TECHNIQUES FOR MEASURING OVER-ALL SPEEDS IN URBAN AREAS

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SYNOPSIS

This report describes the results of studies made to evaluate floating car methods of making speed and delay surveys. The work was done as a part of the research program of the Committee on Operating Speeds in Urban Areas of the Department of Traffic and Operations, Highway Research Board.

Test courses were established on three important signalized streets in Oakland, San Francisco, and Los Angeles. The principal variable was the driving technique of the drivers of the test cars. Travel times of test runs were compared to the average travel time of all cars traversing the entire course, as measured by time and license checks at each end of the course on approximately 20 percent of the cars

Three types of driving techniques were tested. (1) "Average" test runs, in which test drivers attempted to drive at the speed of traffic, (2) "Slower" test runs, in which test drivers paced themselves by the slower drivers, and (3) "Faster" test runs, in which test drivers drove as fast as possible consistent with safety and obedience to traffic regulations

It was found that "average" test runs under most conditions yielded travel times close to the medians and means of the travel times determined from license checks. Travel times as determined from the "faster" or "slower" test runs, however, varied over wide ranges "Average" test runs, therefore, were used in further analyses.

The study also indicates the number of "average" test-car runs needed in various traffic situations, in order to produce average test-car travel times within a sufficient range of accuracy It was found that more test runs are needed to produce significant results for periods of congestion than at other times, and that coordinated signal timing tends to decrease the necessary number of test runs

It is concluded that the operation of test cars in the traffic stream is a practical method of measuring over-all travel time on important signalized streets.

The purpose of this study is to investigate the accuracy of test-car methods of measuring vehicular travel times on major streets controlled by traffic signals

Studies of vehicular travel times are often referred to as speed and delay studies.[1] The results of such studies are used in three principal ways: first, as a measure of congestion; second, as a means of identifying the causes and amounts of delay, and third, as an aid in computing savings in travel time. The last may be with reference to completed or proposed improvements such as major construction or changes in traffic controls

This study is one part of the research program which is being sponsored by the Committee on Operating Speeds in Urban Areas of the Department of Traffic and Operations, Highway Research Board. The committee has as its final objective the development of a sampling technique whereby the speed of traffic on urban facilities can be measured on an annual basis with a reasonable degree of accuracy.

The first goal set by the committee was to evaluate the accuracy of all known methods for determining over-all speeds and to explore the field for new methods. As a part of this phase of the investigation, the Institute of Transportation and Traffic Engineering at the University of California agreed to study the accuracy of the test-car method on signalized streets

The committee plans also to arrange for other studies of test-car techniques in at least two other parts of the country Hence, this

[1] Manual of Traffic Engineering Studies, Accident Prevention Department, Association of Casualty and Surety Companies, New York, N. Y , 1945, pp 20–23

report is preliminary in nature and should be augmented by reports on other studies arranged by the Committee on Operating Speeds in Urban Areas The Institute of Transportation and Traffic Engineering is also planning to continue its investigations of techniques for measuring and recording travel times.

VARIABLES BEING INVESTIGATED

The primary variable investigated is the technique of the test drivers in making the speed and delay runs Three different driving techniques were investigated, as follows:

1. Driver to travel at a speed which, in his opinion, is representative of the speed of all traffic at the time. (Designated as an "average" test run; somewhat different from standard "floating car" technique.)
2. Driver to maintain a maximum speed consistent with safety and existing traffic regulations. ("Faster" test run)
3. Driver to maintain a place in the traffic stream, but to gage his speed by that of the slower vehicles ("Slower" test run.)

The effect of traffic volumes on travel times was also investigated for the three streets selected for the tests.

PROCEDURE

Sections of three streets, each between one and 1½ miles in length, were selected as test sections. Three test cars were driven over each test section, each test car making at least three round trips each hour. The driving instructions corresponded with the three driving techniques previously described Each driver used a different one of the three driving techniques on each successive round trip during each hour.

