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ON THE USE OF FIXED TRIP MATRICES FOR THE EVALUATION OF URBAN HIGHWAY SCHEMES

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A B S T R A C T

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This paper begins with a summary of the theoretical background to the question of fixed or variable trip matrices and briefly reviews current UK advice and practice. The main bulk of the paper is a review of published evidence as to whether network improvements do or do not affect trip matrices. The conclusion is that there is strong evidence of local land use changes, particularly adjacent to major new intersections or access points. However, it is clear that any new development is dependent on the existence of a capacity for relocation or growth in the local economy and a not unfavourable stance by the local planning authority. In the absence of new land development, however, there is little published evidence of changes in trip matrices following network improvements. The conclusion drawn from this evidence, from public interest in the question of generated traffic, and from the lack of reliable forecasting models, is that sensitivity analyses should be carried out to determine the possible effects of changes in the trip matrix before any decision is taken to ignore them.

On the Use of Fixed Trip Matrices for the Evaluation of Urban Highway Schemes

1. Introduction

This paper was prepared as a commentry on a decision by a major firm of transport planning consultants to use a fixed trip matrix in the evaluation of a proposed urban expressway in Scotland. The evidence on which the paper is based draws heavily on an online search of TRRLs IRRD system during the summer of 1984. The search was carried out on my behalf by TRRL's library service. The bibliography thus produced was supplemented by references culled from my previous experience and that of colleagues in academic and governmental fields. It is worth noting that the failure of the on-line search to produce all the references of which I was aready aware must cast doubt on its comprehensiveness in the areas of which I was not aware.

2. Current Practice

The Department of Transports' Traffic Appraisal Manual (TAM, DTp 1981) suggests that "in the few trunk road cases where a significant redistribution of trips, change in modal split or generation is expected when the proposed scheme is built, a variable trip matrix traffic and evaluation model should be used. Possible candidates include long new inter-urban routes, major estuary crossings, and major schemes in congested conurbations". The manual further remarks that "past evidence suggests tht benefits attributable to redistribution are unlikely to add to the (economic) benefits derived from a fixed trip matrix evaluation by more than 10% in most cases".

The COBA 9 manual (DTp 1982) similarly suggests that for most road schemes the fixed matrix assumption is realistic and that any distortion introduced by the assumption will rarely be significant. However, procedures by which variable matrix evaluations should be carried out are suggested in TAM and the COBA 9 manual. Reference is also made to the MATBEN and NETBEN programs developed by DTp. These programs facilitate sensitivity testing of the fixed matrix and fixed link flow composition assumptions. Both manuals stress the desirability of separating the benefits attributable to permittng a variable trip matrix from those which accrue when the matrix is held constant. There is the strong implication that, if the variable matrix case adds more than 10% to overall benefits, then it is automatically suspect. It is also stressed that the advice of DTps Assessments, Policy and Methods Division (APM) should be sought whenever variable matrix calculations are used.

Against this background there is clearly some DTp support for maintenance of the fixed matrix assumption in all but those 'exceptional' cases where effects other than simple reassignment are prima facie to be expected.

In the case of the network improvement whose evaluation stimulated this paper, the position is further complicated by the fact that Scottish highway appraisals are the responsibility of the Scottish Office rather than DTp, that the Scottish Office use NESA (Network Evaluation from Surveys and Assignments) rather than COBA and that MATBEN and NETBEN are not directly compatible with NESA. Scottish Office advice does, however, have some parallels with that of DTp in that a single, fixed, matrix should be used except in very exceptional cases.

The problem with the particular network improvement under investigation was that there was no agreement as to whether or not it did constitute an exceptional case!

Given the inevitable lack of hard evidence on the precise effects of urban road schemes on economic activity it has become established practice to ignore such changes in the formal evauation of schemes. If included at all it is only informaly via political intuition (Gwilliam and Mackie 1975).

