UTILITIES' STREET WORKS AND THE COST OF TRAFFIC CONGESTION

Phil Goodwin

February 2005

Phil Goodwin is Professor of Transport Policy at the Centre for Transport & Society, University of the West of England, Bristol (Phil.Goodwin@uwe.ac.uk), and Emeritus Professor at University College London. He was formerly Director of the ESRC Transport Studies Unit at Oxford University and UCL, a member of the government's advisory committee on trunk road appraisal, an adviser to the House of Commons Transport Committee, and Chair of the Deputy Prime Minister's advisory committee for the 1998 Transport White Paper.

A draft of this report was discussed with officials of the Department for Transport, the National Joint Utilities Group, and Halcrow Group Limited, who all provided useful information and comments. Their assistance, and Transport for London's permission to reproduce figures 1 and 2, are gratefully acknowledged. The analysis, conclusions and recommendations in the report, and any mistakes, are solely the responsibility of the author, and do not necessarily represent the views of DfT, NJUG or its member companies, the Halcrow Group, or TfL.

CONTENTS

② SUMMARY

Research suggests that utilities' street works are responsible for about 5% of the total amount of congestion. This total is widely cited as about £20b per year, which would imply that the cost due to utilities' street works is about £1b per year, though other methods give a lower figure. However, a recent calculation by consultants for the Department for Transport has suggested that there are an estimated 7 million days of utilities' street works per year, the congestion they cause costing on average over £600 each, to produce an annual cost over four times larger, at £4.3 billion.

This report argues that the £4.3 billion must be greatly overestimated. It further proposes that in fact *both* methods give an exaggerated picture of the congestion cost of street works, due to several problems including: the way they treat the very small time differences produced by the majority of works; the erroneous assumption that drivers never adapt their behaviour to avoid works eg by travelling at different times of the day; and the use of a 'congestion-free' benchmark of comparison which could never apply. But anyway, calculation of the total cost is not useful for any practical policies: the important issue is not whether the 'true' figure is £1 billion or £4.3 billion, but whether realistic savings (worthwhile, but not to be measured in billions) can be made without imposing costs which are greater than the benefits.

Thus, congestion in general is important, and it makes sense to reduce that part of it which could be saved by sensible policies to improve the efficiency of street works. These can be compared with the much bigger savings in congestion that would be achieved if road users themselves were charged for the congestion they cause. The DfT has developed a more reliable method for calculation of the effects of road pricing, and this should be extended for utilities street works, to compare the marginal benefits, with the marginal costs, of changing present practice. Suggestions are made for how to do this on the basis of a level playing field, balancing the interests of both road users and utility users. Such a balance should include explicit consideration of:

- The value to road users and society as a whole of delays in travel time, and indirect effects on health, safety and the environment. This should be matched against the corresponding values (estimated in similar ways) of the costs to utility users and society as a whole of delays in delivering utility services, and the effects on health, safety and the environment.
- How to ensure that the money values of these costs are included in the charges made to those responsible for them, in such a way as to create equitable financial incentives to highways authorities and road users, as well as utilities and their customers, to take decisions in proportion to costs.
- Both of the above should be done with explicit inclusion of their effects on the behaviour of individuals and companies.

INTRODUCTION

Virtually every reader of this report will have had the experience of waiting in a traffic queue slowly filtering past street works. It seems to be part of the universal experience of travel by road in a modern economy.

Sometimes flowing water everywhere suggests that there is an urgent problem with blocked drains or water mains, and the whole thing is over by the following day. Sometimes a suspected gas leak may mean that traffic and people must be kept completely away for reasons of safety. Sometimes it goes on for months, as ageing infrastructure for electricity or sewers or telecommunications is replaced. Sometimes we are particularly cross when the barriers are up but there is no sign of any actual work being done, and sometimes human patience is tested to the absolute limit when no sooner has one organisation filled in its hole, than another digs it up, over and over again. Local newspapers compete to find the street with the longest list of holes, and are often rather careless in reporting exactly who is responsible for them.

At this time, there is serious discussion of road pricing, focussing on the potential benefits to be gained by charging road users, in part to take account of the delays their travel cause to others. This is the background to legislation enabling charges for other causes of congestion – including street works – as an incentive to reduce the duration or scale of the works to the minimum. The logic is rather similar, based on making the market work more efficiently, though there are other considerations as well: the disruption caused to daily life if water or electricity or sewers fail is, for many people, far more in need of urgent action than if travel is delayed.

Irritation is not always a good guide to economic reality. This report stemmed from a discovery that there were some strange calculations being made, by the Government and its advisers, suggesting that the total economic cost of all this disruption was given such a high value that the figures seemed unreal. That is dangerous, for one simple reason: if the charges are set at a level which overestimates the real actual cost of the delays, the negative effect on other, vital, services and their customers could be worse than the benefit of reduced traffic congestion.

TWO DIFFERENT METHODS OF CALCULATING THE CONGESTION COST OF STREET WORKS

The objective of this report is to try to unpack the way in which the congestion cost is calculated, in order to find out what the true cost really is.

There have been two main methods used in general to calculate the costs to the economy of congestion, in total and associated with specific causes. The first, 'top down', method has a pedigree[1] dating back about 50 years, and proceeds in three steps as follows:

> Step 1: Calculate the total economic cost of congestion from all sources
> Step 2: Calculate the proportion of congestion that is due to the specific cause under discussion, in this case street works
> Step 3: Multiply the total cost by the proportion, to obtain congestion costs due to street works.

The second method is less well tested at a global level, though part of its logic has been applied for specific local road schemes for about 40 years. It also has three steps, but proceeds 'bottom-up' rather than 'top down'.

> Step 1: Calculate the congestion costs for specific individual works, by observing or modelling queue lengths
> Step 2: Ascertain how many works there are in the country as a whole
> Step 3: Multiply the average cost per works by the number of works, to get the national total.

In both methods, there is likely to be a need to distinguish different types of road (trunk roads, local roads etc) and different types of area (urban, rural, etc) and possible different times of day or days of week or seasons, as the traffic levels and resulting congestion will vary accordingly.

---

[1] For example, an early calculation of the total cost of congestion was made by Glanville WH and Smeed R J (1957) The basic requirements for the roads of Great Britain, Proc. Conf on the Highway needs of Great Britain, Institution of Civil Engineers

In principle, if the data and methods of calculation are robust, these two different methods should come to about the same result, and indeed this would be one way of increasing confidence in the numbers. ‘About the same’, in this context, would mean that the figures should be within about 20% of each other, and ideally within about 10% - closer than this is not a realistic expectation.

However, in practice, calculations carried out so far have not remotely been within 10% or 20% of each other: they have differed by a factor of between 4 and 5. The ‘top-down’ method leads to an estimate that the total economic cost of street works carried out by utilities is less than £1 billion per year[2], whereas the ‘bottom-up’ method has produced a most recent estimate – this being the one that has informed DfT thinking – of £4.3 billion a year, more than four times as much.

The value of time

Both methods rely heavily on the idea of the ‘value of time’.

