Monograph:
Montgomery, F.O. (1984) Accurate Travel Times Using Portable Tape Recordings. Working Paper. Institute of Transport Studies, University of Leeds , Leeds, UK.

Working Paper 171

Published paper
Montgomery, F.O. (1984) *Accurate Travel Times Using Portable Tape Recordings.* Institute of Transport Studies, University of Leeds, Working Paper 171

Working Paper 171

May 1984

ACCURATE TRAVEL TIMES USING PORTABLE TAPE RECORDERS

by

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Contents

ABSTRACT

F.O. MONTGOMERY (1984) Accurate travel times using portable tape recorders. Leeds: University of Leeds, Inst. Transp. Studs., WP 171 (unpublished)

This paper describes the development of a method for accurately recording the number plates and times of passing of a high sample of vehicles in heavy flow situations using low cost portable tape recorders. The method has been extensively tested and found to be better than existing methods in terms of timing accuracy, the sample size obtained, and ease of transcription.

A similar method has been developed for recording data from moving observer surveys, enabling the job to be carried out by only one observer with consequent savings in survey costs.

ACCURATE TRAVEL TIMES USING PORTABLE TAPE RECORDERS

1. Introduction

There are many applications in traffic analysis where vehicle registration number plates are used, some examples being parking, origin-destination, and travel time studies. Traditionally, number plates have been recorded by the 'pencil and clip board' method, with the observers recording all or part of the number plate and its associated time. (Sometimes the time has been recorded to the second, sometimes only to the nearest minute or even to the nearest quarter hour.)

Often however, especially with O-D and travel time surveys, it is very difficult or impossible to record all the number plates of interest, hence many practitioners have resorted to using portable tape recorders as a means of enabling the observers to collect more data more easily.

Several variants of the tape recorder method have been reported but many of these do not utilise the fact that the tape is moving at a fairly constant speed, and those which do require rather difficult transcription procedures. In Section 3 the existing methods of using portable tape recorders will be briefly described, followed by a full description of the method developed by the author at ITS. Firstly however it may be useful to describe the circumstances which led to the development of the method.

2. Background

The development of the method described in this note was prompted by a study of the effects of rescheduling work journeys in Wakefield (May, Montgomery and Wheatley, 1980). In this study we were looking at the distribution of travel times over small (15 minute) periods in the morning peak. In order to obtain results which would be statistically useful, it was therefore necessary to have sufficient numbers of matches in each period, and that the times of the matched vehicles should be as accurate as possible.

The basic method developed in the Wakefield study was refined in a later study of travel time monitoring for urban radials (May and Montgomery, 1983), the refinements pertaining mainly to the data collection and statistical analysis stages of the process. The method described here is as used in the latter study.

3. Review of Existing Methods

3.1 Recording of number plates

Number plates can be recorded either in full or in part. The consequences of recording only part of the plate (usually the 3 numbers and the year letter) in terms of spurious matches are described in another note (Montgomery and Fowkes, 1983) where also is given an indication of error rates likely to be made by observers and transcribers. One of the most effective ways of cutting down on transcription errors is to train observers to use the International Civil Aviation Authority phonetic alphabet (Alpha, Bravo, etc.), a copy of which is included in the appendix.

3.2 Recording of time

It is in the recording of timing information that the various methods most differ.

In the simplest method the time is spoken on to the tape at one minute or thirty-second intervals and when the tape is transcribed the number plates are grouped according to which minute or half minute period they belong. This method uses the tape recorder in exactly the same way as a clip-board, and although it does enable a greater number of plates to be recorded, does not lead to any improvement in the accuracy of their times of passing.

