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CAR TRAVEL TIME VARIABILITY ON LINKS OF A RADIAL ROUTE IN LONDON: METHODOLOGY, SURVEYS AND DATA PROCESSING

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ABSTRACT

MAY, A.D., P.W. BONSALL and N.W.MARLER (1989). Car travel time variability on links of a radial route in London: methodology, surveys and data processing. Working Paper 278, Institute for Transport Studies, University of Leeds, Leeds.

This working paper is one of a series of three describing research on travel time variability of car drivers using a north London corridor. The objectives of the work described in this report were to determine the amount of variability experienced within short time periods and between time periods, and to explain these variations in terms of simultaneously-recorded traffic factors.

This report describes the methodology used, the surveys carried out and the data processing procedures. Data were collected on twelve contiguous links on the A41 between 0730 and 1030 on weekdays in spring and again in summer. Link travel-time distributions for cars were obtained by registration-plate matching using hand-held electronic data loggers. The methods of treatment of spurious matches and outliers, resulting respectively from chance matching of partial registration numbers and from stopping or diverting vehicles, are described. The reasons for selecting particular explanatory traffic variables are presented, together with a description of the methods of data collection.

The results of these surveys and their analysis are contained in ITS Working Paper 279. The methodology, data collection procedure and analysis of journey time variability experienced by a panel of car commuters using the same corridor are contained in ITS Working Paper 277.

Car Travel Time Variability on Links of a Radial Route in London: Methodology and Surveys

1. Introduction

1.1 General

This Working Paper is one of three describing a study of travel time variability experienced by car drivers on the A41 radial route in North London, carried out in the spring and summer of 1987.

The objectives of the complete study were:

(i) to produce an estimate of the amount of variability of travel time for car travellers, both within short time periods and between time periods, including different days;

(ii) to estimate the importance of the observed variability to the car users;

(iii) to attempt to explain the observed variability;

(iv) if the variability could be satisfactorily explained in a general model, to use and/or adapt an existing traffic network model to simulate travel time variability which could subsequently be used to investigate the potential effects on it of traffic engineering and transport planning measures;

(v) if variability was found to be of major importance, to develop proposals for the research necessary to investigate user perception of and response to variability more fully.

To achieve these objectives, the study was designed to have two distinct and self-contained parts. One part (the "engineering study") was concerned with measuring variability on links of the A41 and explaining it in terms of the traffic characteristics of the links in order to address objectives (i), (iii), (iv) and (v). The other part (the "panel study") was concerned with recording the day to day travel time variability experienced by a selected group ("panel") of regular car commuters, both for their entire door-to-door journey and for sections within it. The ability of panellists to predict their journey times and the consequences of the variability they experienced were also recorded. This part of the work was designed to achieve objectives (i), (ii) and (v).

This Working Paper is concerned with the methodology and surveys for the engineering study. Two companion Working Papers are also available: one describing both the methodology and results of the panel study (May et al 1989(a)) and the other describing the analysis and results from the engineering study (May et al 1989 (b)).

resources and was a section in which the main junctions were comparatively closely spaced.

In view of the different traffic conditions which occur at different times of the year, it was decided to collect data in both spring and summer in order to incorporate expected differences in travel times, variability and traffic flows. The spring surveys took place in school term-time and the summer surveys in the school summer-holiday period, to cover the widest range of conditions. In both seasons data collection was restricted to weekdays, in order to concentrate on the commuter peak.

The earlier work on Leeds radial routes (May and Montgomery 1984) had suggested a number of factors which might be expected to affect car travel times and their variability. These were used as the basis for the explanatory data collected in this project. The data were:

(i) traffic flows and turning movements in an inbound direction at the downstream end of each highway link. The downstream end was used as it was considered that turning movements out of the link could affect link travel times;

(ii) traffic composition: the presence of large vehicles in the flow might, for example, cause travel times to be greater;

(iii) parking at various distances upstream and downstream from the junctions: parking, particularly close to junctions, is known to be capable of causing a major reduction in capacity with a corresponding increase in travel time;

(iv) whether or not any exit from a junction was obstructed;

(v) whether a queue remained at a junction stop line at the end of the green phase in the inbound direction: this was considered an estimate of the degree of saturation;

(vi) any incidents which might affect travel times, and their location and duration.

Manual data collection techniques were used for the collection of these data. For items (i) to (v) above the information was collected by individual signal cycle.