This treats time as a sort of money – we spend, save, lose or waste it – with a value that depends on a whole range of factors which will mostly not be discussed in this review. Although there are still some important controversies and difficulties in the concept of ‘value’ of time, most of them do not have a material effect on this particular argument. The normal procedure is to take a figure close to the wage rate plus employers’ overheads for the value per hour of time spent travelling in working hours, this being, by assumption, the value of the production that would be increased if the amount of time spent travelling were reduced. There is also a substantially discounted figure (varying in the range quarter to a half of the wage rate) for time spent travelling in leisure hours, including journeys to work, where savings accrue to the individual rather than being used for work. These leisure values are based on research estimating how much money people would themselves be prepared to pay to save some travel time.

---

[2] Throughout this report, ‘billion’ refers to the now standard usage, namely 1,000,000,000. To put this in context, £1b for the UK as a whole is equivalent to around £50 per household.

From time to time the Department for Transport issues recommended values which are used in, for example, appraisal of road construction schemes. The values used in calculations of the effect of street works come to an average of £11.28/hour, for work and leisure time taken together, at 2002 values[3].

There are some recent changes in official thinking about these values which are relevant: first, it was for many years thought that the values increased, in proportion to income, every year. Following research commissioned by the DfT and carried out by Leeds University and others, the DfT is now of the view that the values do not increase as fast as that. Secondly, it was always assumed that the unit value per hour was the same for large time savings as for small time savings, and the same for travelling in congested conditions as in free-flowing traffic. Recent research suggests that the conditions of congested travel raise the value, which reflects the 'irritation' effect, and that the assumption of a constant unit value has problems for very small differences in average travel time, where variability (ie unpredictability) may be more important than the mean.

It may be noted that although the value of time is deeply embedded in transport appraisal, transport is not the only sector of the economy where delays have a value. In this context, individuals and companies waiting for the restoration of interrupted supply of a utility, or waiting to be connected to a new or improved service, also incur penalties in their own standard of living, and the costs of production of the services they supply, which is directly analogous to delays in traffic. (Similarly, effects on public health of, say, clean water or sewage disposal, will have social effects directly analogous to traffic accidents or environmental damage, which are also embedded in transport appraisal).

[3] DfT (2004a) Values of time and vehicle operating cost, DfT TAG Unit, April.

In some cases, a market allows faster services to be bought by those who want them, both in transport and utility supply. In other cases, queues or regulation mean that no such charge is made. But the economic cost of such delays are real whether or not they are partly or fully open to prices in a market.

The practical significance of this point will become clear further on in the discussion. But as a matter of principle, we can say that there are in this discussion two sorts of delays, not one: there are delays to traffic and delays to the provision of utility services. It is not axiomatic that traffic delays are more important than utility delays. If the former is calculated, and the latter not, there is likely to be an imbalance in the outcome.

The two sets of calculations will now be summarised.

METHOD ONE: 'TOP-DOWN' CALCULATION

Step 1: Calculating the Total Cost of Congestion to the Economy

The traditional way of calculating the total economic cost of congestion compares the actual travel conditions we see, with the conditions that would apply if everyone is travelling at 'free flow' speed – ie unencumbered by any other vehicles, and driving as fast as they choose (subject, of course, to the legal speed limit). In simplified form, the arithmetic may be summarised in two parts as follows.

Part 1
(Total time spent travelling in reality)
minus
(Total time if everybody could travel at free flow speed)
multiplied by
(Number of people)
equals
(Total delay due to congestion)

Part 2

(Total delay)

Multiplied by

(Value of time)

equals

(Total cost of congestion).

The most famous example of this sort of calculation was carried out in the mid 1980s and published by the British Road Federation in 1988 and the Confederation of British Industry in 1989[4], suggesting £15 billion per year for the UK as a whole. From time to time since then the figure has been updated, but usually just by adding in the effects of inflation, not by recalculating from scratch. By 2000 the figure most often quoted was £20 billion a year, and it has not been substantially recalculated since then.

The Government has used essentially the same method to calculate the trends in congestion for assessment of its Ten Year Plan for Transport, when the Plan was launched in 2000, and not modified it substantially since. The government did not actually express their figures in terms of a 'total cost', but rather the percentage change in that cost. If it had quoted the total cost figure it would, I think, have come out with broadly the same answer, using this method. Ministers have expressed some caveats about whether such measures actually correspond with congestion as perceived by drivers, and there seems to be no appetite at the moment to produce a revised official figure for the total cost of congestion, although other agencies such as the CBI continue to do so.

It should be said that the figure has always been somewhat controversial and uncertain. For example, NERA produced an estimate in 1997 which was £7 billion – very much less than the £15 billion to £20 billion being discussed – and the difference was never reconciled. Although the £20 billion is the more widely cited figure, the £7

[4] British Road Federation (undated, confirmed as 1988) The cost of congestion
CBI (1989) Transport in London; Task Force Report, London Confederation of British Industry

billion is closer to the methods used later by the Government's main advisory body on transport, the Commission for Integrated Transport, which will be discussed later.

The main problems in the £20 billion figure were not its precision, but doubts about whether it had any meaning. It is very dependent on the value assumed for the 'free-flow' speed, which in a way is not internally consistent: you could never actually observe a real world case where you had the same number of vehicles, but they were all travelling at the free flow speed. (If such speeds were, by some sort of magic, achieved, this would quite certainly attract more vehicles). In addition, even the question of what is the 'real' speed is not unambiguous, some calculations (such as the CBI's) basing this on the actual experience of vehicles on the road, and others (such as NERA) on a calculation of what the model says would be the real speed, rather than what actually is).

The method has some odd and perverse implications in use, such as implying huge benefits in reduction in congestion as a result of drastically reducing the legal speed limit – you could abolish 'congestion', defined in this way entirely simply by reducing the speed limit to the actual average speed on the ground, which is silly. (There are in fact some situations where it is possible to get a genuine benefit by reducing speed, but the effect is smaller, and due to smoothing out traffic flow, not arithmetical trickery).

Nevertheless, these global figures – even taking them as very rough and ready approximations - of the total cost of congestion to the economy, are widely used, and they do have one big advantage. They relate to congestion caused by *all* possible reasons, and therefore can be used as a touchstone when other figures of the total cost of specific sorts of congestion are in scope.

Thus without making any judgement at this stage between the two competing methods, we have two big numbers for the total cost. One is £7 billion a year. The other is £20 billion a year.

We shall return to these.

Step 2: The Component Sources of Congestion

There have been two most useful estimates of the relative importance of different causes of congestion. One is by the Transport Research Laboratory[5], referring to trunk roads, and the other by Transport for London[6] related to London.

TRL identified three different sources of congestion, namely

1. Recurrent congestion due to 'sheer weight of traffic'
2. Congestion due to road works
3. Congestion due to incidents[7].

Their estimates, together with their author's judgement on their robustness, are summarised in the table 1.

Table 1. TRL Estimates of the Relative Importance of Different Sources of Congestion, Trunk Roads

Source of congestion	1995/6 %	1996/7 %	1997/8 %	1998/9 %
Recurrent ('robust')	54	63	67	66
Road works ('broadly supported')	21	14	9	10
Incidents ('least robust')	25	23	24	24

[5] B A Frith (1999) The estimation of recurrent congestion and congestion due to road works and incidents: 1995/6 to 1998/99. Report PR/TT/160/99 3/226, Transport Research Laboratory. This report was not published as a TRL report, but provided to its client, the Department for Transport, who made it available to the National Joint Utilities Group.