In a second method an easily identifiable sound (such as an electronic bleep, or the observer saying "start") is made on all the tapes being used on the survey, at a preset time. A similar sound is recorded towards the end of the tape. During the transcription process the tape is played back and a stopwatch started when the first sound is heard. The transcriber then attempts to enter the spoken number plate and its stop watch time for each vehicle, without stopping until the second sound is heard. At the second sound the stop watch is stopped and its elapsed time recorded. It is thus possible to calculate the actual time of passing of each vehicle by adding the preset start time to the stopwatch time. Any differences in running speeds of the portable vs the transcription recorder are corrected by reference to the difference in preset elapsed time and stop-watch time. This method can therefore enable accurate times of passing of vehicles to be obtained, but its main drawback is that the tape must be transcribed without stopping. This requires the use of a very skilled typist, but even with the best typist, will lead to numerous mistakes through fatigue, inattention, etc.

A third method is similar to the above, except that no correction is made for possible differences in running speeds of the two tape recorders. This is an unreasonable assumption to make as a difference of only 0.5% in running speed (which will not be noticed by most ears) leads to a loss/gain of 13.5 seconds in a 45 minute tape.

A fourth method involves recording the number plate and time of passing of each vehicle. While accurate, this method can only deal with low flows. For higher flows it would be necessary to take a stratified sample of the flow (e.g. white cars only). This method suffers from the extra disadvantage that the observer must constantly alternate his viewpoint from timepiece to vehicle stream, which makes it more likely that vehicles will be missed, and also leads to headaches over a prolonged period.

4. The Leeds Method in Brief

In the method developed at Leeds, the observer records the time of day (in hours, minutes and seconds) at the start of the tape, just before its end, and at approximately five-minute intervals along its length. When the tape is replayed in the office, a higher quality tape deck is used, the main requirement of which is a stable revolution counter. As the tape is replayed, each number plate is entered on a computer file via a VDU, along with its associated tape rev counter position. As timing benchmarks are encountered, they are noted on a sheet of paper along with their tape rev counter positions, and at the end of the tape the benchmark details are added to the beginning of the file.

The file thus produced is then input to a program which fits a curve through the timing benchmarks and then interpolates a time for each number plate.

5. Data Collection

The timing benchmarks do not have to be at specific times of day or at fixed intervals, hence there is no need for the observer to constantly be taking his eyes off the road to check his watch. The method has been carried out so far at 21 different locations with flows up to 2200 veh/hr and it has always been possible to record the timing information during gaps in the traffic flow. The advantage of this is that the observer can keep his eyes on the traffic stream see (Fig. 1) thus increasing the sample rate and reducing reading errors; the latter being more likely when the eyes are constantly having to change focus from near (the watch) to distant (the vehicles).

As far as timing information is concerned, it is obviously vitally important that all observers on a given survey have their watches synchronised to the second. This is quite feasible using digital watches, which should be set the day before and checked during the survey day. It is important that the digital display should show hours, minutes and seconds together continuously, avoiding the need to press buttons for seconds etc. It has been found best to use the simplest digital watches (e.g. Casio F 10) rather than the more complicated multi-function type as the latter can easily be accidentally put into a mode other than the desired one.

In the method as used at Leeds, it was attempted to record the number plates of all vehicles, and these were classified into the three groups car, bus and lorry. When flows became too high to record everything, observers were instructed to obtain all buses and lorries but to concentrate on light-coloured cars. (The choice of colour is immaterial as long as all observers are given the same instructions.)

It was also desired to obtain flows at each observation point, and to this end vehicles whose number plate could not be obtained were recorded as "miss" followed by the classification if appropriate. Thus a typical section of recording would be as follows:

> "The time is seven twenty three and forty seconds ... Now! ... four two one Sierra, five three Tango, six five seven Whisky, miss, one five one Victor Lorry, three seven five November Bus, eight one X-Ray, ..."

The above demonstrates the use of the ICAO phonetic alphabet as in Appendix A. It is essential to use a system such as this when using tape recorders, as otherwise it is almost impossible to distinguish between M and N or between B, D, G, P, T, V, especially against the background noise of traffic.

As already stated, only the three numbers and the year letter were recorded. Recording the full seven digit plate was tested at one stage but found to be too difficult (using the ICAO alphabet) even in light flows.

Reports from the staff employed on number plate observation suggest that the maximum reasonable time to expect any one observer to work continuously is two hours.

