that demand would conventionally be measured".

The practice for calculating assignment of traffic between alternative routes does not have an exact analytical solution, so was (and remains) essentially an iterative procedure of trying lots of alternatives seeking to converge on a solution which met the characteristics for a 'Wardrop equilibrium'[39] where all used routes have the same travel time (or generalised cost) and no advantage can be gained by changing routes.

Official advice

In practice, for over 50 years, the form of curves advised by the DfT to use, for example, in cost-benefit calculations, provided relationships which avoided a very steep part of the cost flow curve by damping or flattening the curve. So the reduction in speed (and corresponding increase in travel time, and cost) arising from flows near capacity was limited, enabling a notional speed to exist greater than the theoretical capacity of the road. There have been many different alternative functional forms for doing this, which I do not need to get into here. In 1970 the UK Department of the Environment a way to do this, which is conveniently summarised by Boyce and Williams (2015)[40] in their Figure 5 below.

Fig 5 Official Advice on Form of Speed-Flow Curves after 1970.



urce: UK DoE (1971) Advice note 1A.
igure 3.2 *Speed-flow curves widely applied in UK transportation studies after 1970*

The original DoE advice[41] which initiated this approach emphasised the need for care as it might imply unrealistically high speeds:

> Para 3: "It must be clearly understood that the relationships and the limiting capacities (Qc) – that is the flow at which it is assumed that the 'straight-line speed/flow relationship will cease to apply – are solely for use in transportation studies and are not intended to be used for design purposes. Equally, it should be appreciated that the relationships as illustrated only purport to represent actual conditions up to the limiting capacity"

[39] Wardrop J G (1952) Some theoretical aspects of road traffic research Proc.Instn Civ Engrs Part II, 325-62

[40] Boyce D & Williams H (2015) Forecasting Urban Travel Past, Present and Future, Edward Elgar, p101

[41] DoE (1971) Speed/Flow Relationships for Use in Transportation Studies, Advice Note 1A, URPA Division DoE

And

(para 8) "When flows exceed the limiting capacity on any link…the computer program should be so designed to attract attention in the output to this fact"

These concerns about possibility of bias were repeated, in a stronger form, in the COBA Manual used up to 2002[42], where section 8, titled 'Treatment of overcapacity on links' contained the following description

"8.1. When the traffic flow on a link in a particular flow group exceeds thecalculated theoretical 'capacity' for a lane, this is reported in PHASE 9 of the output (see Part 7 Paragraph 5.9). Details of the calculation used to determine the theoretical capacity for each by road type is given in Part 5. The overcapacity report is a signal to the user that the COBA evaluation is dealing with flow levels above those normally experienced on links of similar standard. Consequently the modelled situation may not be realistic, and the benefits calculated by the program for the period of 'overcapacity' will become less meaningful the higher the degree of 'overcapacity'. COBA has no control over the traffic flows that are input to the program. It is therefore possible for links in COBA to have traffic flows allocated, either in the base year or at some time in the future, that are not operationally feasible. *Ultimately the user is asking COBA to assess a situation which breaks the bounds of common sense - that is, when future year traffic levels exceed physically practicable flows per lane.* Depending on the Road Class overcapacity may be reached either before or after the calculated speeds fall below the minimum speed cut-off. In exceptional circumstances it may be necessary to lower the minimum speed cut-off to obtain realistic speeds on the network. This is possible within COBA and can be implemented on a particular road class or an individual link. Any change contemplated should be agreed with the Overseeing Organisation in advance of any submission. The concept of minimum speeds on links is similar to that of maximum delays at junctions. *The justification for using cut-offs of this nature is that in practice, one expects traffic behaviour to change to avoid bottlenecks…"*

And

"… 8.3 iii) exceptionally, in some large conurbations, predicted levels of congestion may be sufficiently severe to warrant modification to the COBA assumption that observed minimum speeds will be maintained in the future. In such cases the COBA cut-offs may not represent the full economic cost of trip suppression or alteration of time, route, destination or mode of travel. However, simply lowering the cut-off speeds (or increasing maximum delays) will *ultimately overestimate the economic effect of congestion, because traffic will tend to take action to avoid or mitigate the effect of congestion*. In these cases the advice of the Overseeing Organisation should be sought to ensure that a consistent approach to the problem is adopted."

[42] DfT (2002) The Coba Manual Volume 13 Section 1 Part 5 Speeds on Links Chapter 8 Treatment of Overcapacity on Links. Note that this whole volume was withdrawn by DfT and I am not sure if it has been archived online, but of course it survives on paper, and on the internet in various locations, including at http://www2.westsussex.gov.uk/handt/poe/n.pdf and COBA Manual: Speeds on Links - Road Scheme Economic Assessment

(The italics in these extracts are mine, drawing attention to the implication that the DfT authors at that time evidently advised great caution about this practice, specifically because it was felt to risk a bias in the calculation of the economic appraisal relating to behaviour changes which relate to induced traffic. Indeed, the expectation of what we would now call induced demand was cited as a justification for the assumption).

In successive alternative variants of the cost flow curves tried since, there was much less concern. Similar caveats were not included in the 2012 guidance in TAG 3.19[43], which used essentially the same advice as the latest DfT (2024) advice, in TAG Unit M3.1 on Highway Assignment Modelling[44] with a much gentler suggestion about the need for 'review':

> "E.8.9 The achievement of convergence can be affected by the shape of the over-capacity relationship. If the slope of the relationship is too steep, there is a risk of an oscillating assignment; if the slope is too gentle, links may appear too attractive with the result that convergence is achieved with assigned flows in excess of capacity despite under-capacity alternatives being available. If convergence problems are experienced, analyses should be undertaken to assess the extent to which assigned flows are in excess of capacity. If only a few or a small proportion of the modelled links have assigned flows above capacity, the shape of the over-capacity speed/flow relationship may not be a significant cause and other aspects of the model should be considered. If, however, a significant number or proportion of the modelled links have assigned flows above capacity, the shape of the over-capacity speed/flow relationship should be reviewed."

There is no advice given on how to judge what constitutes a 'significant' number or proportion of affected links. In discussion with present and past DfT officials, it is my impression that there is no accumulated experience of potential concerns that the application of such speed flow relationships allowing speeds higher than capacity may have led to biassed results in appraisals. It seems that there are few or no records of advice being sought, or what the advice would have been if it occurred. However, the ratio of flow to capacity is a standard output of many modelling packages, and is sometimes provided by promoters to local authorities, so it should not be difficult to collate such information, to test its incidence and potential significance.

In discussion with assignment modelers over the decades, and with technical colleagues during preparation of this report, my experience has been that they simply do not feel this is a problem. The view has been that it is an adjustment for reasons of computing efficiency, having a temporary role in the calculations, and not causing any problems of underestimating future problems of capacity resulting from the side effects of increasing capacity at locations of expected congestion. Indeed, the view is that making such adjustments results in more robust results, with more realistic routing across the model.

More recently, there are confident assertions that the whole problem is unnecessary, since there are models based on junction capacity, rather than link capacity, which can handle

[43] DfT (2012) TAG Unit 3.19 Highway Assignment Modelling Appendix E.8.11 p84 [ARCHIVED CONTENT]
[44] https://assets.publishing.service.gov.uk/media/67ed0e54e9c76fa33048c634/tag-m3-1-highway-assignment-modelling.pdf

blockages which reduce traffic speed to zero (as realistically sometimes happens) without any computing difficulties.

However, the use of junction delays instead of link speeds does not of itself remove controversy. It is known that there are sometimes disagreements at public inquiries between local authorities and road promotors about whether the network can 'cope' with the side effects of increased traffic in specific vulnerable places, a classic implication of diverted and induced traffic: a recent example which I sat through in the DCO inquiry on the Lower Thames Crossing was a disagreement between the promotor, National Highways, and an Objector, Thurrock Council, on a specific vulnerable junction, where a link-based model and a junction based model gave very different answers: it was recorded as a 'failure to agree' which the Examining Authority was unable to resolve, and referred back to the parties for further work, outside public scrutiny. I do not know the outcome of those discussions.

I am not aware of any published reports, over half a century, with a systematic retrospective monitoring of the effects, comparing the incidence of links or junctions for which problematic flows are forecast, with later outcomes of their outcome levels of congestion.

It may well be that the problem is not serious, or is easily resolved. But I do find it strange that there has been such a long-lasting lack of curiosity about the effects of this practice about which official advice has been to make such clear warnings. It might be, for example, that investigation would show that the problem junctions give advance warning of particular links or junctions that, after an intervention is implemented, will become congestion hot spots earlier than predicted. If so, it would certainly be worthwhile to include them in appraisal, and focus on them in ex post evaluation.

The interesting investigation here would be to check some past appraisals to test theincidence of forecast flows greater than capacity, for the 'with' and 'without' cases, for the opening year and the latest forecast year (design year or later), checking this against the actual flows in line with the revised POPE evaluation as discussed above. If there is a problem, its incidence would probably increase over time with the general level of traffic, independently of induced traffic. I am aware that received wisdom has it that there is no problem, and this may be true, but it seems wrong to go on making such calculations for several decades without any activity to check.

Other solutions have been suggested to the problem of convergence, notably that the modelled process of clearing congestion should not be assumed to be completed swiftly, so the modelled adjustment could be extended to dynamic analysis over a longer time period[45].

Discussion and implications

Assignment is often described as producing 'short term' results, while trip generation, mode choice and destination choices are described as 'long term'. This might seem to be sensible given that people can self-evidently switch their routes very swiftly, even instantaneously, while changing the origins or destination of work trips, for example, would obviously take longer to evolve. But that simply does not correspond with the nature of most transport demand models. In practice, both short term and long-term equilibrium are assumed to be achieved instantaneously, to be already evident in cross-section data, and to last until external

[45] Eg Peirson J (2025) A short economic analysis of the marginal external costs of road congestion and hypercongestion publication in progress but available from jdp1@kent.ac.uk

circumstances change[46]. There are of course well known results, from SACTRA onwards, suggesting that there is retrospective evidence that induced demand builds up over periods of some years. I think this is broadly agreed by all. But the forecasting models described are not the source of this finding, and could not be since they do not include explicit longitudinal analysis of a type which could measure the actual time scale of short and long. Rather, the models make equilibrium forecasts and discussion then makes use of dynamic interpretations from common sense arguments, longitudinal econometric studies, or retrospective evaluation.

Thus the computing algorithms used in an assignment model do iteratively seek an equilibrium solution, but they should not be interpreted literally as equivalent to day-by-day or week-by-week successive stages in a dynamic process of adjustment of people's choices. However, this is a useful reminder that such real world choice processes do indeed exist. When congestion is common, variation of travel conditions from day to day is inevitable, and occasional bad experiences are the trigger for a proportion of travellers to continually be reconsidering their routes. Next day, or next week, they would try different times of day or different modes or different destinations, etc, in accordance with their own specific possibilities. Such a process of trial demand responses would continue until a satisfactory solution was found, evolving over time as different possibilities are found.

As long as congestion continues, so will day to day variation, and adjustments in response. There might then be a convergence to a form of equilibrium for a time, but more likely a continual process of fluctuating demand. In that case, variation of route choices would simply be one of many different demand responses: one might never actually see 'the equilibrium', but if one did, it would take a number of years, as shown by the results of dynamic estimation of demand elasticities.

Thus in more fundamental terms, my own view is that we should see day to day and month to month variation, including some incidents of traffic jams, as both inevitable and an essential feature of the behavioural adjustment process. Occasional unexpectedly low or zero speeds, and the reaction to them, are real world phenomena, proceeding at different paces. The implication would be that the existence of some proportion of travellers who can make rapid changes to their travel demand is an essential feature of returning traffic conditions up or down to a (just) acceptable level. In practical evaluation it means that the higher-level changes of behaviour – and their implication for induced traffic – are essential and endemic. It also implies, I think, that the appraisal of costs and benefits of induced traffic extend further into the assignment process than is usually assumed.

In general, a complex network, with random variation, but traffic fairly close to the maximum possible, is inherently unstable. Induced traffic is what keeps it close to tolerable conditions.

In ex post evaluation, moreover, we do not have the option to ignore dynamic time processes, since whatever the advance modelling may have suggested about equilibrium, any 'after' study cannot ignore the question of how long after the event the monitoring is taking place

Recommendation

I think, at least, that there should be a survey of the incidence of cases, and thoughtful interrogation of them. If the relevant information has not in fact ever been monitored and

[46] I consider these to be incompatible.

kept, it would be useful to reaffirm the advice, set up a trial, and prepare to analyse it in five years' time.

6. **Freight Demand Modelling**

TAG unit M2.1 Variable Demand Modelling has one sentence on freight, namely

> Para 1.1.5 "Any response in the demand for transport of freight is not considered here, and it is generally assumed that total freight traffic is fixed, but susceptible to re-routeing"[47]

National Highways (2023) has had a more emphatic interpretation of this, stating that

> "TAG Unit M2.1 sets out that LGVs and HGVs do not experience variable demand as their journeys are driven by commercial needs, and therefore remain consistent between the Do-Minimum and Do Something scenarios."[48]

(These words do not appear in TAG M2.1, either in the 2020 or 2024 version).

A rather detailed review of the available empirical evidence, already evolving over several decades, is included in Appendix 1. My judgement is that this evidence is strong enough to be confident that the assumption and practice of fixed demand for HGVs and LGVs is simply wrong. There is substantial empirical evidence that this transport is sensitive to changes in both the money and time costs of travel, whether achieved by infrastructure investment, highways management, or policies affecting money costs. However, measuring and modelling these cannot simply be done by identifying 'HGVs and LGVs' as freight. Empirical evidence, including that from DfT itself, shows a very great variation of function and operation within the broad HGV and LGV sectors, and on their fringes.

There is a degree of interchange between personal and goods traffic. The movement of goods remains important, but especially for LGVs the delivery of services is also a major part of the market, and delivery of goods now also includes a major shift overlapping with delivery of shopping to households, which had previously been mainly considered as personal travel carried out by cars, public transport and walking. Thus individual households have decided that they will reclassify a lot of their shopping from 'personal transport' to 'goods transport'. On the other hand, some commercial parcel deliveries are carried out in the private cars of self-employed staff.

Empirical statistical evidence includes a significant literature measuring demand elasticities for miles travelled of freight vehicle miles, or tonne-miles, related to fuel price directly, and therefore (via values of time) related to travel speeds and journey times.

