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Vol. 9. Test and Evaluation of Computerized Traffic Control System

J. F. Torres

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Final Report

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16. Abstract

The Western Avenue Interchange of the Santa Monica Freeway was instrumented to operate under computerized traffic control. A series of tests was conducted to evaluate the operational performance of the system with respect to pretimed, 3-dial operation. The surveillance system, which is part of the computerized system, was used as one of the basic methods of collecting operational data. Floating-car tests were also conducted over the facility. The broad set of results obtained showed that the real-time control of the facility produced reductions in delay in the order of 20-30 percent. Stop time and number of stops were also reduced. The degree of improvement obtained demonstrated that the computerized control system is cost/effective.

For the other 15 volumes in this series of reports see "List of Project Reports" at the back of this publication.

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PREFACE

This is one of a series of report issued under the Research Program on Control and Geometric Design of Diamond Interchanges. This document describes the testing and evaluation of the computerized traffic control system which was implemented at the Western Avenue Interchange of the Santa Monica Freeway in Los Angeles. The work is being performed under Contract No. FH-11-7568 for the Federal Highway Administration, in collaboration and cooperation with the State of California Division of Highways and the City of Los Angeles Department of Traffic. Jaime F. Torres is the Program Manager of this research program.

The computerized traffic control system was designed, developed, and implemented through the joint efforts of T. E. Banks, C. T. Barooshian, W. H. Stone, and the Program Manager, with support from other SDC staff personnel. T. E. Banks and W. H. Stone assisted in the collection of data, using the computerized system, for application to this report. R. Bhavnani assisted in conducting the test-car field studies and in reducing and preparing some of the collected evaluation data for this report.

The successful implementation and operation of this computerized system would not have been possible without the full cooperation and support of the California Division of Highways and Los Angeles Department of Traffic. Particular appreciation is extended to Messrs. Karl Moskowitz and Harold Garfield of the Headquarters Office, and Bert Clark, Fred King, and Paul Praeter of the District VII Office of the Division of Highways; and to Messrs. Gerry Skiles, Dean Terry, Ed Heidenthal, and Charles Holland of the Los Angeles Department of Traffic.

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1. TASK OBJECTIVE

The Western Avenue Interchange of the Santa Monica Freeway, in Los Angeles, was instrumented to operate under computerized traffic control (cf. reference 1). Briefly stated, loop detectors are deployed at all key approaches of the diamond interchange, including the two nearby signalized intersections. Roadway sensed data is collected and transmitted to the computer control center at which point the data is processed on-line, yielding optimized signal timing parameters appropriate to the interchange traffic demands. The computer then drives the four intersection signal controllers with the optimized signal timing commands. This is a traffic-responsive, second-generation computerized traffic control system.

This computerized traffic control system was designed, developed, and implemented after digital computer simulation studies showed that substantial improvements in operational performance could be obtained. Once the system was implemented, and the preliminary testing and system tuning was completed, the objective of the program was to:

a. Determine, and demonstrate, the operational performance of the computerized traffic control system.

b. Compare the operational performance of the computerized system to the tuned three-dial pretimed system.

c. Identify the preferred operational system configuration for computerized traffic control and determine the corresponding operational performance.

The task to achieve this objective comprised a testing and evaluation program to be conducted on the computerized system. Measurements of the system's operational performance had to be performed and analyzed. The methodology employed to perform this task, and the results obtained, are presented in the following sections.

2. APPROACH TO THE EVALUATION OF THE COMPUTERIZED SYSTEM

2.1 PRELIMINARY TESTING

Once the task of installing and integrating the entire computerized traffic control system was completed, the computerized traffic control system had to be field-checked and set to the proper optimized working configuration. The system was placed through an intensive field testing schedule. During this testing period:

a. The computerized traffic control system was cleared of all bugs that were not evident during the first turn-on.

b. Traffic operations, under computerized control and pretimed control, were observed over the different traffic conditions that occur throughout the day, to determine the operational properties that could be expected.

c. Key traffic control parameters were adjusted and set to the values that gave uniformly better operational performance for the various expected traffic conditions. Among the traffic control parameters that were so adjusted were the lengths of the long-term cycle (which determines the period for updating the signal control parameters), the lane saturation flow rates, the minimum phase lengths, and the maximum cycle lengths.

The system evaluation was initiated upon the completion of the field-testing subtask.

2.2 MEASUREMENT OF OPERATIONAL PERFORMANCE

The computerized traffic control system was evaluated objectively by measuring the actual operational performance of the interchange. Two methods were used for measuring operational performance:

a. The test-car, or floating-car, method.

b. The use of the surveillance network of the computerized system.

A description of these two methods of measuring operational performance at the interchange test site is presented in the following sections. Travel time, or delay, are the basic measures of operational performance used for the evaluation. Other measures of performance have also been used.

2.3 TEST-CAR METHOD OF MEASURING OPERATIONAL PERFORMANCE

The personal vehicles of ten volunteer drivers were instrumented with SDC-developed TRADAC (Traffic Data Collection) equipment for this set of performance evaluation tests. The TRADAC System (described in reference 2) is designed for the convenient collection and reduction of four important traffic operational measures of performance:

a. Travel time

b. Total stop time

c. Number of stops

d. Number of brake applications

All of this data is collected simultaneously by the driver operating only one switch. The test-car driver samples the operational performance of the drivers that surround him as he drives on the prescribed route. The test-car method is well accepted for measuring traffic operational performance.

For the evaluation of the computerized traffic control system, six routes were selected that were considered representative of the major traffic movements through the interchange. The six selected routes are shown in Figure 2.1. These are:

a. The two through-movements on Western Avenue (Routes 5 and 6).

b. The two offramp left-turn movements into Western Avenue (Routes 2 and 4).

c. The two left-turn movements into the onramps (Routes 1 and 3).

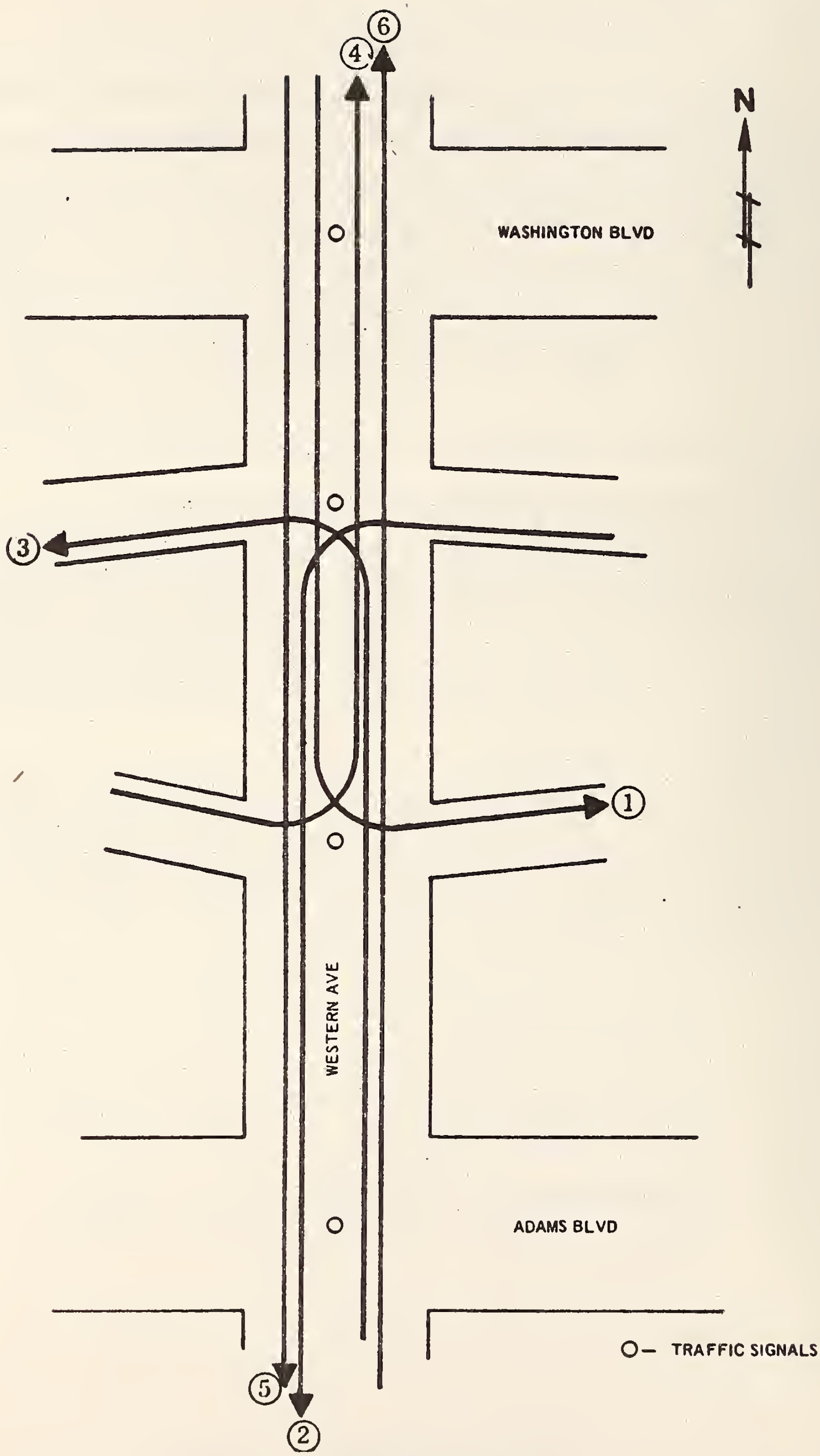

FIGURE 2.1 TEST-CAR ROUTES

For cases a. and c., the test-car runs were started at the detector locations on the external approaches to the nearby signalized intersection. The runs were terminated at the near stopline for the other nearby signalized intersection for case a. The runs were terminated at the curb projection stopline at the onramps for case c. In case b., the test-car runs were started at the detector locations on the offramp approaches. The runs were terminated at the near stopline at the nearby signalized intersection.

Based on previous similar types of test-car studies, it was estimated that sample sizes greater than 60 should be sought for each study made over each route.

The test-car drivers were instructed to drive normally for test runs that started on the freeway. For test-car runs that started on the arterial street, the drivers were instructed to insert themselves into a platoon of vehicles upstream from the start of the test section. The drivers were further instructed to avoid being first or last within their cluster of vehicles moving along the route. Drivers were also dispatched over the routes in such a way as to prevent them from clustering together.

The drivers were also required to record any unusual conditions that might invalidate the measured data over a test-run. The drivers had to follow a prescribed order in driving over the route set. The paths were ordered so that the end of one trip was near the beginning of the next trip.

2.4 DATA COLLECTION USING THE SURVEILLANCE NETWORK

The detector network, which is deployed over all the intersection approaches of the diamond interchange complex, is used for two purposes:

a. Making vehicle counts on a lane basis for the purpose of determing the optimum signal timings.

b. Measuring the operational performance of the interchange facility.

The latter use is the one that is of particular interest for purposes of evaluating the operational performance of the computerized traffic control system.

Programs were developed that can be, and were, used for measuring the operational performance of the test site. The programs make use of the data sensed by the loop detectors and of the sensed state of the traffic signals. From this sensed data, measures of operational performance are computed over sections of the interchange complex bounded by the upstream set of loop detectors and the stop-line for each interchange approach. The surveillance sections for the entire interchange complex are illustrated in Figure 2.2 by hatched areas. The lengths of these monitored sections range from approximately 275 feet to 300 feet.

The measures of performance which are obtained from the surveillance system, for each long-term period*, are:

a. Average travel time (seconds)
b. Average travel time per mile (seconds)
c. Number of vehicles
d. Number of vehicles per hour
e. Vehicle-seconds of travel time

*Defined as the time period between successive executions of the signal timing parameters.

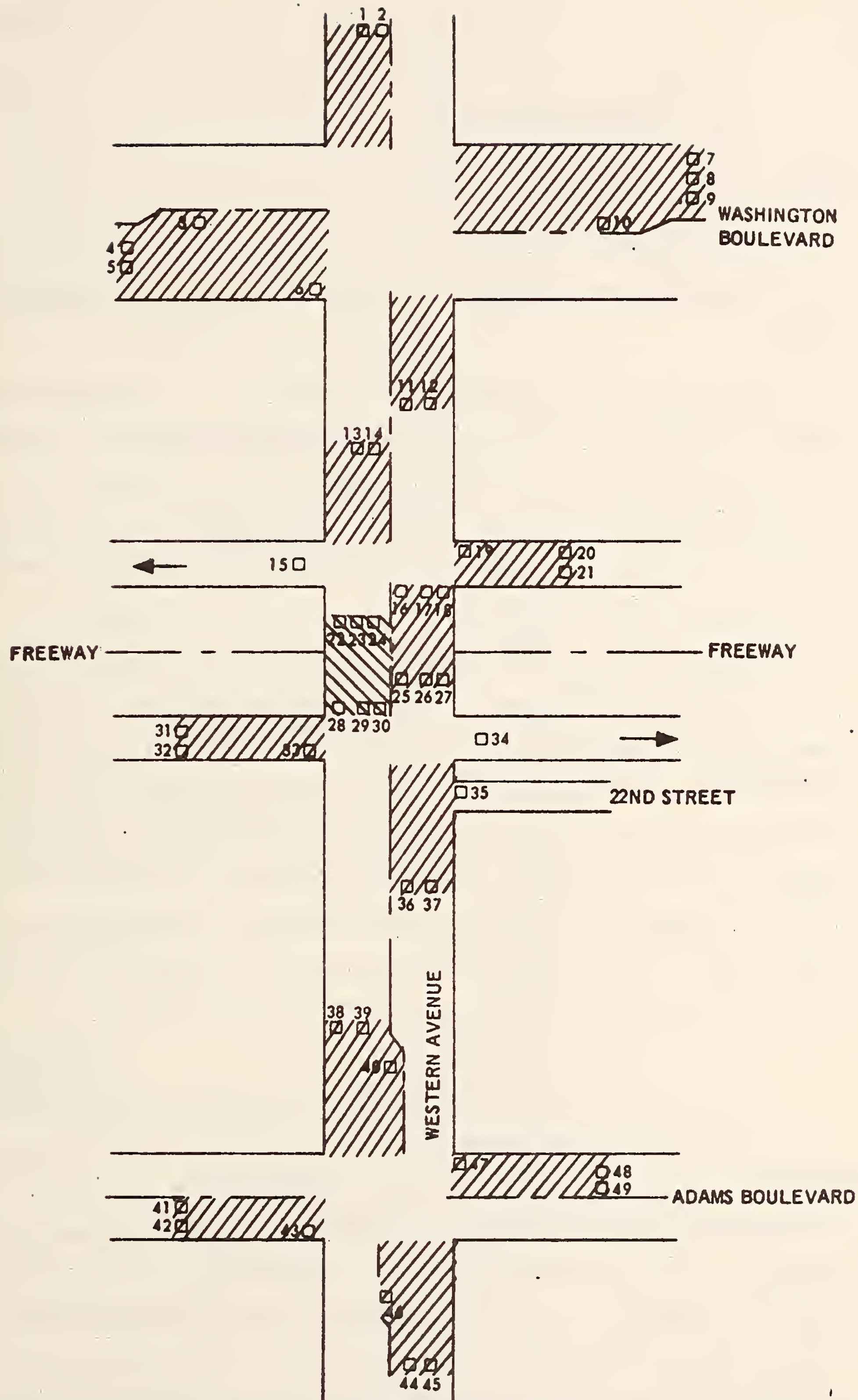

FIGURE 2.2 SECTIONS UNDER SURVEILLANCE FOR OPERATIONAL PERFORMANCE

f. Vehicle-miles per hour

g. Vehicle-hours per hour

h. Average delay (seconds)

i. Average speed (mph)

These measures are obtained on a lane basis and as totals over all lanes.

There are 42 lane-movements identified for the entire diamond interchange complex for purposes of computing the measures of performance. These lane-movements are defined graphically in Figure 2.3. It should be noted that in the region between ramp intersections the through-movements and the left-turn movements from the offramps are identified by distinct lane-movements.

The measurements made on the sections shown in Figure 2.2 sample the operational performance over the entire diamond interchange complex. Most of the delay that will be normally accrued will be accumulated over these hatched sections. Hence, the measurements made over these sections pretty well typify the overall interchange performance. Appreciable discrepancies may occur between the measured and the actual values of operational performance whenever an intersection is so heavily loaded that vehicle queues accumulate past the upstream detectors. Vehicles beyond this point, of course, would not be able to be monitored by the surveillance system.