6. Transcription

It has been found that the best set-up to minimise transcription time and coding errors is that illustrated in Fig. 2 (photo) where the transcriber listens to the tape and simultaneously enters the data via a VDU terminal to a computer file. If a mainframe computer is being used for data entry this may cause problems with connect time rations as transcription time is usually of the order of 3 hours per hour of tape.

Other possibilities are: (a) to transcribe initially on to sheets and enter via the terminal later; (b) to transcribe on to a microcomputer, store on floppy disk and dump to the mainframe.

(a) is not recommended because the extra process of writing then reading off sheets introduces an extra source of error. (b) has not been tested so far but seems to be a sensible solution.

One of the main advantages of the system is that the transcriber is free to stop, start and rewind the tape. To this end it is essential that the tape deck has a stable rev counter i.e. no matter how often the tape is played, stopped, rewound or played fast forward, the counter should read the same for a given tape position. This stability depends mainly on the tightness of the drive belt from the take up reel to the counter and bears little relationship to the cost of the machine so that it is recommended that potential machines be tested before purchase.

During times of high flow the transcriber will not be able to enter all the number plates continuously but rather will play back one number at a time using the pause key. It is very useful therefore if the machine has a standard pause key which can be used to stop and start the tape.

The transcriber's work is made easier if the VDU has a numeric key pad to the right of the main keyboard rather than simply a row of number 0-9 along the top.

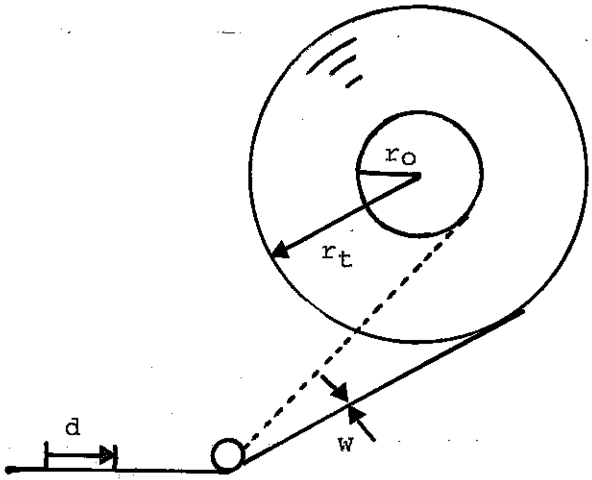
Once again a reasonable maximum continuous spell for transcription is probably about two hours.

7. Calibration

Before describing the program which performs the calibration, the mechanics behind the process will be briefly described.

The rev counter is normally connected via a belt-drive to the take-up reel of the tape, hence the counter value is linearly related to the number of revolutions of the take-up reel. But if the tape passes through the playback head at a constant speed, as in Fig. 3, the rotational speed of the take-up reel will vary depending on the amount of tape on the reel.

Fig. 3



d = distance moved by tape in 1 sec

w = tape thickness

r_o = radius of take-up spool

r_t = outside radius of tape at time t

n_t = no of thicknesses of tape on reel at time t.

Now one revolution of the reel at time t uses $2\pi\, r_t$ of tape

$$= 2\pi\,(r_o + w\,n)$$

Therefore if the tape is moving at d units/sec ., one revolution of the reel at time t takes $2\pi\,(r_o + w\,n)/d$ secs.

Therefore the time passed at the end of N revolutions

$$= \sum_{n=1}^{N} 2\pi(r_o + w\,n)/d$$

$$= \pi\, w\, N^2/d + \pi N(2r_o + w)/d$$

$$= a\,N^2 + b\,N \text{ where } a = \pi\, w/d$$

$$\text{and } b = \pi\,(2\,r_o + w)/d$$

Therefore actual time of day = $a\,N^2 + b\,N + c$

where c = time of day when N = 0

i.e. Time of day is a quadratic function of the rev counter value.

A FORTRAN program (MATCH1) has been written by the author to fit a quadratic curve through the timing benchmarks, interpolate a time for each number plate, and perform several checks on the data.

