ROAD IMPROVEMENT, TRAVELLER RESPONSE AND USER BENEFITS

P.W. Bonsall P. J. Mackie

Institute for Transport Studies
University of Leeds
Leeds LS2 9JT
UK

1. INTRODUCTION

The microeconomic theory of consumer choice suggests that any change to the road network should bring about a behavioural response from the travelling public because there will always be people at the margin for whom a change in travelling conditions will be sufficient to cause a change in behaviour.

Conventional appraisal techniques as applied in the UK recognise the possibility of changes in route ('reassignment') even over wide areas but tend to ignore other possible responses, such as changes in mode, timing, trip frequency or trip distribution, assuming instead that the trip matrix remains fixed with no new traffic 'generated' by the scheme. The recent experience with the London orbital motorway (the M25), which became congested even before it was completed, has rekindled the debate about generated traffic with the public, at least, convinced that it is a major factor. The topic is, however, one of intense debate among the appraisal professionals.

In this paper we will begin by indicating the significance for scheme appraisal of allowing for generated traffic. We will then review existing evidence as to the amount of such traffic before exploring the nature of traveller response in greater detail. Having established the potential dimensions of response we will then indicate some of the difficulties that beset any attempt to measure them. We will then discuss some of the methods of measurement and offer our experience with some of them in pilot studies.

2. THEORETICAL BACKGROUND

2.1 The fixed matrix assumption

For many years, major road appraisals in the UK have been based on the assumption of a fixed travel matrix. The volume and pattern of travel is assumed to be given, and a significant proportion of the benefits of a project result from the difference between the travel times with and without the project implemented. Certain exceptions to this approach have been recognised - major urban road investments, very large inter-urban projects, and estuary crossings are all acknowledged to have consequences for the pattern of travel which cannot be ignored. But, these are exceptions to the general rule, and even in these cases, a fixed matrix appraisal is required as the base against which alternative assumptions are tested.

The meaning of the fixed matrix assumption is that the only response which is allowed for in the appraisal is that of re-routing, or reassignment. The other responses - redistribution, change of mode, change of trip timing and so on - are not. The effect of this simplifying assumption on the rate of return on road projects depends crucially on the relevant supply and demand conditions. In the absence of congestion, the fixed matrix assumption undervalues projects by omitting the benefits associated with the full range of responses. We can illustrate this with figure 1.

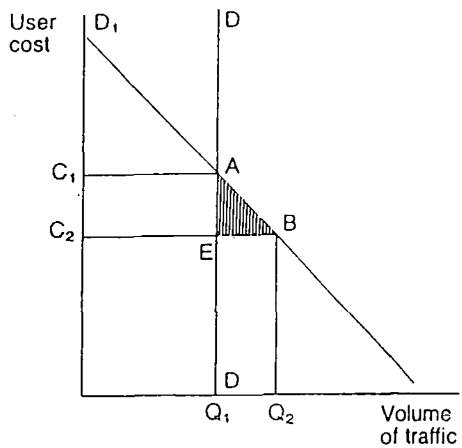

Figure 1

If the "true" demand function is D , (which is responsive to user cost) but the evaluation asumes function D, (which is not responsive to user cost) then the benefit to 'generated' traffic is omitted (shaded in Figure 1).

This is normally judged acceptable for small incremental improvements, but for large cost changes, the ratio of the "triangle" ABE to the "rectangle" C_1AEC_2 can become significant, and the shape of the demand curve between C_1 and C_2 can become an issue. However, the advice of the UK Department of Transport (1) is that

> 'in most cases, the variable trip evaluation of benefits is unlikely to yield more than about 10% extra benefits over the fixed trip evaluation, although this will be scheme specific'

2.2 Congested conditions

In cases where congestion exists (and user costs are thus sensitive to the volume of traffic), the position becomes less clear, and it is no longer possible to say a priori whether the fixed matrix assumption over or undersates the "true" benefits. This is demonstrated in figure 2.