It is well recognized that the most critical area is that immediately surrounding the interchange. This is the area where improvements in operation are particularly desired. This is the area where it is particularly important to keep the traffic moving. The operational performance in this critical region is measured by the sections shown hatched in Figure 2.4. With a recognition of the importance of monitoring this critical region, two sets of lane-movement totals have been provided in the program for computing performance measures from the surveillance system:

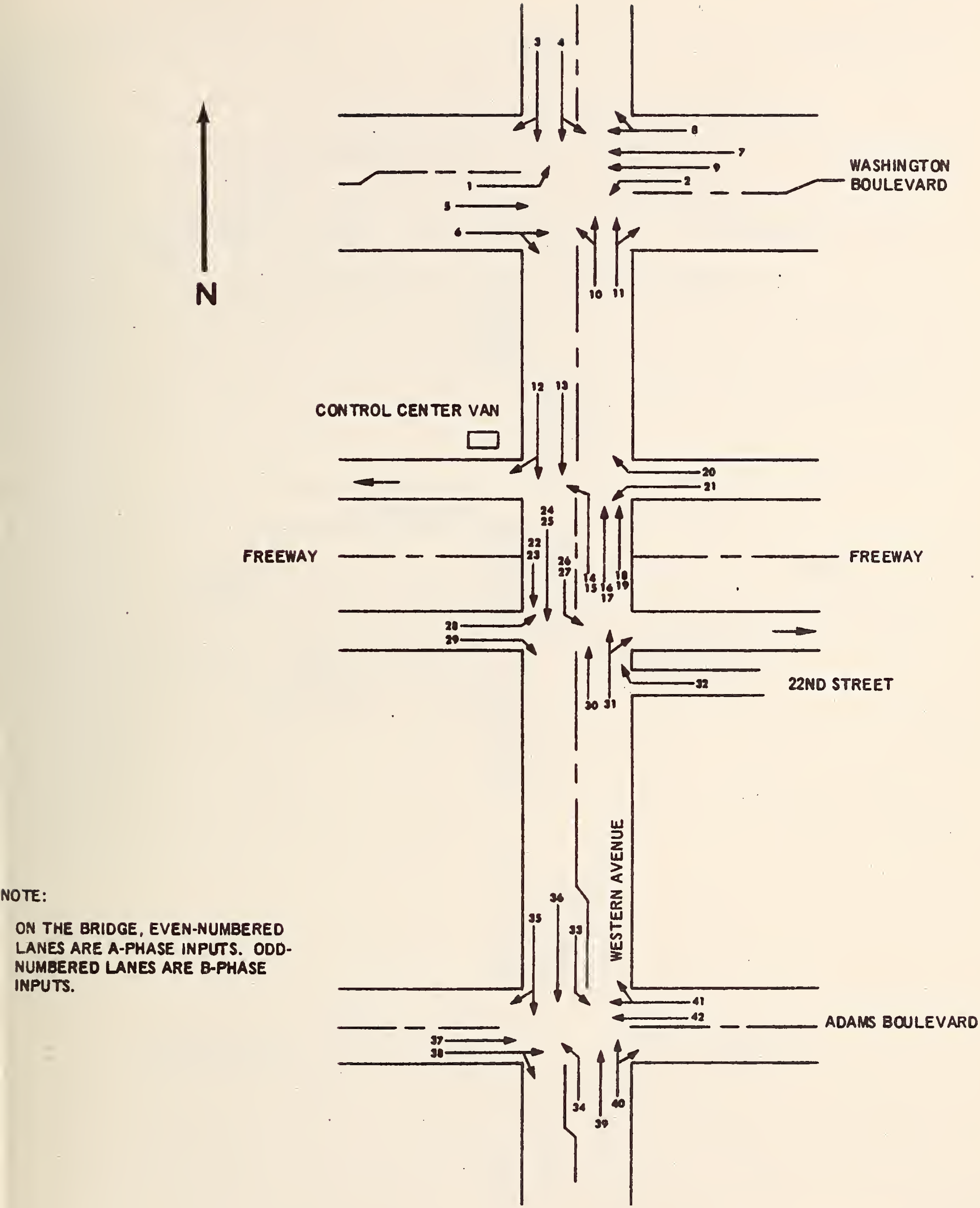

FIGURE 2.3 LANE-DEMAND DEFINITIONS FOR THE PERFORMANCE STATISTICS ROUTINE

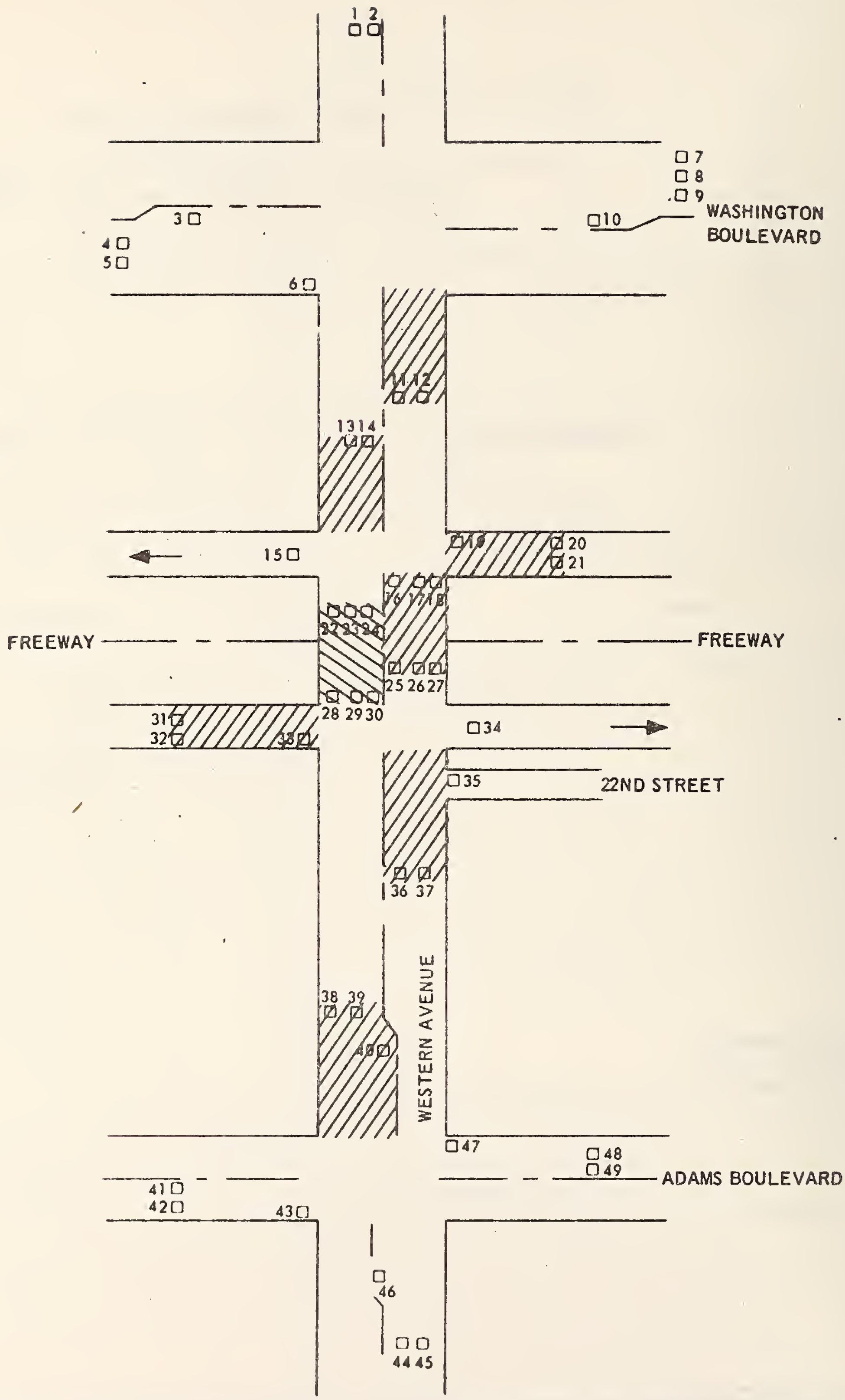

FIGURE 2.4 SUBSET OF CRITICAL SECTIONS FOR SURVEILLANCE OF OPERATIONAL PERFORMANCE

a. Totals over the critical subset of surveilled sections

b. Totals over the entire set of surveilled sections

It was anticipated that the critical section subset would form the principal basis for making evaluation comparisons.

Before applying this surveillance system to the collection of operational data for the evaluation task, the performance statistics program was checked and calibrated by using the Traffic Flow Analyzer that belongs to the City of Los Angeles Department of Traffic.

The calibration results obtained by the use of the Traffic Flow Analyzer are given in Appendix E of this report.

The use of the performance measures collected by the surveillance system was expected to provide a very convenient and expedient way of making high-fidelity evaluation comparisons. This expectation will be seen to have been well-founded.

3. SCOPE OF THE EVALUATION TASK

The computerized traffic control system was evaluated by using two methods of data collection.

a. Test-car survey

b. Surveillance system survey

The test-car survey was applied to one "before-and-after" type of study of the computerized traffic control system. In particular, the performance of the computerized traffic control system was compared to the performance of the interchange system under tuned three-dial pretimed control. A significant improvement in performance for the computerized system through this test would establish its effectiveness from a practitioner's point of view, since the test-car method is a well accepted technique.

The evaluation of several selected computerized system configurations was also considered desirable. The evaluation of these configurations was performed by applying the surveillance system, with its convenient data-gathering and processing capability. Data from the surveillance system is collected and recorded on magnetic tape at the traffic control center. Data from the tape is then reduced and processed, and the results listed, off-line.

The following system configuration comparison evaluations were performed using the surveillance system:

a. Tuned 3-dial pretimed vs. real-time (full detector set)

b. Five-minute vs. ten-minute long-term periods

c. Twenty-minute vs. ten-minute long-term periods

d. Only the ramp intersections under computer control vs. the full interchange complex under computer control.

e. Ramp intersections plus Washington under computer control vs. the full interchange complex under computer control

f. Minimum detector configuration vs. full detector configuration

g. Sixty-second fixed cycle with variable split vs. real-time.

The pretimed signal timing parameters for the three dials are shown in Table 3-1.

TABLE 3-1

PRETIMED SIGNAL TIMING PARAMETER VALUES

AM Peak

Intersection	Cycle (sec.)	Phase A	Phase B	Phase C	Offset (sec.)
Washington	60	30.0	30.0		4.8
North Ramp	60	30.0	16.8	13.2	7.2
South Ramp	60	22.8	14.4	22.8	41.4
Adams	80	46.4	33.6		2.4

Off Peak

Intersection	Cycle (sec.)	Phase A	Phase B	Phase C	Offset (sec.)
Washington	60	30.0	30.0		4.8
North Ramp	60	30.0	18.0	12.0	7.2
South Ramp	60	24.0	15.0	21.0	40.8
Adams	60	34.0	26.0		41.6

PM Peak

Intersection	Cycle (sec.)	Phase A	Phase B	Phase C	Offset (sec.)
Washington	60	30.0	30.0		4.8
North Ramp	60	31.2	16.8	12.0	7.2
South Ramp	60	22.8	14.4	22.8	41.4
Adams	80	43.2	36.8		49.6

4. EVALUATION RESULTS OF THE TEST-CAR SURVEY

4.1 PLAN AND CONDUCT OF THE SURVEY

The test-car survey involved scheduling test-car runs during the two signal control strategies of interest:

a. Tuned 3-dial pretimed signal control

b. Computerized signal control

The logistics and scheduling was organized so that all of the pretimed signal control test-car data was collected first. Advantage was taken of this time period over which pretimed data was collected to complete the checkout and tuning of the computerized control system. Test-car data collection, under computerized signal control, was initiated as soon as it was determined that an adequate sample of pretimed data had been collected.

Three sets of test-car data were collected for each of the two signal control strategies. The three sets were selected to characterize the predominant traffic characteristics at the interchange test site. These three sets were scheduled for data collection for the following corresponding time periods:

a. AM peak period (07:00 - 08:30)

b. Noon off-peak period (11:00 - 13:00)

c. PM peak period (16:00 - 17:30)

The movement demand distribution was observed to differ appreciably over these three time periods. However, it was also observed that southbound traffic predominated throughout most of the day except for about one hour in the morning.

It was observed that the demand distribution throughout the day does not differ much between weekdays. Some cases in point will be demonstrated in a later section of this report.

Test-car runs were scheduled to be conducted only during weekdays. Friday afternoons were avoided, since they did not appear to conform to the other weekday afternoons.

During the conduct of the survey, we were not able to escape the anomalous environmental happenings that appear inevitable when surveys of this type are scheduled. Among some of these we can cite:

a. Roadway construction or maintenance

b. Rain (we cancelled at least two scheduled sets because of rain)

c. Traffic incidents (e.g., car stalling on the bridge)

d. A couple of fender-bending accidents

e. Fire preempt activations of the signals (we note that the firemen do not appear to know how to use the fire preempt signal properly)

f.. Ambulances

Whenever traffic-perturbing events such as these took place, the test-car measurements that were affected were truncated from the data samples.

As is usual during these types of field surveys, some of the individual runs were aborted when the driver, for various reasons, was not able to activate the recording device at the proper time.

4.2 TRAVEL TIME RESULTS

The travel time summary results obtained from the test-car survey are presented in tabular form in this section. Tables 4-1 through 4-3 show the travel time summary results on a route basis. For each of these tables, the results obtained while operating under pretimed signal control are presented in the upper half. The results obtained while operating under computerized signal control are presented in the lower half.

Table 4-1 shows the results obtained during the morning peak period. Table 4-2 shows the results obtained during the noon off-peak period. And Table 4-3 shows the results for the afternoon peak period. These values are derived from the day-to-day statistics which are given in Appendix A.

The net improvement is computed for each time period by taking the average over the routes weighted by the corresponding demand weighting factors. The demand weighting factors, given in Table 4-4, represent the relative proportion of the demands for each route. These factors have been determined from the sample demands shown on the comparison table.

The overall comparison of average travel time, before and after computerized traffic signal control was effected, is shown in Table 4-5.

Very substantial reductions in overall average travel time can be noted. Reductions in the order of 20 seconds per run were obtained during the peak periods. It should be noted that, if a 14 percent reduction in travel time is indicated, this implies a reduction in delay that should be in the order of 25 percent (about twice as much).

This follows, since typically the free flow travel time, t_f, is greater than the delay, d. Thus, if

$$t = t_f + d \qquad \text{for timing plan 1, and}$$

$$t^1 = t_f + d^1 \qquad \text{for timing plan 2}$$

then

$$\%\Delta d = \frac{d - d^1}{d}$$

and

$$\%\Delta t = \frac{t - t^1}{t} = \frac{d - d^1}{d + t_f} = \frac{d - d^1}{d\left(1 + \frac{t_f}{d}\right)}$$

Hence,

$$\frac{\%\Delta d}{\%\Delta t} = 1 + \frac{t_f}{d}, \text{ assuming } t_f = d(1 + \epsilon), \epsilon > 0.$$

A t-test performed on the pooled data indicated on Table 4-5 shows that the improvements are statistically significant at the 5 percent significance level.