[6] P Brown (2004) Implementing the Traffic Management Act, Water UK Traffic Management Conference, 12.11.2004, London

[7] There are many different sorts of temporary interruptions to road capacity. These can include: the effects of unusual weather or provision for it; natural disasters such as earthquakes; accidents between vehicles or between vehicles and pedestrians; political phenomena such as state occasions or demonstrations; the urgent needs of security, police, fire and ambulance services; movements of animals; chemical spillages and fires; untreated deterioration in road surface; building works not on the road but straying onto it from frontages; special loads requiring escort; failure of traffic control systems; special events beyond normal expectations. Some of these are more important on urban streets than on trunk roads.

These figures suggest that the category of recurrent congestion is growing as the volume of traffic grows faster than road capacity, which one would expect given that traffic has grown faster than capacity. Incidents, which are of their nature likely to be random, are approximately constant. And the effect of road works has declined somewhat, as a proportion of the total, perhaps due to better procedures for their control. Note that 'road works' here includes both the works carried out by highways authorities (road construction, maintenance, repairs etc) as well as the works carried out by utilities, which are about the same order of magnitude as each other.

Therefore some 5% of all congestion on the trunk road network is due to utilities' street works.

The figures for London – published with some caution as there were difficulties with data, and the calculations are currently being overhauled and revised – are shown in figures 1 and 2.

Figure 1. TfL Estimates of causes of serious and severe congestion in London

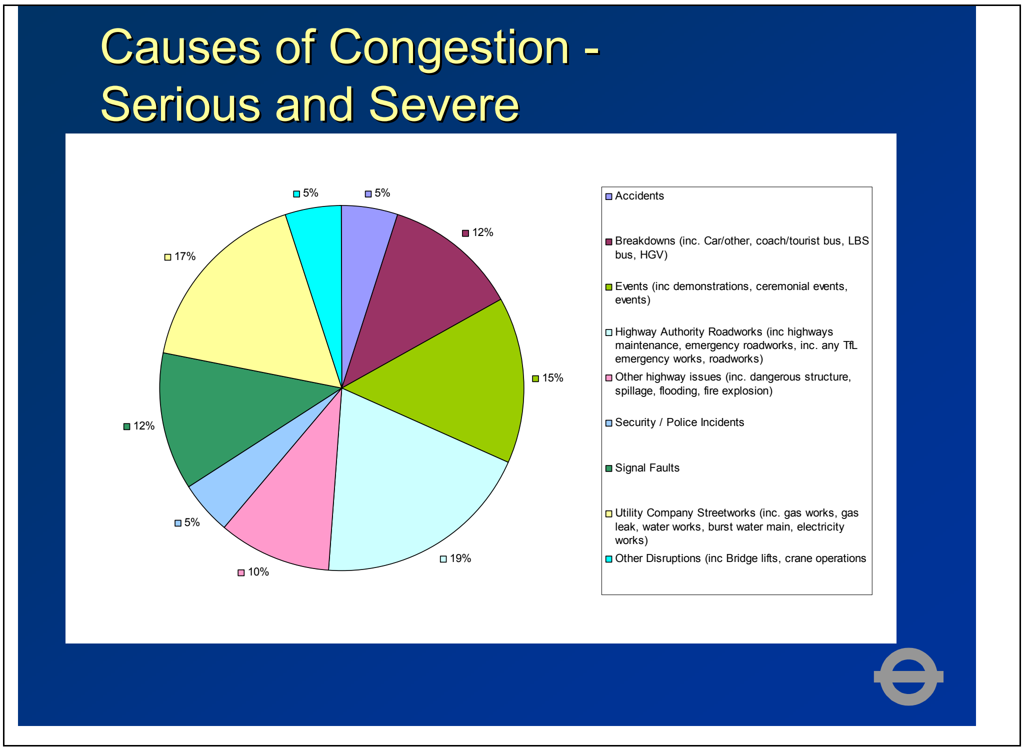
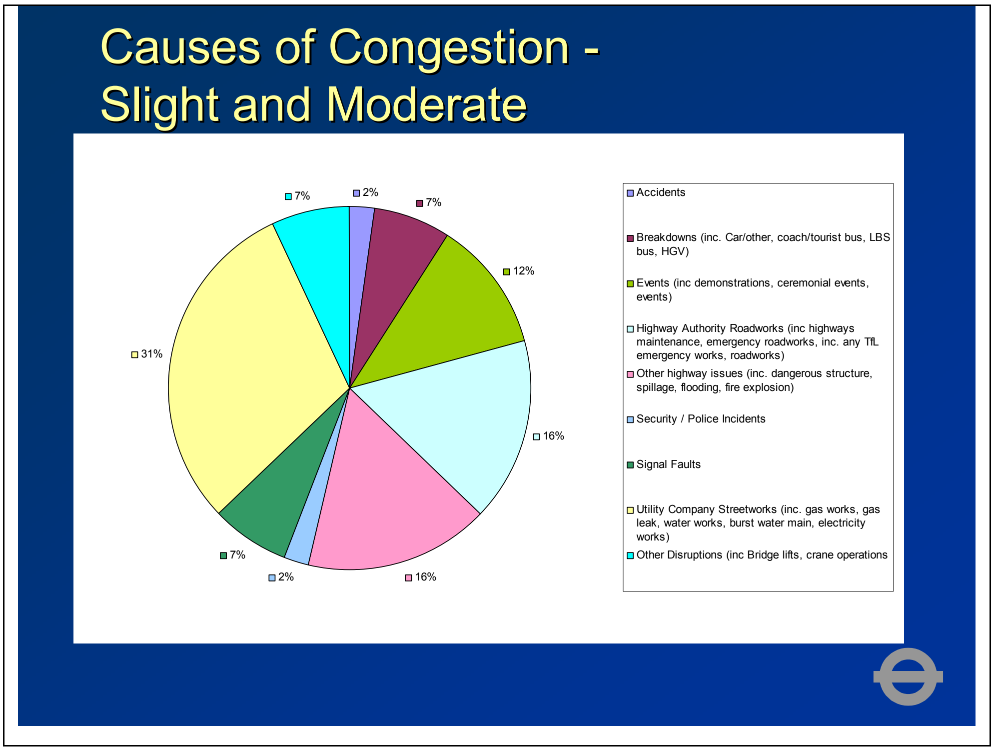


Figure 2. TfL Estimates of Causes of Slight and Moderate Congestion in London



At first sight, these figures seem to imply that the cost of street works is a much bigger proportion of the total in London than TRL estimated for the trunk road network – Brown cites 17% of serious congestion, and 31% of slight and moderate congestion, being due to utilities' street works (as compared with 19% and 16% respectively for road works carried out by highways authorities). However, the two sets of figures are not immediately comparable because the TfL percentages are not expressed as a proportion of total congestion: they exclude the underlying – and biggest – source of congestion, namely what TRL called 'recurrent' congestion due to 'the sheer weight of traffic'. Thus the London percentages are in effect a partition only of the other two categories of the TRL scheme, ie incidents and works. If the TfL figures are therefore recalculated on this basis, assuming that recurrent congestion in London is at the same level as the trunk road network, the 17% of serious congestion and 31% of slight congestion come to 6% and 10% respectively. But recurrent congestion in London must actually be greater than on the trunk road network (because the traffic volumes it copes with are closer to maximum capacity for longer periods of time), and it would be more sensible to take 80% for this. Then the congestion caused by street works, as a proportion of *all* congestion, will be about 4%

and 7% for serious and slight congestion respectively, from which it is reasonable to say of the order of 5% overall.