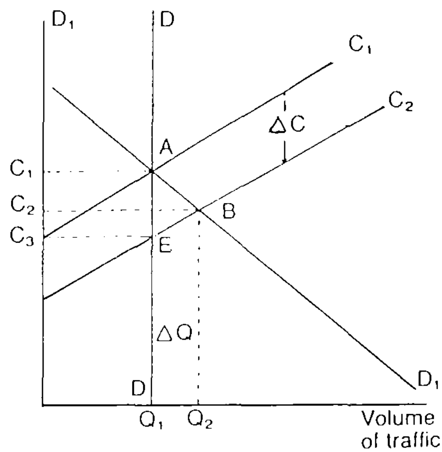

Figure 2

Here, the benefit measured on the fixed demand assumption is C_1AEC_2 - the product of the cost change C and the fixed volume Q_1. The 'true' benefit is C_1ABC_3. The relationship between the two areas clearly depends on the slopes of the cost and demand functions. For linear curves with a cost change at all traffic levels C, we have:

$$\text{Benefits (fixed volume)} = \Delta C . Q_1 \ldots\ldots\ldots\ldots\ldots (1)$$

$$\text{Benefits (variable volume)} = \frac{\Delta C}{b + d} . Q_1 + 1/2 \frac{\Delta C \cdot \Delta Q}{b+d} \quad \ldots (2)$$

where b and d are the slopes of the demand and cost functions. For a given cost change, there exist values of b and d at which the benefits are equalised under the two assumptions.

The requirement is: $d = 1/2b . \frac{\Delta Q}{Q_1}$ See (1)

We now present two limiting cases. Figure 3 shows the case for a single mode in which demand is perfectly elastic.

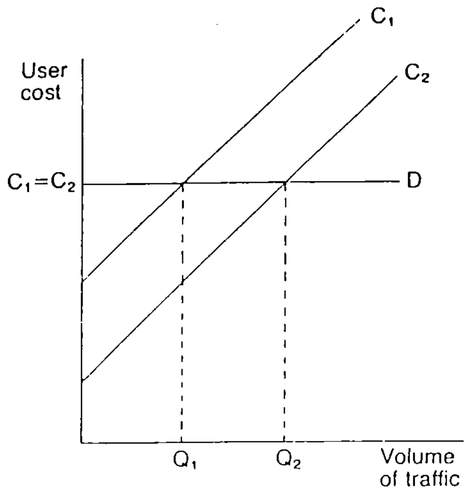

Figure 3

Here an inexhaustible demand for raod space exists at the prevailing generalised cost. If road engineers improve travel conditions, then this merely releases space for suppressed traffic. With a horizontal demand curve, the economic benefit of capacity expansion is zero, since the marginal users are at the point of indifference between travel and consuming other goods and services.

Finally, it is argued by Mogridge (2) that gross benefits of road investments could even be negative. We have to suppose that public transport is subject to economies of density (see Mohring, (3)) but is required to operate commecially while private transport is subject to congestion. We have further to suppose that users allocate themselves between modes according to Wardop's principle (4) - (so that the generalised cost of their chosen mode is no higher than that of their rejected mode.)

Then, with reference to figure 4, with cost curve AC_1PRIV, traffic splits between the modes at x giving (equalised) user costs C_1. When we invest in road space, this reduces the costs at each volume of private car traffic, shifts the optimal mode split in favour of car, shifts public transport back up the density curve (reducing frequency, thinning out public transport routes) and resulting in a new equilibrium Y, giving a new equilibrium cost of C . In this way, Mogridge argues, investment in roads would be expected to raise rather than reduce travel costs in large public transport dependent cities, and thus be counter-productive. The argument depends on a mixture of an absence of traffic restraint or road pricing measures and the evidence of unexploited economies of density in public transport. It is the subject of considerable controversy in the UK (see for example Bly, Johnston & Webster (5)).

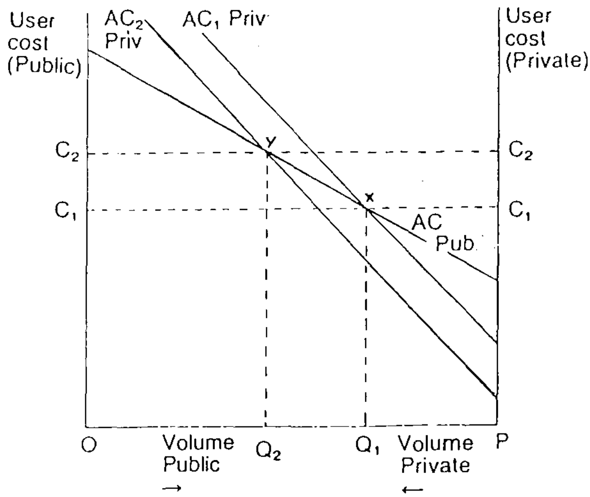

Figure 4

3. POSSIBLE DIMENSIONS OF RESPONSE

3.1 Direct effects

The immediate consequence of most new road construction and most improvement of existing roads capacity is to allow travellers to get from one place to another more quickly. this may reflect reduced distances - as when a new link provides a short-cut by traversing an area where there was no road, or increased speed - as when towns are bypassed, roads upgraded or the capacity of congested bottlenecks increased. The potential reduction in travel time which results from the new or improved link may prove attractive to people in various ways and may tempt them to take advantage of it by doing one or more of the following:

- they may change their route - if they perceive that the newly improved route is now to be preferred to that which they previously used;
- they may travel at a higher speed - if, for example, an upgraded road permits more overtaking than was previously possible (one can imagine that some drivers might even change their car in order to have one that could capitalise on new opportunities for fast driving!);
- they may change the time at which they travel - perhaps simply because with a faster journey they can set off later than they used to but still arrive at an appointed time or perhaps because the removal of a bottleneck which used always to become congested during the peak period now enables them to travel at the peak times, which they previously tried to avoid (this effect is known as 'peak narrowing');

<u>they may change their mode of travel</u> - for example if they find that, whereas the train used to be the quickest means of reaching their destination, driving or using an express bus on the new link is now quicker;
<u>they may increase the frequency with which they make a particular trip</u> - for example if they were previously not keen to take weekend trips from home to the coast more than once a year because of the long journey in congested traffic, but now find that the new faster road makes the journey quite bearable on a monthly basis;
<u>they may travel to destinations which they used not to visit at all</u> - for example they might previously have regarded a trip to shops in a neighbouring town as quite out of the question but now find it quite feasible using the new link;
<u>they might move house (a new trip origin)</u> - for example if they now find it quite possible to commute along the new road from what was previously an isolated village.

3.2 Indirect effects

As an indirect consequence of any of the above it is, of course, quite probable that our driver will be making other trips less frequently.

Another type of indirect effect could occur if, as a result of drivers using other routes, modes or times of day less frequently, these routes, modes and times of day were to become less congested and thus attract drivers from yet other routes, modes and times of day. The 'ripple' effect thus created might, theoretically, extend indefinitely.

However, the most significant of the 'indirect' effects is undoubtedly that involving changes in land use and the location of activities. a change in the transport network can change the accessibility of places and this can affect their attractiveness to developers. If this change in accessibility brings about new development or changes in land use, there will be consequential changes in travel patterns. This raises a whole set of forecasting and evaluation issues which we do not intend to discuss here; (but see, for example, Botham (6)) we simply note that, unless there is completely rigid planning control over land uses, it will be necessary to consider the feedback from transport to land use as a potentially important source of response.

3.3 Timing and extent of the different responses

These various responses, direct and indirect are likely to come about within very different time periods - for example a new route for a regular journey might become established within days of a new road being opened, whereas land use changes or decisions to move house might not be effected for several years, although they could of course occur before completion of the scheme <u>in anticipation</u> of the expected benefits.

The precise extent, mix and timing of responses to be expected will of course depend on the local circumstances and the nature of the road scheme. Other things being equal one might expect the changes to be commensurate with the change in the travel time or cost matrix. Thus a major new estuarial crossing could be expected to have a greater impact than an extra lane on a commuter radial.

However, as was shown in the previous section, the response will also depend on the slopes of the supply and demand functions - thus an increase in capacity on a congested urban radial might cause significant changes in behaviour if demand is elastic and was previously constrained. A typical example might be 'peak narrowing' following increase in peak period capacity.

3.4 The different consequences of the various responses for scheme appraisal

It is important to note that it is not in principle sufficient simply to measure the gross changes in traffic volumes; the different behavioural responses which we have above loosely termed "generation", should not all be expected to have the same effects on the travel costs and benefits of urban road investments.

Trip redistribution is generally associated with increased average journey length but, if trips switch to less congested parts of the network, the net effect may be beneficial. In the appraisal of the East London River Crossing (ELRC), allowing for redistribution (by running a doubly constrained gravity model calibrated to the base year) added about 8% to the benefits under a fixed matrix assumption. However, it is interesting that a test allowing for half of the modelled redistribution showed that the benefits of the scheme in this case were equal to the benefits with the full predicted redistribution. This implies that at the margin, the net congestion effects of redistributed trips were fully offsetting the benefits to the redistributed travellers.