The objectives of the work required data to be collected on the distribution of travel times on links within short time periods, and so it was necessary to collect travel-time data by recording registration numbers and times of passing of a sample of cars at both the upstream and downstream end of each link, with travel times subsequently being produced by matching the registration numbers at each location. Based on pilot surveys in Leeds, and on the findings of an earlier study of data-capture devices (Bonsall <u>et al</u>, 1988) it was decided to use Psion Organisers (small hand-held computers) to record the registration numbers and times.

Table 1: Link Characteristics

Link No	Length (Km)	From (upstream)	To (downstream)	No of Lanes	Permitted Movement	Other Features
1	0.47	Fortune Green Road	Heath Drive	3	** all	Bus lane to 10.00 am, with setback. Mainly residential frontage. Dual carriageway.
2	0.23	Heath Drive	Frognal Lane	3	straight, left	Bus lane to 10.00 am, with setback. Mainly residential frontage. Dual carriageway.
3	0.43	Frognal Lane	Arkwright Road	3	straight, left	Bus lane to 10.00 am, with setback. Mainly residential frontage. Dual carriageway.
4	0.53	Arkwright Road	Finchley Road Tube (Canfield Gardens)	3	straight only	Bus lane to 10.00 am, without setback. Residential with shops in south part. Dual carriageway.
5	0.52	Finchley Road Tube (Canfield Gardens)	Swiss Cottage North (Fitzjohns Avenue)	3	straight only	Bus lane to 10.00 am, with setback. Bus lane goes left into Fitzjohns Avenue. Shopping frontage. Dual carriageway.
6	0.31	Swiss Cottage North (Fitjohns Avenue)	Swiss Cottage South (Hilgrove Road)	3 6	all (left is	Link is part of gyratory system, with signalised junction on it. Office, residential and shopping frontage.
7	0.88	Swiss Cottage South (Hilgrove Road)	Grove End Road	2	all	Mainly residential frontage. Dual carriageway in north only, with rest 2-way.
8	0.16	Grove End Road	Circus Road	2	all	Residential and shopping frontage. 2-way road.
9	0.44	Circus Road	St John's Wood Road	2	straight only	Residential and institutional frontage. 2-way road. Lords Cricket Ground at southern end.
10	0.37	St John's Wood Road	Hanover Gate	2	straight, left	Roundabout (to Regents Park) on link. Residential frontage. Regents Park Mosque near Hanover Gate. 2-way Road.
11	0.42	Hanover Gate	Rossmore Road	2	straight	Residential and institutional frontage. 2-way road.
12	0.25	Rossmore Road	Baker Street	4 5	straight right	Residential and institutional frontage. One-way. Bus lane in south through downstream junction.

* In survey direction only
** at downstream end

The data file thus created in the Psion consisted of a header line with the date and location typed in before the start of the survey, followed by the data lines each of which gave the time; registration number and direction (or 'error') symbol.

It was found that the Psion could hold in its memory between 1200 and 1500 registration numbers in the format described. Very many more could have been recorded if additional memory packs (EPROMS) had been used, but as well as the additional costs, there is a significant time-lag in entering the data into a memory pack rather than into the main memory. One disadvantage of the method chosen was the memory limitation, but in few cases was the memory capacity exceeded in a 3-hour survey. A further potential disadvantage is the loss of data if the battery fails (this is not important with the EPROM memory packs) as all data would be lost. For this reason batteries were replaced at the very safe rate of one per six hours' use, and this was never a problem.

Experiments in Leeds and London before the surveys took place were carried out to find out the rate at which various surveyors could enter the registration numbers under heavy traffic conditions, and from this to design a method of sampling cars which would give a comparable rate. It was found that with practice, most competent surveyors could record up to about seven 4-item alphanumeric registration numbers per minute over a prolonged period. Later experience showed that one or two exceptional and experienced surveyors were able to reach a rate of about 10 per minute over long periods at busy locations. These people were often provided with a spare Psion in the actual surveys in the event of their first one filling up.