TABLE 4-1

TRAVEL TIME ROUTE DATA SUMMARY

AM PEAK

PRETIMED CONTROL			
Route	Average (Min.)	σ (Min.)	Sample Size
1	1.631	.393	121
2	1.298	.391	125
3	1.948	.541	119
4	1.513	.360	120
5	1.830	.401	151
6	2.260	.478	145

COMPUTER CONTROL			
Route	Average (Min.)	σ (Min.)	Sample Size
1	1.065	.370	80
2	1.284	.316	77
3	1.900	.377	65
4	1.571	.455	58
5	1.556	.350	104
6	1.957	.339	83

TABLE 4-2

TRAVEL TIME ROUTE DATA SUMMARY

NOON OFFPEAK

PRETIMED CONTROL			
Route	Average (Min.)	σ (Min.)	Sample Size
1	1.552	0.337	87
2	0.924	0.304	89
3	1.530	0.406	85
4	1.556	0.419	89
5	1.904	0.399	110
6	1.817	0.418	113

COMPUTER CONTROL			
Route	Average (Min.)	σ (Min.)	Sample Size
1	1.290	0.308	79
2	1.328	0.296	82
3	1.883	0.388	76
4	1.429	0.364	44
5	1.597	0.335	101
6	2.049	0.379	56

TABLE 4-3

TRAVEL TIME ROUTE DATA SUMMARY

PM PEAK

PRETIMED CONTROL			
Route	Average (Min.)	σ (Min.)	Sample Size
1	1.661	0.396	80
2	1.520	0.308	84
3	1.873	0.423	78
4	2.329	0.623	82
5	2.224	0.420	102
6	2.430	0.509	95

COMPUTER CONTROL			
Route	Average (Min.)	σ (Min.)	Sample Size
1	1.570	0.401	64
2	1.677	0.327	57
3	1.764	0.370	62
4	1.572	0.420	60
5	1.850	0.310	70
6	2.170	0.335	68

TABLE 4-4

DEMAND WEIGHTING FACTOR BY ROUTE

	Demand Weighting Factors		
Route	AM Peak	Noon Offpeak	PM Peak
1	4	2.7	2.5
2	2	1	2
3	2	1	1
4	1	2.3	4
5	8	7	13
6	9	5.5	10

SAMPLE 10-MINUTE DEMANDS BY ROUTE
(April 1973)

	10-MINUTE DEMANDS		
Route	AM Peak	Noon Off-Peak	PM Peak
1	66	50	36
2	25	20	26
3	30	18	13
4	16	38	50
5	133	140	168
6	144	105	120

TABLE 4-5

BEFORE-AND-AFTER

OVERALL COMPARISON OF TRAVEL TIME

CONTROL MODE / TIME PERIOD	AVERAGE TRAVEL TIME (MIN.)		IMPROVEMENT (MIN.)	
	PRETIMED CONTROL	COMPUTER CONTROL	Δ	PERCENT IMPROVEMENT
A.M.	1.904	1.625	0.279	14.65
NOON	1.720	1.663	0.057	3.33
P.M.	2.203	1.879	0.324	14.71

4.3 STOP TIME RESULTS

The stop time summary results obtained from the test-car survey are presented in tabular form in this section. Tables 4-6 through 4-8 show the stop time summary results on a route basis. For each of these tables, the results obtained while operating under pretimed signal control are presented in the upper half. The results obtained while operating under computerized signal control are presented in the lower half.

Table 4-6 shows the results obtained during the morning peak period. Table 4-7 shows the results obtained during the noon off-peak period. And Table 4-8 shows the results for the afternoon peak period. These values are derived from the day-to-day statistics which are given in Appendix B.

The net improvement is computed for each time period by taking the average over the routes weighted by the corresponding demand weighting factors (given in Table 4-4).

The overall comparison of average stop time, before and after computerized traffic control was effected, is shown in Table 4-9.

Very substantial reductions in overall average stop time can be noted. Reductions of 10 to 15 seconds in stop time were obtained on the average during the peak periods. Up to 31 percent reduction in stop time was obtained.

We note here that the average stop time obtained on route 2 is almost zero under pretimed control. This is the route followed by left-turning vehicles from the westbound offramps into the arterial. The reason for this is that it was impossible to control the release of vehicles from the upstream interchange so that the vehicles would arrive randomly at the offramp. The synchronization of signals is such that when a vehicle is released during the C-phase at the

TABLE 4-6

STOP TIME ROUTE DATA SUMMARY

AM PEAK

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	0.791	0.306	117
2	0.371	0.284	120
3	0.798	0.435	114
4	0.621	0.270	116
5	0.489	0.277	148
6	0.662	0.346	141

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	0.312	0.278	80
2	0.382	0.269	80
3	0.785	0.316	63
4	0.757	0.433	59
5	0.307	0.261	104
6	0.561	0.236	82

TABLE 4-7

STOP TIME ROUTE DATA SUMMARY

NOON OFFPEAK

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	0.630	0.295	83
2	0.059	0.015	84
3	0.446	0.351	80
4	0.667	0.378	86
5	0.487	0.286	107
6	0.302	0.266	110

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	0.449	0.249	74
2	0.375	0.227	79
3	0.782	0.337	70
4	0.517	0.292	38
5	0.283	0.208	97
6	0.583	0.313	52

TABLE 4-8

STOP TIME ROUTE DATA SUMMARY

PM PEAK

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	0.660	0.284	74
2	0.421	0.227	78
3	0.731	0.363	72
4	1.182	0.450	70
5	0.707	0.345	96
6	0.801	0.374	90

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	0.662	0.321	60
2	0.600	0.275	57
3	0.693	0.313	60
4	0.631	0.353	60
5	0.412	0.236	68
6	0.592	0.273	67

TABLE 4-9

BEFORE-AND-AFTER OVERALL COMPARISON OF STOP TIME

	AVERAGE STOP TIME (MIN.)		IMPROVEMENT (MIN.)	
CONTROL MODE / TIME PERIOD	PRETIMED CONTROL	COMPUTER CONTROL	Δ	PERCENT IMPROVEMENT
A.M.	0.615	0.455	0.160	26.02
NOON	0.452	0.448	0.004	0.88
P.M.	0.774	0.534	0.240	31.01

Normandie interchange, it invariably arrives during the B-phase at the Western interchange, unless there are substantial queues awaiting service. This bias effect was not as pronounced for the eastbound offramp movement. The bias effect results in an unfair comparison for route 2, and to a lesser degree route 4.

4.4 RESULTS FROM NUMBER OF STOPS

The summary results for the number of stops obtained from the test-car survey are presented in tabular form in this section. Tables 4-10 through 4-12 show the results for the number of stops on a route basis. For each of these tables, the results obtained while operating under pretimed signal control are presented in the upper half. The results obtained while operating under computerized signal control are presented in the lower half.

Table 4-10 shows the results obtained during the morning peak period. Table 4-11 shows the results obtained during the noon off-peak period. And Table 4-12 shows the results for the afternoon peak period. These values are derived from the day-to-day statistics which are given in Appendix C.

The net improvement is computed for each time period by taking the average over the routes, weighted by the corresponding demand weighting factors (given in Table 4-4).

The overall comparison of average stop time, before and after computerized traffic control was effected, is shown in Table 4-13.

The reduction in the average number of stops is seen to be very substantial. For the three indicated time periods, the reduction in the average number of stops per vehicle ranges from 0.33 to 0.89. Up to 31.4 percent reduction in the number of stops was obtained.

TABLE 4-10

NUMBER-OF-STOPS ROUTE DATA SUMMARY

AM PEAK *

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	2.1	.975	117
2			
3	2.4	1.337	118
4	2.1	1.036	120
5	1.9	1.128	153
6	2.5	1.658	143

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	1.0	.880	79
2			
3	2.0	1.132	62
4	2.2	.730	58
5	1.3	.870	104
6	1.8	1.082	84

*Route 2 data not used because of the effect of the Normandie interchange (See page 4-9).

TABLE 4-11

NUMBER-OF-STOPS ROUTE DATA SUMMARY

NOON OFFPEAK*

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	2.06	.926	86
2			
3	1.58	.920	84
4	2.41	1.020	87
5	2.05	1.076	115
6	1.51	1.137	116

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	1.48	.781	79
2			
3	1.87	.883	71
4	1.69	.739	42
5	1.30	.903	100
6	1.89	1.032	55

*Same as footnote on Table 4-10

4.5 RESULTS FOR NUMBER OF BRAKE APPLICATIONS

The summary results for the number of brake applications from the test-car survey are presented in tabular form in this section. Tables 4-14 through 4-16 show the results obtained for the number of brake applications on a route basis. For each of these tables, the results obtained while operating under pretimed signal control are presented in the upper half. The results obtained while operating under computerized signal control are presented in the lower half.

Table 4-14 shows the results obtained during the morning peak period. Table 4-15 shows the results obtained during the noon off-peak period. And Table 4-16 shows the results for the afternoon peak period. These values are derived from the day-to-day statistics which are given in Appendix D.

The net improvement is computed for each time period by taking the average over the routes, weighted by the corresponding demand weighting factors (given in Table 4-4).

The overall comparison of average number of brake applications, before and after computerized traffic control was effected, is shown in Table 4-17.

The reduction in the number of brake applications is seen to be very substantial. The reduction in the average number of brake applications per vehicle ranges from .25 to 1.00. Up to 30 percent reduction in the number of brake applications was obtained.

TABLE 4-14

BRAKE APPLICATIONS ROUTE DATA SUMMARY

AM PEAK

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	2.9	1.231	112
2	2.6	1.164	115
3	3.5	1.442	112
4	2.7	1.155	114
5	2.9	1.480	143
6	4.1	1.942	130

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	2.0	.878	76
2	2.2	.886	78
3	3.3	.976	58
4	2.3	.770	56
5	2.2	1.202	104
6	2.4	1.297	82

TABLE 4-15

BRAKE APPLICATIONS ROUTE DATA SUMMARY

NOON OFFPEAK

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	2.7	1.115	75
2	1.9	1.159	76
3	2.7	1.309	75
4	2.9	1.195	77
5	2.7	1.020	99
6	2.9	1.412	98

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	2.5	.913	58
2	2.2	.862	63
3	2.6	.960	57
4	2.5	.995	32
5	2.4	1.237	81
6	2.6	1.261	47

TABLE 4-16

BRAKE APPLICATIONS ROUTE DATA SUMMARY

PM PEAK

PRETIMED CONTROL			
Route	Average	σ	Sample Size
1	3.11	1.259	73
2	2.73	1.158	78
3	3.14	1.270	71
4	4.62	1.999	72
5	3.72	1.716	95
6	4.29	2.163	90

COMPUTER CONTROL			
Route	Average	σ	Sample Size
1	3.07	1.429	48
2	2.83	1.115	46
3	2.82	.861	49
4	3.14	1.047	46
5	2.72	1.207	54
6	3.80	1.535	54

TABLE 4-17

BEFORE-AND-AFTER OVERALL COMPARISON OF NUMBER OF BRAKE APPLICATIONS

TIME PERIOD \ CONTROL MODE	AVERAGE NUMBER OF BRAKE APPLICATIONS		IMPROVEMENT	
	PRETIMED CONTROL	COMPUTER CONTROL	Δ	PERCENT IMPROVEMENT
A.M.	3.331	2.327	1.004	30.15
NOON	2.739	2.482	0.257	9.38
P.M.	3.380	3.140	0.740	19.07

5. EVALUATION RESULTS USING THE SURVEILLANCE SYSTEM

5.1 PRESENTATION OF DATA

Several measures of operational performance have been indicated to be obtainable from the surveillance subsystem of the computerized traffic control system implemented at the Western Avenue Interchange site. A preliminary analysis performed on the data that was being obtained from this subsystem revealed that the preferred ways of making the comparative evaluations of operational performance were by:

a. Using time series plots of average delay per vehicle, total vehicle-seconds of delay, etc.

b. Plotting vehicle-hours/hour versus vehicle-miles/hour.

These two principal ways will be used to present the results of the comparative evaluations from the measurements made possible through the surveillance system.

The above methods of data presentation will be supplemented by histograms of selected variables.

5.2 DEMAND VARIATION

Initial interest is in determining the demand behavior throughout the major portion of the day. The total demand* variation throughout the time period 0700 to 1600 is shown in Figure 5.1. Two graphs are presented in this figure. One was measured while the system was under computerized, or real-time, control. Total demand, shown on the ordinate, is defined to be the sum of all vehicles measured over all the monitored lane sections in the interior, controlled portion of the interchange complex -- the region bounded by the two nearby intersections. The measurements have been made over ten-minute periods. It is noted that although the data was collected on two different, arbitrary weekdays, the demand variation is very consistent for the two days. The fact that the data was collected under two different control conditions is irrelevant.

The demand variation for the time period from 1600 to 0100 is shown in Figure 5.2. Here, again, the graphs for two different days are shown to vary remarkably consistently.

It can be concluded from this data that operational performance data for one day can be compatibly compared to operational performance data collected on another day. Differences in operational performance can be attributed to factors other than demand differences.

* Data collected in May 1973, for weekdays.