Thus for the two breakdowns we have – trunk roads, and London – utilities' street works in both cases contribute about 5% of the total volume of congestion. We do not have similar figures for other towns and cities (where congestion from all sources is less than London, though still appreciable), or for rural areas (where congestion tends to be confined to specific seasons and locations), but there is no reason to think that the *relative* importance of works, as compared with other sources, is likely to be systematically and substantially different.

Step 3: Total cost of congestion due to street works

Thus we can say that taking the most widely cited figures, street works contribute some 5% of £20 billion a year to the total cost of congestion, namely £1 billion a year. Using the NERA method, it would be significantly less – 5% of £7 billion, ie about £350 million per year, though allowing for other sources of congestion not included in the NERA method could put this up to about £0.5 billion.

This can be compared with a study supported by the Rees Jeffreys Road Fund, Marvin and Slater in 1996[8], which cited an 1989 Department of Transport calculation suggesting a rather lower figure: "They [the DoT] estimate the utilities total contribution to congestion cost the nation £55m per year", though no details are given about the method of calculation, which has not been cited in any recent work. An estimate of £55m reported in 1989 and presumably referring to an earlier year's statistics, could lead to a figure of broadly the same order of magnitude as the NERA method after inflation and traffic growth.

Thus these methods lead to an estimated value of £1 billion a year at most, but possibly less than £0.5 billion.

[8] Marvin S and Slater S (1996) 'Holes in the Roads; Roads and utilities in the 1990s, Centre for Urban Technology, University of Newcastle, citing DoT (1989) Charging for the occupation of road space by undertakers of works: proposal for legislation, London, September. I have not tracked down this DoT document.

Method 2: 'BOTTOM-UP' CALCULATION OF THE CONGESTION COST DUE TO ROAD WORKS

The Regulatory Impact Assessments for the Traffic Management Bill, enacted in July, asserted that "A report published in 1992 by TRL concluded that disruption resulting from utility companies' street works cost the economy £2.4 billion per annum" and noted that further work, still in progress, suggested that the figure had since then grown considerably.

The further work[9] was reported, in draft in July 2004, and published in September.

This report calculates the economic cost of delays to traffic caused by utilities' street works as about £4.3b per year. It does so by the following method.

Step 1: Calculate the delay costs of specific works

A number of computer models, known as SATURN, VISSIM, AIMSUN and QUADRO, were used to calculate the delay that would be experienced by drivers queuing up to pass through unexpected street works (or, in some cases, to divert to longer routes), in a variety of different road conditions defined by higher or lower traffic flows, type of road, and size of works. When multiplied by the average value of time, these calculations gave figures ranging from £355 worth of delay per day for small works on a rural road with light traffic flows (apparently comprising 19 seconds delay per vehicle, although this was not stated) up to £11000 per day (apparently 3.6 minutes per vehicle) for the biggest works on the rural roads with the most traffic. For urban areas the range was £200 a day (11 seconds per vehicle) from small works on minor roads, up to £25,000 per day for large works on the most congested urban streets (3.3 minutes per vehicle).

Fifty different conditions were distinguished, using urban and rural conditions each with five levels of scale of works, and five 'reinstatement categories' (a judgement by

[9] Halcrow Group Ltd (2004) Assessing the Extent of Street Works and Monitoring the Effectiveness of Section 74 in Reducing Disruption, 3rd Annual Report, Volume 3 – Estimation of the Cost of Delay from Utilities Street Works, September, Department for Transport, London.

highway authorities of the importance of the road from a traffic point of view), this being the best available proxy for traffic flow which was not available.

An overall average figure of delay costs per works is not given directly in the report, but 32.1% of all works on which notices were available were allocated to the smallest urban category, 9.5% in the next smallest, and 25.9% in the smallest rural category. This means that two thirds of all works were associated with an estimated average delay of under 20 seconds per vehicle, and less than one tenth of 1% of all works were in the highest categories of delay of some minutes per vehicle.

Step 2: Calculation of the total number of works

Halcrows monitored the number of notifications of works received in 25 authorities, and extrapolated this up to a national total: this extrapolation clearly requires a caveat, because of the great variation in characteristics between authorities, and the small base sample. It was calculated[10] that there were 1.1 million works per year, increased to 1.3 million to allow for unclosed and abandoned works. The average duration of works was 5.3 days, hence 6.9 million days of works per year.

The calculations were done at the level of the fifty different road conditions and the fifty different costs per day (and further disaggregated by types of works and which utility was concerned) with only the overall results cited, not the separate stages of the calculations. But working backwards it appears that figure used in the calculations for the overall average estimated cost per works per day was £633.

Step 3: Calculation of total congestion cost of works

As the simplified essence of the more complex matrix manipulation by which the calculations were done, we can multiply the cost per works per day of £633 by the total number of days of works, 6.9m, to give a total figure of about £4.3 billion.

[10] Department for Transport (2003) Second Annual Report, Volume 1, Main Report.

WHICH FIGURE IS CORRECT?

The two methods cited give something less than £1 billion a year, and over £4 billion a year, as the estimated cost of the congestion attributed to street works. These figures are too far apart simply to say 'well, the true figure must be somewhere in the range £1b to £4b'. To explain such a big discrepancy, there must be some important methodological problem involved, and prima facie it is reasonable to assume that at least one of the methods must include some error. As argued below, it is my judgement that there are errors involved in both methods, leading *both* to produce overestimates of the useful reductions in congestion to be made by reducing street works, though more seriously so for the 'bottom-up' method.

Five problems of method and principle will now be discussed, namely

- The problem of aggregating very small time savings and losses;
- The implications of defining congestion cost by comparison with free flow conditions;
- The implications of ignoring adaptation of driver behaviour;
- The effect of general congestion on specific congestion;
- The reliability of the data base.

The problem of aggregating very small time savings and losses

As noted above, for the large majority of street works, the bottom-up method is based on aggregating millions of delays, each of some seconds per vehicle, into billions of valuable hours. The same is true for the top-down method, except that the delays per vehicle, being spread on average over all journeys, are even smaller. This is normal practice for road appraisal, but has always been somewhat controversial, with recurrent arguments that below some small threshold, time savings cannot actually be made use of for productive purposes or more favoured activities.

This problem is especially material where the changes in journey time are substantially smaller than the differences in journey time that happen due to random causes anyway. Research on this establishes[11] that it is fairly typical for there to be a substantial random day-to-day variation in travel times. For a hundred journeys to work, broadly between 10 and 20 will be travelled with an overall door-to-door time more than 20% faster than the average, and a similar proportion will travel more than 20% slower than the average. But even this variation is itself not stable from day to day – when the weather is bad, or when traffic flows are higher than usual for some random effect, then the unreliability will be higher than on ‘normal’ days. So we have various levels of experience – the ‘average’ day which is a statistical calculation, the ‘usual’ random variation even when conditions are rather similar, and the ‘special’ variation in unusual conditions.

So for an average car journey of 20 minutes, the expected range in times will be, for most cases, 15 to 25 minutes. Within this variability, figures of 20 seconds for a delay due to works do not lend themselves to clear perception, except in the case of works which are sufficiently prolonged, or sufficiently well publicised, to be fitted into the driver’s expectations, which will be discussed further below. The significance of this problem of perception is that because travel time is varying anyway, a driver will need repeated experience before it is possible to tell whether a particular street works is the source of a serious delay: the smaller the average delay in proportion to the normal variation, the longer it takes to be sure it is real.

