MEASURING JOURNEY SPEEDS AND FLOWS

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The paper sets out to compare three methods of measuring journey speeds and flows. The methods studied are license matching, moving observer, and arrival output. In particular, the results obtained from the moving-observer and arrival-output methods were compared directly with those obtained from the license-matching method, which was taken as the standard method. Observations were taken simultaneously for each of the three methods at five locations. The locations chosen covered highways in urban, suburban, and rural areas and involved highways of varying design standards. A statistical analysis of the results showed that the arrival-output method, which is seldom if ever used, gives far more consistent and accurate results than the more conventional moving-observer method. Moreover, the arrival-output method can measure variations in flow over relatively short time intervals in addition to the usual hourly flows. The paper also shows that the moving-observer method and the arrival-output method involve almost identical cost, whereas the license-matching method is considerably more expensive. It concludes that there is no logical reason why the simple arrival-output method should not be used in preference to the moving-observer method.

•QUANTITATIVE information about road traffic is necessary in order to deal with problems of traffic congestion. For example, vehicle speeds and flows should be known so that an economic assessment of road improvement schemes can be made. Methods must therefore be available whereby these speeds and flows can be determined quickly and accurately on various types of roads for different traffic flow conditions.

The object of this paper is to examine in some detail the relative merits of three methods of measuring journey times (and hence speeds) and volumes over a given length of road. The three methods considered are the (standard) license-matching method, the moving-observer method, and the arrival-output method.

In particular, the paper is concerned with the effectiveness of the arrival-output method, which, as far as the authors are aware, has not previously been compared with the more conventional license-matching and moving-observer methods.

TEST SITES

Four sections of road were chosen for the study so that information could be collected and a comparison made of roads of varying lengths and types. The sites chosen were as follows:

1. City center route—part of the Headrow in the center of Leeds and 330 m in length (Fig. 1a);
2. Radial route—a section of Meanwood Road, Leeds, a little more than 1.5 km in length (Fig. 1b);
3. Ring road route—part of the Leeds Ring Road, 1.41 km in length (Fig. 1c); and
4. Rural route—a section of the M1 motorway from intersection 41 to intersection 43 (at the time of the study, intersection 42 was not open) (Fig. 1d).

MEASUREMENT METHODS

License-Matching Method

Table 1 gives the reported number of license matchings (as recommended by Sawhill and Berry) that have to be made on various types of facilities in order that the mean journey time and speed can be determined with an error of less than 5 percent with a 95 percent degree of confidence.

Because the heavy volumes of traffic at all sites in this study made it impracticable to record all licence numbers, samples were instead selected in accordance with the requirements given in Table 1. To be truly representative, a sample has to be distributed systematically throughout the periods of observation, during which time there is little change in traffic volumes. In this study, the method selected to ensure a systematic distribution was to record all vehicles whose registration number ended with an even digit.

Moving-Observer Method

Flows and speeds are obtained from the following formulas, which were derived by Wardrop and Charlesworth (2):

$$q = \frac{x + y}{t_w + t_a}$$

and

$$t = t_w - \frac{y}{q}$$

where

- q = flow in vehicles per unit time,
- t = mean journey time,
- x = number of vehicles met in the section when observer is traveling against the stream,
- y = number of vehicles that overtake the observer minus the number of vehicles that he overtakes when traveling with the stream,
- t_w = journey time of the observer when traveling with the stream, and
- t_a = journey time of the observer when traveling against the stream.

The mean journey time and, hence, the mean journey speed were first determined for each run of the test car; the overall mean journey speed was then determined.