Observers in each car recorded such information as the times of starting and ending the test run, the lengths of time the vehicle stopped for traffic signals, and the numbers of vehicles passed and being passed by the test car. Two stop watches were used in each car

Observers were stationed at each end of a test section to record the license numbers of vehicles as they passed each end of the section. Only license numbers ending in zero or five were recorded Stop-watch times were also recorded; watches at the two ends of each section were synchronized to permit determination of travel times for vehicles passing through the test course License numbers and times were recorded by voice on battery-operated disc-recording machines.

Automatic-recording traffic-volume counters were used to record traffic volumes continuously at 15-min intervals

DESCRIPTION OF TEST COURSES

Three test courses were selected, representative of three different conditions of traffic signal control Data in respect to each section are given in Table 1. A brief description of each test course follows

Wilshire Boulevard Section. Wilshire Boulevard is a major street extending from downtown Los Angeles westward to the city of Santa Monica. The 1.5-mile test section passes through a prosperous business district known as the "Miracle Mile," as shown in Figure 1. The traffic signals are timed progressively with program timers. Progression favors the westbound traffic after 4:30 p m

Potrero Avenue. Potrero Avenue in San Francisco (shown in Fig 2) leads south from the central business district. Traffic signals are close together and are irregularly spaced, without good progression in signal timing. The signals control speeds within a fairly narrow range.

Broadway. Broadway in Oakland, leading north from the business district, is an example of a major street without progressive signal timing. This street has a medial divider for a portion of the 1.5-mile test section. U. S. 50, a major route leading from the Bay Bridge, crosses Broadway at MacArthur Boulevard, at the center of the test section Figure 3 shows Broadway north of this intersection

PRESENTATION AND ANALYSIS OF DATA

Travel Times—Test-Car vs. License-Check Methods.—Table 2 summarizes the data obtained by the test cars and from license checks Table 2-A includes the mean travel times for test cars on the three test courses, together with the license-check times for the corresponding periods. The table lists the mean travel times for th "faster," "slower" and "average" runs of the test cars. It also lists the mean, median and mode values of the travel times of the entire traffic stream as measured by the license-plate check Table 2-B shows the number of observations which were included for each period, and also the standard deviations for each group.

themselves by the slower drivers averaged 5.02 min. The faster drivers, who drove as fast as possible consistent with safety and obedience to traffic regulations, averaged 3.69 min.

TABLE 1
BRIEF DESCRIPTION OF TEST COURSES.

Section	Wilshire Blvd. Los Angeles (La Brea to San Vicente)	Potrero Ave. San Francisco (Division to 25th)	Broadway Oakland (28th to College)
Length	8029 ft.	5150 ft.	7902 ft.
Widths	70 ft. and 80 ft.	80 ft.	70 ft. and 69 ft.
Moving Lanes (Each Dir.)	three	three (four between 4:00 and 6:00 p.m.)	two
Parking	both sides	both, except 4:00 to 6:00 p.m.	both sides
Streetcars	none	two tracks	none
Intersections	15	13 (Southbound)	12 (Northbound)
Signals	14	13	7
Average Signal Spacing	618 ft.	411 ft.	1035 ft.
Signal Timing	triple offset progressive	synchronized by groups	variable
Peak Hour Volume	1455 Westbound (5:00 to 6:00 p.m.)	1760 Southbound (4:30 to 5:30 p.m.)	1890 Northbound (5:00 to 6:00 p.m.)
Average Daily Traffic	14,590 Westbound	16,720 Southbound	15,000 Northbound

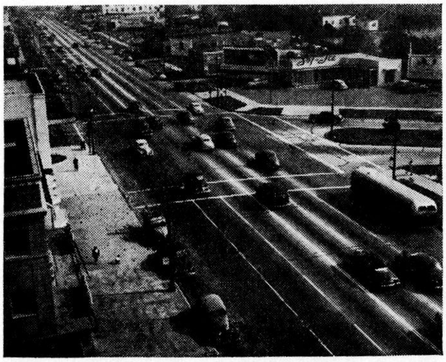

Figure 1. Wilshire Boulevard Test Section Looking East, with Crescent Heights Boulevard in the Foreground

