ROUTE CHOICE IN CONGESTED URBAN NETWORKS

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1. BACKGROUND

1.1 The Importance of Route Choice

The growth in road traffic combined with constraints on major infrastructure investment have led to an increased emphasis on fine tuning of the network to meet the demands put upon it and on attempts to influence the pattern of demand by the techniques of traffic management. An understanding of the reasons behind drivers' choice of routes through the network is obviously fundamental to such actions.

Faced with a change in travel costs a change in route is probably the most readily available alternative for the car driver. The route selected can influence not only the individual's travel time, delay and comfort but the environment and safety of others and the performance of the road system as a whole.

All of these issues have been the focus of traffic management action. Recommendations have been made for improved signposting and route guidance (1, 2); electronic in-vehicle route guidance equipment is being developed to advise drivers of optimum routes as traffic conditions change (3, 4); environmental management measures have been designed to reduce "rat-running" traffic (5); signal settings have been designed to influence route choice (6) and proposals have been made for route control which would achieve system-optimal rather than user-optimal routeing (7).

Our work has been stimulated by a concern that the current generation of network assignment models (8) including detailed models such as CONTRAM (9) and SATURN (10), with their assumptions that route choices can be represented by an appropriately weighted sum of time and distance costs, may not adequately reflect the behaviour of drivers in congested networks, and more particularly their response to traffic management measures.

A clearer understanding of the ways in which drivers do respond to changing network conditions in urban areas would clearly be of importance in improving the design and evaluation of traffic management measures and the formulation of the analytical tools required.

This paper presents the results of a study of drivers' response to two major traffic management measures in the city of Leeds, England. The remainder of this section briefly summarises the findings of related research and the context of the Leeds case study. Section 2 describes the study method. Section 3 provides evidence from the study on drivers' prior knowledge of available routes, their basis for route choice, their variability in route and their response to the traffic management measures. Sections 4 and 5 consider in turn the performance of an assignment model in reflecting route choice and the appropriateness of the various survey instruments. Section 6 summarises our conclusions and recommendations for further work.

1.2 Previous Work

There have, in the last two decades, been several studies of the factors affecting drivers' route choice. The key findings have been discussed in a recent review (11) but it is useful to summarise some of the most significant results here. Many of the studies have been concerned with inter-urban journeys where the drivers are unfamiliar with network conditions but several have been concerned with regular journeys made in congested urban conditions where the drivers' familiarity with network conditions may be higher but where travel times may be unpredictable (12).

Some studies have included an assessment of the information on which drivers base their choice. For inter-urban journeys, it is generally accepted that the majority of drivers attempt to minimise travel time; most studies agree that, with the exception of leisure journeys, minimisation about time and distance together account for between 75% and 90% of all choices (13, 14). For urban journeys the position is less clear; while some researchers have found that shortest time is still the dominant criterion, others found the quality of the journey to be a major consideration. An early study by Wachs (17) found that routes were chosen primarily in favour of limited access roads, those that experienced less congestion, and those that appeared safer. The idea that drivers might wish to minimise the stress involved in driving in unsafe or congested conditions has long been supported by physiological evidence of driver stress (18). Later research (19) found that lack of congestion and good road design were typically the third and fourth most important criteria after minimum time and distance, while other work (20) found avoidance of stops the third most important criterion. It seems likely therefore that measures which improve the perceived quality of a journey may influence route choice, and may indeed encourage some drivers to select routes which are longer either in time or distance.

Whether drivers in practice select the routes which meet their objectives depends on the amount of information avalable to them, and their perception of that information. The most basic information is on the routes available. Benshoof found that most drivers to work in an urban area considered two or three routes, though less than half admitted to sometimes deviating from their preferred one (15). Huchingson found that 60% of urban commuters had used more than one route to work, and that 37% always or often took a different route on the homeward journey (20).

Several inter-urban studies have found that a substantial proportion of drivers fail to meet their objectives; current UK estimates of the benefits of improved route guidance are based on surveys which suggest that up to a third of time and distance minimisers fail to meet their objectives (11). Similar estimates have been made for other countries. Evidence of sub-optimisation of route choice in urban areas is again less clear cut; both Ratcliffe (16) and Wright and Orram (22) using very different techniques find a good correlation between route taken and stated or assumed objectives. However, Russam (23) estimates that routes taken in urban areas involve on average 3-7% excess distance and 9-15% excess time, implying the potential for a 10% saving in resources. This is consistent with the CACS experiment in Tokyo, which achieved a saving in journey time of 15% (24).

While several studies have attempted to relate stated objectives to actual conditions, very few have studied response to a change in conditions. This is unfortunate since it is only through study of the processes of adaptation that a firm basis for prediction can be created. Apart from a study of route diversion due to accidents (25), the only study of adaptation we have found in the literature is one which concentrates on inter-urban journeys (26).

1.3 The Case Study in Leeds

In 1983, an opportunity arose in the city of Leeds (pop. 500,000) to study the response of drivers to changes in travelling conditions. Within the NW sector of the city, shown in Figure 1, a restrictive bus lane was introduced in three stages between September 1983 and March 1984 to throttle outbound evening peak traffic through the Headingley bottleneck on the A660, and, in July 1983 a major junction improvement was completed at Sheepscar. As Figure 1 shows, the two measures between them affect routes which provide alternatives for several destinations.

2. DATA SOURCES

2.1 The Survey Instruments

The main intention of the study was to obtain details of route choice from a panel of home-bound commuters. This approach was selected to focus on the outbound evening peak movement which was specifically affected by the bus lane and to provide longitudinal data on route variability from day to day and between stages in the implementation of the bus lane. Employees of selected firms based in Leeds city centre who drove home through northern Leeds were invited to participate in the study. The invitation referred to a study of "congestion in north-west Leeds" to avoid undue emphasis in their minds on route choice or the traffic management measures. As an inducement to participate in the survey, a cash prize of £50 was to be awarded to a randomly selected respondent after each phase of the study.