Arrival-Output Method

This method of gathering speed-flow data is not at all well-known and so will be described here in some detail. It is somewhat similar to the moving-observer method in that a test car carrying an observer with a stopwatch is fed into the stream of traffic; roadside observers with stopwatches are also posted at the start and finish of the test section. The observers with stopwatches are also posted at the start and finish of the test section. The observer in the test car, observer A, records the time taken for the test car to cover the test section. Meanwhile, when the test vehicle enters the test section, the first roadside observer, observer B (Fig. 2), proceeds to count the number of vehicles that pass the starting point during each successive, say, 1-min interval. Immediately after the test vehicle passes the finishing point, the second roadside observer, observer C, proceeds to count the number of vehicles passing that point in each successive 1-min interval.

When the test vehicle has completed the test section, it makes its way back to the starting point. As it passes the beginning of the test section for the second time, traveling in the same direction as for the first run, observer B completes his first run

Figure 1. Test sites: (a) central city route, (b) radial route, (c) ring road route, and (d) rural route.

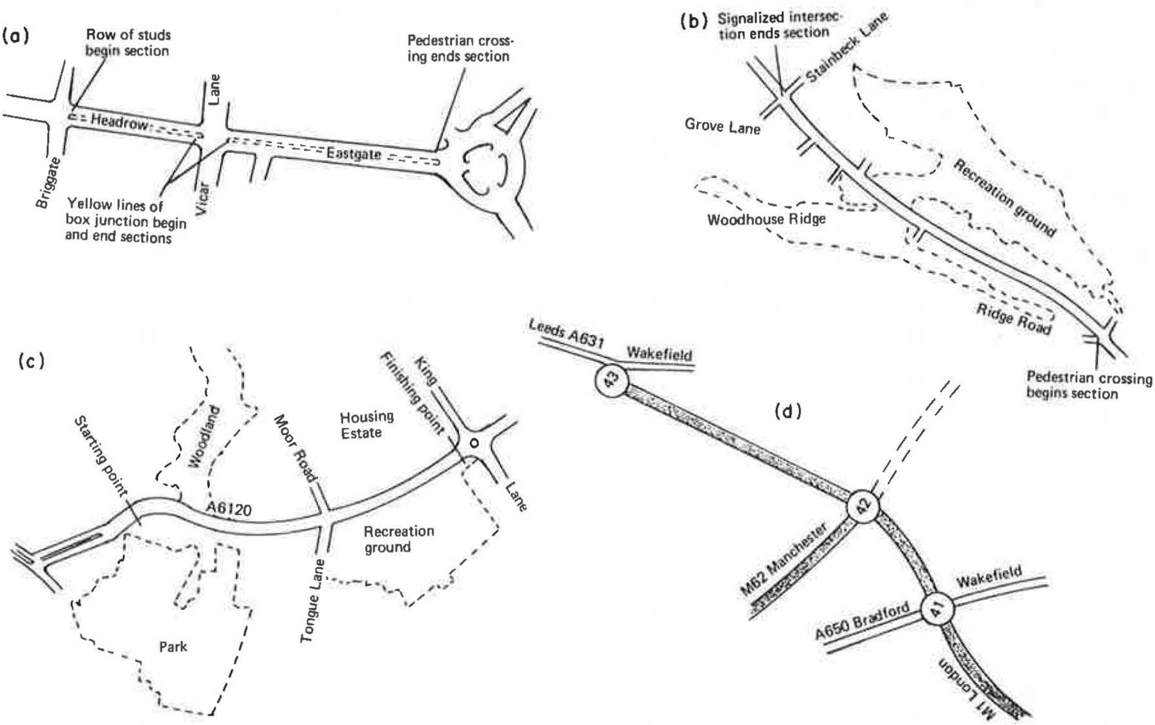
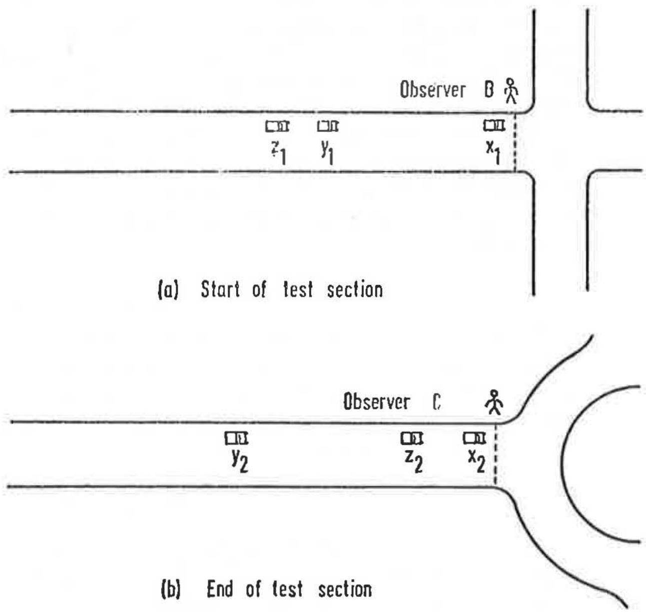