The program is run once for each side of tape, the input consisting of header information (survey date and location identification), timing benchmarks information (time of day in HH MM SS and counter values), and number plate information (number plates and counter values, 8 per line).

The program uses NAG subroutine E02ADF to fit a second power Chebyshev polynomial to the benchmark points by least squares. The residual error for each benchmark is then calculated, and if any residual is greater than $\pm$ 6 seconds an error is reported. The fitted curve is then used to estimate a time for each number plate. Data checks include the following:

1) All benchmark times and counter values must be monotonically increasing.
2) All number plate counter values must be monotonically non-decreasing.
3) First benchmark counter must not be greater than first number plate counter.
4) Last benchmark counter must not be less than last number plate counter.
5) Year letter must be within the range of values valid at the time of the survey.
6) Vehicle type code must be blank (car) L (lorry) or B (bus).
7) Maximum number of missed vehicles at one time.

Errors 1, 3 or 4 are fatal, causing the program to stop, but for errors 3 and 4 the program calculates a pseudo-benchmark for the user to insert in place of the missing one.

All other errors cause messages to be printed on the output file, and the next program in the suite (MATCH2) will not run until all errors have been removed from the file.

Program MATCH2 reads the output of several runs of MATCH1 (usually four files for the upstream point and four for the downstream point - one file per side of tape). This program checks the headings of each file to ensure they are all from the same location, checks times are monotonically non-decreasing (i.e. that the order of the files is correct) then produces four output files. The first one lists the total flows and number plates recorded by vehicle type, and the other three contain the number plates and time data in the format suitable for direct input to a standard matching program.

8. Matching

Any suitable matching program can be used, such as NOPCOP (TRRL, 1982) which was used on the travel time monitoring study (May and Montgomery, 1983) with TRRL's permission.

Some matching programs (including NOPCOP) contain the option of allowing 'near matches' (typically allowing 3 digits out of the 4 and transpositions). It is strongly recommended that this option should never be used. This is because of the effect of spurious matches (i.e. a 'match' between two different cars having the same last 4 digits).

If the data is being used to obtain O-D flows or travel time distributions then a correction can be made for spurious matches (Montgomery and Fowkes, 1983) but this correction process is confounded if near matches are allowed.

9. Travel Time Statistics

Most matching programs will output the mean and standard deviation of travel times, grouped by sub periods of the survey. Unfortunately spurious matches (and other effects such as vehicles stopping on route) have a disproportionately large effect on these two statistics, to such an extent that we would suggest that no faith should be put in them as they are reported by the programs. Elsewhere (May and Montgomery, 1983) we have described a robust method for removing outliers which consists of calculating the median and interquartile range for each time period of interest, estimating the standard deviation assuming that the logs of travel times are normally distributed, and dropping all matches with travel times greater than $\pm$ 3 standard deviations from the appropriate median.

This procedure is easily accomplished using the SAS package (SAS, 1982).

10. Program Validation

At an early stage in the development of the method, it was thought interesting to check whether the extra accuracy obtained by putting a curve through the benchmarks was worthwhile, or whether straight-line interpolation would be sufficient. The difference between the two depends on the degree of curvature, and the distance of the estimated point from the benchmarks either side. For a typical benchmark interval of eight minutes it can easily be shown that the maximum error due to straight line interpolation is approximately 16 seconds near the start of the tape. This was considered too large for our purposes.

During the Leeds travel time monitoring study, the number plate matching method was carried out in parallel with moving observer surveys. The moving observers recorded on paper forms their times of passing various timing points on the route, including the two points where the number plate observers were stationed. It was thus possible to compare the times recorded by the two methods for those occasions where the survey car was noted. Table 1 shows the results of this comparison.