3. Theoretical Background

It is quite clear from conventional travel demand theory that any change in network conditions will have some affect on the pattern of demand. Even a marginal change in the network, such as an increase in speed on a single link will, theoretically, have an effect because the change will be sufficient to influence the behaviour of those people who are at the margin of prefering one option to another. The distribution of tastes across the population (e.g. different valuations of time) and the heterogeneity of conditions which they experience (e.g. different walking distances to a bus stop) ensure that some members of the population will be at this margin.

Even in the case of a fairly modest network change, where the change in total generaised cost does not exceed ten per cent for any journey, there will be a substantial population crossing the threshold from prefering one option to prefering another. For many of them the adaptation to new conditions will merely involve a change in route choice but, theoretically at least, the new equilibrium behaviour will see changes in mode, trip timing, trip ends and even trip rates.

The length of time that a new equilibrium might take to develop is a matter of some debate. The established theory suggests that different types of adaptation will come about over different timescales. Thus a mode choice decision might be delayed until it is possible to purchase a new car, residential relocation might be delayed until there is a change of job or family crcumstances, and an industrial relocation might have to await obsolescence of current premises. It is therefore likely that a given pattern of trips will represent, not adaptation to the then current network conditions, nor adaptation to any previous year's network conditions, but partial adaptation to each of the various sets of network conditions that haveprevailed during the last

decade or more.

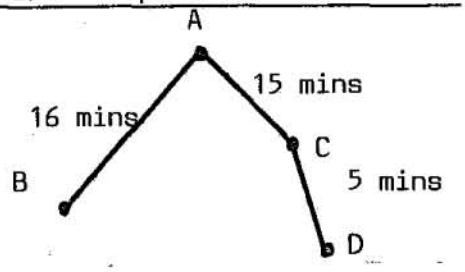
This would suggest that any attempt to find evidence of adaptation to new network conditions will be even more complex than is often supposed and secondly that any attempt to model future behaviour in perfect adaptation with a proposed new set of network conditions would be quite artificial. This latter objection is often overuled by those who suggest that each scheme should be evaluated purely on its own merits, and may in any case be defused by using dynamic adaptation models rather than the more common static models to forecast future behaviour.

It is not unknown for it to be argued that traffic restraint policies or public transport priority measures will act to preserve the current trip matrix after some network enhancement is carried out. This argument is by no means straightforward; firstly, as TAM points out (see section 18.4.6 5-6), economic evaluation of restrained schemes is by no means straightforward, and secondly it is difficult to sustain the argument that traffic restraint could be so designed as completely to cancel out the effect of the network enhancement for all users. For example, the theoretical result of a constraint on total city centre trip ends combined with improved access down one corridor is that the number of trips down the other corridors should decrease relative to the number down the improved corridor.

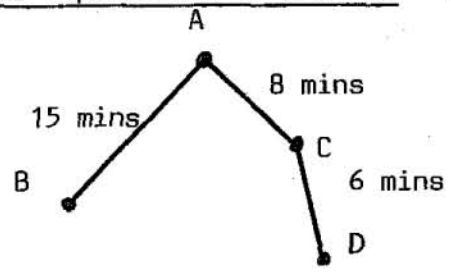
The use of a fixed OD matrix rather than separate ones with and without the new scheme does of course influence the calculation of benefts due to the new scheme. In general the effect will have been to decrease the consumers' surplus benefit that would have been calculated according to the normal (rule of a half) assumptions. There is, however, no guarantee that this will be the case; consider the example in Figure 1 where improvement in one part of the network attracts additional traffic to an already congested adjacent part. The disbenefit to users of that part could outweigh any benefit to those who changed their destination as a result of the network improvement. The consequences of this possibility are further explored in COBA 9's appendix on 'variable trip matrix economic methodology'.

Figure 1

a) before an improvement of link AC assume A B has ample capacity
A C is to be improved
C D is congested



b) after improvement of link AC note AC is quicker but has attracted traffic from AB onto CD. CD has become much (20%) slower. AB has become slightly faster.



Commentry on Figure 1

People from A who previously travelled to B might now travel to D causing extra congestion on link CD. People who previously travelled from C to D will suffer this extra congestion and get no benefit from the improvement on AC. If the C to D travellers are very numerous their disbenefit may outweigh any improvement to those travelling from A.