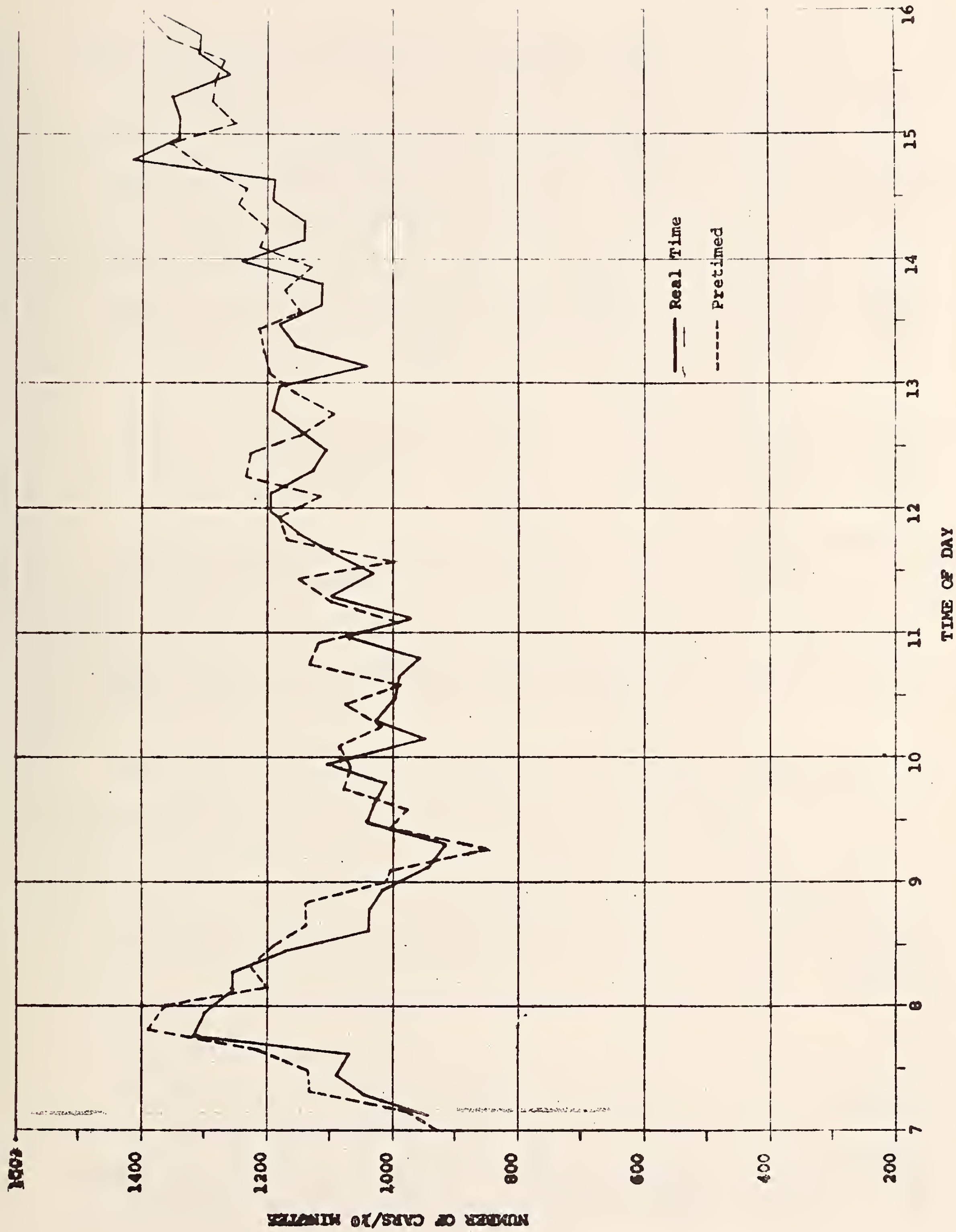

Figure 5.1 Total Interchange Demand Distribution

0700 - 1600

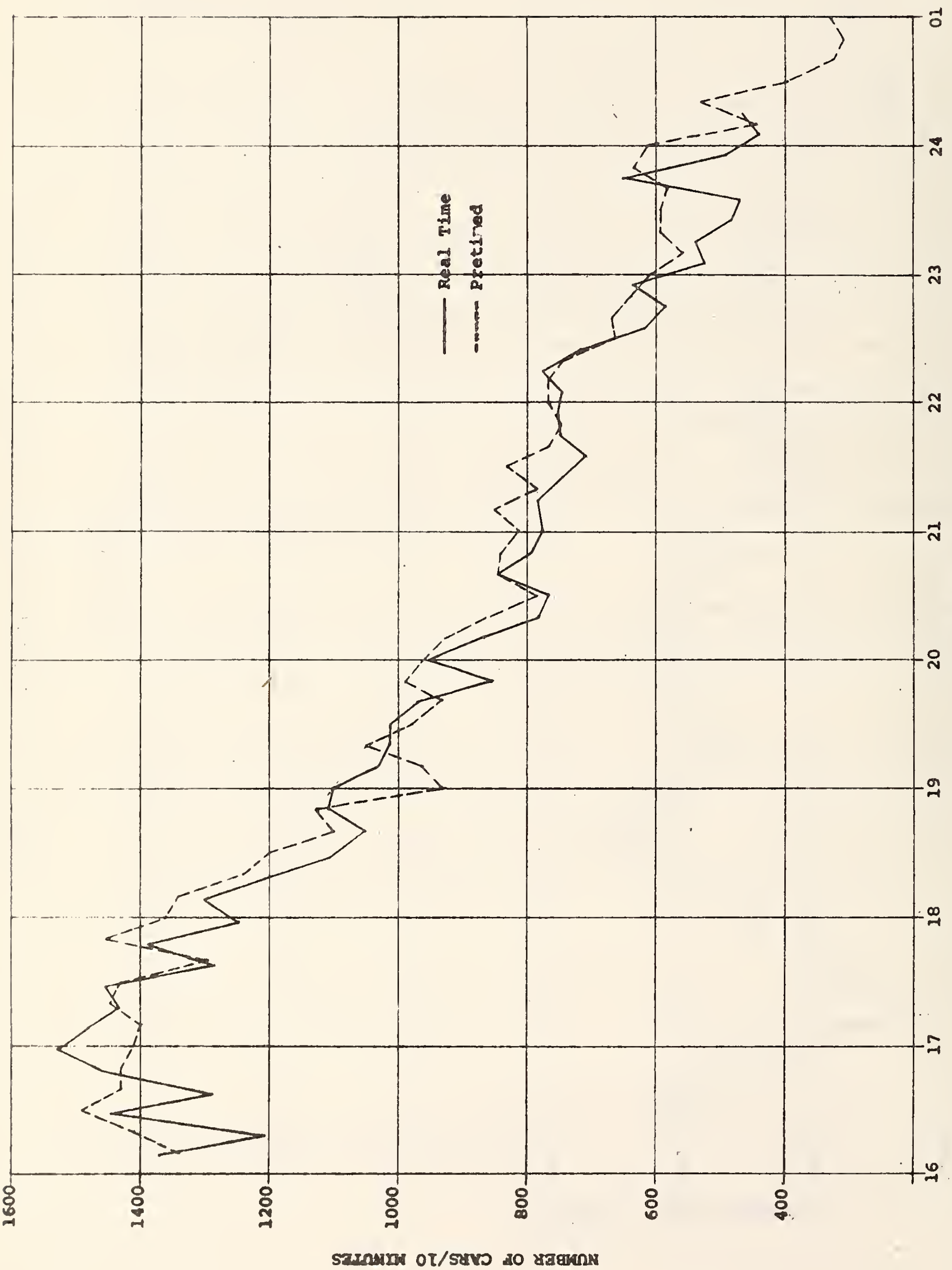

Figure 5.2 Total Interchange Demand Distribution
1600 - 0100

5.3 COMPARISON OF TOTAL VEHICLE DELAY FOR FULL SET

Total vehicle delay (in vehicle-seconds) over the entire diamond interchange complex, including all approaches to the nearby intersections, is compared in Figure 5.3 for the system under computerized traffic control versus pretimed control. It is noted that under computerized control, the total delay in the system is uniformly lower than the pretimed system. Here, again, the measurements are made over ten-minute periods. The ten-minute period will later be shown to be the preferred sampling period. (See Section 5.6.)

Delay is computed by subtracting the estimated free-flow travel time from the prevailing measured travel time over the monitored sections.

The total vehicle delay over the fully monitored system under computerized traffic control is compared to the total vehicle delay under the pretimed system in Figure 5.4 for the period 1600 to 0100. Under computerized control, the total delay is uniformly less than under pretimed control. This data was collected using 10-minute long-term periods.

Note that a conservative estimate of the delay reduction per ten-minute period is 3000 vehicle-seconds. For a one-hour period, the delay reduction is about 18,000 vehicle seconds, or five vehicle-hours. For an entire day, the delay reduction is conservatively about 120 vehicle-hours. The largest delay savings occur during the off-peak hours. It is concluded that there is a substantial net improvement in operational performance when the interchange is under computerized traffic control.

At this point, it is of interest to compare the actual measured delay in the computerized traffic control system to the predicted delay obtained from the simulation model exercise that was performed in an earlier task in this project. The corresponding graphs of delay

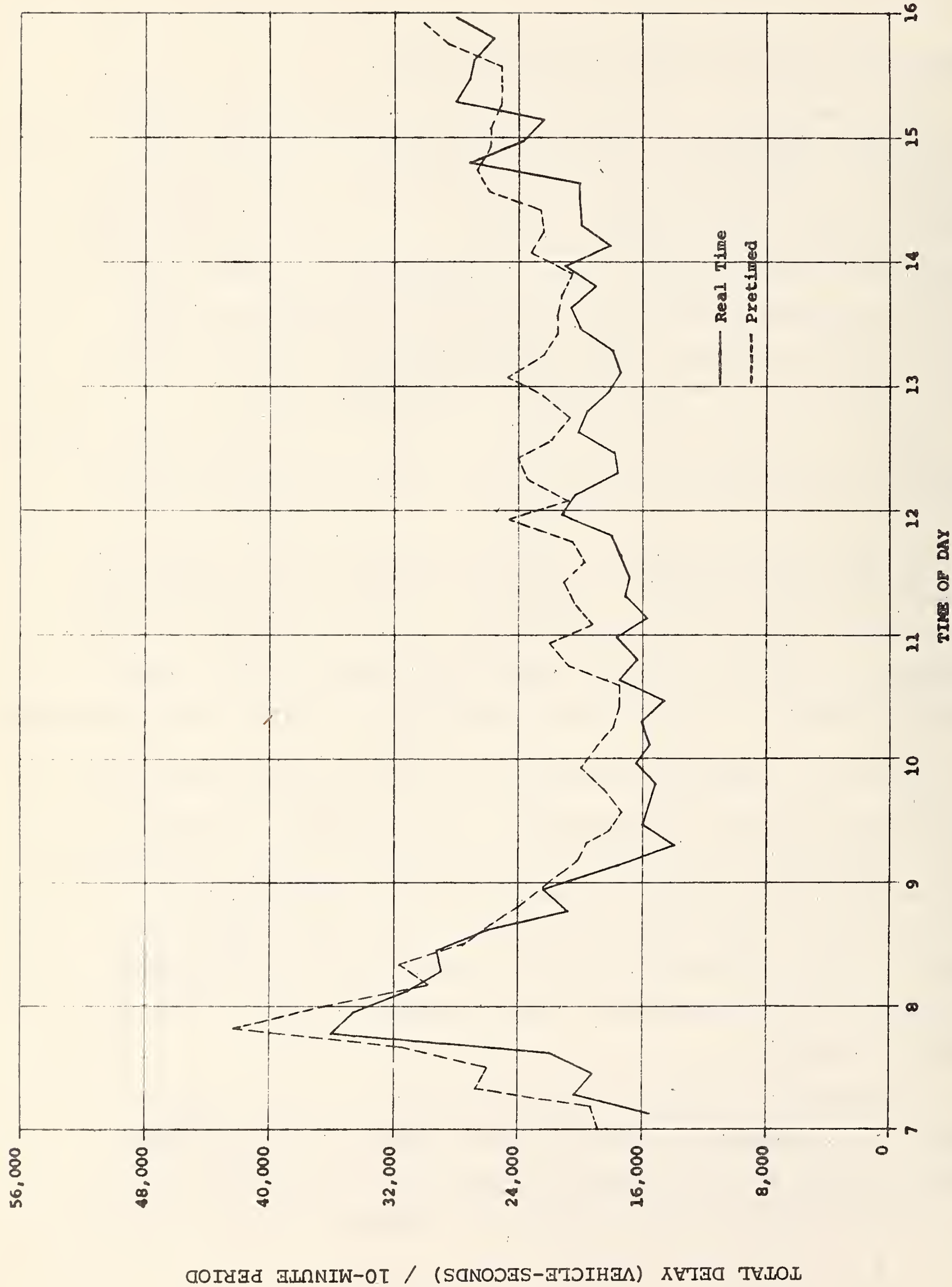

Figure 5.3 Total Interchange Demand Distribution (May 1973)
0700 - 1600

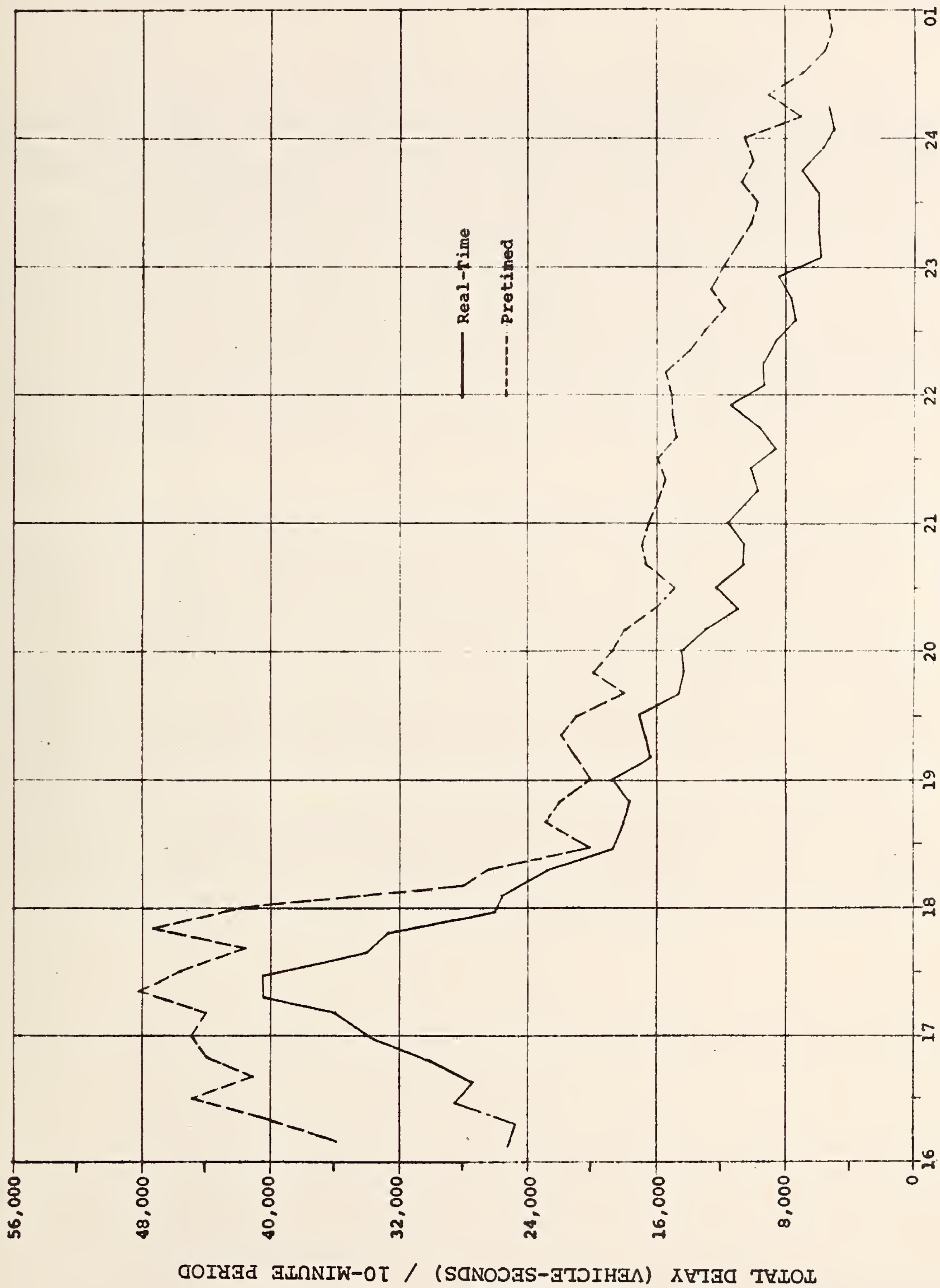

Figure 5.4 Total Interchange Demand Distribution (May 1973).
1600 - 0100

versus time of day, obtained from the use of the macroscopic simulation model are shown in Figure 5.5.* This data was obtained using 15-minute long-term periods, where delay was cumulated over one-hour.

* Cf. SDC Report No. TM-4601/006/01.

Three graphs shown in Figures 5.3 and 5.4 are compared to those shown in Figure 5.5, in Figures 5.6 and 5.7. Figure 5.6, in particular, compares the actual delay measured at the Western Avenue site using the computerized surveillance system against the delay predicted by the computer simulation model. The diamond interchange is under real-time traffic control for both actual and simulated operations.

Figure 5.7 compares the actual delay measured using the computerized surveillance system against the delay predicted by the computer simulation model when the diamond interchange is under pretimed 3-dial control.

Excellent agreement is shown between the simulated values and the measured values shown in Figures 5.6 and 5.7 for the offpeak hours after observing that the ordinate scales are related; for example.

1600 vehicle-minutes/hour = 16,000 vehicle-seconds/10 minutes

However, the actual experienced delay during the peak hours is shown to be greater than that predicted from the simulation model for both the computerized system and the pretimed system. The trend in the variation of delay throughout the day is, nevertheless, consistent for both approaches. This suggests that the delay cumulation algorithm in the simulation model can profit from some further calibration.