A further comparison was available using the results collected on Kirkstall Road, Leeds on 18th June 1982. On this day two observers were stationed at each number plate station, one collecting data by tape recorder in the way as described, the other collecting the number plates and times of passing of white cars only, by writing down on paper forms. (For a comparison of these methods in terms of reading/transcription/coding errors see Montgomery and Fowkes, (1983.)) For the 119 number plates which were recorded correctly by both methods, the mean difference in recorded passing time was 1.2 seconds, with a standard deviation of 3.7 seconds. The latter comparison shows better agreement than the former, where a few of the results are quite far out. This is most likely due to a) errors by the moving observer, either misreading the watch or mislocating the timing point, b) the number plate observer noting the survey car before it crosses the timing point. This last error can be quite high if the timing point is a traffic signal stopline.

Table 1 Comparison of some times of passing of moving observer survey cars.

Date	Location	MVO Time*	NPM Time*	Difference
11.5.82	Otley Road	26121	26122	-1
	outer point	28773	28780	-7
		29158	29156	2
		29942	29938	4
		30644	30620	24
		31610	31607	3
		32336	32335	1
		33035	33028	7
		34270	34268	2
11.5.82	Otley Road	29940	29913	27
	inner point	30908	30906	2
27.5.82	Otley Road	26560	26542	18
	inner point	27334	27330	4
		28227	28263	-36
		28795	28789	6
18.6.82	Kirkstall Rd	27309	27313	-4
	outer point	28411	28407	4
		29100	29103	-3
		29572	29571	1
		30496	30492	4
		31910	31907	3
		34216	34217	-1

* Times are in seconds after midnight.

11. Other Applications

During pilot surveys of the moving vehicle observer method (Wardrop and Charlesworth, 1954) it was found impossible when travelling "against the flow", for one observer to note the times of passing the timing points and also make a classified count of vehicles travelling "with the flow". The main source of difficulty was signal controlled junctions, where the observer had to attempt to read his watch as he passed the stopline, write down the time, then count and write down the opposing flow which would often be queued at the lights in two or three lanes. Even the use of tally counters did not ease the task by much because the main problem was in trying to do too many things at once with one pair of eyes. It was therefore decided to try the use of tape recorders, in much the same way as already described for number plates. This innovation proved very successful and was used for all subsequent moving observer surveys in the Leeds study as follows.

The tape recorder was started a few seconds before each "against flow" run, and a timing benchmark entered. A further benchmark was entered at a convenient gap in the traffic roughly midway along the run, and a final one immediately after the end of the run, before switching off the recorder during the with-flow phase. During the "against flow" run, the observer noted when timing points were passed by naming them, e.g. "North Lane now". The flow of vehicles in the opposing direction was recorded in groups as the vehicles were met, thus "seven cars, bus, four cars, lorry, ten cars, ...".

These tapes were transcribed onto forms, and unlike the number plate data, usually required only one pass through (i.e. approximately 1 hour transcription per hour of recording).

It would have been possible to calibrate each run separately, as only three benchmarks are required to fit a second power function, however this would have made the detection of errors in the benchmarks almost impossible, and instead a program MOUT2 was written to calibrate all the runs on one side of a tape together. This program fits one stepped curve through all the benchmarks, and can therefore detect outlier benchmarks (usually due to miscoding) and cater for cases where the observer has only given two benchmarks (or even only one in isolated instances).

The program has been used successfully on the 1018 moving observer runs of the Leeds travel time monitoring study.

12. Summary and Conclusions

This note has described the development of a method for accurately recording the number plates and times of passing of a high sample of vehicles in heavy flow situations using low cost equipment.

The method has been extensively tested and found to be better than existing methods in terms of timing accuracy, the sample size obtained, and ease of transcription.

A similar method has been developed for recording data from moving observer surveys, enabling the job to be carried out by only one observer with consequent savings in survey costs.

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APPENDIX A

INTERNATIONAL CIVIL AVIATION ORGANISATION ALPHABET

Alpha
Bravo
Charlie
Delta
Echo
Foxtrot
Golf
Hotel
India
Juliet
Kilo
Lima
Mike
November
Oscar
Papa
Quebec
Romeo
Sierra
Tango
Uniform
Victor
Whisky
Xray
Yankee
Zulu

TN/FOM
FOM/plh
22 12 83