The experiments also suggested that selecting the sample of cars by looking at the registration number and recording only those ending in a number, say, 3, 5 or 7 was wasteful of time, as surveyors had to read all number plates in order to make the decision. In addition, in nose-to-tail traffic and especially in outside lanes, all plates cannot easily be seen. Instead, a method was developed based on car colour. Before the main surveys it was found, in the traffic on the A41, that white or off-white cars gave a sample almost large enough to keep the surveyors fully occupied. So, the final sampling method was to instruct the surveyors to record all white and off-white cars as their priority, and when none were available (and <u>only</u> when none were available), they should then also record as many red cars as possible. They were instructed always to take the <u>next</u> red car, to avoid lane bias. This approach proved successful, as it was usually possible to select the target white (or red) cars at a considerable distance, and so be ready to record the number, and at the correct instant of time. A limited survey of car model and colour of white and randomly selected non-white cars, carried out on one day of the survey in both spring and summer, suggested that white-car sample was not biased in terms of car make and model.

surveyor stood just downstream of the junction, close to the location of the registration number surveyor, as this was the place where the turning movements and vehicle classes could most easily be seen without visual obstructions from large vehicles in a slow moving or stationary junction queue. The flow recorder stood close to the surveyor recording number plates.

The surveyor recorded the number of vehicles in each of four classes: light, medium, heavy and bus/coach. The definitions are given in the notes in Appendix 2. Motorcycles were not counted. Vehicles were recorded separately as travelling straight, or turning left or right out of the downstream end of the link. The unit of recording was one cycle. The surveyor recorded, to the nearest second, the start of green on the A41 in the 'towards London' direction, and then entered a symbol in the 'left', 'right' or 'straight' box on the form according to whether the vehicle was light (l), medium (m), heavy (h) or bus (b). At the start of the next green on the A41 the process was repeated on the next line of the form.

The instructions for the surveyors and the forms used are shown in Appendix 2.

2.5 Parking and Congestion Data Collection

It was the duty of one surveyor to collect information at each junction on four further items believed to be likely to influence travel times. These were whether or not any exit from the junction (left, straight or right) was, at any time during the green period on the A41, obstructed. Normally, this blocking was due to traffic backing up on the downstream link, or on the roads to left or right or, in the case of right-turners, to obstruction from the opposing traffic flow. The second item recorded was whether or not a queue of traffic remained at the stop-line when the lights went red for the A41 flow (this did not necessarily mean that the approach was saturated throughout the green period). The third item was the presence of parked vehicles, both upstream and downstream of the stop-line. Both the upstream and downstream link were divided into zones at 15m, 30m and 45m from the stop-line. These were marked by thick white tape either on the kerb or on a wall, railing or lamp-post, as appropriate to the site. The surveyor recorded (using clipboard, survey form, pencil and a watch), at the moment the lights on the A41 went red, the number and type of vehicles parked at that moment in each of the zones 0-15m, 15-30m, 30-45m and more than 45m, upstream and downstream on the 'towards London' side. These were recorded in the appropriate boxes on the form. Each line on the form related to a single cycle of the lights, and as with the traffic enumerators, the start of the green on the A41 was recorded to the nearest second, using a synchronised watch. The final item of data recorded by this surveyor was the occurrence and duration of any incident in or close to the junction, which could affect travel times, such as accidents, or the appearance of a road gang, or building works spreading onto the carriageway. Forms to record such incidents were issued to all congestion surveyors. Throughout a single cycle the sequence of actions of this surveyor was therefore as follows: record the start of green; keep continual watch throughout the green for blocking

Surveyors were instructed to be in position 15 minutes before the start of the survey (i.e. at 0715 am). At this time, the supervisor would be at the most northerly point to receive the prepared Psion Organisers (see below), and to give the appropriate equipment to the registration number surveyor at this point. He would then drive south (to be on the correct side of the road) and hand out the equipment to the three surveyors at each of the four 'downstream' ends of the links to be covered on that day. He would then drive along the section again just after the start of the survey period at 0730 to check that there were no absentees, recording personnel deployment on his supervisor's record form. After parking (not always easy) he would then spend most of the rest of the survey period visiting each location to check on the surveyor's work, ensuring that items were being correctly recorded, that form headings were complete and correct and perhaps standing in for a while for any surveyor who needed a short break (the drinking of coffee, tea, etc, before or during a survey was discouraged!). In the case of a single absentee, the supervisor would stand in until he had to leave at about 1015 to prepare for his end-of-survey duties. If more than one person was absent, it was up to the supervisor to re-deploy as necessary in such a way as to ensure that the registration number and traffic flow data was always collected and in the case of the congestion data, to cover those locations which experience had shown to have more blocking, queuing and parking.