4. Evidence on the Impact of Network Changes on Economic Activity

It is commonplace to suppose that the historic pattern of urban growth, of increased vehicular traffic, and of increased economic activity, has been associated with improvements in the level of transport service (see for example Kellet 1969). Economic historians are, however, divided both over their estimates of the extent to which transport has been a stimulus to economic growth and over where to draw the line between cause and effect (compare the views of Kellet with those of O'Brien, 1977 and those of Davis et al, 1972; Overy, 1975 and Finer, 1958 with those of Floud and McLosky, 1981. Also see Harris, 1974 and Parkinson, 1981 for a more complete discussion of the theoretical relationship between transport and economic activity).

The existence of any such relationship, while intuitively reasonable, is difficult to verify even at the regional or national level (see Taylor 1979 and Botham 1983 for a discussion of the problems). Current thinking is that transport improvements are more likely to stimulate growth in developing economies than in developed ones and that even in developing economies their role is as a necessary condition rather than as a sufficient condition (see for example Jones, 1973). It is further supposed (e.g. Bly, 1981) that the pre-existence of a relatively highly developed network and of high car ownership, as will usually be the case in urban areas of Western Europe and the U.S., will ensure that a typical scheme represents no more than a marginal improvement in an already high level of accessibility and can not therefore be expected to influence economic activity other than at the margin.

The literature search revealed many examples of attempts to predict the impact of network changes on economic activity or trip patterns (see for example, Lebondier and Sartre 1973; Edwards and Venden 1973; Blase and Ryder 1982) but produced rather fewer documented impact studies. Such U.K. studies as have been carried out relate, in the main, to large scale network improvements (typically inter-urban motorways, estuarial crossings and rural bypasses) rather than to urban schemes. Some of the US studies do, however, relate to schemes which are more comparable in function and in scale of investment if not in economic background.

Empirical studies of the impact of highway investment on regional economic activity in developed countries have produced a deal of inconclusive evidence (see Dodgson 1974). Some studies have discerned an increase in regional activity (e.g. Takeda's, 1972 study in Japan - though arguably Japan was very much a developing economy at the time). One of the most comprehensive UK studies (Gwilliam and Judge 1978) can be shown to suggest that the transpennine M62 motorway generated between 7.6% and at least 15% (Botham, 1983) extra traffic depending on what assumption is made about what would have occurred without the motorway. Other studies have suggested that there is either no discernable imput

(e.g. Botham, 1980 and the Leitch Committee view - DTp 1977) or that the net effect is to decrease regional activity because the improved network allows the regions to be served from the centre (see Davis 1969, Botham 1983).

Studies of whole-town bypasses (e.g. Kipnis and Balasha, 1977; Moore and Hood, 1980) have suggested that a decrease in passing trade is often offset by the increased growth stimulated by improved environmental conditions.

Studies of the impact of new or improved public transport services (e.g. Knight and Trygg, 1977) have suggested that, where pressures for development already exist, the new investment does appear to stimulate growth. Other studies (e.g. Kreibich's 1978, study of the Munich transit system) further suggest that there is a substantial relocation of activities and residence even without any net increase in activity.

Empirical studies of the local impact of major highway investments have generally suggested that, where planning regulations permit, dramatic local improvements in accessibility (e.g. at highway intersection or access points) almost invariably lead to new developments and changes in land use. In rural areas of the US the initial development has often been associated with road user services while in other areas distributive trades and housing have been among the most common new users. (There is a substantial body of evidence on this - see for example Twark et al, 1980; Brown and Michael, 1973; Babcock and Kasnabis 1976; and Takeda, 1972).

It is not clear, however, to what extent such developments are spontaneous and to what extent they are encouraged or thwarted by the actions of local planning authorities (see McAlonan, 1981). It is also unclear whether these developments represent genuine new growth or, more likely according to current thinking, they are more accurately to be seen as evidence of replacement or relocation of existing businesses. For example, Dawson (1979) apparently detected a shift in service sector activity away from Glasgow city centre following construction of the local motorway system.