This aspect leads perhaps to a degree of caution in expectations. The large majority of works, comprising the larger part of the estimated £4.3 billion (or any other figure), do not involve delays which can be easily perceived by road users. This is a potential political problem due to unrealistically raised expectations: media reports are more likely to focus on the very small number of particularly disruptive street works, but most are not in this category, and in reality the largest part of the expected benefit of any new procedures is much more likely to have the character, for example, of changing a 20 second delay for 5 days to a 15 second delay for 4 days, but in the context of a normal day to day variation of say 10 minutes.

[11] Some of this research is reviewed by the author in Goodwin (2004) The economic costs of road traffic congestion, Rail Freight Group, London

Such small changes will be difficult to measure with confidence even by researchers using precise measurements and sophisticated statistical analysis, and will be invisible to many drivers using the road.

The practical implication of this difficulty is that it is particularly necessary to be sensitive about the individual costs compared with the individual benefits at the level of a specific scheme. It may be useful to have a 'de minimis' rule such that the actual costs of administration should not exceed, say, a quarter or a half of the expected net benefits of the changes expected.

Problems of defining congestion cost by comparison with free flow conditions

Both methods of calculating congestion cost proceed by comparing the real world conditions (as observed or modelled) against a notional universal congestion-free benchmark, roughly equivalent to every vehicle experiencing the same conditions as if it were the only vehicle on the road. This could never occur in practice, of course, and in any case is internally inconsistent – if such road conditions did apply, one of the consequences would be a greater number of vehicles travelling.

This issue has been much discussed in recent years, especially following the publication of the Government's Ten Year Plan for Transport in 2000. This suggested that the combined effect of all the policies and projects in the plan would produce a reduction of 6% in the total cost of congestion over the ten years, a headline result which sounded worth having. However, it was calculated against the benchmark of zero congestion as defined above, which had the effect of exaggerating a very small actual change in the average travel time – the 6% amounted to an estimated reduction in journey times of 1.6 seconds per kilometre travelled, which as noted above is very much smaller than the normal day to day variation, and probably undetectable[12].

[12] In 2002, DfT changed these calculations, estimating that the combined effect of all the schemes and policies in the 10 Year Plan were probably not enough to produce a reduction in congestion at all, because of the increasing volume of traffic, and there would be an increase in congestion not a reduction. The same result applied, that a rather small increase in travel times was in this case exaggerated to a much bigger percentage in congestion. It was felt that the percentage change in the total amount of congestion was a hostage to fortune, and its use is not expected to continue. The policy consequences, notably reflected in the reports on road pricing and on 'soft' measures of reducing traffic published by the DfT in July 2004, are not discussed further in this report.

For this reason, there is now much less enthusiasm, by Government or other agencies, to measure the total cost of congestion in this way, and more interest in developing measures that can be more meaningful to the actual experience of road users. From this point of view, the total value of congestion caused by utilities' street works is something of a hangover from earlier methods of assessment, no longer of great usefulness or importance.

The practical implications of this difficulty are that little consequence follows from concluding that the total costs of street works is £4.3 billion, or £1 billion, or indeed any other figure. It cannot be used as a guide to the importance of the problem, nor the scale of benefit available. For this reason, the troublesome size of the discrepancy in the figures may not matter as much as it appears, since neither is a useful guide to specific policy or practice.

The implications of ignoring adaptations of driver behaviour

Of critical importance in the Halcrow bottom-up method, and of some, though less, importance in the top-down method, is the presumption that congestion costs are calculated by comparing the time spent in a queue with the time spent – by the same vehicles, going to the same places, at the same times – if there were no congestion. This was enshrined in the Halcrow calculations by their modelling work which was based on what traffic engineers call a 'fixed trip matrix' – ie no changes to the numbers of trips, or their frequency, or the pattern of origins or destinations, or the method of transport used, or the time of day of the journey. The only form of adaptation allowed (in some, but not all, of the modelling) was that instead of staying in the queue, a proportion of the drivers were allowed to travel on an alternative, albeit longer, route.

This is important, as if drivers are able to adapt their behaviour in a wider range of ways, a proportion of them will find alternatives which reduce the cost of the delay, eg by travelling earlier or later, or putting off some discretionary journeys until next week or month, or taking the train, or going to a different shopping centre, etc[13]

There has been little direct research on the specific nature of drivers' travel responses to road works, though wider research suggests that the more publicity and notice are given to works, or the longer they last, the greater adaptation is possible.

Consider the following three narratives.

---

[13] There is a well-established method of calculating the change to costs and benefits of these adaptations, known as the 'rule of a half'. If we know that 1000 journeys are made at a 'cost' of 20 minutes, and 900 at a cost of 19 minutes, then the average loss to the 900 is one minute each, but the average value of the loss to the other 100 is half a minute each. We know that the total volume of travel is quite sensitive to travel times – somewhere between half and all of any time saving is actually ploughed back into more travel – which explains why road construction induces more traffic, and reduction in road capacity produces a reduction in traffic, with both effects well documented in, for example, SACTRA (1994) Trunk Roads and the Generation of Traffic, HMSO, and Cairns et al (1998) Traffic Impact pf Highway Capacity Reduction, Landor Publishers, London. The effect is to reduce the congestion relief brought about by extra road capacity, and reduce the disruption brought about by reduced road capacity, hence in both cases reducing the estimated congestion from street works. Using a fixed matrix model in these circumstances has always caused problems, and should not be done.

Case 1.

You leave home in your car, knowing exactly where you want to go, ie the local town centre to do some shopping. Half way there, you come across an unexpected very serious road works. It is too late to turn back and get the train instead, or to wish that you had left earlier, or delayed your journey until next week, or gone to the neighbouring town centre instead of your usual one. Depending on how far in advance you see the works, you either have no choice at all: you simply have to sit it out. Or, you might have enough warning to make a detour onto another road which (because of the other drivers choosing, or being directed to do the same thing) is also congested. You have the delay of queuing, or the delay of the other route.

Case 2

The week before, the local newspaper has warned you that the works will start, and that morning the local radio reminds you. For some proportion of journeys, it is clear that you can consider an alternative.

Case 3

Whatever you decide to do in cases 1 or 2, the same thing happens again the next day. And the next day. The local newspaper tells you the works will continue for three months. Even when they finish, you are wily enough to work out that the next phase of the work will then be started a mile further up the road. And even when the whole project is finished, you know perfectly well that somewhere or the other there will be other road works more or less similar in scale elsewhere on your route. In this case, you certainly have a wider range of choices open to you than simply queue or divert. The most likely thing you will do is change the time of your journey to a time when, since the basic level of congestion is less, the smaller amount of traffic can pass the road works without much delay. You may rearrange your travel patterns to take account of the delays that you now, being reasonably intelligent, expect. For some journeys (though not all) this will include going somewhere else, going less frequently, going by bus or train. Now each of these will, to some extent, probably be a second best in your preferences – you have some sacrifice in convenience (though you just might be agreeably surprised). But it will be a smaller[14] loss in convenience than the 'queue or divert' choice.