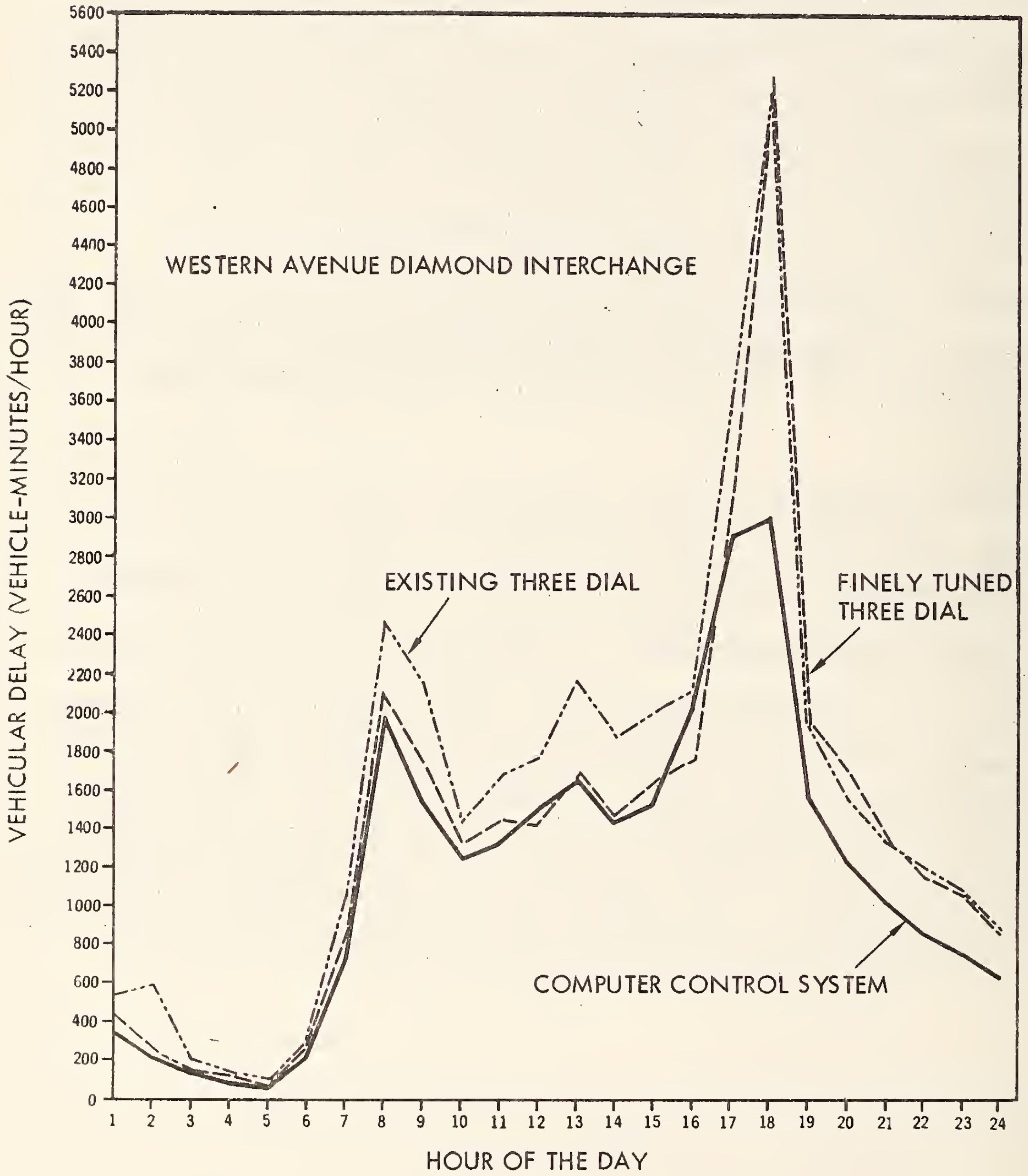

Figure 5.5 Simulation Model Total Delay

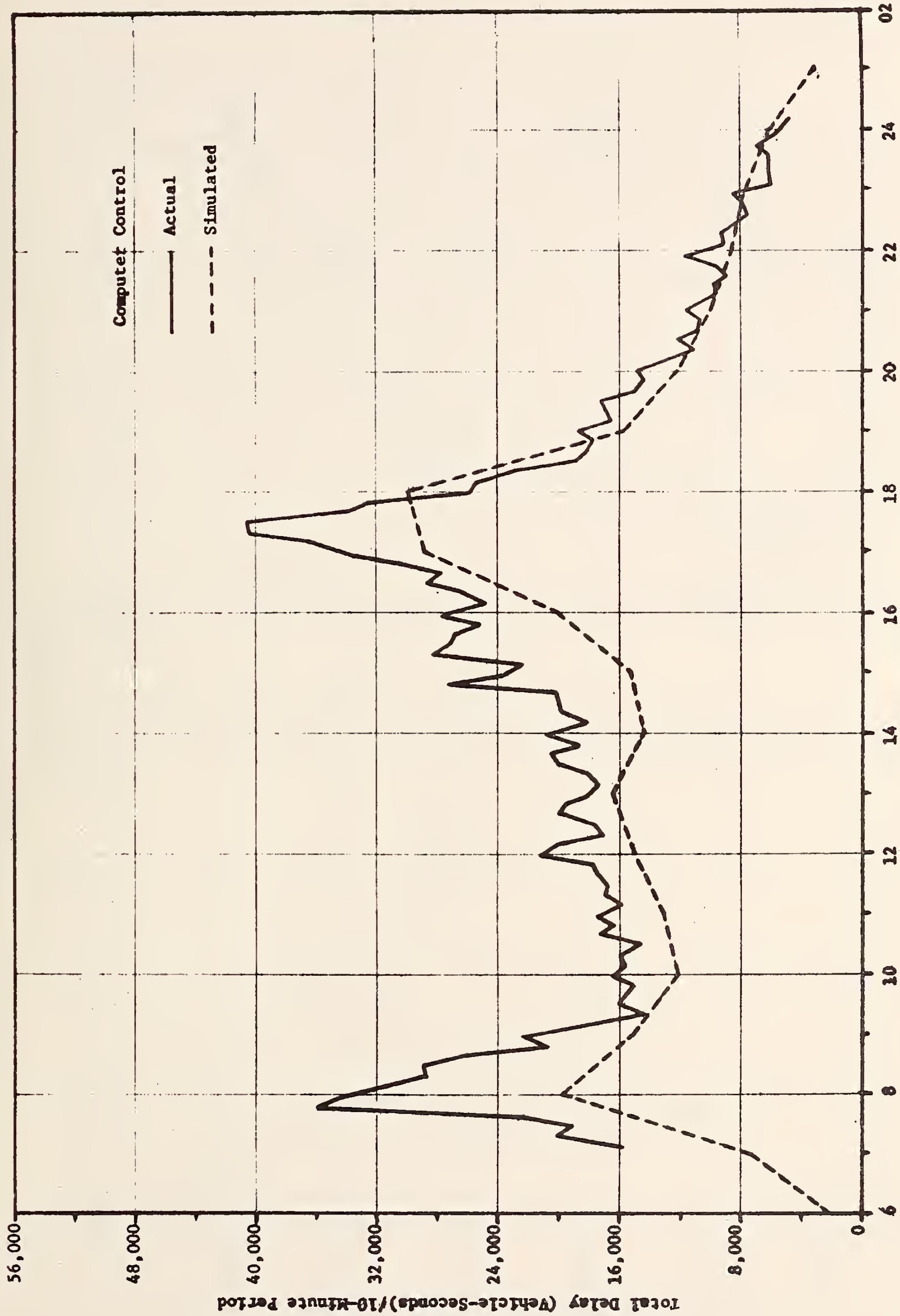

Figure 5.6 Comparison of Actual to Simulated Delay When Interchange is Under Real-Time Control

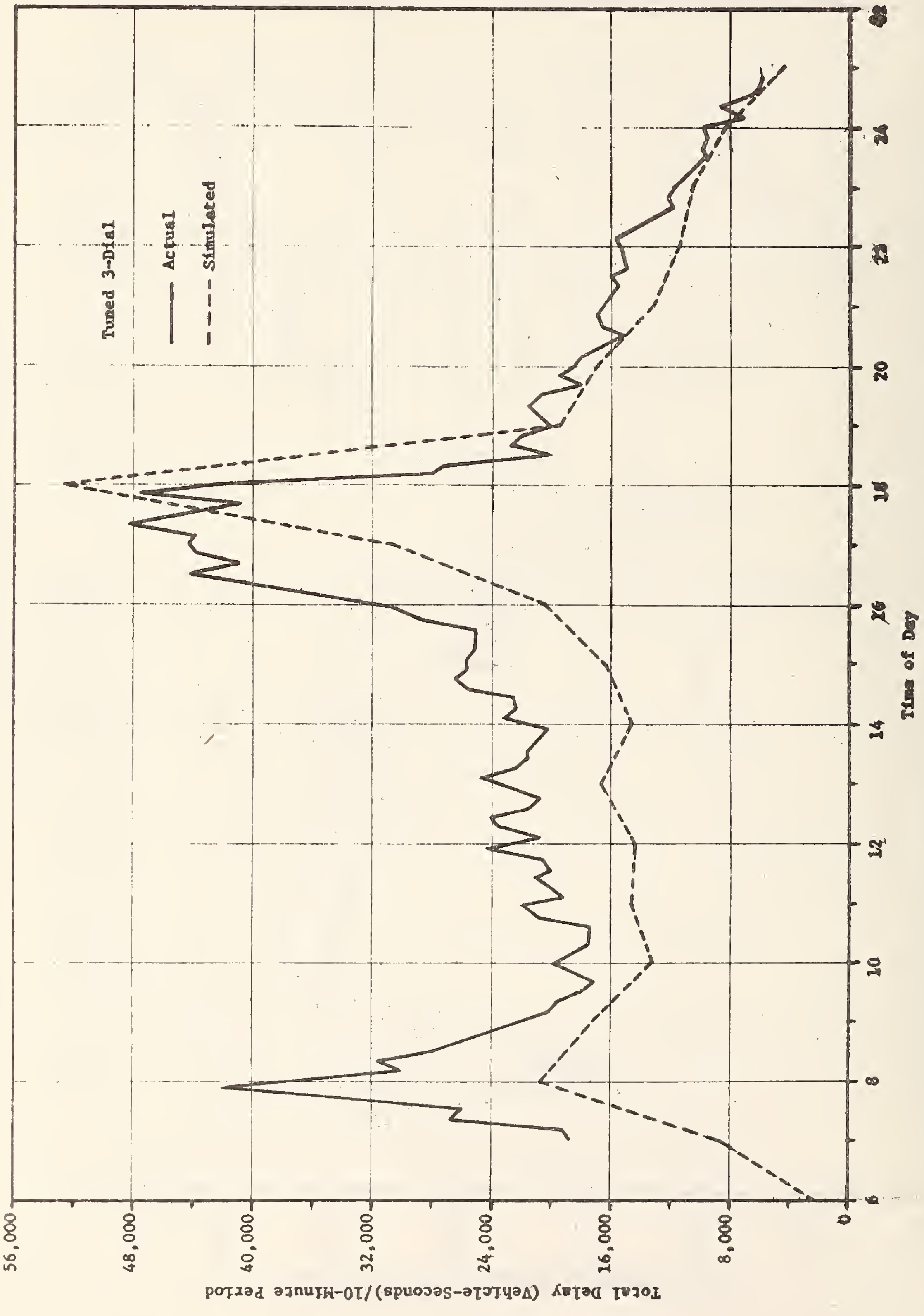

Figure 5.7 Comparison of Actual to Simulated Delay When Interchange is Under Pretimed, 3-Dial Control

5.4 COMPARISON OF VEHICLE DELAY FOR THE CONTROLLED SUBSET

The computerized traffic control system at the diamond interchange site was designed to provide the greatest improvement in the internal area of the diamond interchange complex, that is, the region between the two nearby intersections. It is of greater interest than to observe the operational performance of the system within this subset of the interchange complex. Total vehicle-seconds of delay for this subset is compared in Figure 5.8 for the time period 0700 - 1600, for the computerized control system and the pretimed system. The percent reduction in delay for the computerized control case can be observed to be better for the subset, as would be expected.

The total vehicle-seconds of delay for the computerized system is compared to the pretimed system in Figure 5.9 for the time period 1600 - 0100.

This subset, the region between the nearby intersections, will have the focus of attention in the results presented in the following sections.

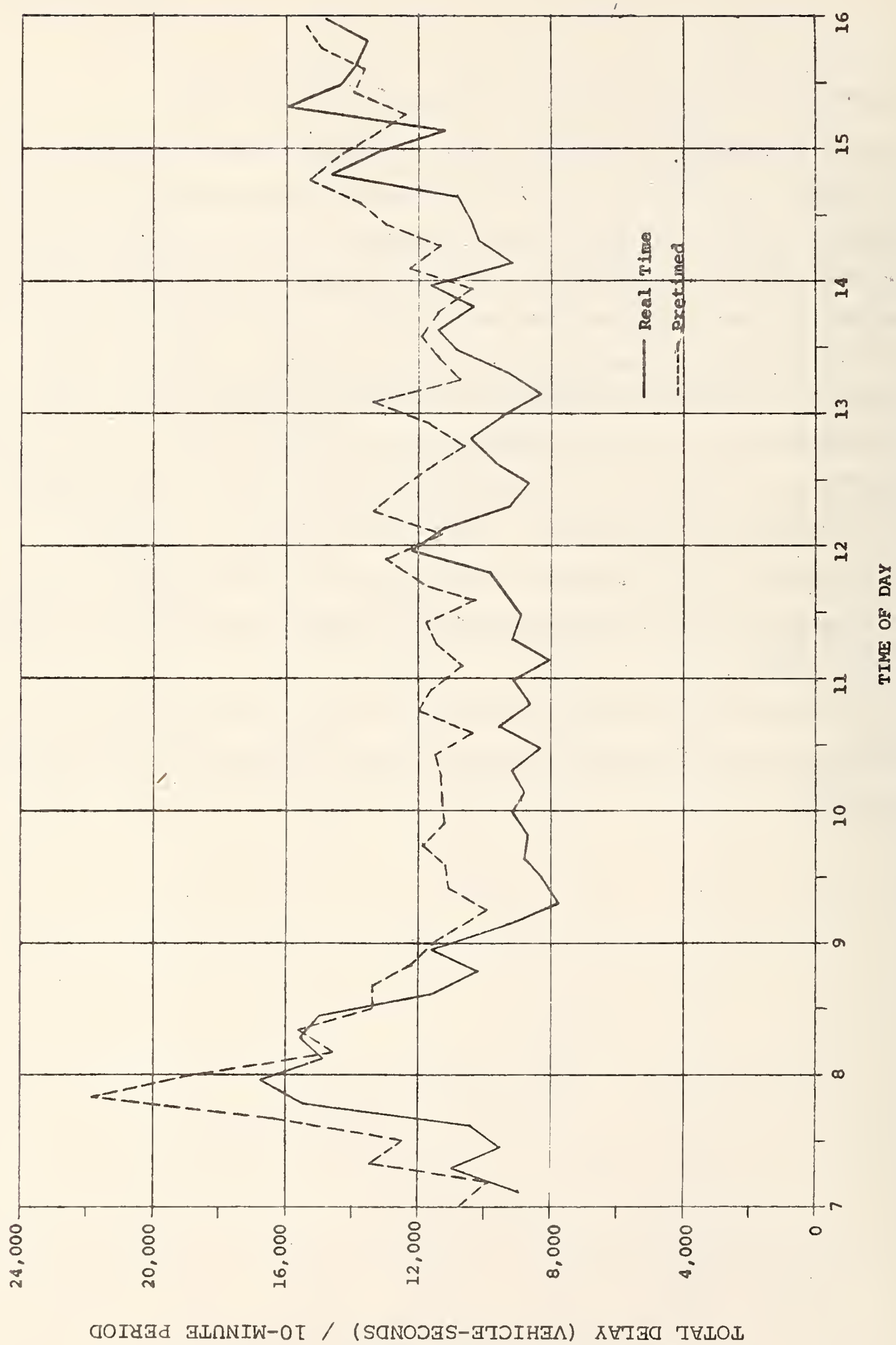

Figure 5.8 Total Delay for Interchange Subset
0700 - 1600

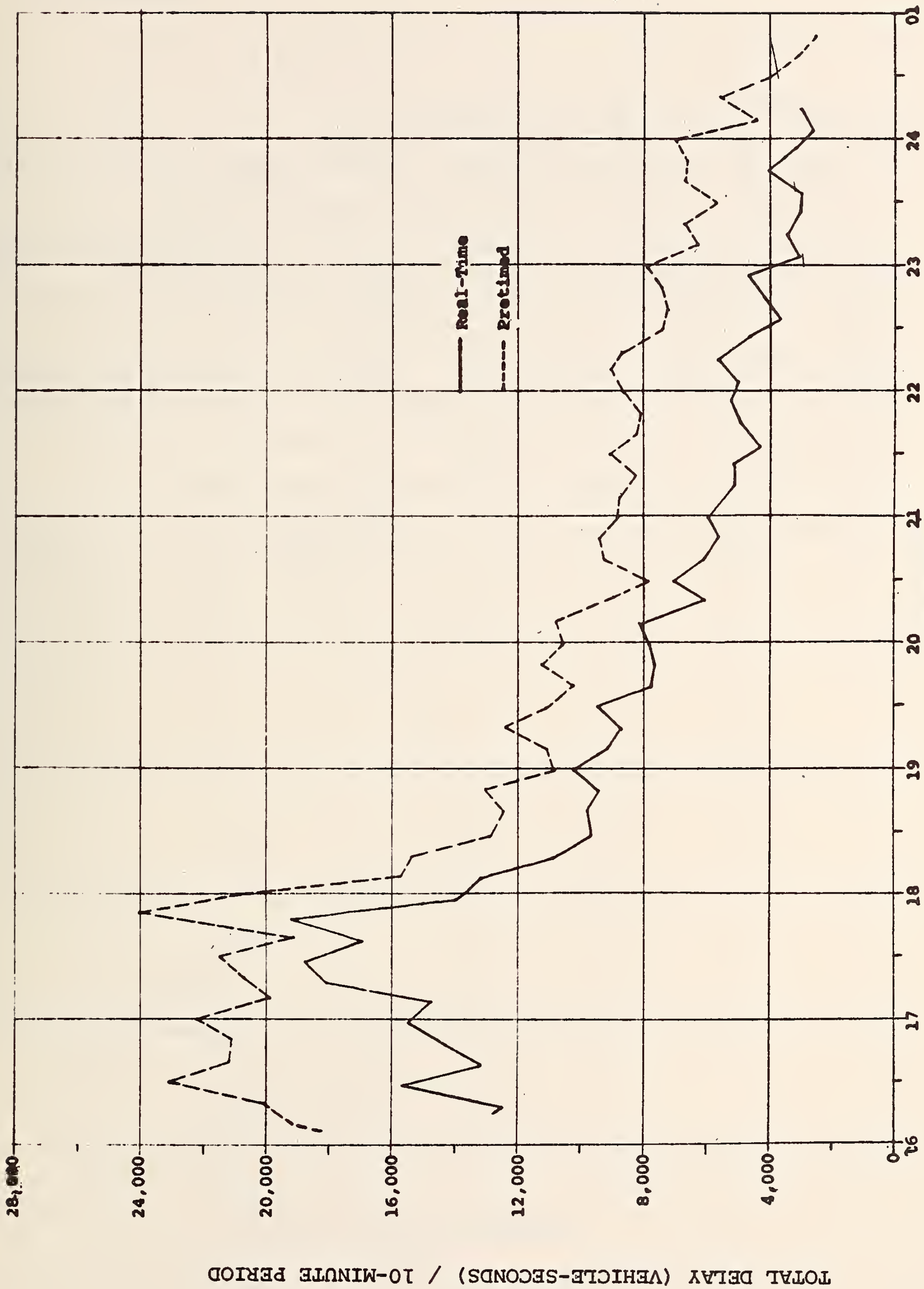

Figure 5.9 Total Delay for Interchange Subset
1600 - 0100

5.5 COMPARISON OF AVERAGE DELAY/VEHICLE

Since it has been indicated that the total demand level and variation remains relatively invariant from weekday to weekday, it was determined that better indicator of relative operational performance would be average delay/vehicle. Average delay/vehicle for the computerized system is compared to the pretimed system for the time period 0700 - 1600 in Figure 5.10. This type of presentation reduces some of the relative variation between the two compared graphs (with respect to total delay), since the ordinate scale is essentially independent of the number of vehicles (for given times).