Other evidence relates to business practices in competing sectors of HGV and LGV use. The big operators have elaborate modelling and optimisation practices of their own, and the small operators are in highly competitive conditions which, for survival or enrichment, make them very aware of traffic conditions and make use of any changes. Satnavs enable very fast

[47] https://assets.publishing.service.gov.uk/media/666af2a3ffd07973a043d10f/tag-unit-m2.1-variable-demand-modelling.pdf

[48] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR010032/TR010032-002966-National%20Highways%20-%20Applicant's%20submission%20of%20documents%2064.pdf Paragraph A3.10 page 49. I note that National Highways suggest that this reasoning is 'well accepted in the industry as being the rationale behind the guidance given in TAG'. I find th is difficult to reconcile with reports of industrial support for the Lower Thames Crossing because it would enable firms to 'extend their markets', which suggests induced traffic.

response. Many LGV sectors providing services are accustomed to constraints affecting how many calls they can make per day, and if they can fit in an extra call, will do so.

Part of the problem of implementing these changes in variable demand modelling is that the now classical way of modelling personal travel, based on a hierarchy of how many trips, where to go, what mode to use, and what route to take, cannot be simply adapted to large parts of the freight markets – where deliveries of goods and services might be to 20 or 100 destinations per day, different every day. Delivery charges are an active consideration, with different models (by subscription, or per delivery) aimed at different markets. Ready to eat food delivery has seen a new transport provider segment, direct from fast food outlets by bikes on the borderline of legality.

Thus the optimisation process does exist, but is essentially focussed on logistics, including the location of production and warehousing, transfer facilities, and planning of very elaborate route and sequence sequences. 'Access to new markets' is a manifestly salient consideration for company managers.

All this establishes a very strong expectation that volume of freight traffic on the road is and must be affected by changes in the cost or speed. It does not establish in what form that effect will be revealed, ie the different dimensions of demand, or the way that it be related to business practices, or competitive pressures.

Therefore I conclude that

(a) Induced traffic must be possible, and is likely to be substantial, in this inadequately titled 'freight' sector;

(b) If this is to be modelled, it will require a different sort of model, not a modification of the sort thought to be suitable for personal travel;

(c) This is a major exercise, likely to take a significant time. If the DfT is in agreement about its need, it should be programmed as a matter of some urgency;

(d) The short-term focus unavoidably will have to depend on approximate and highly simplified methods of making some suitable allowance by pragmatic adjustments. This might include using empirical results on demand elasticities, or temporarily mirroring the known scale of personal adjustments by commercial ones. It also ought to be a prime focus of revised ex post evaluation of induced demand from traffic counts, which do not depend on the ex ante forecasts. This is included in section 9.

Continuing the blanket elimination of induced demand in the current practice cannot be justified, and produces a major bias in economically crucial activities. This is not a marginal question of little practical significance.

7. **Limiting Cases?**

Vertical demand curves

Given two demand curves, the more elastic[49] one will always show additional benefit to the induced traffic, than does the low elasticity curve. However, the low elasticity curve always benefits from more consumer surplus than the high elasticity curve.

In the case of assumed equilibrium in the base case, and instantaneous response to a new equilibrium, year by year, to new equilibria, the comparison between 'with' and 'without' is symmetrical: it makes no difference whether when is appraising adding new capacity or taking it away[50].

On this basis, we can approach the limiting case, working up from the more to a less elastic curve and then towards a zero elastic curve. In this case the amount of induced traffic gets less and less. As we cannot assume "willingness to pay" to be the same for all travellers, elastic demand implies that there are consumers with low WTP that still benefit from the price point. Demand becomes inelastic, insensitive to price, only if the price is zero or willingness to pay for those remaining consuming at that price have a very high WTP or an infinite consumer surplus.

So the question is what is the consumer surplus in the case of completely fixed demand? As demand becomes less and less elastic, this means that people are (by definition) willing to pay more and more to maintain their consumption. This is, in effect, inherent. So zero elasticity would imply an infinite consumer surplus, and an unbounded willingness to pay, which is absurd, or meaningless, or both. There is simply no category of traffic which one can convincingly say would be willing to pay any price charged, without any change in their behaviour.

The conclusion that I take from this is that the zero elasticity demand curve, considered as the 'limiting case' of lower and lower elasticity, simply is not a normal economic relationship[51]. It does not make any sense to treat its benefit as the 'change in consumer surplus', given by subtracting a fixed cost rectangle from an infinite utility.

The zero elasticity demand curve can only possibly exist within some bounds, outside which the consumer is faced with financial pressures such that willingness to pay becomes impossible. Nobody, and no company, has infinite income or time. The real limiting case is that constrained by the income or time available to the individual traveller, or the commercial

[49] Just as a reminder, elasticity is not the slope of a straight line (except on a log scale) but is defined as (% change in demand)/(%change in price) or (-dlog D/dlog P). So in the theoretical demand curves, when drawn as a straight line, it's not strictly correct to identify the slope of the line as the elasticity. But the exposition is still qualitatively correct.

[50] However, there is a different analysis required if we want to appraise change over time, which in practice is always the case: the question then is how the elasticity of the demand curve itself evolves over time.

[51] Economic textbooks usually allow for the possibility of circumstances where demand might increase when prices go up. One case, for example in dire conditions of the Irish potato famine, where the price of potatoes, as the cheapest food, became so high that impoverished people could not afford any other superior but dearer food. At the other extreme, some fashionable goods get an extra cachet from their high price and exclusivity, among rich people. There have not been suggestions, as far as I know, that either effect should be allowed for in transport modelling, though it is possible to imagine circumstances in the bottom end of the second hand vehicle market or the top end of high performance cars or luxury mobile homes where there could be such perverse effects. Either would be an interesting topic for a student thesis.

viability of a company. The 'option' of going bankrupt always intervenes long before one reaches a vertical line. More realistically, a company can always opt out of a particular product line or activity when it doesn't make a sufficient profit, and another company can always enter a market when its own conditions allow it to make a profit. Given this hypothetical argument, the question is whether empirically an elasticity is so small as to be unimportant, or difficult to estimate. The important case is that of Freight transport (or more strictly, HGVs and LGVs) and the evidence on this is considered below.

Horizontal demand curves

'Filling up' as a limiting case with no benefits

The other limiting case, called 'filling up', was not triggered by being championed by a responsible body, but was interesting because of its potential significance for policy assessment. The question was, did it address the concern that there might be some conditions in which induced traffic negated all benefit?

The fixed demand case was based on the idea (mistaken) that it could be described as a vertical line. The corresponding other limit was that of a horizontal line. The significance of this seemed to be as follows. The more elastic the demand curve, the greater the amount of induced traffic. Would there be a position where there was so much induced traffic that there was no benefit at all – any road improvement would immediately fill up to the point where the speed of travel was the same as before? In this case there would be more people travelling, but was there a benefit to them in doing so, even if the resulting levels of congestion showed no improvement? Evidence submitted to the Committee by John Dodgson suggested that in such a case there would indeed by no benefit at all, provided that the 'filling up' were immediate and total. If there was a delay, so that for a period congestion was allayed, there would be a benefit to the travellers. The problem with this answer is that all the modelling used assumes instantaneous and sustained equilibrium, with no delay. Any delays would require some form of dynamic modelling.

But the real problem, as previously, is that the other implications of assuming a horizontal demand curve do not fit the conceptual basis of a demand curve. What it requires is a body of travellers who are so uninterested in the benefits of travel that the road is completely empty if the costs, or travel times, are minutely more than the prescribed level, and full to overflowing at minutely less. There is no detectable benefit of anybody being there, and no detectable loss if they all went away. The case is simply not interesting.

By choosing a more elastic real demand curve, it can be seen that the benefits, though small, do exist, but it will certainly be a possible outcome that the benefits do not justify the costs of making the improvement. That is sufficient to calculate conditions where the project will not be worthwhile. No extra useful information can be given by the limiting case.

8. **Wider Evidence on Induced Traffic and Benefit**.

Questions of the wider conditions which influence the scale and direction of induced traffic effects was a recurrent topic of interest in the aftermath of the 1989 traffic forecasts and road programme, intensifying in parallel with SACTRA's work, and seeing a strong emphasis on demand management and multi-modal appraisal by the Conservative Government from 1994 and the incoming Labour Government from 1997. The work identified several main cases where the simple intervention of road investment to solve problems of traffic growth was inadequate. In summary these were as follows.

Positive feedback ('Vicious Circle')

SACTRA (1994) referred to the work of Mogridge et al (1987, a, b)[52] proposing what he called the 'Downs/Thomson Paradox' with the idea that a dynamic 'vicious circle' of traffic growth, road capacity increases, public transport demand decreases, leading to reductions in public transport service quality or fares increases, leading to further traffic growth, would make conditions worse and worse. This idea could have been proposed at any time following publication of the Buchanan Report 1963[53], the Smeed Road Pricing report in 1964[54] (of which Thomson was Secretary and did much of the drafting of the report), and Smeed and Wardrop's study of bus and car use also in 1963[55], but I think the first time the vicious circle was actually articulated might have been in about 1969 by Pharoah.

Multi-modal studies

Marsden[56] has written on the Multi-Modal Studies which explicitly replaced the search for an ideal programme of road investment, by the search for a combination of public transport investment, road investment, and demand management including pricing which together would achieve greater benefits. Congestion charging was particularly important in those cases where it was not possible or sensible to provide road capacity sufficient to meet all the forecast traffic growth. Not all their recommendations were followed, especially on pricing, but this was to recur.

Reduction of road capacity

Cairns et al (1998[57] 2002[58]) collated the results of about 100 cases where road capacity had been reduced or reallocated as an act of policy, and some accidents, to achieve intended benefits to public transport, walking, cycling, quality and economic efficiency of town centres, and other objectives, and some accidental cases also, and found that the corresponding reduced traffic effect of the induced traffic: just as the benefits of induced traffic from increased road capacity were often less beneficial than intended, so the disbenefits of reduced traffic from reductions in road capacity were often less than feared.

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[52] Mogridge M J H, Holden D J, Bird J and Terzis G C (1987b). The Downs/Thomson Paradox and the Transportation Planning Process. International Journal of Transport Economics XIV(3). Mogridge M J H and Holden D J (1987a). A Panacea for Road Congestion?- A Riposte. Traffic Engineering and Control 28(1): 13-19.

[53] MoT (1963) Traffic in Towns ('Buchanan Report') HMSO

[54] MoT (1964) Road Pricing: the Economic and Technical Possibilities ('Smeed Report') HMSO

[55] Smeed R J & Wardrop J G (1964) An exploratory comparison of the advantages of cars and buses for travel in urban areas, Institute of Transport Journal, 30 (9) March

[56] Marsden G (2005) The multi-modal study transport investment plans, Proc Inst Civ Eng (Transport) 158 (2) 75-87

[57] Cairns S, Atkins S, Goodwin P (2002) Disappearing Traffic? The story so far, Proc.Inst Civ. Eng-Municipal Engineer 151(1) 13-22 https://nacto.org/wp-content/uploads/disappearing_traffic_cairns.pdf .

[58] Cairns S, Hass-Klau C, Goodwin P (1998) Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence , Report commissioned by London Transport and DETR. Landor Publishers. Available online in multiple sites, including https://www.cycling-embassy.org.uk/sites/cycling-embassy.org.uk/files/documents/Traffic%20Impact%20of%20Highway%20Capacity%20Reductions-%20Assessment%20of%20the%20Evidence.pdf

DfT advice concerning fixed demand for 'small schemes'

DfT advice is given in TAG Unit M2.1[59]

> "Although the modelling effort needs to be proportionate to the scale of a potential intervention, the need to consider variable demand is not simply a question of the size of the intervention. Since both demand changes and benefits tend to scale with the size of the scheme, changes in demand can have similar proportionate effects on benefits for both large and small schemes. Thus, changes in demand can have fundamental implications for the justification of a scheme of any size, in terms of economic, environmental and social impacts and should be represented appropriately and proportionately".

There is an interesting comparison here with the way in which 'small time savings' arenearly universally given the same unit value as big time savings in spite of recurrent objections that it does not make sense to give a value to a time savings of a few seconds which nobody can use, or sometimes not even perceive. The traditional pproach has been that even if small time savings were judged to have a lower unit value because the small savings could not be perceived or used, that would imply that schedules must contain a degree of slack based on the unusability of earlier small time savings. There must therefore be a proportionate number of occasions when a small additional saving could be added to other unused ones and enable a larger, useful, response. Not everybody is convinced of this, but it is firmly established in transport appraisal and all time savings, however small, are included in the benefits.

The same argument suggests including small benefits and costs of induced traffic for small schemes. Not to do so would encourage division of large schemes into several small ones with spurious increases in benefits.

The DfT advice above seems right to me. The only additional comment I would make is that the word 'proportionately' needs to be applied with some care: in this case it should not be used as an argument for simply ignoring the problem. Rather, smaller schemes should also include allowance for smaller benefits, but it is fair to do this with simpler approximate methods than large scale models. This might be done, for example, by making an approximate adjustment to the BCR, in the same proportion as for the bigger schemes, which does not require burdensome additional modelling.

9 . **Recommendations for further work**

(The project Terms of Reference include to make recommendations for further work 'set against some idea of cost and timescales'. If the general approach of these ideas is of interest in principle, I would propose to offer suggestions to DfT about what sort of budgets might be suitable, subject to discussion and of course their own deeper experience of existing and previous contracts).

POPE research proposal

The existence of the POPE evaluations since 2002 has for most of its life had little impact on the knowledge base for the evidence on induced traffic resulting from road capacity increases. It hardly exists in the public research literature, and the comments on induced traffic made in

[59] **Department for Transport (2020).** *TAG Unit M2.1: Variable Demand Modelling.* Section **1.1.4**, Transport Analysis Guidance (TAG).

its own reports, based on an inappropriate evaluation methodology, have been misleading, and either ignored or criticised. However, since a change in the recommended methodology in 2024, and implied proof of concept in at least one of the new reports issued in 2026, it offers the largest and most relevant 21st Century data base that I know of anywhere in the world, with potential for making a very important contribution to understanding, evidence and improved practice.

As discussed above, the largest and most recent data base about the outcomes of road projects completed since 2002 is the set of around 100 POPE appraisals, each of which have been subject to an assessment of the evidence or otherwise of induced traffic. These calculations have not been successful, primarily (but perhaps not only) because the entire set of projects have been implemented during a period where actual traffic growth has been substantially less than forecast, which requires recalculation of the 'do-nothing' forecasts to compare with the actual measured outcome traffic using the improved roads. I recommend that this should be done retrospectively for all the schemes. There is no other data base which could be more appropriate, and a very large proportion of the necessary technical work has already been done and paid for. I would recommend that this should be done, following the principles of the National Highways POPE methodology manual 2024, and with the assistance of an independent, knowledgeable and transparent steering group. As a retrospective recalculation, it would be very useful to include the original specifications of an opening year and five years after, but also a latest available calculation for some selected schemes.