In heavily congested conditions peak narrowing is less likely than redistribution to be beneficial. Travellers gain from re-timing their trips to a preferred time when travel conditions improve. But, against this, they impose net congestion costs by relocating from a less congested to a more congested timing.

Modal split and new generation are the most likely responses to have a negative effect on traffic benefits because they represent a net increase rather than a transfer of traffic in time or space. At the ELRC Inquiry, it was agreed between the professionals that prediction of the generation effect of the scheme was beyond the state of the art, though since then, further unpublished work to test the sensitivity of system performance to the extent of generation has been carried out for TRRL (7). The only conclusion which can be drawn is that both from theory and from practical experience, it is very important to obtain an improved understanding of the magnitudes of traveller responses when urban road capacity is expanded.

4. EMPIRICAL EVIDENCE ON THE BEHAVIOURAL RESPONSE TO NEW ROAD SCHEMES

Our examination of the literture (reviewed in part by Bonsall (8) and by Allard (9)) leads us to conclude that, although there have been some well documented studies of user response to major new inter-urban roads (such as, in the UK, the M62, the Humber Bridge and the Severn Bridge), rather little work has been done on user response to more modest inter-urban or urban schemes. Furthermore, such work as has abeen done has tended not to distinguish between all the possible dimensions of response; most concern has been to distinguish between re-routing and the rest. Most of the published work on the impact of new road schemes relates to the question of economic development rather than user response. The seminal M62 studies (10, 11, and 6) concluded, on the basis of traffic counts and interviews, that the new motorway generated something between 6% and 15% extra traffic over and above that which re-routed from pre-existing roads. (The range of values reflect uncertainty as to what would have happened in the absence of the new road.) In the case of the Humber Bridge, which saved travel distance of 45 miles, and the equivalent time, traffic crossing the Humber estuary increased from 2000 to 7250 vehicles per day in the first year of the Bridge's operation (1982).

Some simple calculations based on Tuckwell, Fell and Hague (12) suggest that the benefits to generated traffic (ABE in Figure 1), based on the rule of a half, were about 60% of the total benefits of the scheme, and that as discussed in that paper, the magnitude of the scheme benefits are then of course sensitive to the shape of the demand curve. In their study of the Severn Bridge, Cleary and Thomas (13) concluded that, a year after opening the bridge, 56% of the traffic crossing the bridge had been reassigned with 44% "generated" by the bridge (including 12% who had made a journey specifically to see the bridge). Weekday data suggested 58% "generation" including 4-5% modal shift from rail. Inter-urban schemes like the M62, the Humber Bridge and the Severn Bridge can be considered to be most like Figure 1 in type. Congestion is unlikely to set in until well into the life of the scheme as the schemes are designed with surplus capacity available at most times. However, in urban areas, response feedback to congestion is far more likely to be important, though studies so far have concentrated on traffic volumes rather than travel times.

In a recent study in London, Beardwood and Elliot (14) relied primarily on traffic counts across screen lines and in control corridors to estimate the effects firstly of the Westway urban motorway and secondly of parts of the then incomplete M25. In the Westway corridor it was found that flow increases exceeded those in a control corridor seven or eight fold. In the case of the M25, before and after screenline counts suggested that only 57% of the traffic using that stretch of the M25 could be explained by reassignment. These figures have however been challenged on the grounds that the screen lines were too short to encompass wide area reassignment.

Little is known about the propensity of travellers to re-time their trips in response to a road improvement. some evidence presented at the ELRC Inquiry (15) demonstrated that the peak did narrow somewhat at the main river crossing (Blackwall Tunnel) in response to the opening of the north-eastern section of the M25 London orbital motorway.

5. PROBLEMS OF MEASUREMENT

With a range of possible responses such as that outlined in section 3 potentially occurring over such a range of time scales, measuring them is bound to be difficult but the problem is further complicated firstly by the inherent variability of the phenomena (eg of daily flows on a link) which makes the detection of any change difficult and secondly because, over time, other influences will come to bear on behaviour.

These external influences may be at the macro sacle (as was the case with the Humber Bridge where ambient changes in the level of economic activity in the region made it very difficult to isolate the effect of even a massive change in the network) or might be very local, for example the opening of a new superstore might cause changes in all the dimensions outlined above.

Changes in behaviour caused by new land use developments or by changes in the location of facilities can cause severe definitional problems. This is because, if it can be argued that the land use has changed as a result of the network change, it follows that behaviour associated with the new land use is indirectly attributed to the network change. The definitional problem is further complicated if it is argued that the new land use is associated with the network change but is not a direct result of it(it may for example form part of the same strategic plan).