Respondents were involved in the study on three separate occasions: in April/May 1983, before the implementation of the bus lane and junction improvement; in November 1983, 8 weeks after stage I of the bus lane and 15 weeks after the junction improvement; and in February 1984, 8 weeks after stage II of the bus lane. The effects of stage III of the bus lane were not studied because they were expected to be small and because panel resistance was occurring (see below).

On each occasion, respondents were asked for details of their homebound routes on six (normally consecutive) working days. These were recorded on maps together with details of the time of departure and of crossing the inner and outer ring roads, parking location at the start of the journey, any rerouteing decisions during the journey, frequency of use of the selected route and reasons for selection, assesssment of traffic conditions and identification of any special circumstances. A half scale copy of the daily questionnaire is included as an appendix to this paper.

In addition, in the first survey repondents completed a background questionnaire describing home and work locations, flexibility of travel times and habits, knowledge of available routes and frequency of using them. A subset of respondents were also asked an additional question about their criteria for choosing routes.

To supplement the panel survey a stop line questionnaire survey was mounted to obtain responses from a larger sample and to provide details about both inbound and outbound journeys.

The questionnaire was handed to inbound am peak drivers stopped at traffic lights crossing a screenline across the corridor. The five survey points are shown in Figure 1. Each driver received two questionnaires, one for the journey to work and one for the journey home. Only one day's travel was recorded for each direction. The design of the form was similar to that used in the panel survey; details sought included origin, time of departure, route taken, frequency of use, reasons for use, arrival time, parking locations, assessment of conditions and any special circumstances. the respondents were not required to provide their name or address and therefore remained anonymous.

Further details of both surveys are documented in the project report (27).

2.2 Response Rates

131 employees volunteered for the panel surveys, of whom 39 were judged to be unlikely to use the A660. After some chasing, 112 of these 131 (85%) responded to the first survey. 74 (56%) responded to the second survey. An attempt was made to arrest the decline in response by offering, in the third survey, a second prize of £25. Nonetheless the decline continued; 63 (48%) responded to the third survey. Only 38 (29%) responded to all 3 surveys. Fortunately the main decline in responses was among the 39 we had judged less likely to use the A660, but even so the decline made it increasingly difficult to identify responses to the traffic management measures and we decided not to carry out a fourth wave of the panel survey.

In the stop line surveys, a total of 488 drivers (around 25% of the total flow during the survey periods) were approached, of whom 450 accepted questionnaires. Of these 215, or 48%, were returned. The response rate was considered very successful, although inevitably the question of possible response bias remains.

3. RESULTS

3.1 Extent of Respondents' Previous Knowledge of the Network

Members of the panel were asked, in an initial questionnaire, to indicate their knowledge of the network by tracing, on a map provided, all the routes they had ever used on their journey home.

The maps showed a wide variation from those (approximately 50%) who had apparently only ever used one route to those (a few percent) who claimed to have tried almost all the alternatives available, many of them rat runs through residential areas. There was no very clear relationship between the number of alternative routes that a driver had tried and either the length of time that he had been making the journey or the precise origin and destination of his journeys. We conclude that propensity to use a variety of routes is very dependent on personal characteristics.

3.2 Influences on Choice of Route

Previous research, briefly reviewed above, suggests that journey time is the dominant criterion in a route choice decision. Answers to a general question on route choice criteria put to a subset of our panel members confirms this finding in general terms (see table 1) but highlights the importance of various measures of delay quite separately from total journey time.

When asked why they had chosen a particular route to work on the survey day, the majority of respondents to our stop-line questionnaire similarly mentioned time related reasons with, in this case, even more mentioning congestion or delays than mentioned overall journey time (see table 2). A significant proportion of the total sample (17%) said only that it was their usual route, suggesting perhaps that inertia might play an important part in some drivers' choice of route. The 'other' reasons quoted included safety, reliability, and the desire not to invade residential areas.

Our analysis of the maps in the journey logs completed by our respondents showed some tendency for those who travelled at the height of the peak to select more circuitous routes than those travelling when congestion was less marked. This is clearly consistent with the stated desire by many drivers to avoid congestion and delays.

After allowing for the fact that some drivers have to visit intermediate destinations, we found several instances where quite different routes between a given pair of points were being chosen. The most dramatic differences were, as expected, between routes selected by drivers with differing stated criteria for route choice. However, there were significant differences between routes where both drivers claimed to be seeking the least congested or the quickest route. 'Congestion' may, of course, be interpreted in different ways and, since the quickest route will also vary with the level of traffic, it is possible that there may be more than one 'correct' answer. However, given the similarity of times at which some pairs of journeys were made, there is prima facie evidence of one (or both!) of the drivers choosing the 'wrong' route. The drivers' own estimates of journey duration are not sufficiently precise (or accurate) to resolve the question.

Another reason for different routes being legitimately regarded as valid by time minimisers making an apparently similar journey, is the influence of slight but significant differences in the precise origins or destinations (affecting, for example, access to one way streets or the need to enter a traffic stream via a difficult turn). We are confident that such reasons explain only a small proportion of the anomalies referred to above.

Much less open to debate are those examples of drivers claiming to be following the 'shortest' or 'most direct' route since the 'correct' answers can be adjudged objectively from maps. From a sample of 29 drivers claiming to be following the 'shortest' or 'most direct' route, 3 were seen not to be doing so.