This can be done as a coordinated, staged, research plan as follows.

Scoping review

A compilation of all the published reports issued to date, and collation of the state of play of all others pending, just to check their availability and the current state of the earlier data from which they were constructed. This should include the current availability of the national and regional trend data on traffic volumes over the entire appraisal period, and its breakdown by road type and vehicle type, and (where known) information about the current potential availability of staff, if still professionally active, who worked on the earlier reports, and the background files assembled in writing them.

Review of the 2024 NH Evaluation Manual, and any POPE reviews that have yet beencarried out using it with the expectation that it (or a methodology rather similar to it) will be the basis for the new studies, but may need revision in the light of the objectives of the new programme and the limited experience so far in applying it.

Basic construction of recalculated induced traffic

The four basic quantities required to calculate induced traffic for each scheme are the'Before' and 'After' traffic volumes on the treated road or roads, and corresponding traffic volumes on the national or regional untreated roads being used as a measure for the counterfactual growth rates. This should be done for all the schemes. It would be sensible to select some trial cases first, one or two from each of the three decades of opening dates, and review, before completing the task for the rest. The results can then be used to investigate relevant groups of studies, eg date, area of the country, road type, separately for broad traffic groups (cars, LGVs, HGVs). The reason it should be done for all the schemes is because for any one scheme there is likely to be large variance in the with scheme 'after' counts, which are likely to have been simply due to day to day statistical variance in the traffic counts themselves. The main role of these calculations is not to test the accuracy or otherwise of the ex ante forecasts, but simply to identify how much induced traffic there has been, and any patterns in its variation.

Insight about model performance

Since it is known that the entire period of these forecasts has been one where traffic growth nationally has been overestimated, and local models are influenced to national forecasts, it is highly likely that traffic forecasts for schemes will also show some tendency to over-forecast. It is essential to try and distinguish those over-forecasts due to these general trends, from those affecting induced traffic. Allowing for recalculation of a counterfactual in the way suggested will tend to increase the estimates of induced traffic compared with not doing so.

There are likely to be some cases where the models used for ex ante forecasting and appraisal are significantly different from the outcome, especially in aspects that the models used could not have operated, notably in induced traffic arising from any behavioural changes which were outside the model treatments of trip rates, distribution, mode choice, and possibly time of day choice, or which relate to delays and cumulative build up of effects over time which cannot be treated as settled equilibria. This research activity is likely to be most useful in discussion of any weaknesses in existing or potential new models.

Insight into appraisal of effectiveness and value for money

Treatment of induced traffic may not have the greatest effects on project appraisal: on past experience this is likely to be errors in forecasting the rate of traffic growth due to external factors such as economic growth, land use, etc. But the contribution of induced traffic to any such errors is distinct, and operates in a different way, because the benefit of induced traffic is valued according to the rule of a half calculations, and the contribution that induced traffic makes to congestion, environmental and other costs counts directly as a cost or benefit of the scheme.

This is of course the area which is likely to be sensitive and subject to controversy. It is one of the reasons why carrying put such calculations should be carried out in a professional way with an element of independence and transparency. I would suggest that the style of working should enable contributions and insights and discussion with National Highways, DfT officials engaged in both methodology and scrutiny, commercial and academic consultants, and other stakeholders in local government, business the voluntary sector and the political sphere, with a mode of encouraging discussion, debate and alternative interpretations, without too much pressure to define 'the official view'. This would be consistent with the views about transparency proposed by the Road Investment Scrutiny Panel, Lyons et al (2023)[60] 'about the potential conflict of interest arising from the dual responsibilities of asset owners both to carry out appraisals and act as scheme promoter for their preferred option'. This exercise is about understanding and learning from past experience, not taking decisions about new policies and projects.

Short-term/Long-term Effects

A footnote (p5) in the NH POPE Manual reports

> "Previously we undertook evaluations at one and five years after opening. We have moved to a single three years after evaluation as there is often insufficient data at one year after to draw significant conclusions. A three years after study addresses this and enables us and customers to access timelier results, rather than waiting until five years after."

The proposed replacement of 1 and 5 year assessments by single 3-years is understandable, but has one major disadvantage, which is its inability to discuss the difference between short run and long run impacts of induced traffic, which SACTRA had concluded may double over the period from 1 to 5 years after implementation of a scheme This indeed was one of the points which DfT underlined in accepting most of the Committee's recommendations on induced traffic. DfT (1994) issued a technical guidance note on how this should be done, which includes a table of recommended generalised cost elasticity values. The note says:

> These values represent short-term elasticities and should be used for sensitivity tests of opening year flows. Larger values of up to twice the above should be used for sensitivity tests of design year flows."

In turn this requires consideration of the timing and content of a behavioural adjustment path as it would be impossible to calculate a net present value (which sums up the whole profile of costs and benefits over the appraisal period) unless such a path is assumed.

Thus in accepting the existence of induced traffic, it is necessary to accept the behavioural adjustment process which would bring it about. If this adjustment is not instantaneous - which may be taken as axiomatic - then unbiased measures of benefit must be based on the path and pace of a process which takes place over time and it becomes apparent that the "zero induced traffic" assumption led to not one source of bias, but two.

Levels of accuracy. Another implication is to question the current view that traffic forecasts +/- 15% is an acceptable degree of accuracy. In some contexts that is reasonable, but not when drawing conclusions from many studies, and when considering induced traffic, for which a figure of an additional volume of traffic of 10% is not uncommon, and certainly large enough to cause a significant effect on operations, benefits, congestion costs, and value for money. My understanding of the background of this +/-15% acceptable error band is that it relates specifically to the likely random errors in a one-off traffic count used to augment the analysis

[60] Lyons G (chair), Anable J, Christie N, Davies Z, Glaister S, Gooding S, Goodwin P, Lucas K, Crudgington A (2023) Key questions for road investment and spending, Road Investment Scrutiny Panel, University of the West of England, road-investment-scrutiny-panel-key-questions-for-road-investment-and-spending-17-01-2023-1.pdf

of ex post accuracy. This error band would automatically be reduced substantially when assessing the overall error structure of many schemes, or when calculating errors in other evidence about traffic trends in an area.

Commercial vehicles. An unexpected aspect is that the POPE assessments made have mostly used all traffic not distinguishing cars and commercial vehicles, for which, for other reasons, National Highways had assumed that there was no induced traffic. If this assumption had been correct, the use of 'all traffic' in the POPE analyses would have underestimated what induced traffic they could have found for car traffic, depending on the proportions of CVs and cars (often of the order of 80/20 for vehicle miles, and 70/30 for pcu miles, with even greater proportions of freight for some major arteries).

Perspectives for Demand Modelling

While the classic model has proved extremely resilient, it does not fully reflect alternative approaches to segmentation, influences on choice, behaviour, policy objectives, real-world problems, modelling in the context of uncertainty, and vision-led planning. For example, we are called on to carry out appraisal in the context of 2°C and 4°C average increase in global temperature. We have observed new trends in travel choices including on-line activity, the effects of the pandemic, home working and home delivery, an unexpected and unmodelled increase in the design sizes of cars, age cohort as a key response influence, new approaches to street design and non-vehicle travel, and recognition of the vehicle-as-a-workplace (and a place of leisure) which is changing car and public transport design.

A recurrent issue in this review has been that proper consideration of induced traffic isnot only an issue of turning on or off a ready-to-use 'variable demand,' option derived from the features of modelling as it was determined in the period from 1965-1975 or thereabouts. Other things have happened in transport research and modelling since then, of which two of the most important are

(a) the 'four-stages' of generation, distribution, mode choice and assignment, plus the uncomfortable addition of time of day, do not represent all the possible choices – or even all the important choices – that people make in response to travel conditions. From time to time it is important to review how out of date the present structure might be, and what can be done to make allowance for the demand responses that are not in the model at all, or to take account of their omission. At the moment there is interest in the Department in activity modelling, for example, but I am not aware of how that fits into appraisal. Similarly the mechanisms of response to 'soft' policy interventions is known for walking and cycling policies, but they all also have significance for highway capacity and its alternatives.

(b) There is increasing stress in allowing for the varying time-scale of responses using a modelling framework in which all observed data are already in equilibrium with the factors affecting it, and all forecasts will be swiftly in equilibrium with changes in those factors. I understand there is interest in using system dynamics alternatives, using agent-based modelling. to the assumption of permanent equilibrium, for example, and there is the manifest importance of response time scales in the inclusion of age cohorts in the behavioural choice scenario, but no perspective for including different time scales for responses to trip rate, mode choice, destination choice and so on. It is often assumed that assignment is ‘short term ‘and the other included dimensions are ‘long term’, but there is no empirical basis for that, or definition of how long is long, or recognition that the time scales logically must be different for different population segments.

This is clearly a long term programme. But I think there should be an early consideration of how the current modelling plans fit into such a strategy, especially when considering modelling of broad policy scenarios rather than specific local schemes. This might be in the form of a one-day brainstorm, as a first step.

Strategic freight modelling

I am in favour of a major change in the modelling of HGV and LGV forecasts, which will require major planning and professional work both by Department staff and probably by external consultants. There is not currently a plan of exactly how this would be done, the structure of suitable models or amendments to the existing models, or the resources and timetable. I appreciate that DfT is currently carrying out a programme of work on freight modelling and hope that this will include variable demand methods which will allow for and calculate induced traffic in response to capacity enhancement, or reduced traffic in response to rising congestion. This is, as I have argued, necessary in order to give realistic appraisal.

I appreciate that such a programme of work cannot be sensibly determined by oneexternal person. Even the preparation takes more time and resources – and skills – than I have. It seems right to commission a scoping paper, but it is also evident that previous attempts to do something like this have not succeeded. It might be that colleagues carrying out the current freight modelling plans might be asked to set aside the current plans for a brief pause in which the significance of such a longer term project for their current plans could be considered. It might be suitable for the type of discussions that can happen with a residential awayday, or a one-day workshop of suitable internal and external experts, or a ‘beauty-parade’ brainstorm of consultants working in the field of freight about how they might approach the question. It would be a mistake, I think, to set aside the whole issue of induced freight traffic until the current work plan is completed.

The issue in principle is how to respond to the possibility that better freight modelling overall may be too difficult to achieve swiftly, or maybe even at all. If so, it seems quite wrong to just continue to assume that the demand is fixed. Given that the empirical elasticities seem rather similar for freight and cars, a tentative adjustment to mirror the changes in flows might be better than to assume no change at all. So it is important to develop quick interim procedures to adjust or reinterpret forecasts in the absence of such a model. This might start with a discussion note on feasible short cut methods, for example to mirror calculated induced traffic for personal transport with equivalent adjustments for freight, given that the elasticities seem to be similar.

New econometric modelling

Recent consultant studies commissioned by DfT, by Dunkerly et al (2018)[61] and WSP/Rand (2020)[62], summarised in Appendix 1, have recommended new econometric modelling, and my own review would support this. I have not seen cost estimates for carrying out their own proposed programme of work. The characteristics of this should be informed by diagnosis of the main actual and potential errors in forecasting, related to induced traffic, that have emerged in the period 1989-2019 (ie up until Covid) together with preliminary indications that have emerged during the recovery from Covid in the period 2023-2025. I summarise below tentative conclusions which indicate the possible focus of the econometric modelling.

Persistent overestimate of forecast traffic over the whole period.	Two main explanations: (a) inaccurate input data, primarily income, also population; (b) failure to include behaviour change mostly related to persistence of reductions in car use by young people, persisting into middle age. Correction for either of these separately produces car traffic trends closer to reality, but correction for both requires unexplored interaction.
Declining car traffic shown by NTS	Behaviour change explains this, income errors do not, on current assumptions about income impacts.
Increasing freight traffic at a time of decreasing car traffic	Could be evidence of an interaction effect. Two explanations: (a) some behaviour choice between goods and personal travel, primarily in the area of home shopping and delivery. Evidence that this has happened, but (b) reduced car traffic would reduce congestion, inducing additional freight traffic.
Time dimension of responses. DfT modelling sometimes described as assignment in 'short term' equilibrium but trip generation, mode choice, distribution in 'long term' equilibrium: responses are instantaneous and permanent until conditions change, and equilibrium re-established immediately.	Induced traffic analysis suggests responses take place over a number of years, (eg doubling over 5 years). This is consistent with findings of a 20 year effect of income on car ownership (Tanner, Dargay), and 2-5 (or perhaps 10) year effects for mode choice. Distribution effects influenced by the speed of work changes and home changes (say 3 years, 7 years). Land use changes consequent on transport infrastructure depend on planning and building. All these can be accommodated in econometric models with an explicit, empirical, time scale.
Test results dependent on access to unpublished or non-publicly available models	Failure to give informed public confidence.

[61] **Dunkerley** F, Whittaker W, Laird J, & Daly A (2018) Latest evidence on induced travel demand: an evidence review, Department for Transport https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762976/latest-evidence-on-induced-travel-demand-an-evidence-review.pdf

[62] **WSP/Rand** (2020) Deepening the understanding of how to address induced travel https://assets.publishing.service.gov.uk/media/6172d37b8fa8f5297a62a241/deepening-the-understanding-of-how-to-address-induced-travel-on-the-strategic-road-network-options-for-improving-the-measurement-of-induced-travel.pdf

A full scale review of the DfT's national modelling with these points in mind would, in my view, be entirely useful. However, this will not give even tentative answers to inform current project and policy decisions. Econometric modelling on the POPE project evaluations, enhanced by additional data to inform the baseline demand changes, wil l also be useful.

One aspect which they do not mention is that both DoE in 1996 and DfT in 2002 completed the specification stage of projects to develop econometric models. These were both led by Joyce Dargay, whose leading work on econometric modelling was internationally known. I had the privilege of working with her at Oxford and UCL, and she then became Professor of Transport Econometrics at Leeds University Institute for Transport Studies. Sadly, she died last year, but her work from these two projects is available and should be useful in setting up a new programme. The two projects were TESS, for carbon dioxide emissions from transport, and ATFM, an aggregated transport forecasting model. Dargay et al (1996)[63] (2002)[64].