The average delay/vehicle for the computerized system is compared to the pretimed system for the time period 1600 - 0100 in Figure 5.11.

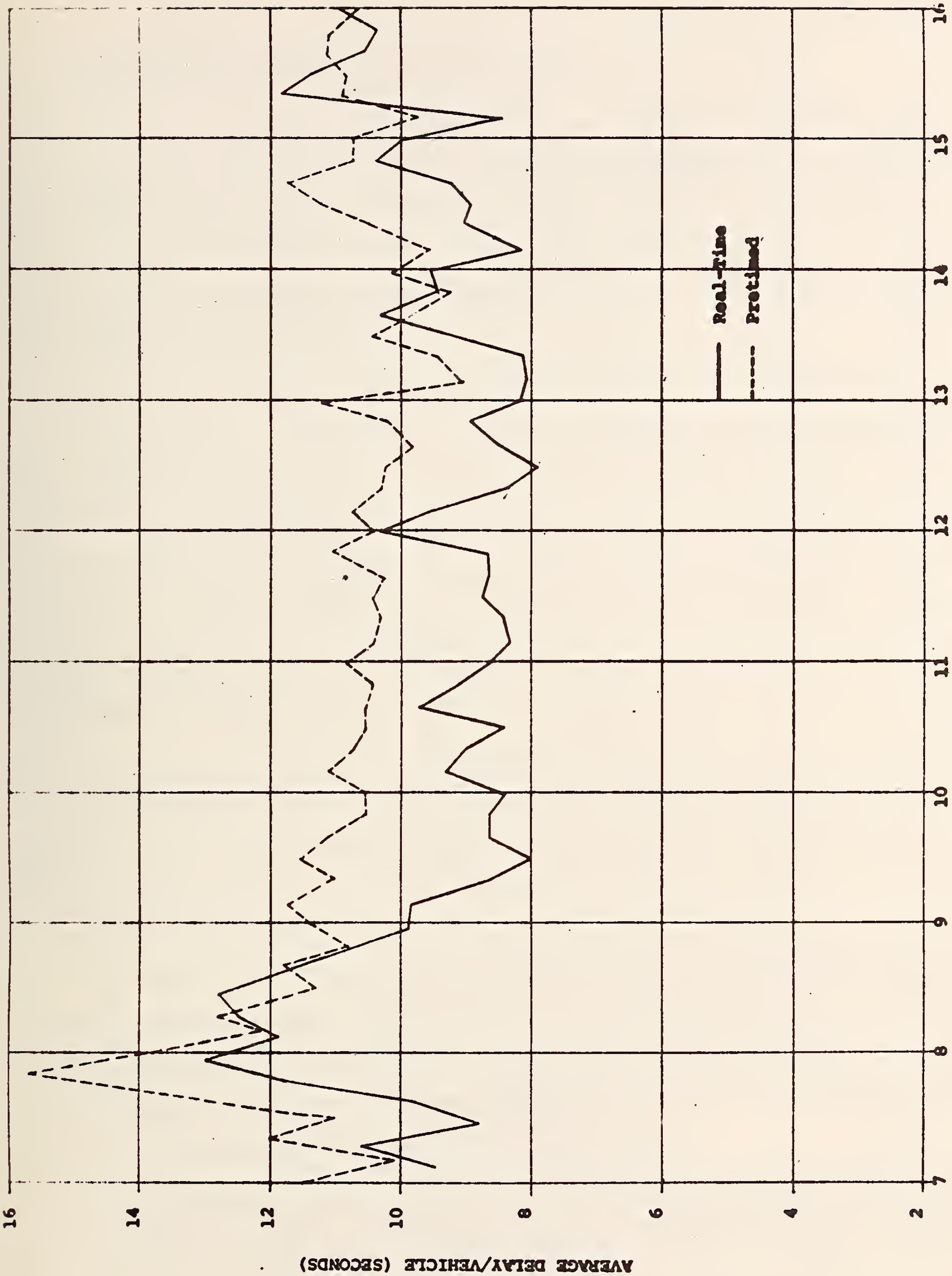

Figure 5.10 Average Delay/Vehicle
0700 - 1600

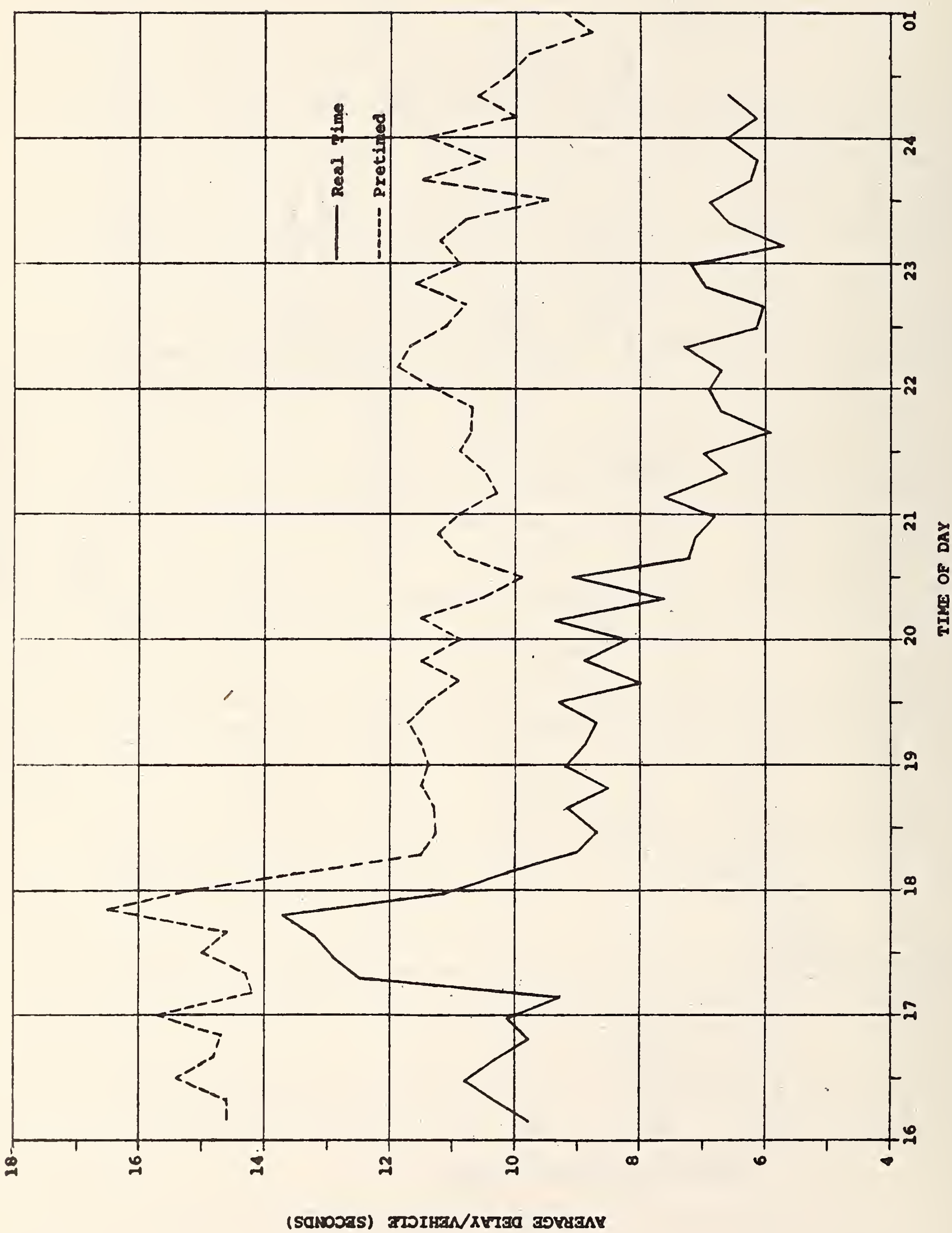

Figure 5.11 Average Delay/Vehicle
1600 - 0100

5.6 DETERMINING THE PREFERRED LONG-TERM PERIOD

The length of the long-term period was observed to appear to have a significant effect on the operational performance of the computerized traffic control system. To identify the preferred long-term period, a set of experiments was conducted. Average delay/vehicle was selected as the measure of operational performance to use in determining the preferred long-term period.

In Figure 5.12 the operational performance of the computerized traffic control system using a 5-minute long-term period is compared to the 10-minute long-term period case, for the evening off-peak. The 5-minute long-term graph is observed to have a generally higher moving average than the 10-minute case. Also, the 5-minute case has a considerably greater number of fluctuations. These large fluctuations are attributed to random traffic variations that have no definite trend. These variations can affect the cycle length and splits, degrading the operational performance.

Figure 5.13 compares the operational performance of the computerized system using a 5-minute long-term period against the 10-minute long-term period case for the evening peak period. Here again the 10-minute long-term is indicated to have a generally lower moving average than the 5-minute case.

In Figure 5.14 the operational performance of the computerized traffic control system using a 20-minute long-term period is compared to the 10-minute long-term case. This graph covers the morning peak as well as the off peak. The 20-minute graph is shown to have generally larger average delay than the 10-minute case.

It is concluded that the preferred long-term period is about 10 minutes in length.

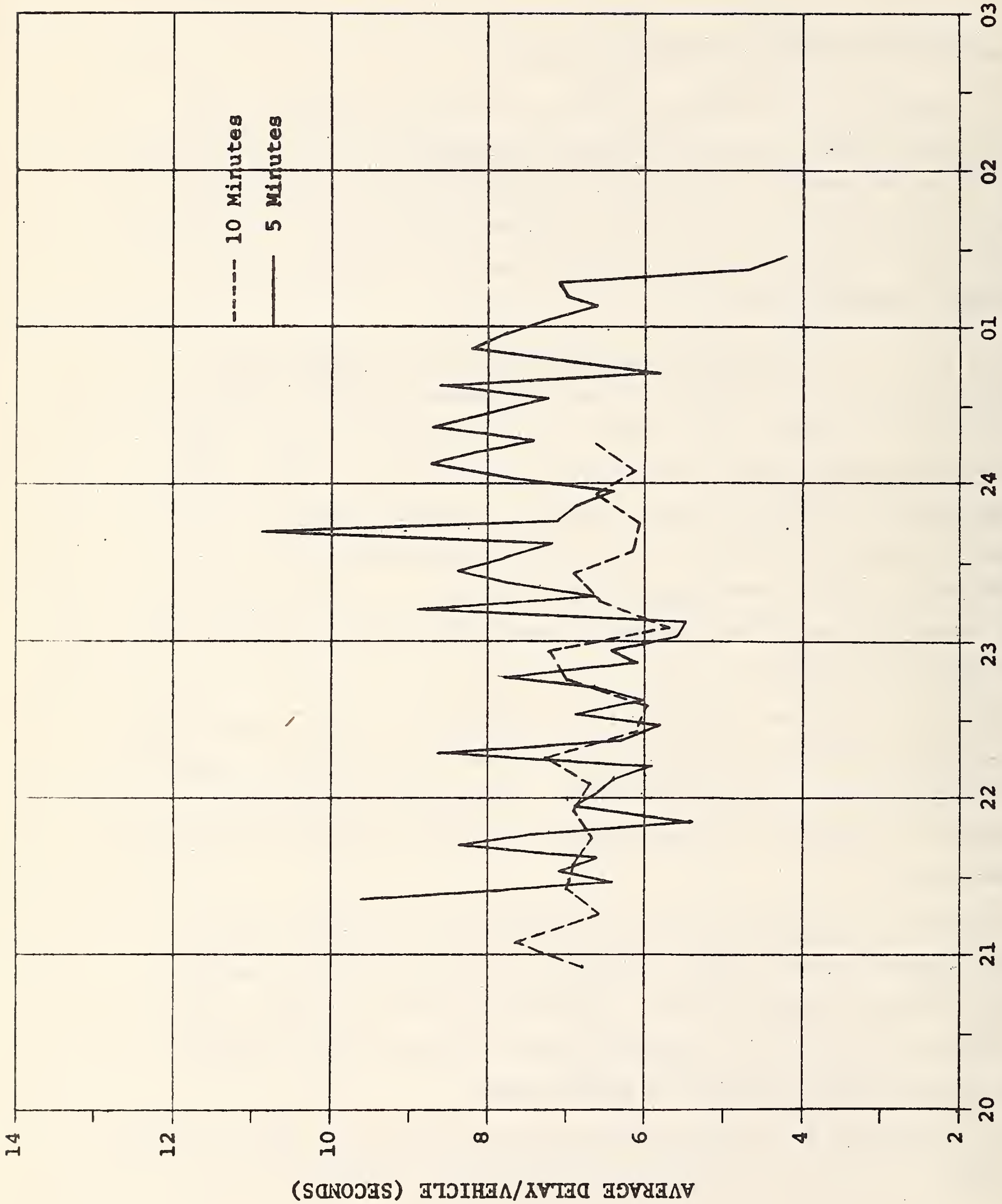

Figure 5.12 Comparison of 5-Minute to 10-Minute Long-Term Period (Night Offpeak)

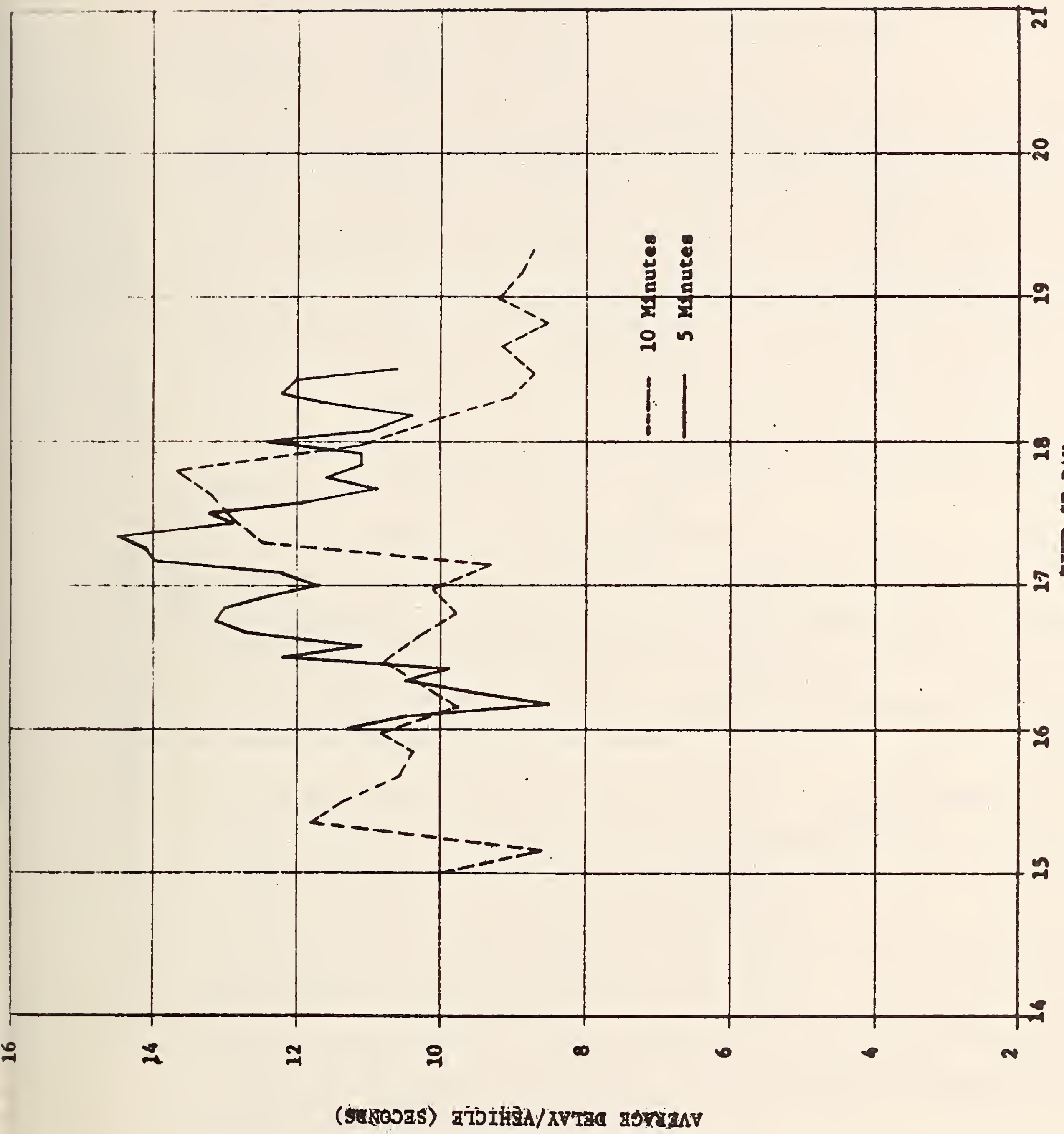

Figure 5.13 Comparison of 5-Minute to 10-Minute Long-Term Period (Evening Peak)