3.3 Comparison of Morning and Evening Routes

Comparison of the routes logged by our stopline respondents for their journeys to work with those for their journeys from work shows that, even after allowing for one way streets in the city centre, less than half (46%) of evening routes were a mirror image of that day's morning route. 29% of cases showed a major difference between the two routes. Interestingly these percentages varied markedly depending on the stopline at which the respondents had been approached during their morning journey; 53% of those who were stopped on the A660 made a mirror image journey while only 22% of those stopped in Queenswood Drive (a notorious morning rat run) did so.

Comparison of the morning and evening logs also showed that drivers were more likely to stop en route on their evening journey and that the timing of evening journeys was more variable; 88% of respondents claimed always to arrive at work within 5 minutes of the time logged on the survey day but only 23% made a similar claim in respect of their time of leaving work.

With reference to table 2, comparison of the criteria mentioned in the context of the journey from work with those mentioned for the journey to work shows more emphasis, in the evening journeys, on 'special circumstances' including the need to visit intermediate destinations (particularly for shopping) and to give lifts on a one-off basis. Comparison of columns 1 and 3 in table 3 and columns a and b in table 4 also shows the greater importance of such factors as reasons for varying the evening journey. This is not to say that more passengers are carried in the evening (indeed we note that 23% of our stop line respondents claimed to take passengers every morning while only 10% claimed to do so every evening) but that passengers carried in the evening are more likely to require a diversion to be made from the driver's usual route.

3.4 The Extent of, and Reasons for, Route Switching

We have estimated the extent to which an individual's route choice varies from day to day using data from a number of sources. The estimates vary quite substantially and those derived from the panel and stopline surveys are among the most conservative (28). Nevertheless even these show that route choice is far from fixed.

Analysis of the route maps completed by our panelists showed that, at the time of the initial survey, around 10% of drivers used at least 3 distinctly different routes during the 6 days of the survey, that some 25% used a distinctly different route on at least one of the 6 days and that only about 40% used precisely the same route on all 6 days.

We also note that 4.2% of journeys to work logged by our stopline respondents were claimed to be on routes which had 'rarely or never' been used before The equivalent figure for the journey home from work was 6.1% - indicating a greater variability in the evening journeys.

Analysis of panelists' journey logs showed that, during the first survey, the vast majority (98%) of routes were selected before the journey began. It is again interesting to compare responses to the equivalent question posed for the morning and evening journeys in the stopline survey. The percentage of respondents claiming to have selected the precise route* before setting off was 91% for the evening journey and 83% for the morning journey. This may reflect the fact that patterns of congestion, relative to the direction of travel, in the morning and evening, are such that there are fewer opportunities to avoid congestion by changing route on the evening journey.

Table 3 is drawn for answers to questions in a household interview survey carried out in West Yorkshire in 1981. It shows that the routes used for journeys to work varied more than routes on the homeward journey and that traffic conditions were the most widely quoted reason for varying the route used for journeys to work but that 'employer's business' was also important and indeed was the most important reason for journeys home from work. A disaggregation of the data to show drivers from households with subsidised cars available, primarily company cars, shows that their return journeys are particularly affected in this way. Interestingly the desire for 'variety' is apparently an important reason for changing the route, particularly among drivers with subsidised cars available.

Comparison of columns c and d in table 4 suggests that awareness of the impact of personal commitments on route choice is higher on the days when an unusual route is being used (col d) than on days when the normal route ia being used (col c). This conclusion has obvious implications for the interpetation of data collected, as most data is, on 'normal' days. This finding highlights the difference between general criteria for route choice and those relating to specific journeys.

Comparison of data in table 3 with that in columns a and b of table 4 might be thought to show a contrary conclusion to that discussed above. A more likely explanation, however, is simply that the two tables are based on data from different population samples.

Note * The difference between the 97.5% and the 91% is due to the fact that the former relates to 'route' and the latter to 'precise route'.

3.5 The Effect of the Traffic Management Measures on Route Choice

3.5.1 Changes Apparent at the Aggregate Level

An analysis of outbound traffic flows in the evening peak in the North West quadrant of Leeds carried out by the Highway Authority shows that between 1981 and 1985 the flows for the sector as a whole increased by 20% while those on the A660 fell by 10% and those on the link from the A660 to the Sheepscar intersection rose by almost 50%. The data in table 5 shows that this divergence was most apparent following the completion of the Sheepscar scheme and the initiation of the bus lane in 1983 (between 1983 and 1984 the A660 flow fell by 10% while that on the link road rose by 17%).

The table also shows great variation in the flow on Burley Road; it appears that the flow on this road, which is an alternative to the A660 and to Kirkstall Road, has been very dependent on the balance of advantage between them. It seemed, for example, to take traffic from Kirkstall Road in 1983 and from the A660 in 1984 (following introduction of the bus lane) but subsequently yielded it back. The increase in flows on Kirkstall Road in 1984 and the reduction in 1985 are also consistent with the effects of the bus lane (diversion from the A660 to parallel routes) having been greatest in 1984 with a slight reversal of the effect in 1985.

More detailed flow data shows that, following introduction of the bus lane, flows on the southern part of the A660 (where the bus lane was) fell further than did those further out, suggesting that some of the traffic which left the A660 to avoid the bus lane rejoined it further out. This supposition is supported by analysis of turning movement counts.

3.5.2 Effects Apparent from Panelists' Behaviour

The timing of the three phases of the panel survey was designed to yield information on route choice before introduction of the management measures, during their phased introduction and after completion of the main elements.

Analysis of the maps of routes taken during these three phases, and of the supplementary questions asked, suggests that introduction of the junction improvement and the first phase of the bus lane caused quite significant adjustments to journeys which previously used the A660. There is evidence of substantial experimentation and variability during the second survey followed by a settling down to new patterns in the third survey. It is clear from an analysis of the reasons quoted by panelists for changing their route on a given day that increased congestion was causing drivers to move away from the A660 during surveys 2 and 3.