These reports are quite lengthy and detailed, covering data, specifications, functional forms and default values, the second one being supported by a separate analysis of income and price elasticities for use in the modelling by Hanley et al (2002)[65]. I have copies of the reports: TESS and the Elasticities Review were published, and ATFM remained a draft to DfT.

The reasons why the projects were not taken to the implementation stage may be relevant. This was because in both cases there were concerns elsewhere in the DfT that the use of a new model, which might contradict the findings of the existing traffic and transport forecasting model, could cause public confusion and complicate transport and environmental planning and policy. (In my view it is true that the models were likely to have produced such different outputs, which were more likely to be closer to the actual subsequent evolution of traffic levels). There could still be such an issue, but it is much less likely to be troublesome because the DfT now has explicitly favoured recognition of uncertainty by recognising a range of different valid modelling assumptions.

Hyper-congestion records

I have been puzzled that there seems to be so little published analysis of the effectsof the critically important 'flattening' of the speed flow curve to allow assignment to be modelled by the convergence of an iterative trial and error procedure. The advice notes have always stressed the importance of checking to see whether 'too many' links are shown with flows greater than capacity, so I assume this has been done, but it is certainly not routine to report the results except rather vaguely in terms of a 'satisfactory' degree of compliance with at an overall level. I suggest that it should be a standard practice to produce a map which highlights all links or junctions where this applies, and then a form of checking procedure later, ideally both in the short and longer terms, to see if these places have shown any particular problems of congestion. (I apologise if this has already been routinely done, and I just have not

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[63] Dargay J, Dodgson J, Goodwin P, Holman C, Mackett R, Vythoulkas P (1996) TESS, Report to the Department for the Environment on the development of a forecasting system for carbon dioxide emissions from Transport, ESRC Transport Studies Unit, University College London.

[64] Dargay J, Goodwin P, Hanly M (2002) Development of an Aggregated Transport Forecasting System, Stage 1 Final Report, Contract PPAD 9/65/92, Department for Transport, Centre for Transport Studies, UCL.

[65] Hanly M, Dargay J, Goodwin P (2002) Review of Income and Price Elasticities in the Demand for Road Transport, DfT Contract PPAD 9/65/93, University College London.

recognised the significance of results reported, which is possible). I know that some modellers provide maps showing volume/capacity on links, but I do not know how extensive this is, or what use is made of the information.

Appendix 1 Additional Evidence from the Literature Review

In the Project Brief (see Appendix 3) there was not a requirement for a major general literature review, with the rather more modest expectation that I should carry out a "short survey of literature relevant to the brief, explaining how it is relevant to the issues/questions raised above. This should not be time-bound, and include relevant articles from any year, but does not have to be systematic. We are trusting the supplier to use their expertise to pick up the critical strands of literature".

Induced traffic has implicitly or explicitly been a key component of most important national and local transport studies, including those related to wider economic benefits, agglomeration, the effect of uncertainty of forecasts, all transport policy related to environmental impacts including climate, and many safety studies. Sometimes induced traffic implications have been muted, but they are always important.

Two recent UK literature reviews of induced traffic

Two recent studies commissioned by DfT, specifically related to induced traffic have been carried out by teams led by WSP. Dunkerly et al (2018)[66] concluded in summary that

> "The evidence reviewed in this study supports the findings of the SACTRA 1994) report that induced traffic does exist and may be significant in some situations. There remain wide variations in the quantitative evidence that make it difficult to draw conclusions as to the magnitude of the impact of induced demand on road capacity improvements made to the Strategic Road Network".

Its own summary of findings was clear and well written: I repeat it in whole below. A particular strength of this review was that it was able to report empirical results from econometric studies that do not derive from the 'standard model' as discussed in section 1, but from econometric studies, usually based on statistical analyses of time series data. I quote their own summary of conclusions directly in their own words as it is a good summary and I would not improve it by paraphrasing.

Their follow up study WSP/Rand (2020)[67], following the same general argument as in their 2018 report, focusses on their main recommendation, which is further research based on econometric methods, essentially using time series data on traffic and various components of the cost of travel, which I would support.

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[66] Dunkerley F, Whittaker W, Laird J, & Daly A (2018) Latest evidence on induced travel demand: an evidence review https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762976/latest-evidence-on-induced-travel-demand-an-evidence-review.pdf

[67] WSP/Rand (2020) Deepening the understanding of how to address induced travel on the strategic road network https://assets.publishing.service.gov.uk/media/6172d37b8fa8f5297a62a241/deepening-the-understanding-of-how-to-address-induced-travel-on-the-strategic-road-network-options-for-improving-the-measurement-of-induced-travel.pdf (authorship not stated but John Collins, Charlene Rohr and Bryan Whittaker are named as checking and authorising).

Authors' Summary of main evidence from Dunkerly et al (2018)

5.1.1. Much of the evidence reviewed in this report comes from econometric studies, with a smaller body of evidence from case studies and models.

The evidence from econometric studies is varied but there are some consistent findings

5.1.2. Elasticities of demand with respect to capacity expansion provide a measure of the induced demand effect that can easily be derived from econometric analysis. Elasticities represent the percentage change in traffic (VKT) relative to a percentage change in road capacity. A wide range of elasticity values are, however, reported in the literature. Specifically we find that:

- LR estimates of induced demand are larger than SR estimates. This is consistent with the expectation that there are more sources of induced demand in the long run when changes in employment, residential location and land-use may play a role than in the short run. Of course, it is not clear whether these changes in employment and residential location are transfers from other areas, which may see reductions in travel. Short run estimates range from 0.03 to 0.6, long run estimates from 0.16 to 1.39.
- Studies that differentiate between urban and non-urban areas find a larger induced demand effect in urban areas (Rentziou et al., 2012, Duranton & Turner, 2011). Urban areas are expected to have high initial levels of congestion and potentially higher levels of suppressed demand. However, only one study (Pasidis, 2017) analyses the effect of a metro system on road traffic and finds a much smaller induced demand effect in cities with metro systems. The implication is that cities with good public transport provision may have less suppressed demand for road travel.
- Induced demand elasticities that are close to one are associated with studies that estimate long-run elasticities for specific road types, particularly in large metropolitan areas, outside of the UK. They also mainly use the same methodological approach (Duranton & Turner, 2011, Hsu & Zhang, 2014, Pasidis, 2017). As they focus on particular road types, the demand response reported in these studies generally include re-assignment effects and is larger than the induced demand response.
- There is no recent econometric evidence on project level investment. van der Loop et al. (2016), consider the overall impact on the network of 150 separate capacity improvements. The review studies report short-run elasticities of 0.24 (Cervero, 2003) and 0.29 (Strathman et al., 2000).
- There are clear differences in the magnitude of long run elasticities estimated using different methodological approaches. These differences cannot be fully explained by the geographical scale at which the elasticities are estimated or the type of roads included in the analysis. One explanation is that some studies suffer from endogeneity; while induced traffic is the VKT response to increased capacity, some of the observed increases in road capacity may themselves have been as a result of increases in VKT. Not fully controlling for this latter effect may lead to smaller elasticity estimates. Another possibility is that approaches estimating smaller elasticities control differently for the background traffic component of VKT.

It is difficult to compare the econometric evidence with the evidence from case studies and modelling

5.1.3. The evidence from case studies and modelling is reported as percentage changes in traffic relative to the baseline, having controlled in some way for background traffic growth and reassigned traffic. These percentage changes are not related to a corresponding percentage change in capacity and may also be measured in numbers of vehicles rather than vehicle-kilometres. This makes them difficult to compare with the elasticities reported in econometric studies.

- Case studies reported a wide range of short-run percentage changes in traffic flows (5 % to 38%). These cover a range of different projects. Large percentage changes are reported for improvements to highly congested routes (Davies, 2015) or roads that fall within large metropolitan areas, such as the M25 (Sloman et al, 2017).[43]

[43] We note that this is our categorisation using the terminology of some econometric studies.

Authors' Summary of main evidence from Dunkerly et al (2018) continued

- Modelling studies reporting at the city region scale find smaller percentage changes in traffic flows due to induced traffic (0.7% to 3.84%), compared with 5 per cent on a main road link.

5.1.4. Based on the evidence from the different study types, we identify some broad, overall findings.

More induced traffic is associated with road capacity increases where there is a high level of congestion and suppressed demand

5.1.5. There is econometric and case study evidence that indicates the induced demand effect is greater when there is a high level of congestion. Much of this evidence is from large metropolitan areas, where congestion and suppressed demand are expected to be present. The range of values reported in the evidence makes it difficult to quantify for RIS2. However, most studies that report elasticities indicate that a 10 per cent increase in capacity would result in at least 5 per cent induced traffic. The starting level of congestion is important for the size of the effect. However, the empirical evidence does not really quantify this beyond differentiating between urban and non-urban settings.

A smaller induced demand effect is associated with capacity changes at an aggregate scale or for changes that increase accessibility.

5.1.6. Studies that estimate elasticities of demand with respect to road capacity considering all road types (and therefore controlling for reassignment effects) at the state or regional level find smaller induced demand effects, such that a 10 per cent increase in capacity would result in induced demand in the range 1 to 4 per cent (e.g. Hymel et al, 2010, Gonzales & Marrero, 2012). For the trunk road network in the Netherlands, an elasticity of 0.2 is estimated (van der Loop et al., 2016). Where the impact of road capacity that adds to the length of the road network is distinguished from lane capacity increases for the existing network (Hsu & Zhang, 2014, Pasidis, 2017), the former can be interpreted as an accessibility effect. This is associated with a smaller elasticity (approx. 0.3).

The size of the induced demand effect relative to background traffic growth in the long run is not clear

5.1.7. This could be important if road building is designed to cope with future expected growth rather than to relieve congestion and is discussed further in Appendix A. van der Loop et al. (2016) find a 3 per cent induced demand effect (corresponding to an elasticity of 0.2) compared to 12 per cent background traffic growth over a 14 year period. Modelling studies covering long run changes also find small induced demand effects relative to background growth (Kang et al. (2009) estimate 0.7 percent induced traffic and 19.3 per cent background growth). However, many studies either focus on the short run or do not report the background effect in addition to the induced demand effect.

5.1.8. With the exception of models, the evidence presented in this review is based on observed traffic, from which the induced traffic component is then derived in some way. The observed traffic includes background growth as well as re-assigned traffic and the methodology used to control for these two types of traffic will have an impact on the resulting estimation of induced demand and need to be clearly explained.

Recent evidence from the UK and Europe is consistent with the findings of SACTRA 1994

5.1.9. The evidence they reviewed included before and after studies from the UK (including London) and Amsterdam, which showed that traffic level increases on new routes were not offset by corresponding reductions in traffic on equivalent unimproved routes. This was consistent with the existence of induced traffic but it was not possible to show the sources or size of effect. The report also highlighted the potential difficulties for research on induced demand such as isolating a statistically significant effect due to one factor, causality, establishing suitable controls and the problem of comparing evidence drawn from different sources.

Some highlights of studies in other countries

When the SACTRA report was published some other countries were considering similar issues. The European Conference of Ministers of Transport (ECMT, now titled the International Transport Forum) arranged a Round Table Conference in Paris with major reports, compiled into a book[68] of over 300 pages, including a summary of the SACTRA report[69] and other UK developments and some policy implications, and reports from Austria, Spain, France (several reports), Germany and Greece. The Conference was chaired by Dr Derek Wood, QC, Principal of St Hugh's College Oxford, who had chaired the SACTRA investigation. Its overall summary conclusions stated

> "Situations and individual responses vary substantially, reflecting the complexity of the real world. However, there is no doubt that the phenomenon of induced mobility is likely to remain with us in the future".

It called for better monitoring, including the collection of data for every major infrastructure project, collecting data over time at different periods both before and after construction of the infrastructure, using a variety of different methods in combination. 'Survey techniques and models need to be improved, even if this should prove costly'.

Concerning policy implications, there was a notable review by Noland and Lem (2002)[70] with a discussion of evidence and implications for transportation and environmental policy and an interesting comparison of developments in the US and UK. Noland has also written several other papers on induced traffic.

Since then there has been a steady stream of research papers from academics, including in the USA, Australia, New Zealand, and Northern Europe. I am also aware of interest in Russia, China and South America. I think it is probably time for another systematic international literature review, ideally sponsored by an international organisation.

A good review by Abelson and Hensher (2000)[71] picked up an important point from Litman (1999), based partly on the SACTRA work plus other US studies, shown in figure 6, namely the key time profile of induced traffic development.

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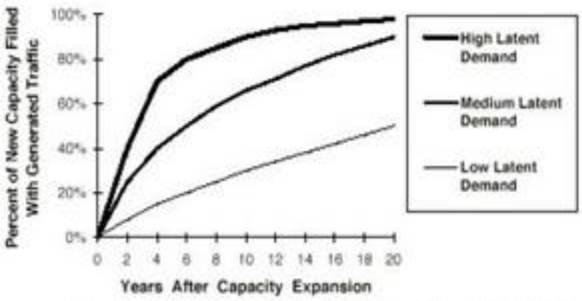
[68] ECMT/OECD (1998) Infrastructure-Induced Mobility, Report of Round Table 105 held in Paris November 1996, https://www.oecd.org/content/dam/oecd/en/publications/reports/1998/06/infrastructure-induced-mobility_g1gh1f2c/9789264163294-en.pdf

[69] Goodwin P (1998) Extra traffic induced by road construction: empirical evidence, economic effects and policy implications, in ECMT/OECD (1998), op cit, pp145-220

[70] Noland R B and Lem L L (2002) A review of the evidence for induced travel and changes in transportation and environmental policy in the US and UK, Transportation Research Part D & (1) pp1-26. https://www.sciencedirect.com/science/article/abs/pii/S1361920901000098

[71] Abelson, P.W. and Hensher, D.A. (2001) Induced Travel Demand and User Benefits: Clarifying the Definition and Measurement for Urban Road Infrastructure, in Hensher, D.A. and Button, K. (Series and volume eds) Handbook in Transport Vol 3, Transport Systems and Traffic Control, Pergamon Press, Oxford, 125-142.

Figure 6 Elasticity of Traffic Volume with Respect to Road Capacity



This illustrates traffic growth on a road after its capacity increases. About half of added capacity is filled with new traffic within a decade of construction under normal demand conditions.

One particularly impressive recent study was published by the New Zealand Government[72], with well-informed reviews of UK work (James Laird, one of its authors, is British and has been an active contributor to transport research here). It is a substantial report (128 pages), includes a stronger emphasis on the implications for climate change than has been common in the UK work and it has been able to go into much more detail on specific modelling recommendations than has been possible for my own much smaller exercise. It recommends an approach based on elasticities of vehicle kilometres with respect to lane kilometres of road, with short term application and a longer term research programme. Its recommendations, I think, chime well with my own line of argument.