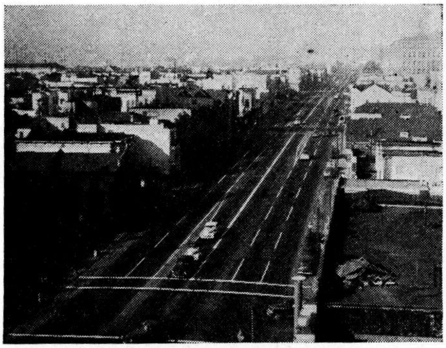

Figure 2. Potrero Avenue Test Section Looking North at the Intersection of 25th St.

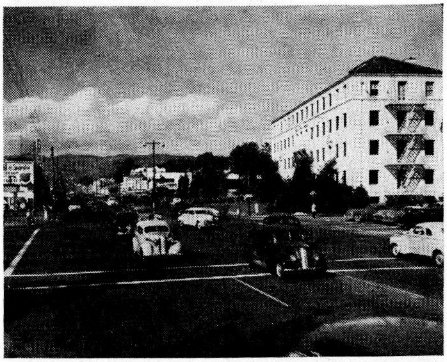

Figure 3. Broadway Test Section Looking North at the Intersection of MacArthur Boulevard (U. S. 50)

Figure 4 shows graphically the test results for the homeward-bound traffic moving westward on Wilshire Boulevard in Los Angeles during the peak period between 4:30 and 6:00 p.m. The curve shows the distribution of travel times obtained by recording vehicle license numbers and stop-watch times at each end of the 1.5-mile test course.

As shown in Figure 4, the mean travel time of all vehicles checked was 4.59 minutes, which corresponds to a speed of 19.7 miles per hour. The median value of travel time was 4.40 minutes, and the mode was 4.30 minutes.

The chart also shows the average values of the travel times as obtained by the three different techniques of test-car driving. The drivers who attempted to drive at the average speed of traffic negotiated the 1.5 miles in 4.36 min., whereas the drivers who paced

It is readily apparent from this chart that the "average" test runs yielded travel times closer to the mean, median and mode travel times as determined by the license checks than did the "faster" or "slower" test-run techniques.

For eastbound traffic during the same hours, as shown in Table 2-A, the travel times as obtained from the license check are higher than for westbound traffic because of the unfavorable signal timing for east-bound traffic at this time.

Figure 5 shows similar information for non-

TABLE 2

A. LICENSE-CHECK TRAVEL TIME VERSUS TEST-CAR TRAVEL TIME

Street	Time of Day (p m)	Direction	Test-car time (mean)[a]			License-check time[a]		
			Faster Runs	Slower Runs	Average Runs	Mean	Median	Mode
Broadway	2 00 to 4 00	Northbound	4 53	5 57	5 33	5 64	5 29	4 82
Broadway	5 00 to 6 00	Northbound	6 85	7 94	7 52	7 27	7 19	-
Broadway[b]	5 00 to 6 00	Northbound	6 51	7 94	7 47			
Wilshire	2 00 to 4 30	Westbound	4 27	5 36	4 69	5 16	4 84	4 76
Wilshire	4 30 to 6 00	Westbound	3 69	5 02	4 31	4 59	4 40	4 30
Wilshire	2 00 to 4 30	Eastbound	4 39	5 46	5 07	4 99	4 93	5 17
Wilshire	4 30 to 6 00	Eastbound	4 64	5 96	5 16	5 55	5 23	5 23
Potrero	2 00 to 4 30	Southbound	4 13	4 97	4 48	4 34	4 37	4 32
Potrero	4 30 to 6 00	Southbound	4 38	4 72	4 62	4 61	4 48	4 31