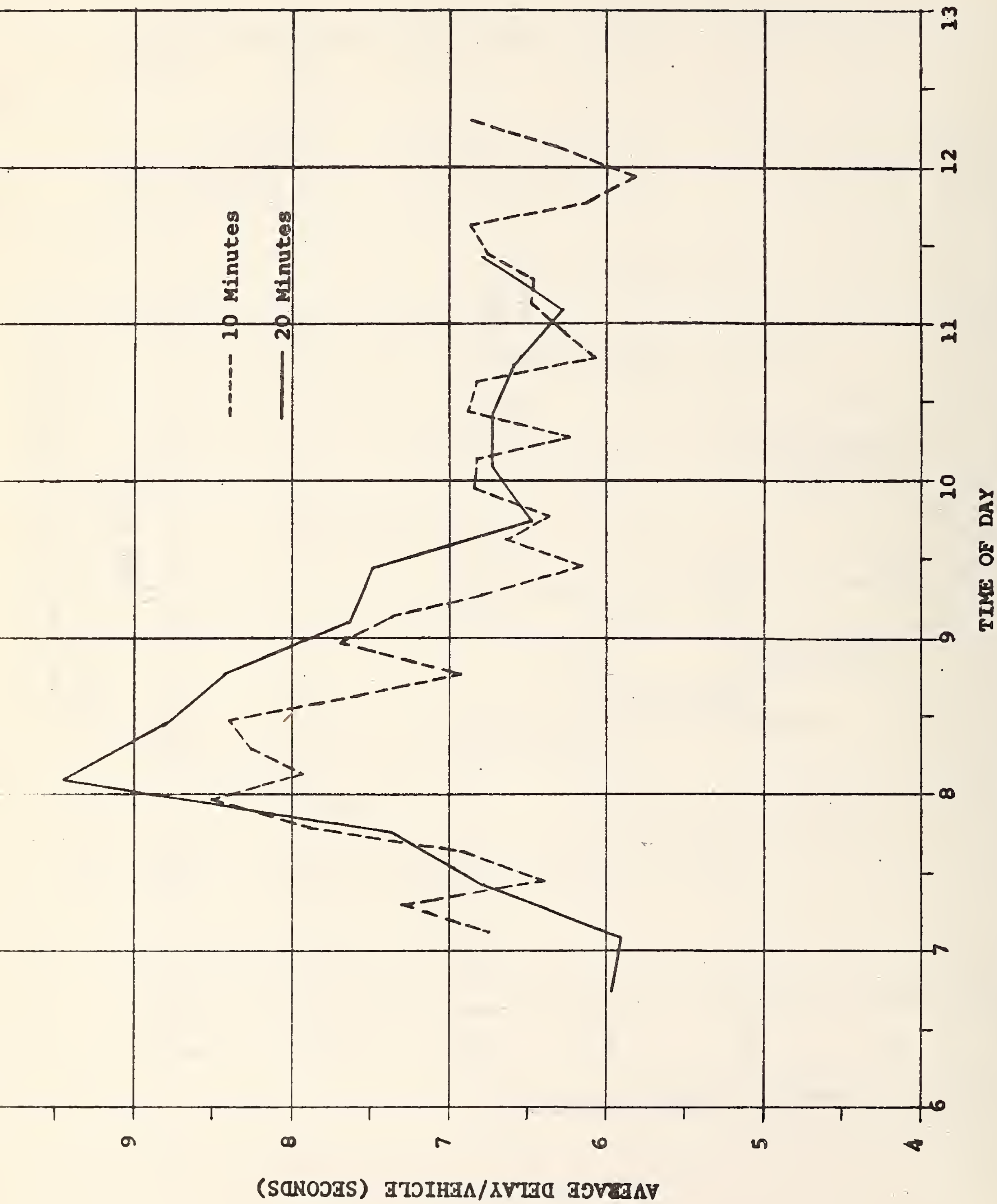

Figure 5.14 Comparison of 20-Minute to 10-Minute Long-Term Period

5.7 DETERMINING OPERATIONAL DETECTOR SET

The computerized system configuration at the Western Avenue Interchange site employed 49 detectors. It was never anticipated that this detector array would be necessary for operational application in the field. However, it was considered important to have a sufficiently large number of detectors in order to be able to reliably monitor the operational performance of the interchange. Without such a surveillance system, it would have been very difficult to make objective, reliable, and economical comparisons of operational performance. The operational configuration of the detector array was expected to have a substantially smaller number of detectors.

The minimum detector configuration that was determined to be able to monitor the major interchange traffic movements is shown in Figure 5.15. The configuration is comprised of a total of 18 detectors. The minor movements were to be determined by inferring the values based on the major movements. The data collected showed strong correlation between the major and minor traffic movements.

The operational performance of this minimum detector configuration was field-tested in the computerized traffic control system. The relative performance observed for the minimum detector configuration (detector subset) is compared to the performance using the full complement of detectors in Figure 5.16. No significant difference is discernible between the two detector configurations. We point out that during the period 12:15 - 13:00, there was a tractor-trailer truck stalled on the north approach to the bridge area. Degraded performance is clearly discernible for this time period.

It is concluded that 18 detectors can be effectively used for real-time control of an interchange complex with no significant degradation.

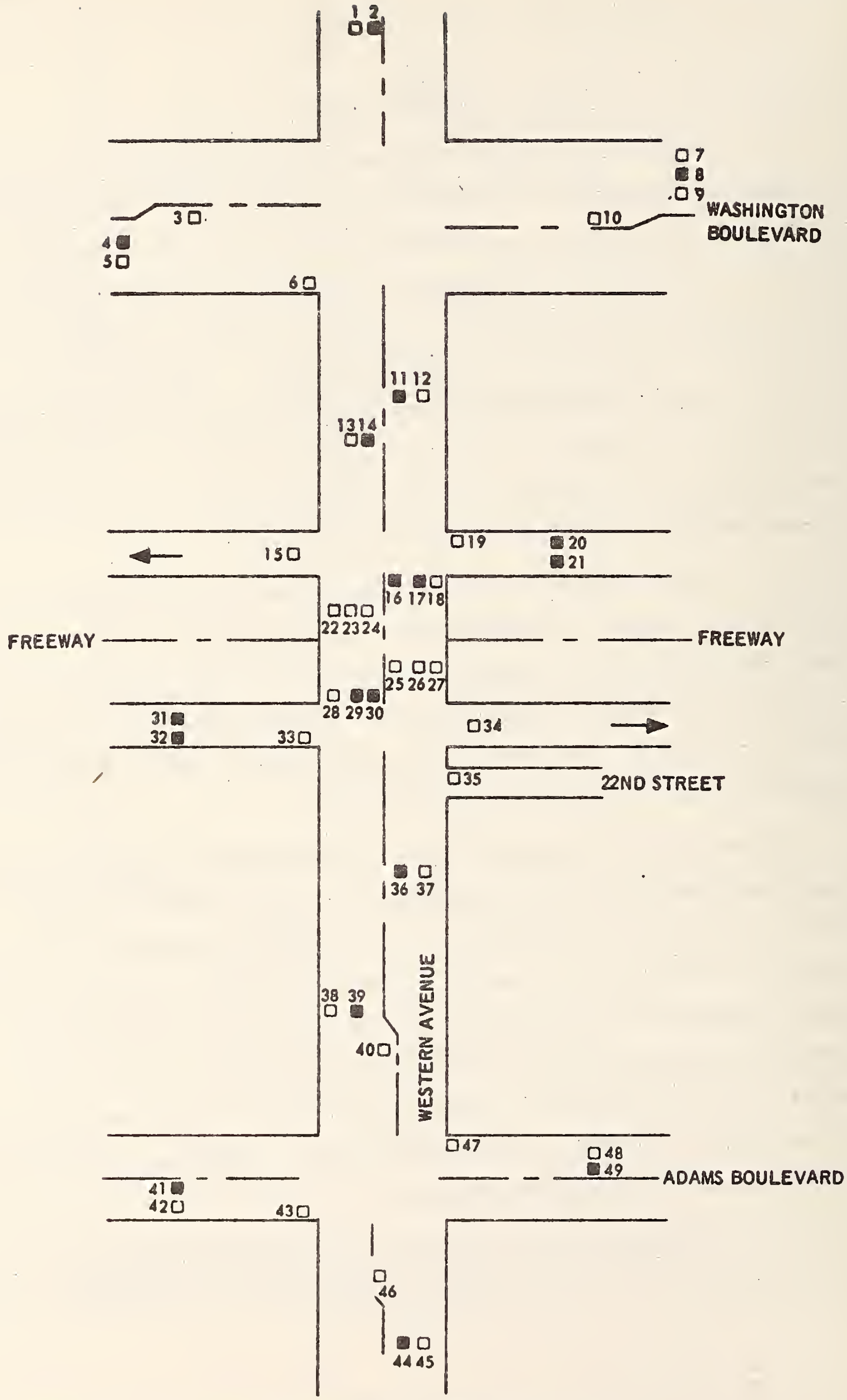

FIGURE 5.15 MINIMUM DETECTOR CONFIGURATION

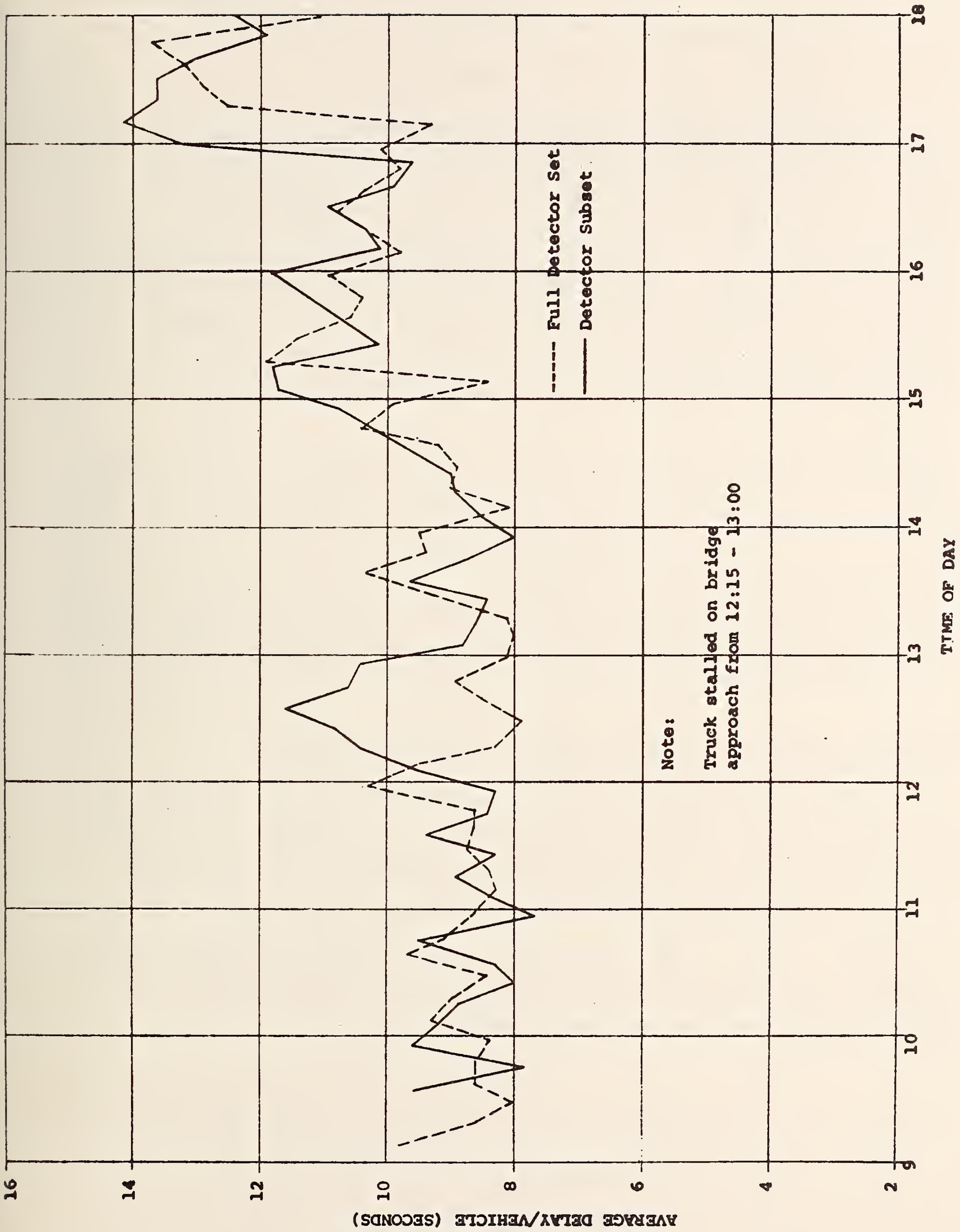

Figure 5.16 Comparison of Detector Subset to the Full Set

5.8 REAL-TIME CONTROL OF ONLY THE RAMP INTERSECTIONS

The diamond interchange complex was operated with only the two-ramp intersections under computerized control. The operational performance of the system operating in this mode was compared to the operational performance while the system had all four intersections under computer control. The comparison of performance is shown in Figure 5.17. It can be seen that there is significant improvement in operational performance by controlling all four intersections in real-time versus controlling only the ramp intersections.

Data was unavailable for the period 13:30 - 15:30 for the case where only the ramps were controlled in real-time. The peak shown at 17:30 for the graph of delay for the whole interchange is attributable to the fact that a 70-second cycle was demanded by the Washington intersection. This forces a 70-second common cycle which doesn't help the Washington traffic since it is saturated at this point of time. On the other hand, a larger cycle length degrades the ramp intersection operational performance.

5.9 REAL-TIME CONTROL OF THE RAMP INTERSECTIONS AND WASHINGTON

The diamond interchange was also operated with all the intersections under computerized control with the exception of the Adams intersection. The performance of this configuration is compared to the system with all four intersections under computer control in Figure 5.18. It can be seen that there is some degradation in operational performance under this limited configuration. Here, again, data was unavailable for the "Adams dropped" case for the period 10:00 - 11:15.