Analysis of the maps for each period of six days shows that, at the time of the second survey, there was an increase in the number of routes being used (the percentage of respondents using three or more routes was 7%, 12% and 8% in surveys 1, 2 and 3 respectively) and in the number of drivers using routes they had rarely or never used previously (4.3% in survey 1, 5.1% in survey 2 and falling to 3.8% in survey 3). The fall in survey 3 is to be expected since our panel would, with the normal passage of time, be becoming more familiar with the network, against which background the rise in survey 2 is all the more significant. Analysis of individual drivers' routes, and comparison of them with those they had used at the time of the previous survey, shows an increased use of tortuous routes, many of which they had not claimed experience of at the time of the initial survey.

Analysis of the maps completed by those panelists who responded to all 3 surveys shows a decline in the use of the A660 - from 35% of logged journeys in the first survey to 32% in the second and third.

Of regular users of the A660 at the time of the first survey (i.e. those using it on at least four of the six days) only 25% were still using it regularly at the time of the second survey. 37% had moved to Meanwood Road and 30% to Burley Road. It is interesting to note that, at the time of the third survey, some traffic had moved back to the A660 (the figures being 29% A660, 34% Meanwood Road, and 27% Burley Road). This is a similar effect to that observed in the aggregate flow data.

We also note that, during the second survey, an increased proportion of routes were not being finalised until after the journey had begun (2.5% in survey 1, 4.7% in survey 2, 4.1% in survey 3) and, again, there is evidence that the effect had diminished somewhat by the time of the third survey.

Close examination of individual logs showed some tendency, again particularly during the second survey, for drivers to alter the time at which they made their journeys; most particularly a tendency to travel outside the busiest part of the peak period. This behaviour was often associated with their having experienced higher than average journey times on the previous day.

4. PERFORMANCE OF AN ASSIGNMENT MODEL

4.1 Introduction

In order to assess how accurately a state-of-the-art assignment model was able to replicate actual route choices between specified origins and destinations we took a random sample of 38 logs of journeys-to-work recorded by respondents to our stopline questionnaire (excluding those with intermediate destinations) and compared the routes shown with paths generated between the same pairs of points by an assignment model. The model used was an equilibrium model (8) incorporating link based speed flow relationships, it did not incorporate turning penalties or banned turns. The routes assessed were minimum time paths generated after convergence had been reached by the equilibrium process, following assignment of a morning peak hour trip matrix. The network was based on one developed by the Highway Authority for a city wide assignment model, updated to include the new traffic management measures and with an extra 5% of links added by us so as to include all significant rat runs in the area.

We are well aware that such models are intended to reproduce aggregate flows rather than individual routes and that, to the extent that they allow for variation in behaviour, it is through the range of paths generated en route to convergence (our comparison was only with the path generated after convergence had been reached). However, we thought the comparison worthwhile as an indication of the 'accuracy' of the converged path, particularly because the use of minimum time algorithms is being suggested in the context of route guidance systems.

4.2 The Results

In only 11 out of the 38 cases (i.e. 29%) were the paths generated by the model identical to those logged by our drivers and for a substantial proportion of the remaining 27 routes the differences were substantial. There was a general tendency for the model to generate paths along shorter, more congested routes than those selected by the sample of drivers. The model was particularly poor at representing the use of the rat runs which we had included in its network.

It is interesting to note that, although the model was building paths on the basis of minimum time, it generated 'accurate' paths for only 6 (35%) of the 17 drivers who stated that their route was chosen on the basis of minimum journey time. For these time minimisers, 3 of the 11 failures to replicate a minimum time path were due to the absence of minor rat runs from the modelled network.

The journey times predicted for the model's paths were plausible and there was thus no obvious evidence of any miscoding in the network, of any distortions in the trip matrix assigned or of any gross errors in the speed flow relationships used in the model. It was apparent, however, that because the model did not include turning penalties or bans, it could not generate realistic paths through junctions which were affected by such restrictions.

The converged paths generated by the model did not differ substantially from those generated en route to convergence and therefore, although we have not yet compared these intermediate paths with the drivers' chosen routes, we doubt that they would have replicated many more of the 38 routes.

4.3 Discussion

The minimum time paths generated by the model often differed quote substantially from those estimated by the drivers and this must clearly be due either to inaccuracies in the model, its network or flow matrix, or to incomplete knowledge on the part of the drivers. We cannot yet say which is the more likely, but we were unable to detect any obvious errors in the model or its input data.

Many of our sample of drivers were clearly choosing routes very different from the minimum time paths generated by the model en route to, or after, convergence. It follows that the model cannot, through its process of convergence, replicate the variety of behaviour observed at the micro level. It is clear that representation of variety requires the direct incorporation of a multi-routeing device. The results of our survey, and the analysis of the anomalies described above, suggests that this should involve the construction of paths according to a variety of generalised cost formulations (including, in particular, some incorporating a disproportionate weighting of time spent in slow moving queues) rather than a randomisation routine such as that suggested by Burrell (29). It is interesting to note that recent work on behalf of the Dutch Ministry of Transport (30) succeeded in replicating 90% of a sample of interurban journeys by means of 6 alternative formulations of the 'generalised cost' in the tree building model. It is not clear, however, that their criteria for 'replication' of inter urban routes were as exacting as ours for urban routes - they reported an ability to replicate 70% of routes on the basis of minimum time whereas, as described above, we managed only 29%.