Indirect estimate of the likely order of magnitude of adaptations in behaviour due to street works

Consider that approximately £450 per year is spent per household in England on motor fuel, not counting motorways and trunk roads. Now suppose we take the Halcrow £4.3 billion figure, and convert it into a sum comparable with this fuel bill. £4.3 billion is equivalent to £200 per household, of which roundly half would be on average in the form of individual travellers' delays, and half would be the implied effect (via professional drivers' wages etc) on all other prices. On the 'time is money' principle used, £100 a year in delay would be equivalent to a sustained increase in real petrol price of over 20%.

A very large amount of empirical research, and incorporated into the standard DfT modelling methods, estimate that the effect of such an increase in fuel cost, spread over the whole network, would be a reduction in traffic of about 7%. Including the cost of highways authorities' road works on the same principle, would increase the net reduction in traffic due to the congestion caused by all works to some 10% to 15%. This is big enough to have a further material effect on drivers' responses, and so on.

Conversely, if by magic we were able to prevent all street works and road works without any effect on the economy, this would generate an additional 10% to 15% of traffic which would in turn increase the amount of congestion on some part of the network (though not necessarily in the same places as the avoided works).

It will be seen that this argument depends on the assumption that drivers have sufficiently good knowledge that they can adapt to the congestion caused by street works and road works.

---

[14] This is logically necessary. If it is not a smaller inconvenience, overall, you won't choose it – you'll choose to queue or divert. So this always gives you the worst case, and anything else is a bit better.

At high levels of congestion, small changes in traffic volume can cause a disproportionately large change in congestion[15]. This suggests that *if* the congestion caused by utilities street works is as big as £4.3 billion without any adaptation of driver behaviour, then that would be big enough to guarantee that there would be such adaptation, which would therefore reduce the figure – the result is internally inconsistent.

Depending on what parts of the network, and at what times, the induced/suppressed traffic manifested itself, the potential effect is big enough fully to bridge the gap between £4.3b and £1b – ie prima facie the use in the Halcrow calculations of a full range of behavioural adaptation could bring its estimated value down to £1b, or less.

The practical significance of this difficulty is that the assumptions made about how drivers respond to delays due to street works is not only a theoretical question which affects the calculated cost – though it certainly does that – but also affects all calculations of traffic disruption and remedial action at the level of an individual street. Works which are too small to be noticed can of course be left out of this, but for big, important or long lasting schemes it is essential for local authority traffic managers to allow for drivers' responses in assessing both the costs and the traffic arrangements to be adopted. Anything which has a cost big enough to merit charging and control, cannot be assessed using a fixed matrix method which assumes drivers do nothing but queue.

A further practical implication is the strong likelihood that congestion costs can be reduced by giving advance notice, warnings, and real-time information, about the scale of works going on. It is this that allows drivers a greater degree of adaptation, which in turn reduces the economic costs of the delays.

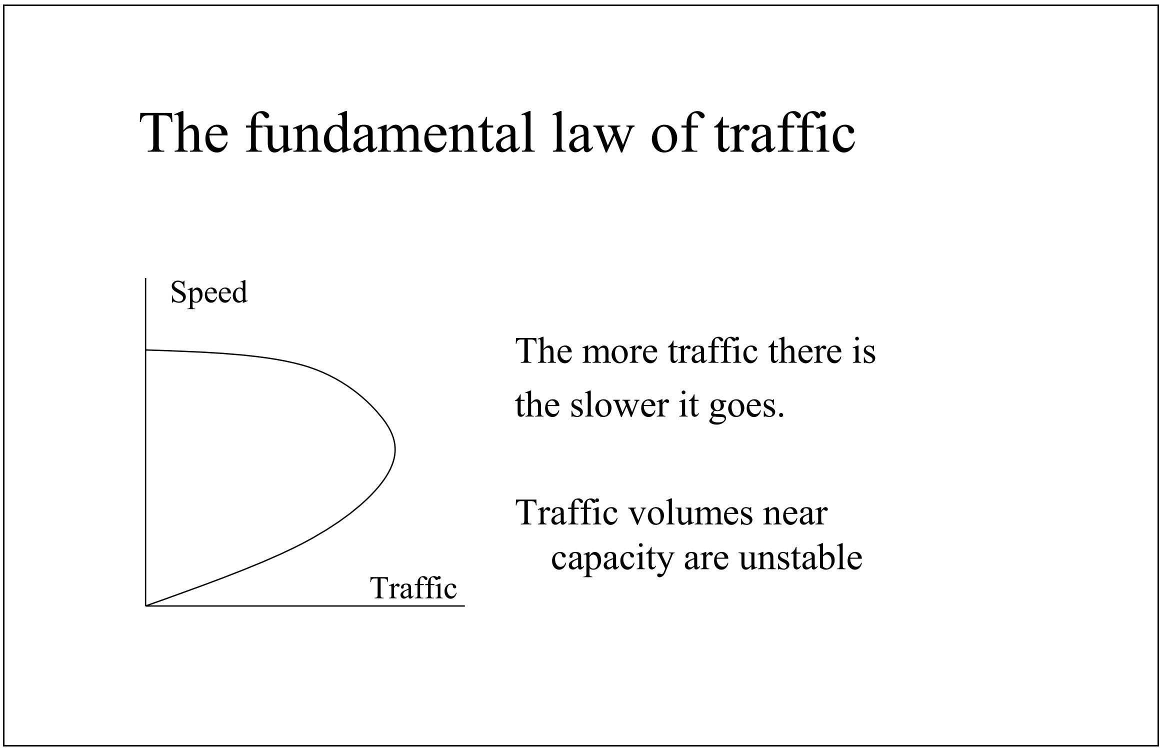
[15] The halving in congestion cost estimated by the road pricing report was brought about by a smaller net traffic reduction than this. This is because the user charging would be efficiently targeted at the most congested areas, whereas a general price increase – like street works – occurs over the whole network.

The effect of general congestion on specific congestion

Of smaller importance quantitatively, but central to the question of deciding who should be charged for congestion, is the problem that in reality the congestion caused by street works, or indeed any other specific cause, is not independent from the congestion caused by the general level of traffic. This indeed is the reason why the Halcrow figures of costs are higher for roads with more traffic.

This arises from the nature of the 'speed-flow curve' relating speed to the general volume of traffic. This has the general form of figure 3[16] below

Figure 3. Non-linear Relationship between Traffic Flow and Speed



At low levels of flow, there is little congestion, but more important, little additional congestion is caused by either an increase of traffic or an effective reduction in road space. But when traffic flow approaches the maximum capacity of the network, then small increases in traffic, or small reductions in effective road space, have disproportionate effects on speed. When the maximum capacity is reached, the whole system becomes unstable, and even very small changes in traffic, or road space, or incidents, etc, can make everything grind to a halt. In these circumstances, the behavioural response will also be correspondingly greater.

This effect is quite large, due to the non-linear[17] nature of the relationship when roads are operating close to maximum capacity. Table 2 gives an indication of how important it is.

Table 2. Effect of general traffic levels close to maximum capacity on incremental congestion caused by further changes in traffic or road space[18]

Base Traffic as a Percentage of Maximum Capacity of the Road	Increase in congestion cost caused by a 1% reduction in effective road space
25%	2%
50%	3%
75%	5%
93%	12%
98%	20%

Thus if the general traffic volume is kept sensibly to a level not too close to the maximum capacity of the road, there is elbow room to reduce capacity to some extent to allow for street works, or indeed any other temporary interruption, without causing excessive problems. If the general traffic level is too high, then even a small interruption can cause disproportionate additional congestion.