Table 1. Number of license matchings required for various facility types (1).

Location	Type of Facility	Number of Matchings Required
Urban	Signalized, two lane, uncongested	32
	Signalized, two lane, congested	36
	Multilane, uncongested	80
	Multilane, congested	102
Rural	Two lane, up to 1,130 vph	25
	Two lane, up to 1,440 vph	41
	Four lane, uncongested	30

Figure 2. Positioning of cars and observers for moving-observer method.



measurements and proceeds to record data for the second run. Observer A simply records the time taken for each test run, i.e., the time taken for the test vehicle to travel from the starting point to the finishing point of the test section. This he does for each run of the test vehicle. This procedure is repeated until the required number of runs has been completed.

The theory behind the method is as follows. Assume that x is the test vehicle and y and z are two following vehicles and that x_1, y_1, and z_1 in Figure 2a are their relative positions as they pass observer B and x_2, y_2, and z_2 are their positions as they pass observer C (Fig. 2b). Let ty_1 and tz_1 be the headway between the time that the test vehicle crosses the starting point and the time that vehicles y and z cross the same point. Similarly, ty_2 and tz_2 are the corresponding headway times at the finishing point. Let T be the time taken for the test vehicle to cover the test section. Then the time taken for y to cover the test section is $T + ty_2 - ty_1$ and the time taken for z to cover the test section is $T + tz_2 - tz_1$. Therefore, the mean time taken by y and z is $\frac{1}{2}(T + ty_2 - ty_1 + T + tz_2 - tz_1)$.

This may be extended to show that, when there is a continuous stream of n vehicles following the test vehicle, the mean time (T_s) for them to cover the test section is given by

$$T_s = T + \frac{1}{n}\Sigma\, t_2 - \frac{1}{n}\Sigma\, t_1$$

Timing every individual vehicle as it passed the roadside observers would be a very difficult operation, particularly when the traffic flow was heavy. Hence, vehicles are considered in groups that pass the observers in each successive 1-min time interval after the test vehicle. The distribution of these vehicles through the 1-min interval is assumed to be uniform, and hence they are all assumed to pass the observer midway through the 1-min time interval, i.e., the first group of vehicles is assumed to be 30 sec behind the test vehicle, the second group 1.5 min behind the test vehicle, and so on.

If a shorter time interval is chosen for recording the following vehicles, then it is reasonable to assume that more accurate results would be obtained. It would, however, lead to more work in the field and also to more computation in the office. A time interval of 1 min was chosen arbitrarily for this particular study and was found to give satisfactory results. Where there are moderate to heavy flows of traffic, the rate of flow over a short time period will tend to become more constant and any errors introduced will be of a compensating nature.

The mean journey time for the traffic stream is then determined, and, from this, the mean journey speed is easily calculated. In addition to this information, flows and variations in flows over the test period may be determined, inasmuch as the roadside observers are recording the numbers of vehicles passing them during the short time intervals.

DATA COLLECTED

In this study, data were collected simultaneously by each of the three methods to enable a direct comparison of vehicle speeds. In fact, the same test vehicle and test runs were used to gather the moving-observer and arrival-output data, and separate sets of results were recorded for the license-matching method to coincide with each run of the test vehicle.