It is clear that the incorporation of turning penalties and banned turns would improve the model's ability to reflect real behaviour and it seems likely that this would be further improved by a more sophisticated representation of junction capacities as is provided in simulation/assignment models such as SATURN (10). However, our analyses to date suggest that, in the absence of multiple formulations of generalised cost, even these models would fail to replicate the majority of routes selected in congested urban networks. Further work on all these questions is under way at ITS, Leeds.

5. ASSESSMENT OF DIFFERENT SOURCES OF DATA ON ROUTE CHOICE

5.1 Aggregate Data on Flows and Turning Movements

These data, derived from manual or automatic counts, are perhaps the simplest to collect and, to the traffic engineer, must remain the most valuable source of information about the shifting pattern of demands put on the transport network. They do not, however, yield direct information on changes in the underlying pattern of demands for travel between specific origins and destinations. Therefore, although likely O-D matrices can be deduced through mathematical modelling (31), they are of limited use in behavioural analyses.

Our own use of flow data highlighted the problem that, unless one can predict which roads and turning movements are likely to be affected, effective monitoring of changes in flow can require a comprehensive coverage of the network. In our case some of the more interestng effects of the traffic management schemes (as evidenced from our drivers' logs) did not show up in the flow data because counts had not been made on some minor roads which turned out to be significant rat runs. Comprehensive coverage is, of course, expensive.

5.2 Moving Vehicle Surveys

We had access to very limited objective information on journey times and patterns of delay in the network. This made it impossible to check the estimates made by our questionnaire respondents (except by comparing the records of two or more drivers using the same part of the network at similar times). This necessarily limits our analysis of the routes chosen and comparison with those not chosen.

We recognise, however, that collection of such data in the quantities required is ruled out by resource constraints. Also, one would need such a substantial fleet of cars engaged in moving observer surveys that their very presence would begin to affect network conditions.

Wright (22) has shown that useful and objective information of driver route choice can be collected by means of car-following surveys but again we question the efficiency of this method as a means of collecting substantial volumes of data.

5.3 Vehicle Registration Plate Data

Registration plate matching surveys can be useful in three ways; they can provide some information on journey times (by comparing the times at which given plates were observed passing selected points in the network), they can be used to determine the routes taken by a sample of vehicles (by tracing their appearance at selected points through the network) or, more unusually, they can provide information on the regularity with which journeys are made (by examining the daily reappearance of individual vehicles at specified points). Unfortunately, however, even using the latest techniques (32) the resource requirements for such surveys are substantial if a detailed picture is to be gained. Also, some of the more interesting analyses are hampered by surprisingly complex problems of statistical reliability (33).

5.4 Direct Questions and Attitudinal Information

Direct questions on issues such as the criteria for route choice decisions, or the regularity with which specified journeys are made, can yield very valuable information for studies of route choice but there are some problems. Firstly there is the problem of bias in some answers, in particular we have found quite strong evidence (29) that respondents overstate (and possibly over-estimate) regularity in their behaviour. Secondly the treatment of attitudinal data requires great care. The basic problem with traditional styles of question is whether to force answers into prescribed categories or to risk misclassification of free format answers. (Our own preference has shifted from the latter to the former having suffered from problems of inappropriate codes having been allocated). An alternative approach to the derivation of drivers' route choice criteria is through stated preference techniques. This approach has already been used to considerable effect in the studies of cyclists' route choice (34) and drivers' values of time (35). We see substantial scope for its further use in urban route choice analyses.

5.5 Journey Logs

We have found journey logs, comprising maps of the routes taken and supplementary information about the journeys to be extremely valuable. They have provided valuable information, not all of which has yet been analysed. The only problem encountered was in trying to get precise information on the timing of events such as journey starts and stops; the frequency with which multiples of five minutes were recorded strongly suggests the presence of imprecision.

We are aware of the success claimed by TRRL in persuading motorists to complete partial journey logs in the course of roadside interviews in rural areas (36). There is, however, little prospect of such techniques being possible in congested urban areas where, because of the disruption caused, it is increasingly difficult to carry out even the simplest roadside interviews.

5.6 Selecting the Sample for the Questionnaires

We used two samples for our journey log surveys; a panel of drivers recruited from among employees of large firms in Leeds living to the North West of the city and drivers given self completion questionnaires while stopped at traffic lights on a cordon across our area of interest.

The panel was undoubtedly the most efficient way of observing changes in behaviour consequent upon introduction of the traffic management measures, but there were some problems.

Comparison of data derived from the stopline questionnaire with that from the first phase of the panel surveys shows that the panel members were less likely to use rat runs. It may be that, since rat running is widely regarded as antisocial, the panelists were dissuaded from admitting to using rat runs by their knowledge that we could identify them. (Alternatively it may be that the type of person predisposed to join a panel might have more of a social conscience!).

There was also a slight tendency (barely significant) for panelists to have been making the surveyed journey for longer than the stopline respondents - the percentages of the two groups who had been making the journey for 12 months or more were 80 and 78 respectively. This difference may reflect a similar phenomenon to that described above; people willing to become panel members might be expected to have more stable travel patterns than the population at large. Our evidence on this is inconclusive; compared to the initial set of panelists, a higher proportion of the stopline respondents claimed to drive to work on all 5 days a week (91% compared to 74%) but a higher proportion of them also claimed on the survey day to be using a route they had rarely or never used before (6.1% compared to 4.3%).

We noted a decrease in the variability of routes chosen in the third wave of the panel survey, vis a vis the first and second waves (the percentage of respondents whos logs showed the same route on all days was 53% in the first two surveys but 62% in the third). Close analysis shows that some of the reduction in variability in the third wave is due to the disproportionate loss from the panel of the drivers who had demonstrated greatest variability in previous waves (at the time of the initial survey 76% of all respondents logged the same route onat least 5 of the 6 days - the equivalent figure for the subset of respondents who were to remain in the panel throughout was 84%, also although 6% of respondents reported carrying passengers on at least 5 days a week, none of those who were to stay in the panel did so). It may be that drivers with less regular, complicated, behaviour found the duties of panel membership more onerous than did the average driver and that this contributed to their decision to leave the panel. It is also possible, of course, that some of those who remained in the panel began to tire of completing their logs for each day separately and began to simply copy one day's entry from the previous one. The fall in the response rate from 84% to 56% to 48% despite the increased prizes being offered, must raise the question of respondent fatigue.