[a] Travel time in minutes
[b] Includes test runs in July as well as in April

B NUMBER OF OBSERVATIONS AND MEASURES OF VARIATION

Street	Time of day (p.m)	Direction	Dates (1949)	Average test cars		License-check data		
				N	σ[c]	N	σ[c]	Q_3-Q_1[d]
Broadway	2 00 to 4 00	Northbound	April 26, 27, 28	17	0 63	249	1 48	1 72
Broadway	5 00 to 6 00	Northbound	April 26, 27, 28	9	0 98	231	1 84	2 50
Broadway	5 00 to 6 00	Northbound	April and July	18	1 16			
Wilshire	2 00 to 4 30	Westbound	May 17, 18, 19	22	0 47	218	1.49	1 23
Wilshire	4 30 to 6 00	Westbound	May 17, 18, 19	14	0 34	297	1.36	1 09
Wilshire	2 00 to 4 30	Eastbound	May 17, 18, 19	22	0 55	201	1.18	1 11
Wilshire	4 30 to 6 00	Eastbound	May 17, 18, 19	13	0 45	219	1.74	1 24
Potrero	2 00 to 4 30	Southbound	Aug 31, Sept 12	18	0 39	148	0.63	0 80
Potrero	4 30 to 6 00	Southbound	Aug 31, Sept 12	13	0 49	165	0 68	0 95

[c] Standard deviation in minutes
[d] Inter-quartile range is the number of minutes between the 75 and 25 percent values.

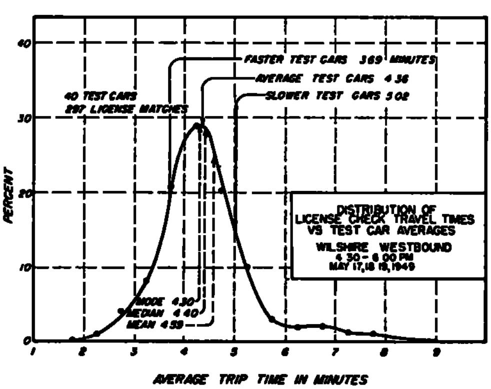

Figure 4

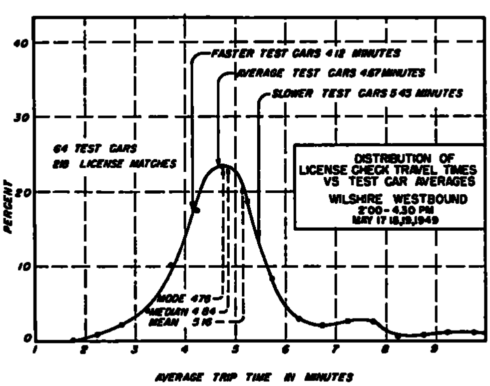

Figure 5

rush hours (2:00 to 4:30 p m) for westbound traffic on Wilshire Boulevard Once again, the "average" test runs yielded travel times close to the mean and median of the travel times as determined by the license checks.

The chart in Figure 6 shows the distribution of license-check travel times for southbound traffic on Potrero Avenue, San Francisco, during the peak period (4:30 to 6:00 p.m) Most of the vehicles are traveling at a fairly uniform speed, as shown by the high peak on the curve, as a result of the signal timing. The standard deviation of license-check travel times is only 0 68 min , as compared with a standard deviation of 1 36 min. for westbound traffic on Wilshire Boulevard during the peak hours.

Once again, it may be noted that the "average" test runs yielded travel times close to the results of the license-check method. The "slower" and the "faster" test runs were not significantly different from those for "average" test-car runs, undoubtedly because the signal timing had more influence on speed than did differences in techniques of driving.

The final chart (Fig 7) in this series of curves shows the distribution of license-check travel times for northbound traffic on Broadway in Oakland during the peak hour of 5·00 to 6:00 p.m Times on this test section varied considerably because of variations in delays encountered at some of the intersections on the three different days the tests were made The distribution curve thus is almost tri-modal, with a relatively large standard deviation—1.84 min. The inter-quartile range is also relatively large, as shown in Table 2.