Most recently, Stanley and Hensher (2025)[73] have a succinct short piece on induced demand in a new encyclopedia, and I have recently seen an interesting and innovative investigation by Batur et al (2025)[74] of the potential for induced traffic effects from the introduction of automated vehicles.

Shahzad and Naveed (2025)[75] have published a remarkable econometric approach to modelling induced traffic for Pakistan, carried out by the University of Seoul. They used a dynamic panel method to calculate the lagged effects of lane kilometres of road on vehicle kilometres of travel, and other associated variables. They found an elasticity of 0.6. It has a

[72] Byett A, Laird J, Falconer J & Roberts P (2024) Assessing induced road traffic demand in New Zealand (NZ Transport Agency Waka Kotahi research report 717) https://www.nzta.govt.nz/assets/resources/research/reports/717/717-assessing-induced-road-traffic-demand-in-new-zealand.pdf

[73] Stanley, J.K. and Hensher, D.A. (2025) Induced demand, in Edward Elgar *Encyclopedia of Transport and Society,* edited by John D. Nelson, Corinne Mulley and Stephen Ison. https://www.e-elgar.com/shop/gbp/elgar-encyclopedia-of-transport-and-society-9781035330515.html?srsltid=AfmBOoon0IVl6UzsoSquQUlQv1IbdKZbj4uGM0IGDISGdzmqFB1ToMPY

[74] Batur I, Mondal A, Alhassan V, Asmussen K, Bhat C, & Pendyala R (2025?) The induced demand implications of alternative adoption modalities of automated vehicles, Transport Policy https://www.sciencedirect.com/science/article/pii/S0967070X25004226

[75] Shahzad K & Naveed A (2025) Dynamic Panel Data Analysis of Induced Traffic Using Generalized Method of Moments Estimation: Evidence from the Gujrat Division, Pakistan https://www.ippapublicpolicy.org/file/paper/68322e6681e41.pdf

very useful review of similar studies in other countries, and impressive statistical estimation techniques.

Evidence on induced traffic of heavy and light goods vehicles

Introduction

DfT (2020)[76] published an 'Analytical Review' of progress on the National Transport Model which includes a section on HGV and LGV forecasting, in two separate sub-models within the NTM suite. This refers to work by MDS Transmodal (2003)[77] who developed the GB Freight Model of which an (incomplete) copy is available in the Government archives. It includes references to the development of generalised cost data which would be appropriate as an input to a variable demand model, but is generally rather guarded about the possibilities of doing so. It also refers to a study by WS Atkins et al (1999)[78] which sounds promising, but I have not found a copy. In general these models produce forecasts of the movement of goods vehicles which do affect the traffic conditions for cars, whose own demand is modelled by a variable demand model, but the Analytical Review states that "there are no congestion feedback mechanisms for the light and heavy goods vehicle models and therefore the elasticity based "volume response" is used in FORGE to take account of congestion impacts experienced by these vehicles." I have not seen an analysis of the success or otherwise of carrying out this adjustment, but would be interested to do so. The more recent advice on Variable Demand in TAG M2.1 does not refer to this.

It seems possible that at an earlier time or times, up to 2020, DfT expected it would be possible to have make an assessment of the sensitivity of the quantity of goods vehicle traffic to travel conditions, but the subsequent experience has led to little or no expectation that this would develop, and there has been a view that therefore induced traffic simply does not exist and is not a possible feature of freight traffic. I do not think that is a possible conclusion from a failure to model it. It would be like a pre-Newtonian conclusion that the absence of a successful model of planetary motion means that they do not move.

Evidence of freight elasticity of demand

There is a long tradition of econometric work on the response of goods traffic to changes in money cost, especially fuel price. This is particularly important because if price affects demand, and the model uses generalised cost, then so also must speed of travel affect demand, via the value of time. This is one of the basic relationships used in generalised cost, including by SACTRA, and provides an avenue to infer responses to changes in travel time from observations of sensitivities to travel costs.

There is an extensive literature of empirical reports on the sensitivity of commercial vehicle traffic to changes in their costs, especially fuel cost. One of the most detailed and most widely

[76] https://assets.publishing.service.gov.uk/media/5fdc9ff3e90e0745298be3cd/DfT-National-Transport-Model-Analytical-Review-accessible.pdf?utm_source=chatgpt.com

[77] https://webarchive.nationalarchives.gov.uk/ukgwa/+/http://www.dft.gov.uk/pgr/economics/ntm/gbfreightmodel.pdf

[78] WS Atkins et al, (1999), Assessing the Effect of Transport White Paper Policies on National Traffic. A study carried out for the DETR by WS Atkins, MDS Transmodal, Oxford Brookes University, Juliet Solomon and Dr. John Bates.

cited reviews was de Jong et al (2010)[79]. They reviewed 36 scientific papers with primary results (not counting other review articles) which included the effects on tonne kilometres, mode share, vehicle kilometres and fuel consumption, of changes in fuel price, with some results which distinguished between different industrial sectors. Their own summary is shown in Table 2.

Table 2 Summary results of effects of fuel price on road freight demand, de Jong et al (2010)

Price change	Impact on		
	Fuel use	Vehicle kilometres	Tonne kilometres
Fuel price	-0.2 to -0.6	-0.1 to -0.3	-0.05 to -0.3
Vehicle kilometre price		-0.1 to -0.8	-0.1 to -0.5
Tonne kilometre price			-0.6 to -1.5

This range of results is rather similar to reviews of car traffic elasticities.

The DfT commissioned its own review of studies (including the above) in 2014. This was by Dunkerly, Rohr and Daly (2014) the DfT in a report on Road Traffic Demand Elasticities[80]. Their overall conclusion was that

> "the elasticity estimates are reasonably consistent, in the range 0.1 to -0.2 for the fuel price elasticity of demand in tonne-km and in the range -0.25 to -0.4 for the fuel price elasticity of demand in vehicle-km."

Its main sources are shown in Table 3.

[79] De Jong G. C., Schroten, A., Van Essen, H., Otten, M., & Bucci, P. (2010). *The price sensitivity of road freight transport — a review of elasticities.* In E. Van de Voorde & T. Vanelslander (Eds.), *Applied Transport Economics* (pp. 205–228). Antwerp: De Boeck. This has appeared in other formats including a pdf at https://significance.nl/wp-content/uploads/2019/03/2010-GDJ-The-price-sensitivity-of-road-freight-transport-a-review-of-elasticities.pdf

[80] https://assets.publishing.service.gov.uk/media/5a7e477c40f0b62305b81f76/road-traffic-demand-elasticities.pdf

Table 3: Summary of freight demand elasticities for shortlisted papers

Paper	Geography	Date of data	Type of data	Fuel price /cost	GDP or other income measure	Comments
Alises et al. 2014	UK, Spain	1999–2007	11 commodity sectors including service (aggregate).	not included in model		Considers changes in RTI=freight tkm/GDP. Finds change of 57% from 1999–2007 but most of this before 2003.
Agnolucci and Bonilla 2009	UK	1957–2003	one aggregate sector	-0.2	0.66	Fuel price used (output from macro-economic model).
de Jong et al. 2010	International	Studies pre-2010	literature review	Fuel price -0.1 -0.2 (veh-km) Fuel km cost -0.6 -0.9 (veh-km)		Consistent set of best guess estimates derived by authors. Allow for change in mode, fuel efficiency, transport efficiency.
Graham and Glaister (2004)	Mainly US, Canada, Belgium.	Mostly before 1988	literature review. 143 elasticity estimates from 7 papers	-1.07 (0.84)	Not included	Based on 143 elasticity estimates. Units of demand and price are not clear.
Rizet and Bougerra (2013)	France	1998–2010	aggregate	lag vkm: -0.3 time trend: -0.25 (1998) to -0.40 (2010) with LR average -0.33.	Lag vkm: 1.3 Time trend: 2.89	Demand in vehicle-km (tonne-km in abstract only). Fuel price (also considered km cost in short run). Lag vkm poor fit R2=0.23).
Shen et al. (2009)	UK	1974–2006	road and rail freight combined. 6 sectors.	Discussed but not included in model	0.72 to 1.485 (all sectors) lagged OLS 3.289 (Agricultural, food and drink) to 0.108 (coal and coke)	Used index of industrial production as measure of economic activity. Six models used.
SDG (2014)	UK	1971–2011	aggregate		1.14 (0.000) 1971–1991 0.88 (0.006) 1991–2000 0.52 (0.146) 2000–2007 1.54 (0.006) 2007–2010	GDP (p-values in parentheses).

Research on the nature of freight response mechanisms

While the reviews above give empirical evidence that changes in fuel cost affect various measures of the volume of traffic, they do not explain the mechanisms that could bring this about. A SACTRA (1999) study Transport and the Economy[81] carried out for the DfT made a review of the likely response mechanisms that companies make to changes in the costs and travel times affecting their operation.

Its chapter 5 How Firms Respond to Transport Changes, cites evidence provided by Mckinnon, Ernst and Young, Mackie and Simon, European Logistics Comparative Survey 1989, the Freight Transport Association, Mackie and Tweddle, McKinnon and Woodburn (full extracts and citations given in that report).

The following two paragraphs point to the most significant findings:-

> "5.28 Just over 20% of the firms surveyed by Ernst and Young (1996, p18) reported that changes in their use of transport as a result of new or improved transport had led (with varying degrees of significance) to wider business benefits. Benefits claimed varied between:
> Ability to access new markets;
> Increased sales;
> Relocated activities;
> Improved staff punctuality;
> Increased size of labour catchment areas; and
> A decrease in stock held.

[81] SACTRA (1999) Transport and the Economy, DfT Archived and also conveniently available online at https://www.ffue.org/wp-content/uploads/2016/08/SACTRA_Full-report.pdf

> "5.29 Mackie and Simon (1986), in examining the industrial impacts of the Humber Bridge, state that three quarters of the firms in their study claimed they were able to utilise their savings productively. The cited operational effects of the bridge were:
> Vehicle re-routing;
> Increased vehicle utilisation;
> Improved market penetration;
> Increased market area; and
> Internal rationalisation (ie, changes to the number or size of depots)."

The study by de Jong et al referred to above also gave a more detailed explanation of the response mechanisms which could be distinguished for the effect of a change in the price of road transport on road transport demand, consistent with (but broader) than those identified in the SACTRA 1999 study, shown in the following table.

Changes in fuel efficiency

1. Using more fuel efficient vehicles
2. Improving fuel efficient driving

Changes in transport efficiency

3. Improving the load factor (the amount of goods measured in tonnes, divided by vehicle capacity) by:

    a. Optimising the allocation of vehicles to shipments
    b. Consolidating shipments originating from the same company
    c. Consolidating shipments originating from several companies
    d. Changing the number and location of depots, including consolidation and distribution centres
    e. Getting more return loads to reduce empty driving.

4. Changing route and time of day
5. Increasing the shipment size

Changes in transport volumes

6. Changing mode: substitution to and from rail, inland waterways, sea and air transport
7. Changing production technology (affecting the weight of the goods, e.g. trends towards lighter products).
8. Reducing kilometres per tonne:

    a. Changing the choice of supplier or the geographical market size of the supplier
    b. Changing production volumes per location

9. Reducing demand for the product.

Finally we need to consider the logical implications of what would follow if freight operators were **not** able to take any advantage of speed increases or time savings that they made as a result of additional capacity or more efficient traffic management, but were confined to following the same patterns of operation, to the same destinations, at the same times, using the same vehicles and the same frequencies. The question would then arise: what do they do with the saved time? They could give their drivers longer rest breaks, or reduce the numbers of drivers they employ, and similarly lay up their vehicles for longer service and maintenance periods or reduce the size of their vehicle fleet. Any of these would have some advantages, but they are not the narrative which is usually suggested[82] of 'developing new markets' or 'expanding their markets' or 'creating new jobs'.

Interchange between freight and personal transport

Nearly 20 years ago, Cairns (2005) wrote

> "Car travel for food and other household items represents about 40% of all UK shopping trips by car, and about 5% of all car use. In the past 10 years, there has been an extremely rapid growth, albeit from a very small base, of home delivery services for such shopping… The evidence suggests that with realistic levels of take-up, a direct substitution of car trips by van trips could reduce vehicle-km by 70% or more. More complex shopper behavioural responses will occur, but, according to available empirical evidence, overall traffic reductions are still probable. Meanwhile, the benefits of services could be maximized by use of appropriate cost structures, new types of delivery location, less polluting vehicles, greater cooperation or out-sourcing by retailers, and measures to encourage greater consumption of local produce."

Some of this has already happened. The previously assumed 'norm' was large lorries filling the supermarket shelves, with the final distribution to homes being carried out by the privately owned cars of individual shoppers. Now, an increasing proportion of the total vehicle miles may be those generated by a fleet of medium size or large delivery vans, many of which never actually go near a retail store at all, but collect their order-picked loads direct from the warehouse, and deliver them to homes on optimised routes as described above. And we can add in to this changing mix the shoppers by bus, bicycle or on foot, who may be making more frequent local trips with smaller packs of shopping, and the home delivery flows by Deliveroo, Just Eat and Uber Eats, plus a small but growing 'cargo bike' sector which manages to take very heavy loads by a human (and increasingly electric) -powered bicycle mode, for reasons of poverty or adventure, with employment practices suitable for one-person, one vehicle, operation, though increasingly becoming an 'industry' in its own right.

The indicative evidence suggests the nature of responses which are economically sensible, and the empirical evidence helps identify on their strength.

I have not seen any criticism of these results, or suggestions that they are illusory or badly flawed. They do of course have some variance, but they are sufficient to establish that freight demand can vary in response to price, and logically therefore also in response to travel times.

If the volume of freight traffic is sensitive to fuel price, the conclusion can be firmly drawn that it must also be proportionately sensitive to journey times. The relationship is that the ratio of the elasticities is in the same proportion as the ratio of time and price as a proportion of generalised cost. To reject such a relationship would undermine a central feature of the economic appraisal and would cast doubt on all the values of time savings.

This establishes a very strong expectation that volume of freight traffic on the road must be affected by changes in the cost or speed. It does not establish in what form that affect will be

[82] I note that National Highways produced a number of videos of consisting of interviews with national and local companies who supported the Lower Thames Crossing precisely because - they firmly insisted – it would enable them to develop new markets or expand activity on existing ones.

revealed, ie the different dimensions of demand, or the way that it be related to business practices, or competitive pressures.