Before the end of the survey period the supervisor collected his car, to be at the most northerly point at 1030. He would then collect the equipment from each location by driving down the route. Surveyors were instructed to wait where they were to have their data and equipment collected and, on Fridays to receive a slip and map showing next Monday's location, before going home. Before the next morning the supervisor had to ensure that all completed survey forms were headed properly and place them in labelled envelopes, ensure his own supervisor's record was complete, complete surveyors' time records, prepare for next morning (as described above), and telephone any absentees to ensure they were present next day, or find replacements.

The Psion Organiser presented a special problem as the information in their memories had to be downloaded to disk, via a microcomputer, after each survey period. An arrangement was made with the Transport Studies Group of University College London, situated about a mile or so from the southern end of the route. Under this arrangement a specified surveyor with a motorcycle was always allocated to the southernmost survey point. When the supervisor arrived after collecting all equipment at the end of the survey period, this person would take the Psions, carry them to University College, and wait until they had been downloaded, cleared, and set up with the survey codes (the header line in the Psion output field, see above) for the next survey day. The Psion internal clocks were known to be reliable, but were checked every second day and always on Fridays with the telephone clock and with each other, before being handed back to the surveyor. This was done by a research student at University College. The surveyor would then take the Psions and meet the supervisor at the most northerly point at 0715 the next morning

2.10 Personnel and Equipment

A main problem, particularly in the spring survey, was the difficulty in finding suitable survey personnel. Being term-time, students were generally not available and it was necessary to use Job Centres, companies supplying manpower, and surveyors attached to the local authorities in whose areas the surveys took place. The Job Centre personnel, with the exception of two, proved extremely unreliable and their use was discontinued. Three from the management company were used, and the rest came from local authorities. These latter two categories proved much more expensive than had been anticipated, and some of the local authority people in particular sometimes found it difficult to cope with surveys which were for them non-standard in their method. The loss of an experienced supervisor less than two weeks before the surveys began also meant that a far less experienced supervisor had to be used. In the summer, recruitment of students proved much easier, and the general quality was noticeably higher. With a longer list of applicants in the summer, problems of absenteeism (though they occurred) could often be countered by recruiting other people on the list at short notice. Had resources permitted, employment of 'spare' surveyors would have been desirable.

During the early stages of the spring surveys, difficulties were experienced with the Psion Organisers. These were; insufficient capacity in some cases of 'fast' surveyors, confusion in heavy (noisy) traffic as to whether a registration number had been entered or not (the 'beep' indicating entry could not be heard) and problems caused by accidental use of wrong keys. These problems were overcome by software modifications which packed data more tightly and efficiently into the machines, and which disabled all inessential keys on the machine's keyboard.

The early problems of personnel and equipment caused significant loss of data in the spring surveys, but this was less common in the summer.

Table 3 shows the number of observation periods for which complete data for travel times and all traffic variables were available. Note that the missing data in the spring consisted mostly of complete days, thus there should be no systematic bias such as would have resulted from consistently missing, for example the first and last half-hours of each day. An observation period consisted of 7 consecutive signal cycles (see Working Paper 279) and so its duration was not the same at each location.

3. Data Processing and Reduction

3.1 Travel Time Data

The registration plate data, principally from the Psion micro-computers, had been downloaded to disk at the end of each day's survey. After the survey was complete, this data was downloaded to the mainframe. Each file was checked to ensure it corresponded to the correct location and day, and edited. The

To produce travel times the registration numbers from all sources were matched using a Fortran program written specifically for this project, but based on matching software previously developed at the Institute for Transport Studies. The program allowed the definition of minimum and maximum travel times, outside which no matching would be attempted. These limits are discussed below.

In addition to matching, this program also carried out the adjustments to the data to accommodate the treatment of spurious matches (see below) and 'translated' the normal registration numbers in the tape recorded and manually recorded files into an all-letter format, to correspond to the Psions. This program produced two outputs. This first was a histogram of travel times, including all outliers. Statistics were also given on the cut-off point (defined below), number of observations, and for travel time the mean, standard deviation, coefficient of variation, skewness, kurtosis, minimum, lower decile, median, upper decile, and maximum. The second output was a file giving clock time (in seconds after midnight) of the matched vehicle at the downstream end, its travel time (secs), and the weight of each observation after treatment (described below) for spurious matches. This file was for subsequent use, in conjunction with the traffic flow data, in the investigation of the causes of travel time variability. This matching process was carried out for each link in the network, and for both seasons.