Results of "average" test-car runs, even for the varying conditions on the three days of the test, still produced averages reasonably close to the license-check information. "Average" test-car runs were also made on four other days (as shown in Table 2) in order to obtain additional information for computing the number of test runs necessary for different degrees of reliability.

The four other cases set forth in Table 2 confirm the relationships revealed in the cases which are illustrated here in chart form.

Travel Times by Time of Day.—Mean travel times were summarized by 15-min. periods for each test section, to aid in evaluating the effects of changes in traffic volume and signal timing. Figure 8 shows mean travel times by 15-min periods for westbound traffic on Wilshire Boulevard in Los Angeles, and shows

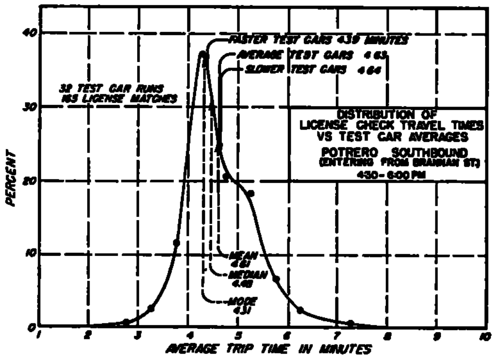

Figure 6

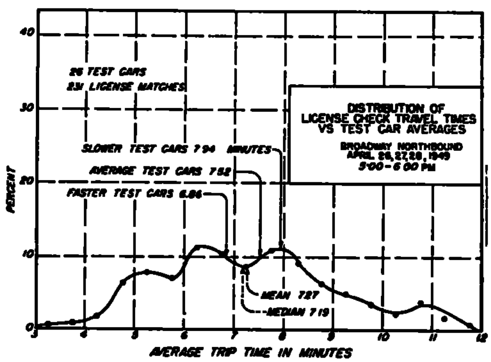

Figure 7

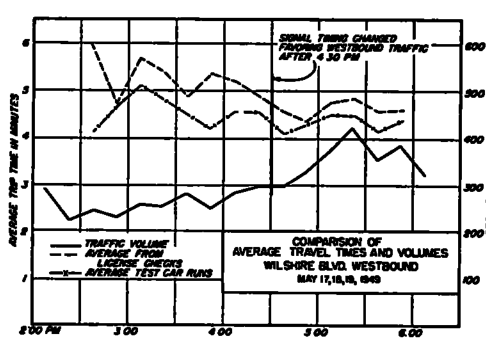

Figure 8

also a comparison with the trend in traffic volumes It may be noted that, in general, travel times decreased after the signal timing was changed at 4.30 p m , whereas traffic volume continued to increase. Mean travel times determined from the "average" test runs approximated those obtained from the license checks.

Similar comparisons for eastbound traffic on Wilshire Boulevard revealed higher mean travel times after 4:30 p m., even though traffic volume between 4:30 and 6:00 p m averaged 8 percent lower than for the period between 2:00 and 4:30 p.m. It was apparent that the adverse signal timing for eastbound traffic after 4:30 p.m was responsible for the increase in mean travel time.

Data by 15-min. periods for Potrero Avenue revealed mean travel times which varied little throughout the period of the test. This situation was undoubtedly due to the fact

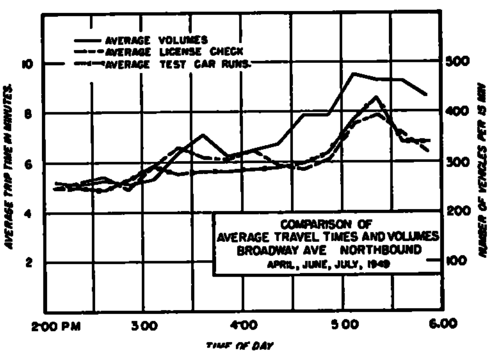

Figure 9

that the signal timing remained the same, while traffic volumes did not attain the capacity of the roadway at any time