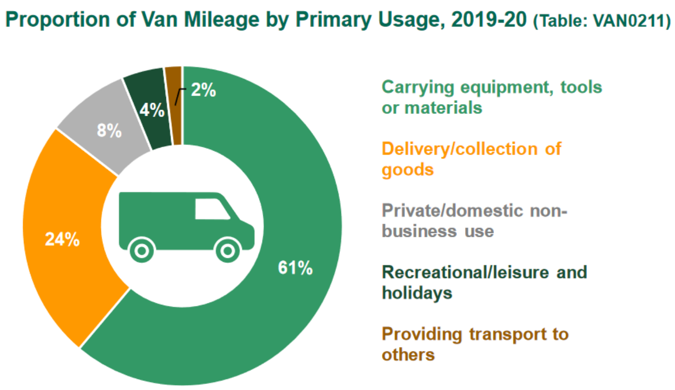
POPE implications for freight

As discussed above, NH has carried out the POPE programme of work since 2002 recording the estimated effects on traffic of every major road scheme costing over £10m. That programme has unfortunately not used methods of reliably assessing induced traffic resulting from those projects, but now has revised their methods to enable them to do so. This therefore represents a potentially very powerful data base, not previously used to measure induced traffic effects, and I hope there is a programme of work to retrospectively make this assessment.

In nearly all cases, the data assembled has been on total traffic, not separately identifying heavy and light commercial vehicles. However, the original calculations will have had those records, since they would have been used to identify the time savings for each class of vehicle for the project appraisals. In nearly all cases the retrospective assessments are done on total traffic, not distinguishing cars from commercial vehicles. The average balance between cars and commercial vehicles is approximately 77%-23% by vehicle miles or roundly 70-30 by pcu miles. Therefore any conclusions from those 'all traffic' studies about induced traffic will either only relate to cars (if the assumption there is no variable demand for commercial vehicles had been correct), and the estimate of its scale will be roundly 50% greater; or alternatively, that any calculated induced traffic will be applicable to both cars and commercial vehicles.

'Freight' is not well described by 'LGVs and HGVs'

At the same time, the presumption that standardised, easily-recognised, light goods(LGVs) and heavy goods (HGVs) together define 'freight', is also inconsistent with some of DfT's own evidence from analysis three years ago on what the much more substantial parc of LGVs – ie vans - are actually used for as shown in the following figure.



Source: DfT (2021)

If we compare this split by mileage with the corresponding split by numbers of LGVs owned, we see that not only is the 'carrying equipment, tools or materials' the largest, but it also travels proportionately a greater share of the mileage.

In order to embrace this complexity we quite certainly need to find ways of modelling variable matrices of LGV and HGV' trips, but also acknowledge that the pattern of those responses will be different between heavy lorries and vans - and within both categories too. As an interim measure, it looks, from the variety of uses, that vans would be better treated in the same way as cars, particularly cars used for 'employers business' purposes. Overall, we will need models which are specifically directed towards the phenomena described above, of a multiplicity of different ways in which LGVs are used, partly driven by formal optimisation procedures focussed on commercial gain. This raises the question of how to identify, if using mobile phone data, what sort of uses are being made.

Implications of new DfT work on freight values of time

The most recent advice from DfT (2025) about values of time[83] together with a 2023 report from National Highways about value of reliability[84] for road freight vehicles, covered in a review article by Graham James (2025)[85] in Local Transport Today, suggest a very substantial increase in the values. The headline results are shown in Table 7.

[83] DfT (2025) The Value of Road Freight Travel Time, Updated Evidence for Transport Analysis Guidance, https://assets.publishing.service.gov.uk/media/68f8aa2180cf98c6e8ed8f5f/value-road-freight-travel-time.pdf

[84] National Highways (2023) Freight value of time and value of reliability https://assets.publishing.service.gov.uk/media/68f21191f5d433238a14c70f/freight-value-time-value-reliability.pdf

[85] James G (2025) Revised values of travel time for road freight: what the new TAG says – and what it could mean. Local Transport Today/TAPAS LTT925 30.10.2025 pp 31- 36 https://tapas.network/103/james.php

Figure 7 Proposed New Values of Time (DfT 2025)

Mode	Journey purpose	Current % share of vehicle kilometres	Current TAG (VTT+b1[1] parameter)	Proposed % share of vehicle kilometres	Proposed VTT
HGV	Work (freight)	100%	£24.36	100%	£81.24
LGV	Work (freight)	88%	£16.39	24%	£21.34
	Work (services)			61%	£19.62[2]
	Average work			*85%*	*£20.11*
	Commute	3%	£14.51	8%	£14.51
	Other non-work	9%	£6.62	6%	£6.62
	Average non-work	*12%*	*£8.91*	*15%*	*£11.15*
	Average LGV	*100%*	*£15.49*	*100%*	*£18.81*

Table A: Comparing current TAG values with the proposed values (£/hour per person in 2022 prices/values)

DfT's summary states

> "Overall, the proposed values represent a significant increase in the valuation of freight travel time changes, moving them into line with those used in appraisal frameworks internationally. The HGV VTT increases by 234% compared to the equivalent, current TAG values (i.e. VTT+b1), while the LGV freight VTT increases by 30% (average LGV increase = 21%). These increases are to be expected, given the proposals reflect a more comprehensive and realistic assessment of the economic value of road freight movements, capturing wider cost considerations, such as potential logistical savings from fleet and depot efficiencies"

Thus this suggests that goods vehicles, particularly HGVs, are willing to pay over three times as much per hour for the benefits of time savings, and LGVs 20%-30% more, and will also suffer the disadvantages of increased congestion at the same rate. Putting this in project appraisal will increase the benefit cost ratio of projects which save these vehicles time, and also suggest that they will be willing to pay an additional amount of the costs of providing those increases in speed. But the increase in values of time seems to have been calculated using methods which assume that the vehicles are actually able to use the time savings in ways contrary to the fixed demand assumptions.

In explaining the results, the consultants discussed what this means in practical terms, for example

> "The carrier valuation derived for HGVs in the main study (£81.24 per hour, 2022 prices/values) can be interpreted to capture the value (WTP) that carriers associate with saving time on a journey. This could relate to the quite direct short-term saving on driver wage costs, but also represents longer-term cost savings and logistical efficiencies enabled by regularly making quicker journeys. When a carrier's journey

> time is reduced, they can undertake more journeys, or the same number of journeys with fewer vehicles and staff. They may also be able to re-optimise their logistics operations in the longer term, for example depot locations and markets served."

And in relation to LGVs (when used for freight), the discussion similarly includes

> "3.40 improvements to journey times can be viewed to lead to opportunities for carriers to save costs, via reorganisation of logistical activities and efficiencies in the use of business LGVs".
>
> 3.44 This assumption is the most logical approach from the perspective of economic and resource cost theory; that is, all saved costs are fully time-dependent over the long-run i.e. 100% sensitive to time. This is equivalent to the cost-saving approach currently applied to wages, and reflects that appraisal aims to capture the economic(resource) value, once consumers (or in this case businesses) have had time to fully absorb the impact of an intervention into their decision-making.

Thus the new values seem to have been calculated that implicitly (and sometimes explicitly) freight operators are able to make use of the time savings for making changes which would, directly or indirectly, induce more movement, which in turn would increase congestion pressure on other traffic.

If the assumption of fixed demand is relaxed, the increased value of time also implies that the elasticity will be greater, in proportion to the share of time in generalised cost, and that freight operators will be more prepared to pay the costs of projects enabling the savings, and the external economic and environmental costs their induced traffic imposes on other traffic and the economy as a whole. The principle of using detailed case studies as a source of evidence is sound, and was used by SACTRA 1994 as one of its multiple methods of investigating the incidence and size of induced traffic. But the point of all these, taken together, is to render completely unrealistic the National Highways proposition that "There is no change in the number of LGV and HGV trips as these matrices are fixed and so are not included in the variable demand model". Rather, we have tangible evidence of features of variable demand analogous to that of cars - shifts in modes used, geographical location, routes, and miles travelled. In fact this is probably more explicitly organised for freight transport, where cost optimisation rules the day, than it is for personal travel where motivations are more complex.

Further details on other modes and policy context

One of the most evident trends in UK studies of induced traffic after SACTRA (1994) was that interest in induced traffic from road building was expanded to interest in a wider range of policy initiatives, especially those aimed at reduced road traffic, on which exactly the same analytical and evidential issues arise, but in the opposite direction.

Multi-Modal studies

Marsden (2005)[86] saw the Sactra report contribute to the Conservative rethinking of roads and transport policy from 1994, extended by the incoming Labour Government as from 1998, and in particular a series of large scale Multi-Modal Studies explicitly intended to find ways of offsetting the tendency of traffic growth to undermine the reductions in congestion which road projects had intended to produce.

> "The road improvements were designed to go hand in hand with the restraint measures to ensure that benefits provided by the extra capacity were not eroded"

One of the limitations to their success, however, was that the forecast increases to traffic (which eventually turned out to be overestimated) seemed to be too large to be tackled by politically acceptable measures of restraint. This theme was to recur later as discussed below.

Traffic reduction as a result of reduced road capacity

A study by Cairns et al (1998)[87] and a follow up progress report (2002)[88] extended the study of induced traffic by considering the reverse case, ie the potential reduction in traffic resulting from a reduction in road capacity, for which the main cases for which evidence was available were pedestrianisation of town centres, implementation of bus lanes (at that time there was limited information on cycle lanes), and reductions due to natural disasters or closures due to major maintenance. Around a hundred case studies were reported. There was a wide range of results, with (as would be expected) large scale changes having bigger effects than small ones. But the pattern of results, in order of magnitude of the estimated effects, and the range of behavioural adjustments, were rather similar, though opposite, to the experience of induced traffic.

Modelling of induced traffic has nearly all used equilibrium models, such that the comparisons of modelled traffic 'with' and 'without' the intervention, mostly provision of extra capacity, are by definition presumed to be reversible. Most of the empirical evidence however is 'before' and 'after'. The 'disappearing traffic' work gives some comfort of a degree of reversibility. The implications are comparable: induced traffic from a road capacity increase will tend to mean that increased speed is not as great as hoped, and reduced traffic as a result

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[86] Marsden G (2005) The multi-modal study transport investment plans, Proc Inst Civ Eng (Transport) 158 (2) 75-87

[87] Cairns S, Hass-Klau C, Goodwin P (1998) Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence , Report commissioned by London Transport and DETR. Landor Publishers. Available online in multiple sites, including https://www.cycling-embassy.org.uk/sites/cycling-embassy.org.uk/files/documents/Traffic%20Impact%20of%20Highway%20Capacity%20Reductions-%20Assessment%20of%20the%20Evidence.pdf

[88] Cairns S, Atkins S, Goodwin P (2002) Disappearing Traffic? The story so far, Proc.Inst Civ. Eng-Municipal Engineer 151(1) 13-22 https://nacto.org/wp-content/uploads/disappearing_traffic_cairns.pdf . This paper was awarded a Gold Medal by the Institution of Civil Engineers.

of a road capacity decrease will tend to mean that reduction in speed is not as great as feared. The project report first reviewed the then current state of transport behavioural choice theory, and concluded that this review in effect supported three negative conclusions, namely that

- It does not support the idea that route choice is the only, or necessarily even the main, response actually made by drivers to a reduction in the capacity facing them.
- It does not establish that models of trip generation, distribution, mode choice and assignment represent the universe of all the choices that can be made by travellers. Other choices can include time of day changes, trip consolidation, trip chaining, trip-swopping, life-style changes, car occupancy changes, car ownership changes and a list of other dimensions which may comprise some twenty or more responses, and is no doubt still incomplete. There is no theoretical case for establishing a universal hierarchy of the relative importance of all these choices, this being an empirical question which may vary from case to case.
- It does not support convenient assumptions that responses are instantaneous, in equilibrium at the time when they are observed, or based only on decision rules which can be fully encompassed in a generalised cost of travel or utility maximisation, as usually defined.

The detailed results reported were broadly similar to those in the SACTRA cases, giving more confidence that the results were real, as also that the necessary but rather unlikely premise of equilibrium modelling that transitions from state A to state B, and from B to A, might, sometimes, be roughly symmetrical. The conclusions helped to fill in some of the elements in the three points above, finding that the range of behavioural mechanisms by which traffic reduction took place was greater than those normally included in transport models.

The studies were influential in giving confidence that such initiatives would tend to give sufficient traffic reductions that predicted 'traffic chaos' and 'the network could not cope', and also that just as induced traffic might offset the benefits from expansion of capacity, so reduced traffic might offset the costs of its contraction. More recently application of similar studies to the case of small scale local low traffic neighborhoods has been controversial, with quite strong claims made, and disputed.

In March 2026 A series of evidence assessments, commissioned by DfT and Active Travel England, on the effects of active travel on the quality of life, dated 2024, were published online, several of which are relevant to induced travel notably one by Parkes et al (2024)[89] . The authors made some caveats on limitations in the scope and completeness of the work, which mainly focussed on academic literature searches, and appear not to have found their way to many relevant publications, but what they had appears to be consistent with the work above.

[89] Parkes S, Parr S, McCarthy L (2024) Evidence Assessment: the Impact of Active Travel on Journey Times, Congestion and Resilience, Sheffield Hallam University, NatCen and Mosodi Ltd, Active Travel England Evidence assessment: The Impact of Active Travel on Journey Times, Congestion and Resilience.

Research on 'Smarter Choices' (formerly called 'soft measures')

Overall conclusion

A major DfT literature review by Cairns et al (2004)[90] on the contribution of 'soft' policy measures to car use reduction tested all the available experience on workplace travel plans, car sharing, teleworking, personalised travel planning, teleconferencing, travel awareness campaigns, public transport information and marketing, home shopping, school travel plans, local collection hubs, and car clubs. They estimated that in total an intensive expansion of these initiatives would be capable of reducing car use nationally by 11%. (This was before the experience of the effect of covid on teleworking, teleconferencing, and 'home shopping', which were substantially greater than expected). This figure is comparable with the local experience of induced traffic from additional road capacity. Altogether, something like 20 or 30 different demand responses have been found (such as car-sharing, trip chaining, virtual alternatives to physical movement, variable working hours and days, changes of functions within households, new modes of transport, substitution of travel by on-line activities, etc etc); and with growing interest in non-equilibrium processes, for example lags, habits and imperfect reversibility.