The practical significance of this point relates partly to the case for traffic demand management as a central component of transport policy: this is discussed further below. But it also relates to the big problem of deciding *who* should pay the cost of disruption, and how much. It is arguably the responsibility of the highways authority (in accordance with national or local policy) to manage the road level of traffic in such a way as not to be operating very close to the maximum capacity of the system.

---

[16] This standard presentation used traffic science sometimes causes some confusion. In the upper part of the curve, the relationship is symmetrical, but in the lower part, not. This discontinuity cannot easily be pictured in two dimensions, though the actual experience is very common.

[17] It is common practice to approximate this by linear relationships, which can tend to underestimate congestion effects in very crowded networks, though it is not clear how important this source of error may be in this particular case.

[18] Inferred from Smeed RJ (1968) Traffic Studies and Urban Congestion, Journal of Transport Economics and Policy II (1). His calculations were for London conditions, but the principle would apply in other locations also.

If it did so, then the congestion cost of an interruption to road space caused by works would be rather low. If however it fails to do so, and the cost of interruptions to road space are therefore higher, the *extra* cost is a mark of the failure of traffic demand management, together with the other agencies responsible for traffic-generating decisions on planning and development. It is not the fault of the agency carrying out the works.

The point may be made clearer by the following 'mind-experiment' about changing the definition of who owns roads. At present, the discussions have assumed that the highways authorities are the effective owner of the road, and therefore (a) it is to the highways authority that charges levied on utilities should be paid, and (b) there is some resistance to the idea that highways authorities should pay for their own works, since they would just be paying themselves[19] which is a waste of administrative resource. However, it is easy to imagine that the owners of the roads are actually a combined stakeholder group comprising those responsible for the carriageway, those responsible for the footway, and those responsible for the 'underway' ie the rights of way beneath the surface. Under this model, the utilities would be co-owners of the network as a whole, and there would be no merit in treating one of the stakeholders as more important than the others. Then each would pay for, and pass on to their respective customers, that proportion of the total congestion attributable to each.

There is a point of equity here that utilities will need to discuss with government. An arguable case is that the costs of disruption for which they (and their customers) are responsible is that amount calculated on the presumption that highways authorities are successful in producing an economically efficient volume of traffic, not the higher amount that is based on the highways authorities' failure to do so. For the major source of congestion not to be charged, and the minor source to be therefore charged more, would be doubly inefficient.

The reliability of the data base

[19] This is an odd argument: the same logic would suggest that government employees should not pay income tax.

In the Halcrow calculations, there are a number of sensitive assumptions which may not be robust, notably:

- Reinstatement category has not been established as an accurate proxy for congestion levels.
- Factors for grossing the individual data used up to national totals have not been verified.
- The relationship between street works, width, length, duration and congestion has not been verified.
- The relative traffic flows for lorries and cars for the relevant streets have not been verified.
- The size of bias introduced by assuming zero adaptation has not been quantified.

Given that there is a strong prima facie case (at least) that the overall estimate produced may be subject to substantial error, it becomes important to track down exactly where along the chain the error has arisen.

This is even more strongly required given that Halcrow themselves suggest that they have underestimated the total cost, and the true figure, using their methods, would be even greater. This puts more pressure on the sources of error in the method.

The practical implication of this is that - to the extent that the resulting congestion cost is used for anything - it is important to carry out a technical audit of these figures, and compare them with independent sources of evidence, in a way which goes beyond the scope of this report. The issue is mentioned for completeness in view of the need to explain quite a large discrepancy. Even if the results are not used for any practical or policy purposes, it would still be advisable to carry out such an audit, in order to avoid similar problems in future.

CONGESTION COST IN THE CONTEXT OF GENERAL APPROACHES TO CHARGING FOR ROAD USE

While a general discussion of the arguments for and against road pricing is outside the scope of this report, as it happens the greatest volume of good quality technical work on the cost of congestion has in recent years been carried out in the context of calculating how far congestion can be reduced by road user charging, ie charging vehicles for the congestion they cause. This is because, as noted above, congestion caused by excessive traffic is much larger than congestion caused by street works.

This work has two important implications. First, it shows the importance of asking the right question: not 'how much congestion is there in total?' but the much more useful question of 'how much can congestion be reduced by appropriate policies?' Secondly, it has been pursued by models and methods which are more advanced than those used for street works, and therefore demonstrate how at least some of the problems discussed above can be solved in practice by established methods.

There had been a series of such studies, carried out by the Government and by Transport for London, before the congestion charging scheme was implemented in central London. They all came to slightly different results, but for central London the figure of around £200 million a year for the congestion costs that would be reduced by charging became the accepted modelled value for forecasts[20].

But this was only for central London. The more relevant figures are those made for the effect of a national road user charging system. There were two main strands of work.

Commission for Integrated Transport 2003.

This study was carried out using the NERA method. It suggested that for day time, weekdays, England only, a network-wide system of charging traffic for road use, on a

[20] In the event, the traffic benefits were somewhat more than had been suggested (and the revenue correspondingly less) because drivers were more responsive and adaptive than had been assumed. In broad terms, TfL feel that the figures were as close as could be realistically obtained.

revenue neutral basis, would reduce congestion by £2.3 billion. Glaister and Graham from Imperial College at the same time (using a different model but a similar approach) suggested a figure of up to £4 billion, higher because they implicitly allowed a rather wider range of driver response than had been incorporated in the CfIT study. (The CfIT study stressed how they had erred on the side of caution in the assumptions, and my own judgement is that as a result they somewhat underestimated the benefit).

Allowing for this, a more central figure from the CfIT study was about £3 billion to about £3.5 billion. This is about 40% to 50% of the total cost of congestion of £7 billion using the NERA method. This is consistent with the conclusion of the CfIT study itself, which suggested that their proposed system of charging would produce a 44% reduction in congestion.

To summarise the result. This study suggested that up to half of the total cost of congestion was due to having rather more traffic in total, and a much less efficient distribution of it over the network, than would occur if there was a more sensible method of charging – even without any net increase in price overall. We can describe this as the proportion of congestion due to not charging an 'economic price' to vehicles using the system.

Department for Transport, 2004

A very much larger study was carried out for the Department for Transport, and launched by the Secretary of State in July as one of several major policy pronouncements and shifts in transport strategy as a whole. This covered a broader range of driver responses than the CfIT study, and had more resources available both for the modelling and for its scrutiny, credibility tests, sensitivity calculations etc: it also had the benefit of a more updated data base, looked at a wider range of policy options, and was able to learn from the earlier CfIT study. None of these aspects guarantees that the results are more reliable, but in my judgement that is in fact the case.

The estimate given in this study for the reduction in congestion costs was much greater than in the CfIT study: £10 billion per year, though part of the difference was due to the more complete geographical and temporal coverage rather the difference in method and assumptions.

In this case, it would not be sensible to express the DfT results as a percentage of the NERA estimate of the total cost of congestion (ie we do not need to confront the problem of how you can get £10 billion of reduction in congestion when the total cost of all congestion is only £7 billion). Rather, it is appropriate – with the caveats made earlier - to compare the DfT's £10 billion with those estimates of the total cost of congestion adding up to about £20 billion – or a little more allowing for inflation differences between the dates.