DISCUSSION OF TESTS

If the license-matching speeds are considered as "standards" (they meet the statistical requirements specified in Table 1), it is interesting to compare them with the speeds determined by the moving-observer and arrival-output methods.

Accuracy

The mean speeds given in Tables 2 and 3 indicate that there is relatively little difference between the values obtained by the three methods. The arrival-output method gives slightly better results than the moving-observer method, the averages of the differences between the mean speeds obtained from the license-matching method and the moving-observer and arrival-output methods being 2.22 km/h and 1.83 km/h respectively.

There is, however, a much more significant difference between the two sets of results when the individual runs are considered.

Data given in Table 4 show that there is a great reduction in the standard deviations of the differences between the speeds obtained from the individual runs on the license-matching and arrival-output methods as compared with those obtained by considering the license-matching and moving-observer methods.

It is possible to apply an "F-test" to these results and to determine the level of significance of the difference between the two sets of results. The results of the F-test, given in Table 5, show quite clearly that the arrival-output method gives results that are far more consistent than those from the moving-observer method.

Costs

A comparison was also made of the costs incurred in gathering the data by each of the three methods. It was found that the collection and analysis of data from the moving-observer and arrival-output methods involved almost exactly the same amount of work and the same cost.

In contrast, the license-matching method was more than twice as expensive in terms of man-hours of work to gather and analyze the data. It should be noted that this latter method only provides information about journey times and vehicle speeds, whereas the arrival-output and moving-observer methods can also be used to provide information about flows.

Each of the methods investigated measured journey times and vehicle speeds in one direction only. If speeds had been required in both directions on a particular stretch of road, the license-matching method necessarily would have involved a second completely independent survey. The moving-observer method would have required one extra observer in the test vehicle, and the arrival-output method would have required two extra roadside observers. Hence it is clear that, where vehicle speeds are required in both directions, the moving-observer and arrival-output methods involve only a relatively small increase in cost to obtain the information in the field, whereas the cost of collecting the same information using the license-matching method would be doubled.

SOME OTHER COMPARISONS

The arrival-output and moving-observer methods each facilitate measurement of flows as well as mean vehicle speeds. The moving-observer method, however, only gives a series of "spot" flows measured for the duration of each individual run. In the arrival-output method, the number of vehicles passing the roadside observers in successive short intervals of time is recorded; hence, not only is it possible to get a more accurate value of the mean flow over the period of the survey, but also any fluctuations that occur in that flow may be detected.

In a recent paper evaluating the moving-observer method of measuring traffic speeds and flows (3), it was concluded that the method was sensitive to minute-by-minute variations in the traffic stream. It was suggested that these variations would need to be overcome by increasing the length of the test run or by utilizing a greater number of test runs or both. In contrast, not only is the arrival-output method independent on the minute-by-minute variations in the traffic stream, but also it actually detects and measures them.

It was also concluded (3) that, where traffic volumes were low, the number of test runs required by the moving-observer method in order to achieve a given degree of accuracy might be so great as to render the method uneconomical and impractical to use. This is not the case with the arrival-output method: The time-intervals into which observed vehicles are classified need only be reduced in order to maintain the required degree of accuracy. If the volumes are exceptionally low, e.g., less than

Table 2. Speeds, in km/h, on the central city route.