Mean travel times on Broadway in Oakland were much higher during the peak hour (5:00 to 6:00 p m.) than at other times, as shown in Figure 9 This significant increase in travel time was due primarily to the increase in the average delay per trip, which in turn was the result of stops for the traffic signal at the intersection of Broadway and MacArthur Boulevard. During the one-hour peak, test cars were stopped an average of 1 05 min because of the lines of vehicles waiting to enter the intersection, indicating that traffic volume exceeded the practical capacity of the intersection For the other six signalized intersections on the Broadway test section, the stopped time for test cars averaged only 9 sec per intersection.

Traffic volume thus has a progressively greater effect on travel times as the traffic volume approaches and exceeds the practical capacity of the critical intersection or other critical section of the street or highway. When traffic volumes remain below the capacity of the critical location on the street, other factors, such as changes in signal timing, appear to have more effect on travel times than traffic volume changes

Effect of Numbers of Passings—During the test runs, the observers in the test cars recorded the number of cars passed by the test car and the number of cars passing the test car. The drivers, however, were instructed to drive in accordance with the average speed of traffic, rather than to follow the usual prac-

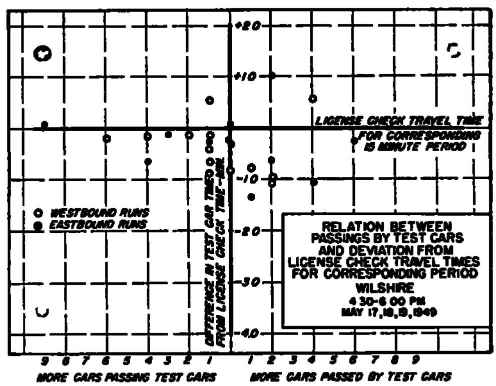

Figure 10

tice of making sure that they passed as many cars as passed them Figure 10 shows a comparison of the passing practices for each test run, in relation to the deviation of the test-run travel time from the average travel time, as obtained from license checks for corresponding periods. Each point represents an "average" test-car run. Both eastbound and westbound test runs were plotted for Wilshire Boulevard for the peak period, 4:30 to 6:00 p m

The chart shows that on about half the test runs, the test-car drivers passed almost as many cars as passed them Forty-six percent of the runs were within plus or minus two passes as shown on this scatter diagram.

The remaining 54 percent of the test runs had an excess or deficiency in number of passings greater than two passes. These runs with unbalanced passings did not, however, produce travel times bearing a significantly different relationship to license-check travel times than that of the test runs with balanced passings.

This chart and similar data taken on the other test sections indicate that the instruction given the drivers of "average" test cars produces, for most runs, a balance in terms of passings. It also produces a cumulative balance in passings for all runs made under the same conditions This study did not, however, attempt to check the results of the "average" test-car runs with test-car runs made by drivers instructed to pass the same number of vehicles as passed them Such an investigation will be made at a later time with further analyses made of cumulative balances in passings.

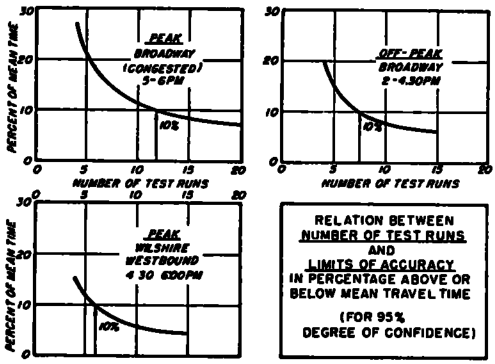

Figure 11

It may also be noted on Figure 10 and in Table 2 that the travel times obtained from "average" test-car runs on most test sections were somewhat less than those obtained from license checks On only one test section, for northbound traffic on Broadway, was the mean travel time from the "average" test-car runs very much greater than the license-check mean.