Another type of confounding effect is where improvements to an adjacent (or even distant) part of the network might affect usage of a link under study. In practice this effect will often frustrate attempts to monitor responses to a given improvement because individual improvements are commonly introduced as components of a strategic plan to improve a corridor or network. Ambient changes such as these make it particularly difficult to detect the longer term responses.

The impossibility of ever knowing what would have happened in the absence of the highway improvement under study is a fundamental problem in the detection of responses to the improvement. It may well be that these difficulties combine to make it impossible to identify all the responses without expending sums on data collection and analysis that are out of all proportion to the value of the result.

Despite these problems the issues involved are too important to be allowed to go by default. It is therefore important to investigate the extent to which an appropriate combination of survey techniques and associated analysis can be expected to identify the various responses to highway improvement.

6. METHODS OF MEASURING TRAVELLERS' RESPONSES

A variety of methods exist and it is useful briefly to review them here.

Before-and-After Observation of Newtork flows This might be done manually or, since if data is likely to be required over a substantial period of time, using automatic traffic counting equipment. The counts would obviously be conducted on the link itself and along a screen line designed to intercept routes from which traffic might have been diverted to the new link. If second order diversion effects are also to be detected, it will be necessary to extend the screen line for a considerable distance. A second screen line in an area not thought to be affected by the new road may sometimes work as a control to detect ambient changes in traffic levels. Counts or estimates of flow on other modes across the screen line should also be conducted. Careful analysis of the flow data thus produced may reveal evidence of re-routing, change in time of travel, and change of mode. It may also be possible to deduce net changes in traffic due to a combination of redistribution and changed frequency, but it will not normally be possible to differentiate between these two effects on the basis of counts alone.

Before-and-After Roadside Interviews or Questionnaires Simple interviews conducted with a sample of users of the new link can discover their origin, destination and trip purpose. If the interview can be extended to discover the frequency with which the driver uses this route, other routes and other modes to travel between the specified origin and destination then the value of the data is considerably enhanced but only at the risk of the interview becoming too long and complex for roadside administration. The use of postal reply questionnaires distributed at roadside interview sites or at stop lines (e.g. traffic lights) may solve the problem provided that non-response bias can be corrected for. Comparison of results from interviews or questionnaires conducted before and after completion of the scheme can provide very useful insights into the effects of the new link on behaviour, particularly if the survey can be carried out along a screenline, can cover competing modes and can be accompanied by a control study to identify ambient changes.

Recall Interviews and Questionnaires Drivers using a new or improved link can be asked for details not only of their current trip (origin, destination, purpose and frequency by this and other routes and modes) but also about how, if at all, they made the trip before the scheme. This technique can be expected to discover re-routing, change of mode, frequency and perhaps timing and may also be able to provide an indication of redistribution. There is however a risk that the recall will be incorrect.

Panel Surveys If a group of people, identified before completion of a scheme, can be persuaded to provide details of their current (before) travel patterns and also subsequently to provide details of what they are doing after the scheme is completed, the resulting data can be very valuable. Provided that certain statistical precautions are taken, this technique can provide information about changes in individual behaviour more efficiently than is possible by taking separate 'before' and 'after' samples. However, in its basic form it cannot reveal anything about groups who were not represented in the original design and would, for example, miss out people who moved house into an area as a result of network improvements.

Stated Preference and Stated Intention Surveys These techniques can be used, along with models of greater or lesser complexity, to help predict traveller response to new or improved roads. They involve asking people either directly how they would respond (a prospective survey) or, more subtly, how they would rank or rate each of a series of options (a stated preference survey). A carefully designed set of questions can be used to explore a number of alternatives such that a model can be calibrated for later use in predicting traveller response to actual schemes. The questions themselves can be entirely hypothetical. The attractiveness of the techniques lies in their statistical efficiency and avoidance of the problems of ambient change and variability which afflict before-and-after techniques. Against this it has to be recognised that there is no guarantee that the respondents would actually behave in full accord with their stated preferences or intentions; their replies may well be biased, even unintentionally.