In that case, the inference drawn from the DfT result is almost exactly the same as the CfIT one. Between 40% and 50% of the total cost of congestion is due to having a volume of traffic, and its distribution on the network, which arises from not having an economic system of charging road users based, in part, on the congestion they cause.

Correspondingly, we can reduce congestion by 40% to 50% by charging road users in an economic manner.

As an order of magnitude, this figure, developed from an entirely different source, is not far out of line with the order of magnitudes given by applying the TRL 'weight of traffic' percentage to the much quoted £20 billion. That implies that some £15 billion of congestion is due to having, in a sense, too much traffic, and the congestion charging study suggests that we can reclaim £10 billion of that by sensible charging over the network as a whole. That sounds realistic. A higher benefit of £13 billion has been suggested if prices are allowed to increase overall to their optimal level, rather than being constrained at the 'revenue neutral' level. This is the highest benefit available – it is not logically possible to do better than that, since there would then be 'not enough' congestion to be economically[21] optimal.

One of the most useful practical lessons from this work is that it shows how much more reliable estimates of congestion can be made by looking at the difference to be made by a specific intervention, after allowing for drivers' responses. The model is quite advanced, already available, and would not be difficult to adapt to consideration of street and road works. With some care about setting up the exercise, it is suggested that this fully adaptive model is used to estimate the impacts of effective reductions on road capacity for the different classes of roads, both assuming high (uncharged) base traffic levels and lower (charged or otherwise reduced) levels.

[21] It is worth saying at this point that all these calculations do not include environmental and safety elements, both of which are certainly important – arguably more important than congestion – but not material to these particular calculations.

A PRACTICAL WAY FORWARD

In each section of the report, I have suggested some practical implications of what at first sight might seem to be theoretical and even somewhat arcane points. This section brings these together into a set of recommendations which are intended to assist the Department for Transport, local authorities, and utilities to base their practice on reliable – and relevant – figures. The resulting way forward is fully based on the principles and best practice of transport appraisal as currently used, though extending that in rather different ways than have been suggested in the discussion so far.

In effect, these suggestions relate to the guidelines and regulations affecting the detailed implementation of the Traffic Management Act 2004. They constitute an agenda of technical studies and definition of practice that, if agreed, should produce net benefits taking traffic considerations, and utility considerations, together.

The following six recommendations are made.

1. Balanced treatment of delays to traffic and delays to utility users.

As a matter of principle, we can say that both traffic delays and utility service delays must be an important part of the calculation of benefit, and it is not axiomatic that one is more important than the other. If one is calculated, and the other not, there is likely to be an imbalance in the outcome. Therefore there needs to be some original work – not yet done, but entirely in the spirit of well-established DfT practice, to add another dimension to the calculations. All the discussion above has assumed that time savings and losses in travel are the only class of cost and benefit that exist. But of course, there are other similar costs and benefits that follow from having clean water or not, power or not, telephones or not. It is, by and large, the same people who want reliable travel as want reliable utilities, and their overall quality of life is not enhanced unless the balance between the two requirements corresponds with their own, and society's, relative importance.

To make such an estimate, at a level of approximation suitable for the task, would be within the existing competence of dozens of research institutes and consultancies, and appropriate simplified default values for use while the research is proceeding could be agreed in discussion. (This follows the earlier practice in road appraisal while values of time and so on were being researched in the 1960s and 1970s).

2. Recalculation of the national figure using DfT best practice modelling

The national figure needs to be recalculated with a focus on the effects on congestion costs of realistic changes in the effective road capacity used for street and road works. Little consequence follows from concluding that the total costs of street works is £4.3 billion, or £1 billion, or indeed any other figure. It cannot be used as a guide to the importance of the problem, nor the scale of benefit available. For this reason, the troublesome size of the discrepancy in the figures may not matter as much as it appears, since neither is a useful guide to specific policy or practice. Thus there should be a shift of focus from 'total costs' to marginal costs and benefits of specific interventions. These numbers may be much smaller, but will be more useful.

At a national level, the appropriate tool for doing the core modelling work is that which has been used by the DfT for its congestion charging study, ie including the consequential effect of delays on the volume, timing and (in broad terms) location of traffic. Its main advantage is that it will produce a more reliable estimate of congestion costs by looking at the difference to be made by a specific intervention, after allowing for drivers' responses. The model is quite advanced, already available, and would not be difficult to adapt to consideration of street and road works. With some care about setting up the exercise, it is suggested that this fully adaptive model is used to estimate the impacts of effective reductions on road capacity for the different classes of roads, both assuming high (uncharged) base traffic levels and lower (charged or otherwise reduced) levels.

This would offer a practical and useful way forward for how to produce more reliable figures for congestion costs of street works at the national level, and an indication of the scale of errors likely if local estimates do not allow for drivers' responses...

3. De minimis rule for small works; full assessment of driver response for large works.

It is particularly necessary to be sensitive about the individual costs compared with the individual benefits at the level of a specific initiative. It may be useful to have a 'de minimis' rule such that the actual costs of administration should not exceed, say, a quarter or a half of the expected net benefits of the changes expected, or, equivalently, that only works whose duration and size is long enough to merit the effort should be fully included. The size of such thresholds would be subject to agreement, and are not recommended here, but are unlikely to include those whose congestion costs are in the order of seconds per vehicle, for a small number of days.

For the larger works which are to be fully included, however that is defined, it is essential that they are assessed with a full range of behavioural responses, by individual drivers and companies affected, in order to take full account of the obtainable net benefits. There should also be encouragement of the sort of advance and continuing notice to road users that would in fact enable them to make these responses, thereby reducing the congestion costs to the minimum possible level: congestion costs can be reduced by giving advance notice, warnings, and real-time information, about the scale of works going on. It is this that allows drivers a greater degree of adaptation, which in turn reduces the economic costs of the delays.
Anything which has a cost big enough to merit charging and control, cannot then be assessed using a fixed matrix method which assumes drivers do nothing but queue.

4. Congestion costs of street works assessed at the level that would apply if highways authorities were maintaining economically efficient base traffic levels

It is arguably the responsibility of the highways authority (in accordance with national or local policy) to manage the road level of traffic in such a way as not to be operating very close to the maximum capacity of the system. If the Authority did so, then the congestion cost of an interruption to road space caused by works would be rather low. If however it fails to do so, and the cost of interruptions to road space are therefore higher, the *extra* cost is a mark of the failure of traffic demand management, not the fault of the agency carrying out the works. Therefore the charge made should relate to the congestion that would occur if there were an optimal general level of traffic, not the congestion costs at the current level of traffic.

5. Reconsideration of exemption to highways authorities from being charged for the congestion they cause by their own works

It is not clear that a system where the utilities are charged 'real' money for their works, whereas the highways authorities are only charged notional money for theirs, will provide effective incentives, or an equitable balance between the interests of road users and the interests of utility users. This needs re-examination.

6. Technical audit on the estimated £4.3 billion.

It is important to carry out a technical audit of the Halcrow estimated figures, and compare them with independent sources of evidence - even if, as suggested, the results are not used for any practical or policy purposes - in order to avoid similar problems in future. The parts of the calculation most sensitive to error seem to be the use of default values for a very large proportion of the works, the use of traffic models not representing a full range of driver behaviour, calculation of the total number of works and their size, and the extrapolation from 25 authorities to a national total, but more detailed examination may reveal others.