The stopline questionnaire survey was also extremely valuable; while not providing any time series data it did provide, at very low cost, a wide sample of journey logs including maps and written commentaries for the morning and evening journeys. Prior to adopting the quesionnaire format we had piloted various forms of stopline interview (i.e. driver interviews conducted while they were waiting at traffic lights), but in no case did we manage to elicit sufficient information from respondents in the very limited time available for each interview. We decided that the balance of advantage lay with a self completion questionnaire despite the risk of selective response bias. (In practice 48% of questionnnaire packs handed out were returned complete - a surprisingly high figure for a relatively complex questionnaire) On the basis of our analysis of the questionnaires returned we conclude that this type of survey has much to commend it although its wider use is of course, dpendent on the availability of suitable sites where the appropriate streams of traffic can be sampled. It is important to be wary of sites downstream of significant junctions since the signal phasing may be such that the sample of traffic which is stopped at the site may have a non random probability of having entered the previous junction from a given direction.

6. SUMMARY AND CONCLUSIONS

Analysis of our survey data has tended to confirm and extend the findings of some of the previous studies of route choice. We have shown that routes chosen by regular travellers in urban areas vary from person to person and from day to day. Furthermore the routes used in the evening are likely to be more variable than those in the morning and are unlikely to be mirror images of the former. It is clear that different drivers have quite different criteria for route choice. A given day's route is likely to be chosen so as to minimise some aspect of journey time but a desire to avoid queues and congestion is apparently almost as widespread as a desire to minimise overall journey time. It is also clear that external factors such as the need sometimes to stop en route or to travel at a particular time, often affect the choice of route.

Despite this broad agreement with some of the earlier studies there are some interesting differences between our findings and earlier ones and between findings which are derived from different sources of data apparently measuring the same thing. This leads us to question whether the apparent differences in the conclusions reached in earlier studies are real or whether they are to some extent the result of differences in the methodologies adopted. This would obviously have serious consequences for any study of the transferability of results between different cities or countries and of trends in drivers' route choice behaviour. Further research is clearly required.

The longitudinal dimension to our panel survey, for which there is little precedent in route choice research, has shown that the introduction of the traffic management measures led to a period of experimentation during which increasingly tortuous routes were tried out prior to some adaptation to the new network conditions.

All these findings have implications for the design and use of assignment models: The nature of equilibrium, the achievement of multi routeing through use of a variety of generalised cost formulations, the appropriate degree of detail in the network and the differences between morning and evening conditions all require attention. Research on some of these issues is, of course, already under way but some of it has been almost exclusively concerned with the niceties of technical modelling procedures. We suggest that the increased emphasis on the fine tuning of networks to meet the demands put upon them will require increasingly sophisticated analytical design aids requiring, in turn, an improvement in the accuracy of assignment models. We believe that it is only by incorporating what is now known about the variety of route choice behaviour that the necessary improvements can be achieved.

The findings outlined in this paper have implications, not only for assignment models, but also more directly for the design of traffic management measures and for route guidance. Further analysis of our own data is expected to yield more insights, but it is clearly necessary to collect more information on some of the outstanding issues. We believe that particular attention should be paid to the estimation of the strengths of drivers' aversions to travelling in congested conditions and to the simultaneous study of driver route choice and precisely logged changes in network conditions.

ACKNOWLEDGEMENTS

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Table 1 Factors considered important in choice of route home from work

Precoded answer	number of respondents regarding it as: important	most important
Total journey time	30	12
Time spent in queues	23	10
Amount of stopping and starting	15	1
Total distance	5	0
Day-to-day variations in journey time	1	1
Other	2	1

Source: 35 responses to initial questionnaire distributed to subset of A660 panel. April 1983.

Table 2 Reasons for choice of today's route

Classification of answers	% quoting the reason for their journey: to work	from work
Quickest	28	27
Shortest/most direct	10	14
Simplest	4	6
To avoid congestion/delays/ heavy traffic/queues etc.	36	24
Special circumstances	6	14
A combination of the above	7	7
Other	10	8
Number quoting a reason	189	207
Number simply saying 'usual'	40	46

Source: Classification of answers to the question "why did you choose this precise route today?" asked of respondents to stopline questionnaire. December 1984.

Table 3 Variation in route choice

		Journey to work a	b	Journey home c	d
% of total sample claiming always to use the same route		21.5	26.9	24.4	32.7
	sample size	205	52	205	52
of those who admit to varying their route, % quoting the following reasons for varying their route	for variety	11	21	12	18
	passenger requirements	9	-	10	-
	traffic conditions	36	21	24	6
	personal business	5	7	20	18
	employers business	27	29	26	41
	other	7	7	4	6
	no response	5	14	4	12

Columns a and c contain data for all households. Columns b and d contain data from households who had a subsidised car available.

Source: Classification of answers to the questions "do you always travel to work/home from work by the same route?" and ... "if not, why do you vary it?" included at our request in household interview carried out by West Yorkshire County Council in autumn 1981.