It is apparent that redevelopment is least likely in urban areas where pre-existing land users are giving a high rate of return and is most likely on slum clearance or 'greenfield' sites (see for example Buffington et al, 1978; and compare Adkins, 1957 with Adkins and Tieken, 1958).

Some observers (e.g. Khasnabis and Babcock, 1977; Parker 1974) have concluded more generally that although there is often substantial development on under utilized sites whose accessibility is increased, the presence or bsence of development at any given site is frequently determined by factors other than transport.

Some evidence (e.g. Deleon and Enns, 1973) suggests that improvement in a conurbation's transport system leads to greater dispersal of economic activity throughout the area - typically a tendency to relocate from the centre out along improved radials.

Analysis of the impact of highway investment on retail trade (e.g. Kern et al 1984) has shown a trong relationship between the two and has suggested that, planning regulations permitting, retail activity migrates to sites with high accessibility.

The effect of infrastructure investment or traffic management measures on the timing of trips is not well researched and despite increased attention to it of late (e.g. Hendrickson and Plank 1984, Abkowitz 1981, Mahmassani and Chang 1984), there is still no readily accepted model of the way in which trip timing decisions are taken. It has, however, been frequently observed (see for example Hurdle, 1981) that the duration of the peak is more sensitive to peak period network improvements than are journey times at the height of the peak. This must imply that travellers are changing the time at which they travel in response to network changes.

5. Summary of Evidence

The literature, most of which comes from the US, suggest that there is strong evidence of local land use change following significant network changes. The evidence is particularly strong in respect of land adjacent to importance intersections or access points. However it is clear that any new development is dependent on the existence of a capacity for relocation or growth on the local economy and a not unfavourable stance by the local planning authority. It is evident that any such new development, be it genuinely new or merely relocated, can have an important influence on travel patterns.

On the other hand the literature search has revealed no substantive evidence of changes in travel patterns in the absence of new land use development. This is not surprising since any such effects are likely to be so margnal that they are not detectable given the lack of sophistication of data collection, and the amount of 'noise' caused by other changes affecting the transport system. The fact that some of the changes may take some time to become apparent further reduces the possibility of their being detected.

6. The Problem of Forecasting

As has been stated above, even a modest change in the cost matrix will theoretically result in changes in the trip matrix in respect of mode, trip timing, trip distribution or trip rates and empirical studies have indeed shown some evidence of all of these. The question is not whether such changes occur but how significant they are.

In the best of possible worlds it would be desirable to use calibrated state-of-the-art models to demonstrate the likely significance of all these effects. In practice, of course, such models are rarely available in a calibrated form. Mode choice and trip distribution models are relativley well developed and are widely accepted, but even so many people would doubt their ability accurately to predict the effects of infrastructure changes of the kind with which we are concerned. Trip timing models are less advanced and are most certainly not calibrated to infrastructure changes. Models of the effect of transport investments on land use (many of them developed from Lowry's Pittsburg model) are being developed (e.g. Putman 1983, Mackett 1983) but are not yet widely accepted, this is a particularly serious problem since the empirical evidence suggests that it is via land use changes that the most significant trip matrix changes occur and it is the supposed developmental effects which are often to the fore in political analyses of transport investment.

In defence of a decision to ignore the possible effects of changes in the trip matrix it can thus be stated with some confidence that, new development apart, there is no clear evidence that schemes of this scale do produce any significant change in the matrix, nor does transport demand theory, provide clear guidance on the speed or completeness to which the trip matrix might theoretically adapt to the changed conditions. Any attempt to produce alternative trip matrices would therefore be, at best, speculative.

Pending the much needed improvement in the forecasting models mentioned above, it is not surprising the preferred option of many analysts is to produce a single forecast of the trip matrix via growth factoring. It should be noted that the choice is between a single trip matrix based on growth factors or trip matrices based on cost matrix models; if cost matrix models are to be used to produce any trip matrices it is illogical not to use them to produce all the trip matrices. The difference between a forecast trip matrix produced by growth factors and one produced by a cost-matrix model is likely to be at least as great as between two matrices produced by cost matrix models relating to the 'do nothing' and the 'do something' situations.