Run No.	Briggate to Vicar Lane Moving-Observer	Arrival-Output	License-Matching*	Vicar Lane to Eastgate Roundabout Moving-Observer	Arrival-Output	License-Matching*	Briggate to Eastgate Roundabout Moving-Observer	Arrival-Output	License-Matching*
1	16.09	15.08	16.87 (40)	21.28	27.00	26.70 (36)	17.38	18.12	19.83 (36)
2	—	12.07	15.56 (44)	13.79	18.97	24.46 (45)	7.56	15.06	18.51 (38)
3	8.01	12.38	14.85 (54)	9.64	17.56	18.96 (50)	9.29	15.26	16.90 (39)
4	7.44	7.10	10.91 (38)	27.00	25.07	26.04 (43)	13.60	12.76	13.20 (39)
5	10.36	13.41	13.55 (63)	26.20	19.51	25.83 (79)	16.77	17.12	17.40 (55)
6	11.02	10.06	11.54 (68)	29.02	8.16	12.42 (92)	17.98	8.63	13.24 (66)
7	7.68	7.10	9.72 (85)	4.02	5.94	7.31 (99)	5.17	6.65	8.14 (55)
Mean	10.10	11.03	13.29	18.71	17.46	20.25	12.54	13.37	15.32

*Figures in parentheses refer to the number of license matchings made on that particular run.

Table 3. Speeds, in km/h, on radial, ring road, and motorway routes.

Run No.	Radial Route Moving-Observer	Arrival-Output	License-Matching*	Ring Road Route Moving-Observer	Arrival-Output	License-Matching*	Motorway Route Moving-Observer	Arrival-Output	License-Matching*
1	36.39	44.56	43.76 (40)	71.39	73.47	69.77 (23)	94.18	94.65	89.72 (44)
2	45.27	47.12	45.67 (45)	73.47	68.49	69.39 (21)	74.67	88.10	89.80 (30)
3	49.99	43.89	43.05 (67)	59.63	64.99	69.72 (23)	86.12	81.35	87.64 (38)
4	49.55	42.58	45.03 (48)	63.36	73.47	72.34 (24)	102.79	84.22	92.26 (38)
5	54.75	40.20	42.91 (41)	74.54	81.75	75.83 (19)	92.36	96.56	99.47 (36)
6	35.26	43.39	46.35 (43)	74.54	56.33	56.81 (45)	93.71	93.71	100.76 (35)
7	43.55	49.55	48.46 (43)	42.60	60.35	61.86 (35)	95.56	91.48	99.88 (30)
8	48.71	50.42	47.48 (39)	61.81	57.60	55.65 (47)			
9				75.08	58.26	57.32 (30)			
10				74.54	59.63	58.02 (38)			
11				69.44	80.47	75.22 (27)			
12				74.54	55.70	53.17 (29)			
Mean	45.43	45.21	45.34	67.91	65.88	64.59	91.34	90.01	94.22

*Figures in parentheses refer to the number of license matchings for that particular run.

Table 4. Standard deviations of the differences between speeds obtained on individual runs.

Site	License-Matching Versus Arrival-Output Method (km/h)	License-Matching Versus Moving-Observer Method (km/h)
Central city (Briggate-Vicar Lane)	1.24	2.32
Central city (Vicar Lane-Eastgate)	2.54	9.14
Central city (Briggate-Eastgate)	1.58	5.20
Radial route (Meanwood Road)	2.27	7.68
Ring road route (A6120)	3.04	12.89
Motorway route (M1)	4.76	8.40

Table 5. Results of F-test evaluation of arrival-output and moving-observer methods.

Site	Location	F-Test (percent)
Central city	Briggate to Vicar Lane	90.0
Central city	Vicar Lane to Eastgate	99.5
Central city	Briggate to Eastgate	99.0
Radial route	Meanwood Road	99.5
Ring road route	A6120	99.9
Motorway route	M1	90.0

about 100 vph in a given direction of travel, the actual times of individual vehicles behind the test vehicle may be recorded (rather than the numbers passing in a given time interval).

A final conclusion (3) was that the moving-observer method was best suited to medium and heavy traffic volumes, in which case the number of test runs required to achieve a given degree of accuracy can be relatively small. The tests described here suggest, however, that, even under such traffic conditions, the results obtained from the arrival-output method are far more consistent than those from the moving-observer method, and, hence, even fewer runs of the test vehicle are required to give the same degree of accuracy.

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