Impacts of soft measures considered separately

The main findings were as follows.

• Workplace travel plans typically reduce commuter car driving by between 10% and 30%, though the best ones achieve significantly more than that. Typical cost to the local authority is £2-£4 per head. So far, city authorities prioritising workplace travel plans have typically managed to engage with organisations representing about 30% of the workforce, whilst county authorities have managed to engage with organisations representing about 10%.

• School travel plans, on average, cut school run traffic by between 8% and 15% with high performing schools commonly achieving reductions of over 20%, and, sometimes, considerably more. Many local authorities are devoting more resources to school travel work than to workplace travel plans, and some expect to reach nearly all schools in their area in the next 10 years.

• Personalised travel planning initiatives typically report reductions in car use of 7%-15% in urban areas, and 2-6% in rural and smaller urban areas. Costs for large scale implementation

[90] Cairns S, Sloman L, Newson C, Anable J, Kirkbride A & Goodwin P (2004)
UCL, Transport for Quality of Life The Robert Gordon University and Eco-Logica 365 Final report to the Department for Transport, London
https://webarchive.nationalarchives.gov.uk/ukgwa/20100304004945/http://www.dft.gov.uk/pgr/sustainable/smarterchoices/ctwwt/. And at https://transportforqualityoflife.com/wp-content/uploads/2023/10/smarter-choices-changing-the-way-we-travel-full-report.pdf
There is also Volume 2: Anable J, Kirkbride A, Sloman S, Newson C, Cairns S and Goodwin P (2004) Smarter Choices – Changing the Way We Travel. Volume 2: Case Study Reports. Department for Transport, London, available at https://transportforqualityoflife.com/wp-content/uploads/2023/10/smarter-choices-case-study-report-july-2004.pdf
There is a summary of the whole project in Cairns S, Sloman L, Newson C, Anable J, Kirkbride A, & Goodwin P (2008) Assessing the potential to achieve traffic reduction using 'soft measures', Transport Reviews 28, 5. https://doi.org/10.1080/01441640801892504

are likely to be considerably cheaper than pilot projects, being in the order of less than £20 per head, (with some suggesting figures of half this magnitude).

• Public transport information and marketing has delivered clearly recorded increases in bus use, with evidence suggesting that it can cause patronage increases from service improvements to double. City-wide budgets for such work of £60,000-£300,000 per year (including public and private sector investment) have helped to deliver city-wide increases in bus use of 1.5%-5% a year, when combined with other improvements.

• Travel awareness campaigns vary in nature, from relatively general campaigns to closely targetted intensive approaches. Both types report evidence of car use reductions, although intensive approaches tend to achieve higher levels of individual change. Many are now focusing on the positive health benefits from alternative transport policies. In many cases, travel awareness campaigns are used.

. • Car clubs have been associated with a reduction of about 5 private cars per car club vehicle. They require start-up funding in the order of £50,000 to £150,000 per club which should lead to them becoming self-financing. In the absence of evidence, there has been a tendency to set unrealistic timescales for breaking even, perhaps partly to justify public funding. Initially, car club initiatives have been focused on high density urban residential locations, although emerging information from rural pilots suggests that low-cost operational models can make clubs viable in rural areas too.

• Organised car-sharing has effects on overall car use, but these depend on other factors, including parking regimes, the balance of users drawn from car driving or from other modes, and the amount of informal car sharing already taking place. Set up and running costs vary significantly and are primarily determined by the extent of associated publicity and marketing that takes place.

• Teleworking is growing rapidly, and typically currently results in a reduction of between 2 and 6 home-work journeys per teleworker per week. Evidence suggests that changes in car use for other purposes, or by other household members, or due to changes in home location, do not substantially offset these reductions, and, in some cases, there may be further cuts in car use. Costs are likely to be offset by business savings.

• Teleconferencing typically reduces business travel by between 10% and 30% in organisations that promote its use. Many commentators suggest that there is great potential for more widespread use of teleconferencing, however public sector promotion may be needed to ensure mainstream adoption. Business savings could be substantial, in terms of reduced travel costs and more efficient use of staff time.

• Home shopping then accounted for less than 5% of the grocery market, but wasestimated to reach 10%-15% over the next decade, leading to potential reductions of 7-11% of all food shopping traffic. Meanwhile, investment in better drop off facilities for all types of home shopping could reduce travel for customers in some circumstances (where their alternative is travelling to a more remote collection point) and could also substantially improve the efficiency of delivery vehicle operations.

Low traffic neighbourhoods

There is a growing volume of reports about the impacts of low traffic neighbourhoods (LTNs), often pursued within the context of rather high profile local controversies: the key question is the balance between traffic evaporation (reduction) and traffic displacement, ie the extent to which the schemes reduce traffic overall, or displace it to other roads, a mirror image of the question of induced traffic from increased capacity. A new article, currently undergoing peer review for publication, by the University of Westminster Active Travel Academy, funded by the National Institute for Health Research, is currently undergoing peer review for publication. The authors have kindly provided this summary and links[91].

> "Five LTNs in London, implemented between 2021 and 2023, showed increased traffic and journey times on the surrounding boundary roads in the first year after implementation. However, by year two and three, average journey times largely returned to pre-LTN levels. The authors interpret this as indicating that what looks like 'displacement' at first may in fact be a transitional phase, with drivers adapting over time – changing routes, shifting to other modes, or rethinking the need for certain trips altogether. In other words, the initial period after an LTN is implemented may be more dominated by traffic displacement, while over time the balance may move more towards traffic evaporation. This would fit with other research that has shown that LTNs are associated with increased active travel and reduced car ownership and/or use by local residents, that these benefits sometimes grow over time. It would also fit with the wider literature on road space reallocation schemes which suggest that traffic displacement may be most acute in the short term".

Eddington report

The Eddington Study (2006)[92] was a broad review of the links between transport, productivity, growth and stability, with four volumes of reports and many supporting references and contributions. It did not particularly feature induced demand, but did collate much useful information on the benefit-cost calculations for road construction compared with that for other modes, and the effects on those costs and benefits in particular of pricing. One of its technical Appendices, 'Transport Demand to 2025 & the Economic Case for Road Pricing and Investment'[93], written by DfT officials using the DfT national forecasting model. It was published initially by the Treasury, and since available online, in the DfT archives, though

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[91] *See Aldred R and Goodman A (2021) (https://doi.org/10.32866/001c.21390),*
Aldred R, Goodman A and Woodcock J (2024) (https://doi.org/10.1016/j.jth.2024.101771,
Goodman A, Urban S and Aldred A (2020) https://doi.org/10.32866/001c.18200,
Goodman A, Laverty A, Furlong J and Aldred R (2023) https://doi.org/10.32866/001c.75470,
Melia S and Calvert T (2021) *(https://doi.org/10.1680/jmuen.21.00014*

[92] Eddington R (2006) Main Report (in 4 volumes)
http://www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/

[93] Transport Demand to 2025 & the Economic Case for Road Pricing and Investment (2006) (publication details and authorship not stated) DfT archive https://web.archive.org/web/20080809030750/http:/www.dft.gov.uk/about/strategy/transportstrategy/eddingtonstudy/researchannexes/researchannexesvolume3/transportdemand

without a cover page, or authorship, and a caveat that 'it dopes not necessarily represent Departmental policy'. or any trace of DfT or Treasury logos. Its caveat states (in para 2)

"This body of work was requested by the Eddington study team and fed into the evidence base of the Eddington study; it does not necessarily represent Departmental policy."

The work considered the effects of a nationwide road pricing system, at prices set to make the price of travel cover the marginal social cost of travel. It suggested that in that case, the amount of new road capacity suggested as needed from 2015 would be up to 80% less than would be proposed under the existing price structure, because of the effects on demand that pricing would deliver – according to the modelling, this was not due mostly to a reduction in the overall total traffic volume of 7%, giving a 52% reduction in congestion due to the incentive for individuals 'to travel on less congested roads, switch modes, switch time of day, or switch the journey destination'. small, but to changes in in the location and timing of trips shifting from more congested roads (where the price would be higher) to less congested roads. Key results are shown in the following extract.

Inter-Urban Road Build under different scenarios

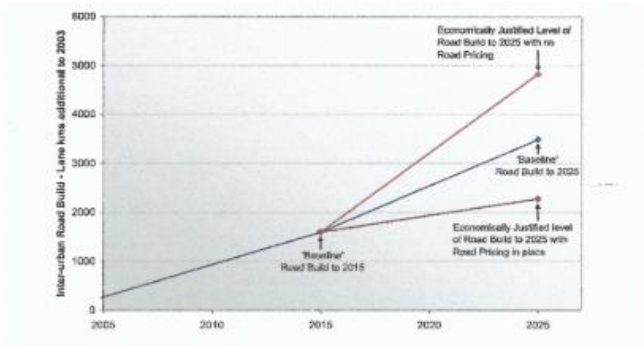

Table 5.1: Road build in Intervention Scenarios

England, Road Lane Km	2015	2025		
Scenario	'Baseline' Scenario	'Baseline' Scenario	Economically Justified, No Road Pricing	Economically Justified, With Road Pricing
HA Road Lane kms - additional to 2003	1,590	3,500	4,850	2,300
HA Road Lane kms - change from 2015 Baseline		1,900	3,250	700
HA Road Lane kms - change from 2025 Baseline	-	-	1,350	-1,200
Traffic (Change from 2003)	22%	31%	32%	22%
Average Delay per vehicle km (Change from 2003)	25%	30%	28%	-37%

4. A package of road pricing and investment would produce benefits worth over £30bn per year in 2025, adding as much as £15-16bn to GDP. Road build alone contributes £620m and £460-£530m to welfare and GDP respectively, with the rest of the benefits due largely to road pricing. This indicates the high share of road pricing in overall benefits. Gains to welfare over the lifetime of the additional road build would significantly outweigh the cost of investment (£5- £8bn).

One of the problems of knowing how to incorporate studies of this sort into policy applications is 'Theory of the Second Best' (Lipsey and Lancaster, 1956[94]) which Wikipedia[95] usefully summarises as

> "In an economy with some uncorrectable market failure in one sector, actions to correct market failures in another related sector with the intent of increasing economic efficiency may actually decrease overall economic efficiency. In theory, at least, it may be better to let two market imperfections cancel each other out rather than making an effort to fix either one. Thus, it may be optimal for the government to intervene in a way that is contrary to usual policy. This suggests that economists need to study the details of the situation before jumping to the theory-based conclusion that an improvement in market perfection in one area implies a global improvement in efficiency"

In this case, the theoretical 'first best' which maximises welfare and efficiency would be the application of a national road pricing system based on marginal social cost pricing on every part of the road network. Not to apply it would count as an 'uncorrectable' market failure, whether it is due to practical impossibility or political resistance. Then it may not at all follow that the 'second best' is to build the quantity and location of roads which appear 'justified' in the absence of economic pricing, hence the interest in pursuing other transport policies entirely – especially if induced traffic is a consideration.

Commission for Integrated Transport

CfIT was a high level independent advisory body established in 1999 under the 1998 White Paper 'A New Deal for Transport', initially chaired by Professor David Begg and subsequently chaired by Peter (later Sir, now Lord) Hendy. It was active in commissioning many expert reports and thinkpieces, involving a high proportion of the academic and consultancy research resource. It was finally abolished in 2010 as part of the 'bonfire of the quangos' which also laid SACTRA to rest. Its very last commissioned study was titled 'Transport Challenges and Opportunities: Getting more from less'' CfIT 2010[96], based on thinkpieces from Laird et al (2010)[97], Goodwin (2010)[98], Bristow (2010)[99], McKinnon (2010)[100] and Flack (2010)[101], all now archived, and its main report section 6 'Improving value from spending' specifically suggested

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[94] Lipsey, R. G.; Lancaster, K (1956). "The General Theory of Second Best". *Review of Economic Studies*. **24** (1): 11–32. doi:10.2307/2296233. JSTOR 2296233

[95] Theory of the second best - Wikipedia

[96] Commission for Integrated Transport (2010) Transport Challenges and Opportunities: Getting more from less [ARCHIVED CONTENT] Commission for Integrated Transport

[97] Laird J, Marsden G, Mackie P, Budd L (2010) Implications of reducing public expenditure through higher prices and taxes in the transport sector CfIT Archive

[98] Goodwin P (2010) Opportunities for improving transport and getting better value for money by changing allocation of public expenditure to transport CfIT Archive

[99] Bristow A (2010) Transport and climate change, identifying the scope for further cost effectiveness in CO2 emissions in the transport sector CfIT Archive

[100] McKinnon A (2010) Transport challenges and opportunities, briefing paper on the freight transport sector CfIT Archive

[101] Flack S (2010) **Transport implications of public sector decisions CfIT Archive**

"There is substantial scope to improve the value for money of transport spending by switching towards scheme types such as smarter choices and local road safety which have the highest benefit cost ratios (BCRs). Larger investments to increase network capacity should not be allowed to crowd out schemes of this kind".

"Transport Challenges and Opportunities: Getting more from less'' CfIT 2010

Key points:
There is substantial scope to improve the value for money of transport spending by switching towards scheme types such as smarter choices and local road safety which have the highest benefit cost ratios (BCRs). Larger investments to increase network capacity should not be allowed to crowd out schemes of this kind.

For all programmes and schemes there is a continuing need to look fundamentally at the scope for efficiency savings through process review. Some of this is already allowed for in baselines, and actual efficiencies tend to fall short of claims, but it is reasonable to assume a 7.5% cumulative saving over 3 years, yielding £1.3bn.

The transport carbon budget can be met at significantly lower cost to the economy by giving more emphasis to measures for travel behaviour and vans and lorries. Alternatively, greater carbon reductions can be achieved within the same cost.

The smarter choices programme should be expanded and accelerated, concentrating more on longer journeys and reducing the current accounting incentive towards capital schemes.

Bus subsidy now accounts for £2.75bn per annum and gives relatively poor value for money. A revised approach could provide better incentives to operators to improve services, accelerate smart and integrated ticketing and gives more modal choice to those entitled to fares concessions. There is potential scope to save £400m per annum, but dependant on a fundamental evaluation of the current concessionary fares scheme.

Safety expenditure will generally deliver much higher value for money if applied to road rather than rail.

Improvements in freight efficiency have lost momentum, and need refreshing.

Wider Government decisions need to take more account of the costs they impose on transport.

There is scope overall to reduce public spending on transport by about £1.7bn, whilst improving its effectiveness, through measures of the kind above.