Matching rates varied according to the proficiency of the surveyors and according to location (on at least two links there are major flows turning out of and into the link thus reducing potential matches). Matching rates were generally in the range of one to four matches per minute. Matched vehicles by day and link are shown in Table 4 for the more complete summer data.

The differences in matching rates were due to varying skill of surveyors and to whether or not side turnings existed along the link. Links 6 and 10 both had major junctions on them (see Table 1) which accounts for their low matching proportions.

3.2 Traffic Flow and Traffic Congestion Data

A Fortran program was used to check the files of traffic flow and composition data, and the files of blocking, queueing and parking data, all of which had been manually transcribed from the survey forms to mainframe computer files. This checking consisted of ensuring that the time of start of the signal cycles increased throughout the file, that permitted and banned turns appeared as they should in their appropriate fields in the file, and that the coding of vehicle types was within the permitted range and in the correct fields. All errors indicated by this checking procedure were manually corrected in the files.

3.3 Combining the Travel Time and Traffic Data

When the checking procedures were complete, the travel time and traffic (flow and incident) data were combined into a form suitable for further analysis, using another Fortran program. For each link, the program required specification of all related

Spurious matching occurs from chance matching as a result of recording only partial registration numbers. Section 2.3 describes the procedure of recording only up to 4 items (number and year letter) of the registration number, to speed up data collection. The four-item sequence recorded is clearly not unique (for example D123 could represent D123ABC, D123WXY, etc) and so there is a possibility of chance matching, giving a travel-time value which is in reality non-existent. This is known as 'spurious matching' and if not taken account of, may cause some inaccuracy in analysis.

Unusual driver behaviour must also be taken into account. The data required for analysis is that from cars which have travelled along the link in question, with drivers employing their own driving style and choice of lane, but without stopping for non-traffic reasons and without detouring and rejoining the link. Cars taking longer than the time expected from the slowest driver in given traffic conditions can be expected to have stopped or detoured en route and should not be included in the travel-time analysis. However, travel times which are just possible with a slow driver could equally belong to a faster driver who has made a brief stop. In the former case the data is valid, but in the latter it is not. There is no perfect way of knowing whether or not such a value should be included, and so a sensible and objective procedure is needed to deal with this problem in a way which is consistent between different links and time-periods, to ensure that comparisons of travel-time distributions for different links and time periods remain valid. These unwanted values by their nature, exist in the right-hand tail of the distribution of travel-times and so are called 'outliers'. They distort by increasing values of central tendency and dispersion and by increasing positive skewness. Of particular importance in causing these distortions are outliers in the extreme right-hand tail, especially those beyond the body of the main distribution. Procedures for treating outliers have therefore been concerned with trimming the right-hand tail in a sensible and consistent way. May and Montgomery (1984) dealt with the outliers and spurious matched in a single procedure, by discarding all observations more extreme than two standard deviations either side of the median of the normalised distribution of travel times. The median was used in preference to the mean as its value is less dependent on extreme values of the distribution. Times thus removed from the left-hand tail were considered to be spurious matches, and those removed from the right-hand tail were a combination of spurious matches and outliers resulting from unusual driver behaviour. No attempt was made to remove spurious matches from the body of the distribution. However, since the present study is concerned with determining, amongst other statistics, the standard deviation of the distribution, it did not seem appropriate to use a technique which removed observations only from the tails of the distribution, and thus reduced the standard deviation, to some extent artificially. It was therefore decided to adopt a two-stage procedure for cleaning the travel time data: one stage involved the removal of spurious matches from the whole distribution and the other addressed the separate issue of removal of outliers from the right-hand tail.

matches outside these limits. However, the specification of such limits was by itself an insufficient and perhaps inconsistent method to remove outliers. Consequently, the range of travel times specified at this matching stage was large (as with May and Montgomery 1984) and served as a coarse first screening of extremely unlikely travel times.