Table 4 Reasons quoted for varying choice of route

Classification of the reason given	a %	b %	c %	d %
Traffic conditions	46	30	28	21
Passenger needs	8	9	15	24
Other commitments	5	22	15	35
Other	41	39	42	20
Sample size	139	139	192	80

(Answer to question a, b, c, d)

a if you ever vary your route to work, why is this?) posed in stopline
b if you every vary your route home from work, why is this?) questionnaire

c if you do not always use this route, why not?) posed in initial
d if you do not often use this route, why did you use it today?) questionnaire to panel members

Table 5 Peak Hour (1700-1800) Outbound Traffic Flow Indices

Year	A660	Claypit Lane	Burley Road	Kirkstall Road	Total NW quadrant
1981	100	100	100	na	100
1982	95	114	105	100	105
1983	96	123	125	95	108
1984	86	144	127	104	113
1985	90	147	111	101	119

Source: WYMCC traffic counts abstracted from their document "Traffic Flows across the Leeds Central Cordon, Monitoring Report 27".

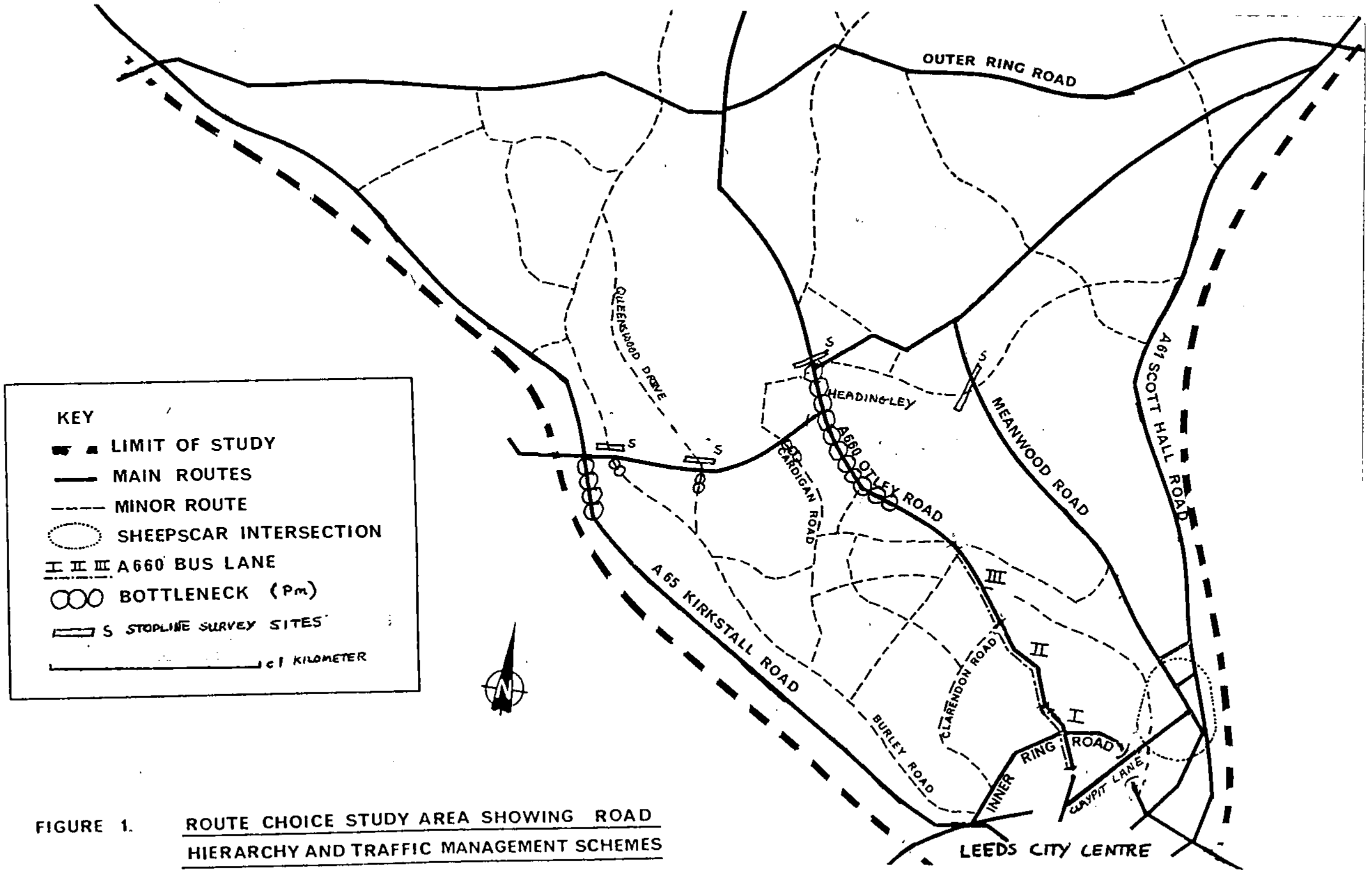

FIGURE 1. ROUTE CHOICE STUDY AREA SHOWING ROAD HIERARCHY AND TRAFFIC MANAGEMENT SCHEMES

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APPENDIX: DAILY QUESTIONNAIRE FORM USED IN PANEL SURVEY
(2 sides of A3 paper)

DAILY QUESTIONNAIRE
(confidential)

Today's date . . . -6 MAY 1983

Times: Note the precise time when you

1) Get into the car . . . . ______
2) Reach the inner ring road . . . . ______
3) Reach the outer ring road . . . . ______
4) Stop for someone to get into or out of the car

______ ______ ______ ______

5) Start after someone has got into or out of the car

______ ______ ______ ______

6) Reach home . . . . ______

Parking

- Where was your car parked while you were at work today?

____

Is this your usual parking place? . . . . Yes [ ] No [ ]

If not: - Why did you park there today?

____

Where do you usually park?

____

Special Circumstances

- Did anything other than traffic conditions affect your journey home today? Yes [ ] No [ ]

If so: please give details (e.g. left work 30 minutes early because of a dentist's appointment).