Error and uncertainty in traffic forecasts

For the entire period since 1989, all national road traffic forecasts have been overestimated[102], as shown in Table 4 below. This has effects on the traffic benefits of road schemes in two ways. First, the achieved benefits are likely to be less than the forecast ones, because base traffic being lower than forecast means that base congestion (ie congestion in the absence of the scheme) is also lower, so the relief to congestion provided by the scheme is also less than expected. Secondly, in principle the calculation of induced traffic should also be less, because there will be smaller time savings to trigger it. However in practice this may not be the case because the actual induced traffic is the difference between the (true, but unobservable) base case and the actual observed 'with scheme' case. This is why the discussion on how to calculate induced traffic in the POPE evaluation schemes is important. It seems likely that the actual induced traffic will be greater than the predicted induced traffic, and if this applies it will reduce the overall benefits by a further amount in addition to that directly from the overestimate of base traffic growth.

Table 4: Successive National Traffic Forecast/Projections

showing their subsequent accuracy

Date of forecast or projection	**Region**	**Period**	**No. years**	**Forecast increase in traffic per year, from base year to 1995 or 2025**			**Actual Increase** provisional
				Lowest	'Central'	Highest	
1965	GB	1965-1995	31		182%		**183%**
1974	GB	1974-1995	21		87%		**88%**
1980	GB	1978-1995	17		34%		**22%**
1984	GB	1982-1995	13		29%		**51%**
1989	GB	1988-2025	37	83%	112%	142%	**44%**
1997	GB	1996-1925	29	(31%)	52%	(73%)	**22%**
2008	England	2003-2025	22	24%	32%	40%	**11%**
2011	England	2010- 2025	15	23%	28%	34%	**9%**
2013		2010-2025	15	12%	25%	41%	**9%**
2015		2015-2025	10	10%	23%	32%	**9%**

Forecasts very close to the actual outcome. Significant overestimates. Significant underestimates. Note that the red figures had in all cases appeared as overestimates before the onset of Covid

Taking the period from 1989 to 2025, it can be seen that the overall actual traffic growth was between a third and a half of what had been forecast in the 'central' estimates, which are closest to those which had been used at the time for the 'core' appraisals. For most cases even the lowest forecasts were greater than the actual outcome, though the more recent forecasts

[102] Goodwin P (2025) National Road Traffic Forecasts 1965-2025: Why did they become so inaccurate, and how can they be improved? https://tapas.network/93/goodwin.php. Note that this table was assisted by Lisa Hopkinson of TQL, and included work by Roger Mackett of UCL (1998) Why are travel demand forecasts so often wrong (and does it matter) UTSG Conference, Dublin, January https://discovery.ucl.ac.uk/id/eprint/144591/1/Mackett_C53%20UTSG%2098%20Dublin%20travel%20forecasting.pdf

were closer to the actual outcomes, and the actual outcome for the 2015 forecasts was almost the same as the forecast. (It is hoped that the forecasts made in 2018 and 2022 will prove even closer as time progresses). The difference between the low and high forecasts was not generated by any consideration of the internal statistical variance of the basic data, but by differences in the external assumptions on factors like economic growth, demographic trends, fuel prices, and technologies.

After preparation for the 2015 and 2018 traffic forecasts, common analytical scenarios were codified in 2022 and launched with a forward by the Permanent Secretary, Chief Analyst and Director of Strategy of the DfT[103] - a more emphatic endorsement than usually given to technical advice - with new rules for how they must be included in project appraisal, specifically because different scenario forecasts would result in substantial differences in the calculated value for money of investments, especially road projects. In 2023 the Department for Transport's 'Uncertainty Toolkit'[104] was produced including the following table

Table 3 Example table summarising impact of scenarios on scheme BCR

Sensitivites	Core	Common Analytical Scenarios						
		High economy	Low economy	Regional	Behavioural Change	Technology	Vehicle-led Decarbonisation	Mode-balanced Decarbonisation
Demand/Supply	1.5	2.1	1.1	2.0	1.2	2.0	1.8	1.4
Cost	1.5	0.8	2.2	-	-	-	-	-
Parameter	1.5	1.6	1.4	-	-	-	-	-
Other	x	x	x	-	-	-	-	-

The benefit cost ratios reported were not derived from specific projects (though the figures do actually look rather similar to some that I have seen reported for specific projects), but the interesting cases are the two lowest benefit cost ratios, for the scenarios described as 'low economy' and 'behavioural change', which are close to each other but for entirely different reasons.

The 'low economy' scenario had a low benefit cost ratio because the traffic volumes were lower due to lower incomes, therefore congestion was lower, therefore road improvements had little effect on reducing congestion. It was a sign essentially of poverty and would in conventional terms be seen as an undesirable situation albeit with some compensating advantages. One would not normally choose lower incomes as a policy option to reduce traffic congestion.

The 'behavioural change' option was quite different. Traffic volumes were also lower, but economic growth was assumed at the same level as the Core scenario. The reason for the higher benefits was because of a trend for successive cohorts of young people to choose to make less car travel since the early 1990s, identified first by the DfT Chief Statistician Barbara

[103] Kelly, B, Rowlatt, A & Morgan, L (2022) Transport Business Case Guidance, DfT https://www.gov.uk/government/publications/transport-business-case/transport-business-case-guidance
[104] Department for Transport (2023) TAG Uncertainty Toolkit para 4.9 https://assets.publishing.service.gov.uk/media/65a6bc74867cd8000d5ae9b3/tag-uncertainty-toolkit.pdf

Noble (2005)[105] , and work by Stokes (2013)[106] who suggested a model of car use incorporating this trend, which suggested that if the trend persisted

> "the base forecast for overall car use per person will broadly stabilise for the next 20 years or so – rising by just under 1% up to 2019 and then falling by 3% of the 2013 level by 2036".

The DfT commissioned an important study of this phenomenon in 2016, which was carried out by a team of transport academics at the Universities of the West of England, and Oxford, reported by Chatterjee et al (2018)[107], partly connected with employment precarity of young people's employment, and partly with a distinct trend to use online engagement as an alternative to travel for some but not all activities.

Earlier, Headicar[108] on trends in the Census, and Metz[109] in a review of the 'peak car' thesis, suggested that wider social, land use and geographic were also changing in such a way as to damp, or offset the previously dominant tendency for increases in car use.

Thus, there has been not only a reduction in traffic growth, but according to the National Travel Surveys an absolute reduction in car trips and car distance travelled per person per year for the period 2002 to 2023, with some indication that this has continued post covid. (With colleagues, I am doing some further work to check this). The trend is not solely an indication of general economic growth (though that is likely to have contributed to it) but relates also, to chosen behaviours, some of which will be positive.

All this changes the context for induced traffic. The focus of DfT interest in explaining reduced traffic growth, or even reduced traffic, had been on the tendency for Treasury economic growth forecasts to be overoptimistic, and several sensitivity tests over the years have indicated that if they had assumed the actual outcome economic growth, the traffic forecasts would have been closer to the actual outcome. But it is also the case that there has been a trend reduction in each cohort of young people's travel by car since about 1991 accumulating as they got older, resulting in a trend reduction in overall average per capita car use. The overestimated economic growth forecasts have not been the only factor leading to the new trends in car use, and may not be the most important one. This possibility is also supported by the observation that the transport intensity of economic growth has itself declined over the whole period. However, less car traffic has also been offset to some extent by an increase

[105] Noble, B. (2005) Why are some young people choosing not to drive? Proceedings of European Transport Conference, Strasbourg, France, 18-20 September 2005. https://aetransport.org/past-etc-papers/conference-papers-pre-2012/conference-papers-2005?abstractId=2093&state=b

[106] Stokes, G (2013) The prospects for future levels of car access and car use, Transport Reviews 33(3)

[107] Chatterjee K, Goodwin P, Schwanen T, Clark B, Jain J, Melia S, Middleton J, Plyushteva A, Ricci M, Santos G, and Stokes G. (2018). Young People's Travel – What's Changed and Why? Review and Analysis. Report to Department for Transport. Centre for Transport and Society, UWE Bristol & Transport Studies Unit, University of Oxford. https://assets.publishing.service.gov.uk/media/5a82a485ed915d74e3402d3e/young-peoples-travel-whats-changed.pdf

[108] Headicar P (2013) The changing spatial distribution of the population in England: its nature and significance for 'peak car' Transport Reviews 33 (3)

[109] Metz D (2014) Peak car: the future of travel, Landor Links ISBN-13 : 978-1899650750

by more HGV and LGV traffic, for which no induced traffic was assumed but some is likely, according to my reading of the evidence.

Taken together, a revised ex post interpretation will need to take account of lower traffic in the do-nothing case, but the possibility of a greater proportion of induced traffic due to HGVs and LGVs in the with-scheme case. Hence we can expect a higher estimation of induced traffic than was done in the original calculations. Taken together, the overestimated general traffic forecasts and any underestimated induced traffic, from freight or personal travel, would probably indicate that the achieved benefits, so far, from road capacity increases since 1989 have been significantly less than forecast.

As far as I know, none of the road projects submitted for approval after DfT had designed the 'Behavioural Change' forecasting scenario, actually used it in their submissions, which may have significantly changed the balance of appraisals.

Appendix 2

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Balcombe R, Mackett R, Paulley N, Preston J, Shires J, Titheridge H, Wardman M, White P (2004) The demand for public transport: a practical guide, Report TRL593, Transport Research Laboratory ISSN 0968-4107 https://www.trl.co.uk/uploads/trl/documents/TRL593%20-%20The%20Demand%20for%20Public%20Transport.pdf

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Appendix 3 Original Project Brief

Impact of induced demand on benefits: think-piece

1. Specifying goods and/or services

Introduction and background

The treatment of induced demand is of vital importance for the economic appraisal of road schemes. Since the early 2000s, DfT guidance has recommended variable demand modelling be used to account for induced demand, following the recommendations from SACTRA in the 1990s. This can make a major difference to scheme benefits, with modelling induced demand usually lowering benefits compared to fixed demand. The reason is that, despite more users benefitting, the per-user benefit can diminish rapidly as roads become re-congested in response to a transport improvement. The economic theory behind calculating transport user benefits under induced demand is well developed and generally robust, deploying the so-called rule-of-a-half (RoH) to estimate changes in transport consumer surplus between the without scheme (DM) and with-scheme (DS) cases.

However, there are some challenges which currently limit our ability to robustly appraise induced traffic:

1) When flow approaches or exceeds capacity, equilibrium-based transport models struggle to represent travel conditions. This is sometimes called hypercongestion, or flow breakdown. As a result, estimates of user benefits when such conditions prevail in the DM and/or DS is problematic. A common approach (e.g. as used in NTMv2) is to hold speeds constant when flow goes above capacity, alternatively some modelling packages (e.g. VISUM) allow average speeds to continue to decline (or equivalently delay to rise) past the saturation point.
2) In some cases, induced demand can raise benefits. It is an empirical question, and it would be helpful to understand the conditions where this would arise. For example, how does it depend on demand elasticities, values of time or congestion levels?
3) Some trips are still modelled as fixed demand – most notably LGV and HGV movements, but also car trips for smaller schemes. This is not in line with the economic literature (e.g. de Jong et al. (2010)) which shows that freight traffic is not perfectly inelastic, and instead has a price elasticity in the same order of magnitude as car traffic.
4) Even if we can robustly model all trips on a variable demand basis, including where links are over capacity, there may still be conceptual issues with the user benefits measure (RoH). These relate to the possible presence of capacity constraints. For strictly capacity limited modes, such as air travel, TAG presents methods for valuing capacity increases based on ‘shadow prices’. These prices are the difference between marginal willingness-to-pay (i.e. marginal benefit) for a trip and marginal generalised travel cost incurred, and reflect the net benefit from allowing one extra trip within the capacity constraint.
5) Even if the experienced generalised cost of travel is the same in the DM and DS, such as the case of ‘total filling up’ where the demand curve is horizontal (Mackie, 1996)

there should in theory be additional user benefits from servicing more travel. Arup & ITS (2017) argued that in such cases the benefits, to the extent they exist, are to be found in WEIs, but this feels inconsistent with the theory behind the aforementioned shadow cost approach.

This research should try and address these issues in turn, drawing on a mix of iterature review, theoretical analysis and where possible empirical work. For example, for items 2-3 it would be particularly useful to shed empirical light to understand the materiality of the issues at play, whereas items 4-5 may be better suited to conceptual analysis in the first instance.

Aims, objectives and scope

The Department overall aim is to improve the quality and robustness of TAG methods for modelling and valuing induced demand within scheme appraisal. This should help make a robust and balanced case for road investment, relative to other forms of investment.

The commission has four main objectives:

1. Complete short survey of literature relevant to the brief, explaining how it is relevant to the issues/questions raised above. This should not be time-bound, and include relevant articles from any year, but does not have to be systematic. We are trusting the supplier to use their expertise to pick up the critical strands of literature.
2. Provide recommendations on how to handle modelling and appraisal under conditions of hypercongestion or flow over capacity. This may not be possible to resolve perfectly, but the best available existing evidence and literature should used to inform this objective.
3. Set out the conditions when induced demand may increase or decrease benefits, as a function of key parameters/conditions. Ideally, this should reference real-world examples and shed light on the scale of impact on benefits (e.g. does it reduce benefits by 10%? 50%?).
4. Collate and present relevant evidence on freight demand, leading to recommendations on how it could be better incorporated into modelling/appraisal and the potential implications of doing so.
5. Develop a conceptual model/framing which can robustly address issued related to capacity constraints and shadow costs, to recommend and approach which can fully capture the benefits of facilitating more travel even if generalised costs do not fall between the DM and DS.

In delivering against these, the five issues listed in the 'Introduction and background' ection should be addressed. It is not expected that this think-piece will solve all the extant issues/questions noted earlier in the brief, but it should provide sufficiently detailed recommendations for a forward work programme which will be able to do so. TASM will then consider its next steps based on these, so it is important that they are specific and actionable, as well as set against some idea of cost and timescales.

Outputs and deliverables

The following outputs are expected:

1. Two formal reports (interim and final) written in usual format (word document, font size 12) detailing findings and conclusions on the key elements of the analysis. The final report should fulfil the objectives stated above, and address the issues raised in the brief. We expect at least two substantive iterations of this to allow for detailed comments.
2. Any code, models or other IPR generated to fulfil this requirement.
3. Presenting the findings in a technical workshop consisting of key officials from DfT, its Arm's Length Bodies (where relevant) and relevant consultants. This will be arranged by DfT for a mutually agreeable date.