The main procedure for dealing with the outliers followed. This was based on the assumption that the true outliers, on relatively short links such as those under study, would appear in a clearly-defined tail of the travel time distribution. So the first principle applied was that the outliers would be found after a clear gap in the distribution. However, to use the first observed gap as the cut-off point might cause distortions, as such a gap might occur in a bi-(or multi-)modal distribution and could for example be a function of the way in which traffic signals were operated and linked. To overcome this, it was considered that less than five per cent of the matched observations would be true outliers. The distribution was then searched beyond the 95 percentile value, for the first period of 30 seconds or greater in which no matched vehicles were recorded. The choice of 30 seconds incorporated consideration of the signal cycle lengths on the junctions on the route under study. This gap was taken as the 'cut-off' value above which all matched vehicles were considered to be outliers and so discarded from the analysis. It should be noted that the 95 percentile value was defined on the basis of the weighted observations, after the treatment of spurious matches, and not on the raw observations.

In this procedure, the choice of the 95 percentile and the 30 second gap were arbitrary but, being based on inspection of the distributions themselves, felt to be realistic and to provide a rational and consistent treatment over all links. The procedure was applied to the distribution of all weighted travel time data on a given link on a green day.

Figure 4 shows an example of the effect of applying the treatment for outliers to the matched travel time data.

4. Comments on the Surveys

Several issues arose as a result of the survey programme, both methodological and practical.

Of the data items collected, the presence of a queue remaining at the end of the green period in the survey direction was found not to be a useful variable. It had been considered to be an indication of the degree of saturation at the junction but was not satisfactory in this respect as observation suggested it gave no indication of whether or not saturation was continuous during the green period. It therefore served only as a rough approximation of the general level of congestion. Additionally, it proved to be difficult to define what 'queue remaining' meant - it was often not clear whether or not vehicles arriving at the stop-line just after the red period began were the end-part of an existing queue.

The tape recorded data was also used as a substitute for the data collected by the Psion Organisers, when link travel-time locations corresponded to end-to-end travel time locations. The tape-recorder problems described thus also caused some loss of link travel times. These experiences in the use of tape-recorders in the spring led to a decision not to collect end-to-end travel times in the summer survey.

In contrast to the experience with tape recorders, the use of the Psion Organisers to collect travel time data was successful, particularly after problems caused by the machines being filled with data early in the spring surveys had been resolved by software modifications. No problems were experienced in the methods used to record the traffic data, other than difficulty in deciding whether a queue remained.

Other general problems which arose included the difficulty experienced by the supervisor in moving, in congested peak conditions, between adjacent survey locations up to 900 metres apart, in order to check the surveyors' work and to identify and cover for absentees. A car was needed to distribute and collect equipment and to carry spare equipment, but movement by car, especially finding parking space near survey locations, was often very difficult. This might be overcome by using two supervisors, one with a car for collection and distribution, and another using a motorcycle for checking surveyors and for standing-in for absentees. Given the large survey area covered on a single day, short-wave radio contact between survey locations might be an advantage if carefully organised. Though additional allowance had been made for the difficulties associated with being based in a city other than the one in which the surveys were taking place, the establishment of a local base office, with easy access to photocopying and computing facilities during and some weeks before the survey period, would have helped to facilitate the survey pilots and organisation, and permitted easier checking of daily survey data as the surveys progressed.

Allowance had also been made for the time needed for data downloading, editing and cleaning, but these activities took longer than anticipated due to unexpected problems, including the difficulty of processing and cleaning the tape recorder files and the need for manual editing of the Psion files, in particular the removal of unwanted control characters.

In order to be of assistance in future similar work, some of the data handling activities which take a lot of time are described here. It should be pointed out that in many of these sufficient time had been budgeted in advance, based on previous experience, particularly during the Institutes work as data loggers (Bonsall et al 1988).

Although use of the Psion Organisers permitted direct downloading to a microcomputer without transcription, a single data file took up to 20 minutes to download. Further downloading from micro to the mainframe took a similar time. Each file also needed visual checking on the screen to ensure that header information was correct and complete, and had to be scrolled through to identify

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Figure 2: The A41 in its North London Context