____

Route

- Mark the route you used today for your journey from work to home on the map overleaf.
- Mark with a cross any points where you stopped for someone to get into or out of the car.
- Mark with a cross the points where you reached the inner and outer ring roads.
- Did you plan to travel this way before you left your parking place? . . . . Yes [ ] No [ ]

If not: - Where did you decide to travel the way you did?

____

Why did you travel the way you did?

____
____

- How often do you use this route for your journey home from work?

rarely or never before	about once per month	about once per week	1-2 times per week	3-4 times per week	5 or more times per week
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

If you don't always use this route, why not?

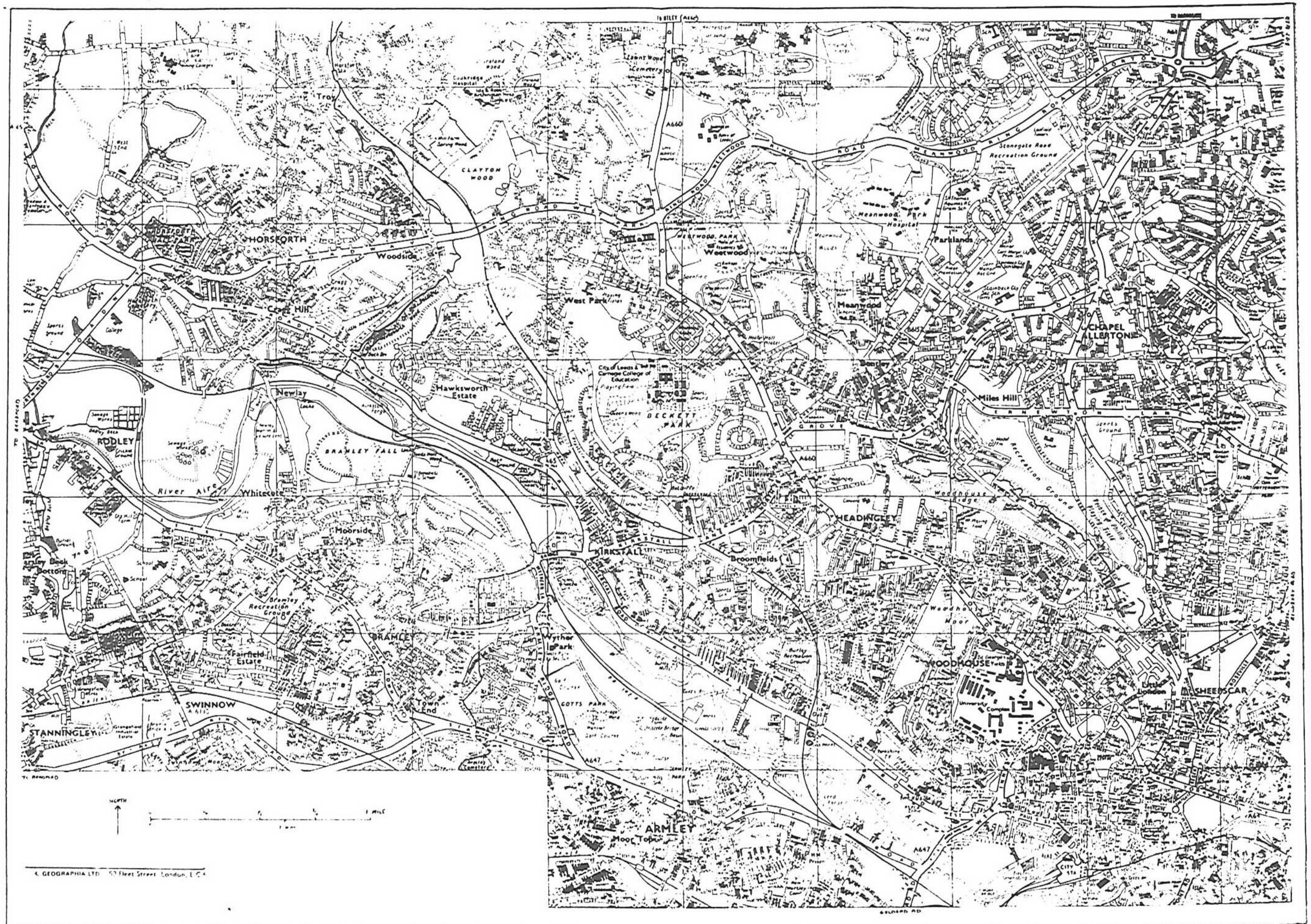
____
____

If you don't often use this route, why did you use it today? ______________________________
____

Traffic conditions

- How would you describe the traffic conditions you experienced on your journey home today?

Much worse than expected . . . . [ ]
Worse than expected . . . . [ ]
About the same as expected . . . . [ ]
Better than expected . . . . [ ]
Much better than expected . . . . [ ]


TO OTLEY (A660)
Lawnswood Cemetery
A660
RING ROAD
MEANWOOD
CLAYTON WOOD
HORSFORTH
Woodside
Cragg Hill
West Park
Weetwood
Meanwood
Meanwood Park Hospital
Parklands
Stonegate Road Recreation Ground
CHAPEL ALLERTON
Miles Hill
Newlay
Hawksworth Estate
City of Leeds & Carnegie College of Education
BECKETT PARK
RODLEY
BRAMLEY FALL
River Aire
Whitecote
Moorside
KIRKSTALL
Broomfields
HEADINGLEY
Bramley Recreation Ground
BRAMLEY
Fairfield Estate
WOODHOUSE
Wyther Park
Woodhouse Moor
Little London
SHEEPSCAR
SWINNOW
Town End
GOTTS PARK
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