Complex stated preference surveys cannot readily be carried out by self completion, still less during a brief roadside interview. The usual solution is to conduct the survey in the household (which has the added advantage that constraints affecting other household members can be more readily taken into account). In most instances the sample for a stated preference or prospective survey can be drawn up on the basis of household location but where it is deemed necessary to have a sample of users of a given route, it may be best to recruit interviewees via a roadside interview or stop line survey. Before-and-after and recall surveys can of course be conducted within households but, since the sample will need to be based on link usage and the questions are normally straightforward enough for self completion or brief interview, this will rarely be sensible.

7. EXPERIENCE WITH QUESTIONNAIRE AND INTERVIEW TECHNIQUES

In the summer of 1988 the authors were engaged on a short pilot project sponsored by the Economic and Social Research Council (ESRC) to test some new methods of identifying user response to new road capacity. Questionnaires were tested at three sites - we will now briefly describe each in turn (further details are contained in a dissertation by Wilcock (16)).

A 'before' survey incorporating establishment of a panel A roadside interview had already been planned for 16 June 1988 on an inter-urban route (the A65) just north of the town of Settle, whose bypass was due to be opened in December of that year. At our request the Department of Transport agreed to add to the standard interview (origin, destination and purpose) some questions about trip frequency and they allowed us to distribute self completion questionnaires to a sample of the car drivers interviewed. Among other things, the questionnaire sought further information about their reasons for choosing the A65 route, about their perception of alternative routes and their expectation as to how their behaviour might change following the opening of the bypass. A final question asked whether they would allow us to contact them again some time after the bypass was opened to find out how their behaviour had in fact changed.

Much of the data collected will only become interesting when it can be compared with after data from a repeat interview or from the panel. (A repeat questionnaire for panellists is being administered during the summer of 1989). In the meantime it is worth noting that the response rate for the self completion questionnaire was 32%, of whom 77% said they would be willing to join the panel. In answer to the questions on anticipated impacts of the bypass on their behaviour, over half the drivers thought it would have no impact, one fifth said they would set off later, one in ten said they would travel more often and a similar number said they would travel further.

An 'after' survey including recall questions in a roadside interview A roadside interview had already been planned for the 13th May 1988 on the York western bypass which had been completed in December of the previous year. At our request the highway authority agreed to add to the basic interview (origin, destination and purpose) questions about current frequency of using the bypass and alternative routes and about the frequency with which the trip was made (and the routes used) at approximately the same time in the previous year. A sample of the drivers were also given a self completion questionnaire which included questions about their reasons for using the bypass and their perception of any changes in their travel patterns (frequency, route, mode, timing, and distribution) as a result of the new bypass.

The response rate to the self completion questionnaire was 41% with no obvious response bias. Analysis of this data suggested that 30% of trips had been re-timed, 88% had been re-routed, 8% were occurring more frequently, 3% had changed mode, 6% had been redistributed and 4% were entirely new. Despite some minor problems with wording we were generally very pleased with the amount of information that the questionnaire had elicited.

An after survey including recall questions in a stop line questionnaire. On the afternoon of 27th June 1988, we distributed self completion questionnaires to drivers at a stop line on a slip road into the Rochester Way Relief Road heading out of London. The questionnaire included questions on origin, destination, purpose and frequency of the current trip as well as on the driver's perceptions of any changes in his travel patterns (frequency, route, mode, timing and distribution) as a result of the new road (which opened in March 1988).

The response rate was 24% and we have no way of knowing whether this is a biased sample. Analysis of the data suggest that 24% of trips had been re-timed, 90% had been re-routed, 10% were occurring more frequently, 3% had changed mode and another 3% had been redistributed, with none being entirely new. These results are plausible and, despite the potential problem of bias, the questionnaire again seems to have elicited useful information.

Our conclusion from these three studies is thus to be generally optimistic about the use of recall questionnaires, prospective questionnaires and panels. We do however note the rather low response rate from the stopline survey which, in the absence of population data (such as is available at roadside interview sites) raises the possibility of unquantifiable response bias. The fact that our response rates were generally good may be attributed to our offer of a prize draw based on returned questionnaires at all three sites.

We believe that questionnaire and interview data of this type should ideally be analysed along with "objective" data from traffic counts. This would enable the two sources of information to be compared and might throw some light on the different problems and benefits of dealing with disaggregate data (interviews) rather than aggregate data (counts).

Finally, we would advise that, where possible, questionnaire surveys should be parallelled by control surveys.