7. Local and Environmental Effects

Views on the variable matrix question expressed in TAM and the COBA 9 manual seem concerned almost exclusively with the calculation of economic benefits. However, even where reliance on a fixed trip matrix does not distort the estimates of overall economic benefit of a scheme, it can create problems in respect of forecasting of environmental and other localised effects.

Public interest in, and objections to, new highway schemes is understandably focussed on local impacts rather than on economic costs and benefits and, despite the lack of documented evidence, there is a fund of anecdoted evidence which causes the public to

home in on the question of traffic generated by highway improvements. Public interest in issues such as traffic generation and environmental conditions on individual links is clearly not easily answered if no allowance is made for change in the trip matrix.

The decision to use a fixed trip matrix would inevitably create a problem. It would not be consistent to list improvements in accessibility and environmental conditions or reductions in congestion on the existing network while denying that these will bring with them any change in trip making behaviour. The argument would have to be made that the accessibility and environmental improvements, though real enough, would either be too limited to have any significant impact on behaviour and/or behaviour would be prevented by some means from taking advantage of the new conditions.

Urban road scheme appraisals often draw attention to the environmental improvements likely to come about on those roads which are currently congested or which act as rat runs. It is likely that these improvements will have some effect on trip patterns. The trading base of shops on any bypassed roads is likely to alter, the evidence from bypass studies is that they will loose some passing trade but gain a new clientele attracted by the improved conditions. Another possibility, but one of rather limited significance, is that the improved residential environment on the bypassed roads will attract a more affluent class of resident characterised by higher car ownership and trip rates.

Despite their local importance and interest to the public, all the effects mentioned above are likely to be of limited impact and, given the lack of evidence of changes in trip matrices in the absence of land use changes, would be extremely difficult to forecast with any degree of confidence.

Rather different arguments must be raised about the question of possible land use changes associated with improved accessibility resulting from significant network changes. It is clear from the literature (most particularly from the US studies) that, given pressure for development and a favourable view by the planning authorities, the occurence of undeveloped land around a major node in an improved transport network is almost bound to lead to substantial growth particularly of housing, distributive trades and retailing. Such growth could obviously alter the trip matrices quite substantially. Despite the difficulty in forecasting such effects, it is difficult to defend their exclusion from a scheme appraisal.

8. So Should We Use Fixed Matrices or Not?

The cautious view is clearly that, if only to counter the criticism that the effects may be significant, evaluations ought to take formal account of any possible changes in the trip matrices. The best way of achieving this would be to carry out sensitivity analyses of the effects on transport system indicators of consequential changes in the trip matrix. Estimates of changes in the trip matrix directly attributable to changes in the cost matrix could be produced using standard models (they would however require the 'do nothing' trip matrix to have been produced with the same models). Changes in the matrix attributable to land use changes might aso be predicted by models but given the relative complexity of such models it might be more practical to test the impact a number of land use patterns hypothesised in the light of planning policy and accessibility changes.

Sensitivity analysis is to be preferred to straightforward incorporation of the modified matrices into the evaluation process because, in the case of matrix changes directly attributable to cost changes, there is no evidence on which to base a single estimate of their magnitude and because in the case of matrix changes attributable to land use development, the whole issue is inextricably bound up with political aspirations and planning policy.

The line of argument thus becomes that, for a given scheme, the working assumption that trip matrix changes are unimportant should be replaced by an onus on the forecaster/analyst to prove, through sensitivity analyses, that they need not be considered. The sensitivity analyses need not be complex - at their simplest level they might involve testing differential zonal growth rates in zones which might be affected by accessibility changes. More rigorous sensitivity analysis, such as those undertaken in similar contexts by Bonsall et al (1977), by Senior and Williams (1977) and by the MVA consultancy on behalf of DTp, would not need to be repeated for all schemes although they might usefully be carried out on case studies in order to establish the magnitude of likely effects.

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