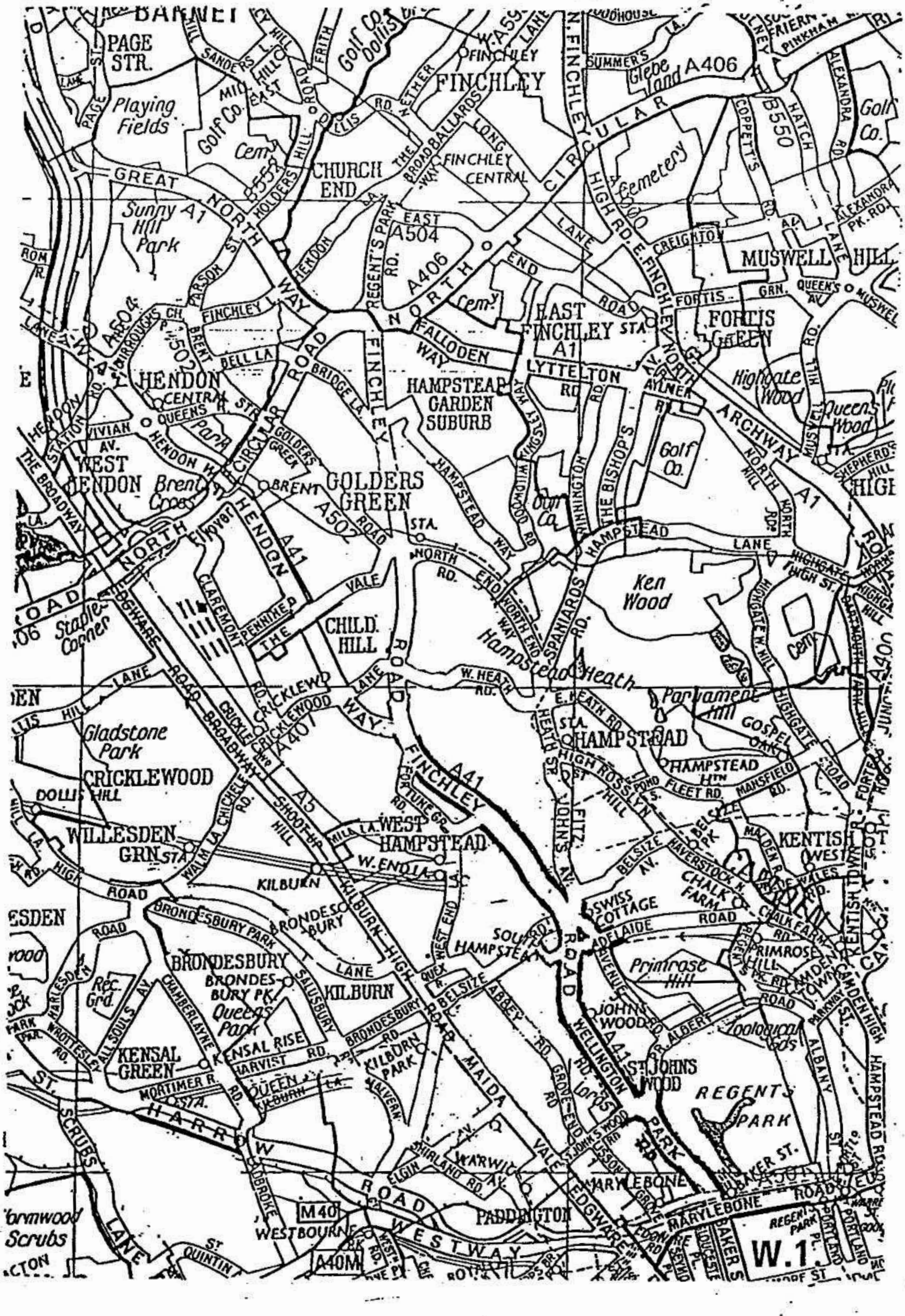

Figure 4 : Example of the removal of outliers
(Link 6 11th August 1987)

travel time (secs)

```
CUTOFF POINT=    126.000 secs
   0 :
   5 :
  10 :
  15 :
  20 :**
  25 :*****
  30 :*******************
  35 :*********************************
  40 :***************************************************
  45 :******************************
  50 :******************************
  55 :**************
  60 :*************************
  65 :******************************
  70 :*************************************************
  75 :*********************************
  80 :****************************
  85 :******************************
  90 :*********
  95 :*******
 100 :*****          <------------  95 percentile
 105 :*********
 110 :**
 115 :**
 120 :**
 125 :**
 130 :        <-------------------
 135 :                  cut-off point
 140 :
 145 :
 150 :
 155 :
 160 :
 165 :
 170 :
 175 :
 180 :
 185 :
 190 :
 195 :
 200 :
 205 :
 210 :
 215 :
 220 :
 225 :
 230 :
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 240 :
 245 :
 250 :
 255 :
 260 :
 265 :
 270 :
 275 :
 280 :**
 285 :
 290 :
 295 :**
 300 :
 305 :*
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