Statistical analyses show that for specific sections and periods of time the differences in these mean times, with one exception, are too small to show positive evidence that some factor other than chance was responsible. Further studies of these differences are planned.

The mean travel times obtained from the "average" test-car runs in general were closer to the median than to the mean license-check travel times. Further studies are planned of the relationship between numbers of passings and the three different measures of central tendency, since there is a possibility that the median travel time is a better measure of traffic performance on a street or highway than is the mean travel time The interquartile range, or a similar range, also may be more suitable than the standard deviation in showing variation in travel times

Number of Test Runs Needed.—The number of test runs needed to obtain a mean travel time within various limits of accuracy was computed statistically[2] using a 95-percent degree of confidence These analyses were based on "average" test-car runs only

On a street such as Wilshire Boulevard the standard deviation of the "average" test-car runs during peak hours was less than 0 5 min as shown in Table 2 Under the test conditions, the number of test runs needed for 95-percent confidence to obtain true means within 10 percent of average travel time was between six and eight test runs, as shown in Figure 11. On Broadway, where there is considerable variation in travel time because traffic volumes at peak periods approach and exceed the capacity of one intersection, eight test runs would be needed during the non-peak hours, and 12 test runs would be needed during the peak hour, for 95-percent confidence.

On streets with even greater variations in travel time, still more test runs would be needed for the same limit of accuracy

CONCLUSIONS

1. The recording of vehicle license numbers and times is an accurate method of determining the mean, median and mode travel times for all vehicles traversing the entire length of a test section. The method, however, is more expensive than the test-car method, because of large manpower requirements in obtaining and analyzing the data

2 Test cars driven at maximum speeds consistent with safety, or at speeds approximating those of the slower vehicles on the street, usually do not yield travel times which

[2] A S.T.M. Manual on Presentation of Data, American Society for Testing Materials, 1941, pp 40–42

are an accurate measure of the average travel time of vehicles in the traffic stream. The range in travel time for these extremes in test-car driving techniques, however, is small for streets with closely spaced traffic signals.

3. Travel time varies greatly as the traffic volume on signalized streets reaches and exceeds the capacity of the intersections of a test section. Travel-time variation is much smaller for traffic volumes below the capacity of the intersections.

4 Test cars driven at speeds which, in the opinion of the drivers, are representative of the average speed of traffic, can provide an accurate means of measuring the mean and median travel times of vehicles in the traffic stream of heavily traveled signalized streets.

5. In the majority of "average" test-car runs, the number of vehicles passed by the test car was within one or two of the number of vehicles passing the test car. However, those "average" test runs which showed larger differences between the number of "passings" versus "being passed" produced results which were no less accurate than test runs with balanced passings

6 Variations between travel times of individual test-car runs are greater when traffic volumes approach the capacity of the test section. Thus, more test runs usually are needed during peak hours than at other times. The minimum numbers of "average" test runs needed to determine an average test-car travel time within a 10-percent range of accuracy are as follows:

(a) For progressive signal timing (volumes below capacity)—8 runs.
(b) For signals not coordinated (volumes at or near capacity)—12 runs.
(c) For signals not coordinated (volumes below capacity)—8 runs.

RECOMMENDATIONS FOR FURTHER STUDY

1. Additional studies should be made to determine whether there are significant differences in travel time as obtained by different test-car drivers following the same driving instructions.

2. Studies should be made to determine the difference in the results obtained by using the standard "floating car" technique and by using the "average" test-run method, as described in this report License-check data should be obtained at the same time to aid in studying further the differences between test-car results and the different measures of central tendency and of variation as determined from license checks

3 Studies should also be made to evaluate techniques of measuring travel time on non-signalized streets and highways.

4. An improved method is needed foi recording the data obtained by the operation of test cars, in order that test-car drivers can make a complete record of each run, without the assistance of an observer