SUMMARY AND CONCLUSIONS

We have indicated some of the many ways in which users can respond to the improved travel conditions which follow from new or improved highway capacity and we have shown that the extent and nature of this response can be crucial not only to our understanding of behaviour but also to the economic assessment of road schemes. Failure to consider the responses can affect both the relative and the absolute value of schemes being assessed.

Nevertheless, as we have shown, it is normal practice in the UK to ignore these behavioural responses on the grounds that they are difficult to predict and "likely to be small". There has long been a public perception that new roads do 'generate' new traffic and the recent much publicised overcrowding of the newly opened M25 motorway around London has made it politically impossible to continue to ignore such effects.

We have outlined some of the problems which frustrate attempts to estimate behavioural responses to new road schemes, drawing particular attention to the problems of ambient change, inherent variability of phenomena and measurement error.

As far as we are aware, no road scheme has ever been studied in sufficient detail , over sufficient time and area to provide statistically rigorous estimates of the behavioural responses.

Recognising the importance of the problem and the difficulties of conventional measurement techniques, the UK Transport and Road Research Laboratory have commissioned work to explore the use of stated preference techniques to explore user response to new urban capacity. More recently they have decided that it is now important to determine more precisely what type of surveys should be included in a definitive study, and what sample strategy would be required. During the preparation of this paper the authors (with others) have been contracted by TRRL to prepare the survey and sampling strategy for such a study and to comment in particular on the feasibility of distinguishing between the different dimensions of response with statistical precision. It is anticipated that the results of that study will be published by TRRL during 1990.

ACKNOWLEDGEMENTS

The authors are grateful for financial support from the Economic and Social Research Council for the field trials of measurement methods described in this paper. They are also pleased to acknowledge contributions to that project by Dr S. Pells and Miss J. Wilcock. The authors must, however take full responsibility for any errors or omissions in the current paper.

The current paper was the first of three to be produced on this topic by the authors in the first half of 1989. The other two appear in the proceedings of the PTRC conference and in Traffic Engineering and Control both dated September 1989, neither of them add substantially to what has been included in this version.

REFERENCES

(1) Department of Transport UK (1982) COBA 9 manual HMSO, London

(2) Mogridge, M. and Holden, D.J. (1987) A panacea for road congestion - A riposte? Traffic Engineering and Control 28 (1) and references cited therein

(3) Mohring, H. (1972) Optimisation and scale economies in urban bus transportation American Economic Review 62 (4)

(4) Wardrop, J.G. (1952) Some theoretical aspects of road traffic research proc. Inst Civil Engineering 2 (2)

(5) Bly, P.H., Johnston, R.H. and Webster, F.V. (1987) A panacea for road congestion Traffic Engineering and Control 28 (1)

(6) Botham, R. (1983) The road program and regional development: The problem of the counterfactual in Button, K. and Gillingwater, J. (eds) Transport, Location and Spatial Policy Gower.

(7) Coombe, D. and Leigh, S.C. (1988) A modelling experience to study benefits from urban road improvements TRRL Working paper WP (TP) 61 unpublished

(8) Bonsall, P.W. (1985) On the use of fixed matrices for the evaluation of urban highway schemes Working paper 215 Institute for Transport Studies, University of Leeds

(9) Allard E.J. (1987) A review of the traffic generating effects of road investments proceedings of PTRC summer annual meeting at University of Bath 1987

(10) Gwilliam, K.M. and Judge, E. (1978) The M62 and transpennine movement 1970-1977: Implications for regional and transport planning Regional Studies Association Conference: Transport in the Regions, London 1978

(11) Judge, E.J. (1983) Regional issues and transport infrastructure: some reflections on the effects of the Lancashire-Yorkshire motorway in Button, K. and Gillingwater, J. (eds) Transport, Location and Spatial Policy Gower

(12) Tuckwell, R.M., Fell, R.M. and Hague, J.H. (1985) Return to the Bridge - Economic prospects of the Humber Bridge Highways and Transportation, January 1985

(13) Cleary, E.J. and Thomas, R.E. (1973) "The economic consequences of the Severn Bridge and its associated motorways" Bath University Press

(14) Beardwood, J. and Elliot, J. (1985) Roads generate traffic proceedings of PTRC Summer annual meeting at University of Sussex 1985

(15) Elliot, J. (1985) Investigations into Peak Narrowing following the Blackwall Tunnel Experience ELRC Public Inquiry Document 555

(16) Wilcock, J.L. (1988) Roads generate traffic - data collection MSc Thesis, Institute for Transport Studies, University of Leeds