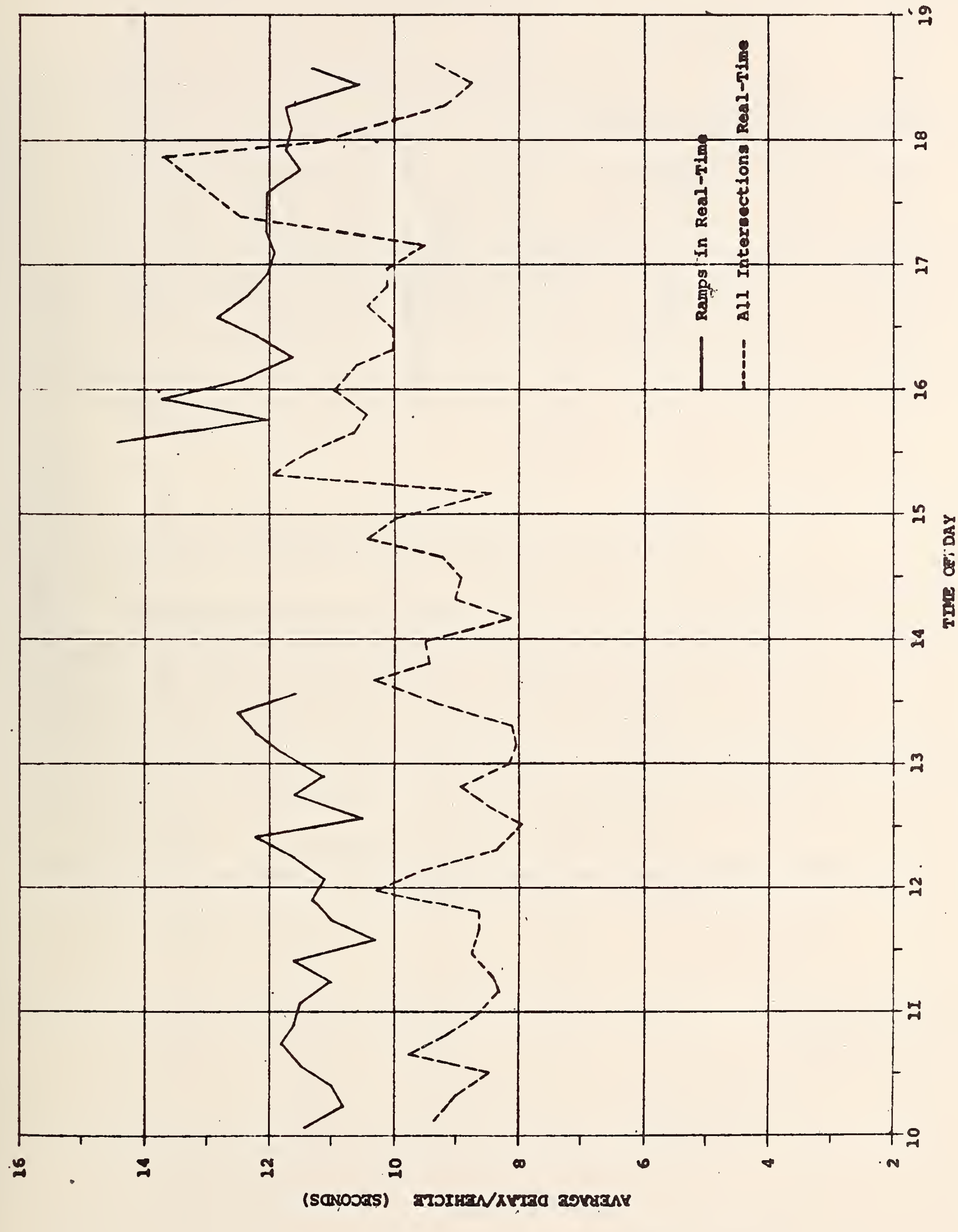

Figure 5.17 Computer Control of Only the Ramp Intersections

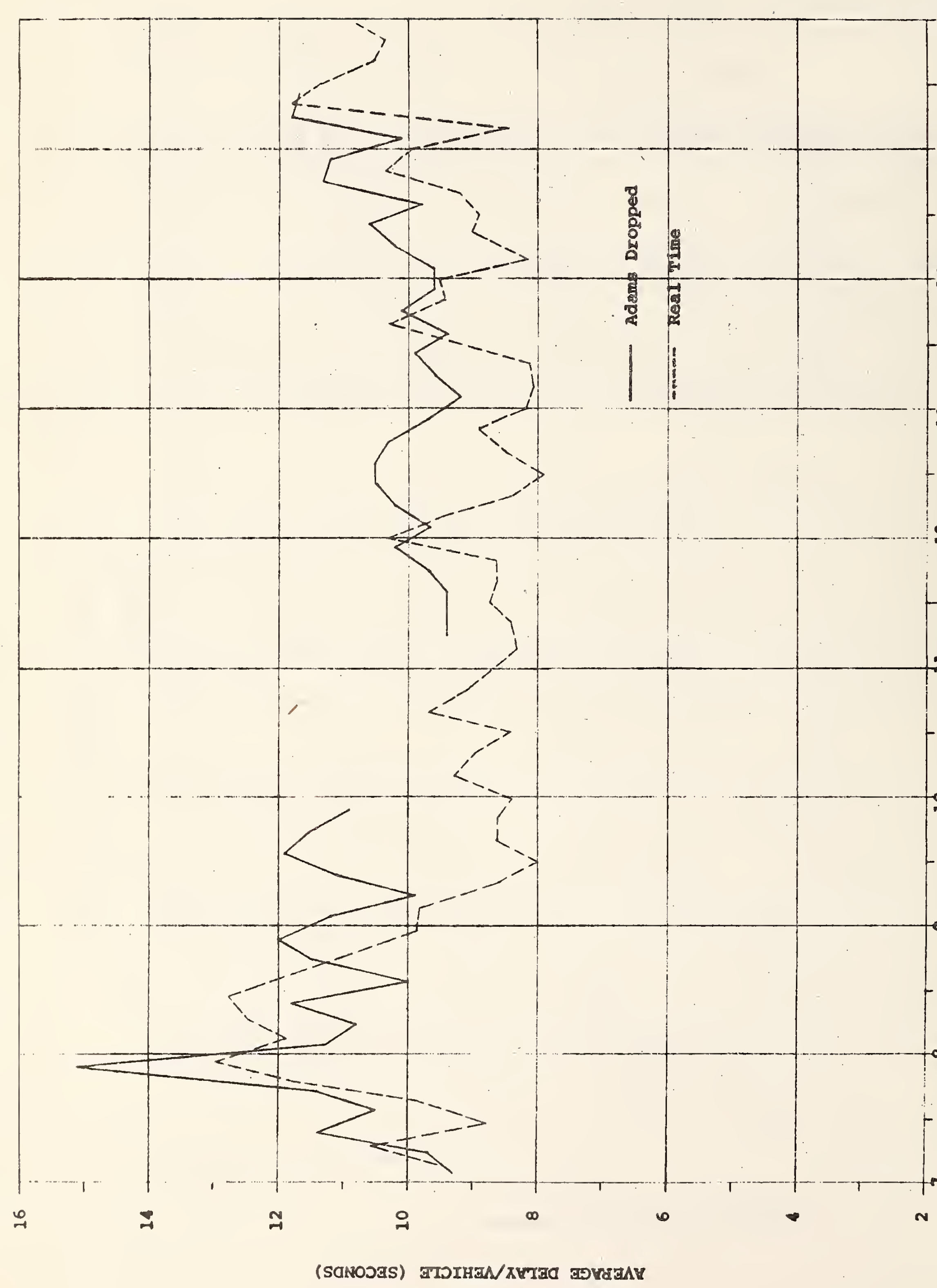

Figure 5.18 Computer Control of Entire Interchange, Excepting Adams

5.10 60-SECOND FIXED CYCLE WITH VARIABLE SPLITS

A 60-second fixed cycle was imposed upon the diamond interchange computerized traffic control system. The system then responded by varying the signal splits in response to the varying demands. The operational performance of this configuration is compared to the standard real-time operational performance in Figure 5.19. Note that there is a degradation in operational performance during the offpeak hours.

5.11 COMPARISON OF AVERAGE DELAY/VEHICLE FOR TWO DAYS

Replications of the computerized traffic control system operation were conducted during the same time periods of the day on different days in order to establish the repeatability of the measurements of operational performance. Figure 5.20 demonstrates two sets of results in terms of average delay/vehicle, measured during the offpeak period. No significant difference is observed between these two sets of results. Any differences that are evident appear to be due to random variations. The mean values are effectively identical.

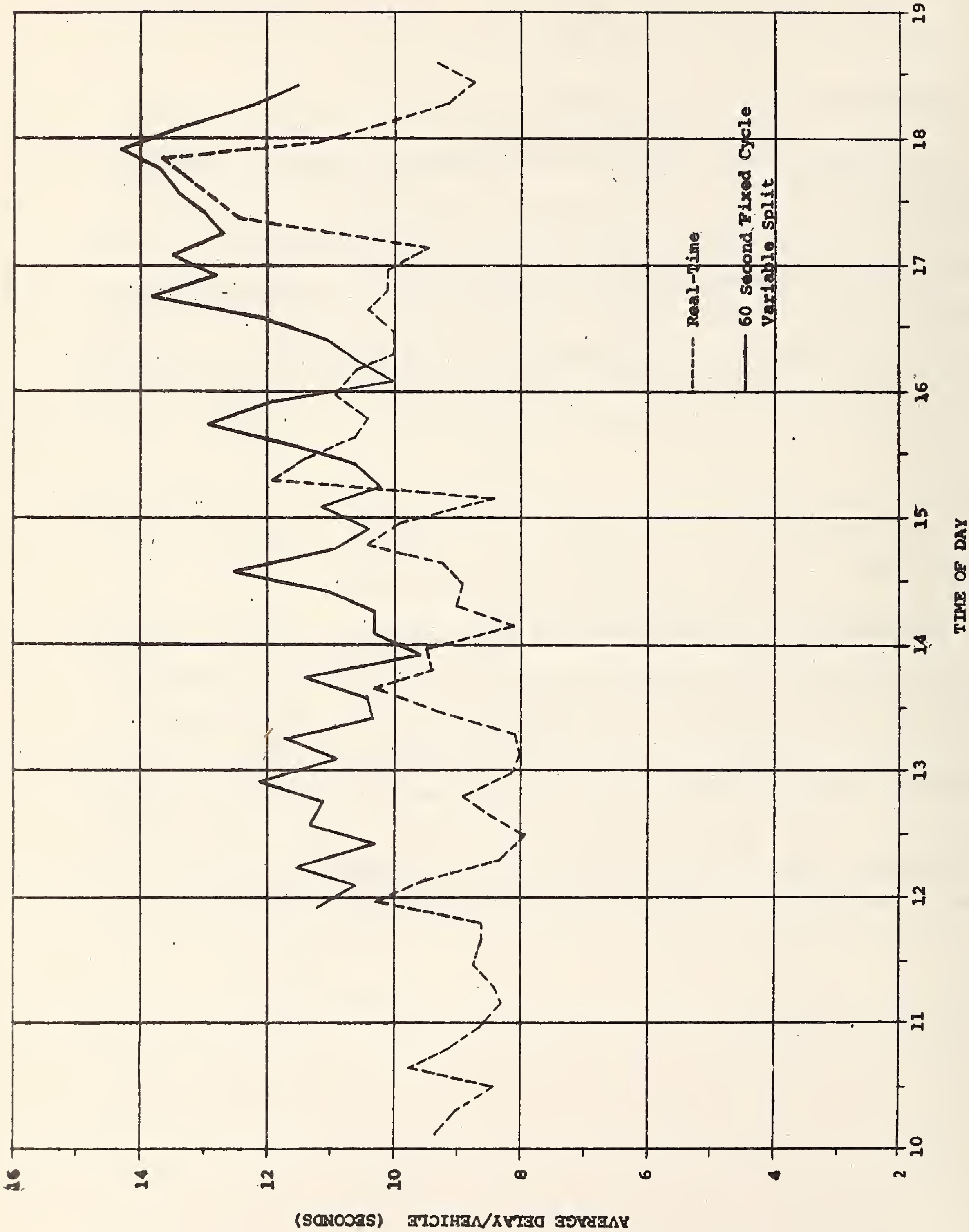

Figure 5.19 60-Second Fixed Cycle Variable Split versus Real-Time

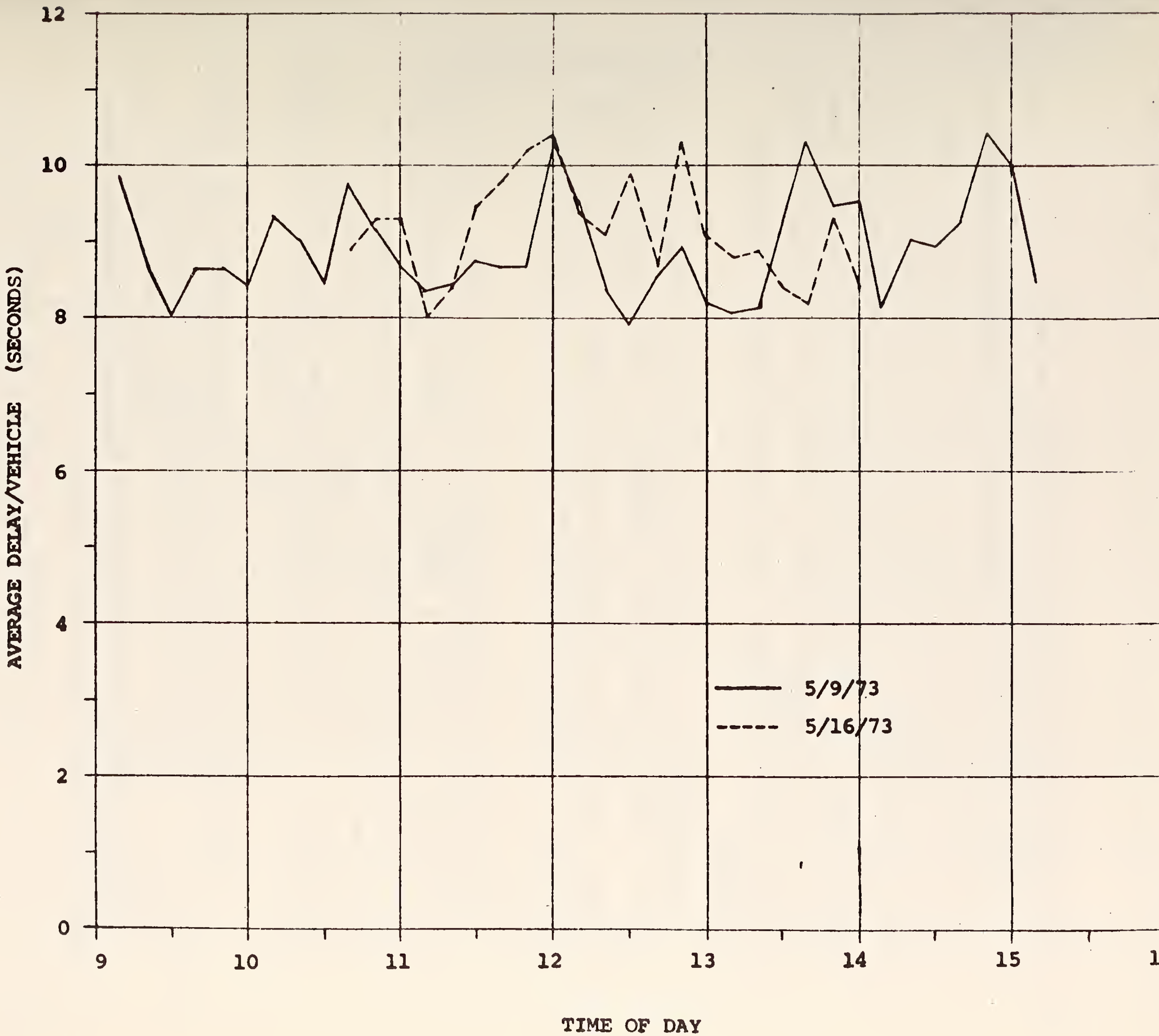

Figure 5.20 Comparison of Average Delay/Vehicle for Two Days

5.12 VEHICLE-MILES PER HOUR VERSUS VEHICLE-HOURS PER HOUR

A useful way of presenting and comparing operational performance data has been found to be through the use of two-dimensional plots*, where the coordinates are vehicle-hours/hour and vehicle-miles/hour. This method was applied to the evaluation of the computerized traffic control system. In particular, the vehicle-hours/hour is determined for all of the monitored sections in the strictly controlled portion of the diamond interchange. The vehicle-miles/hour is determined similarly.

Five different sets of data have been plotted on one graph to compare the relative effectiveness of real-time control against pretimed control. Two sets of pretimed data and three sets of real-time data were used. This data was collected over a broad spread of traffic demands.

Figure 5.21 shows the plot of these five sets of data. Each data set is identified by a different symbol. A straight-line has been visually fitted through each set of points (real-time and pretimed). It is notable that the scatter around the points is relatively small. It also appears that the set of points for pretimed control could be better fitted by a curve which is slightly concave upwards.

An inspection of this figure shows that the real-time curve displays a pronounced improvement over the pretimed curve. The relative improvement is determined by the vertical distance between the two curves. The percent improvement is indicated to be essentially constant as a function of demand (vehicle-miles/hour).

* The Road Research Laboratory has been effectively using this method for a few years, e.g., refer to RRL Report LR 420.

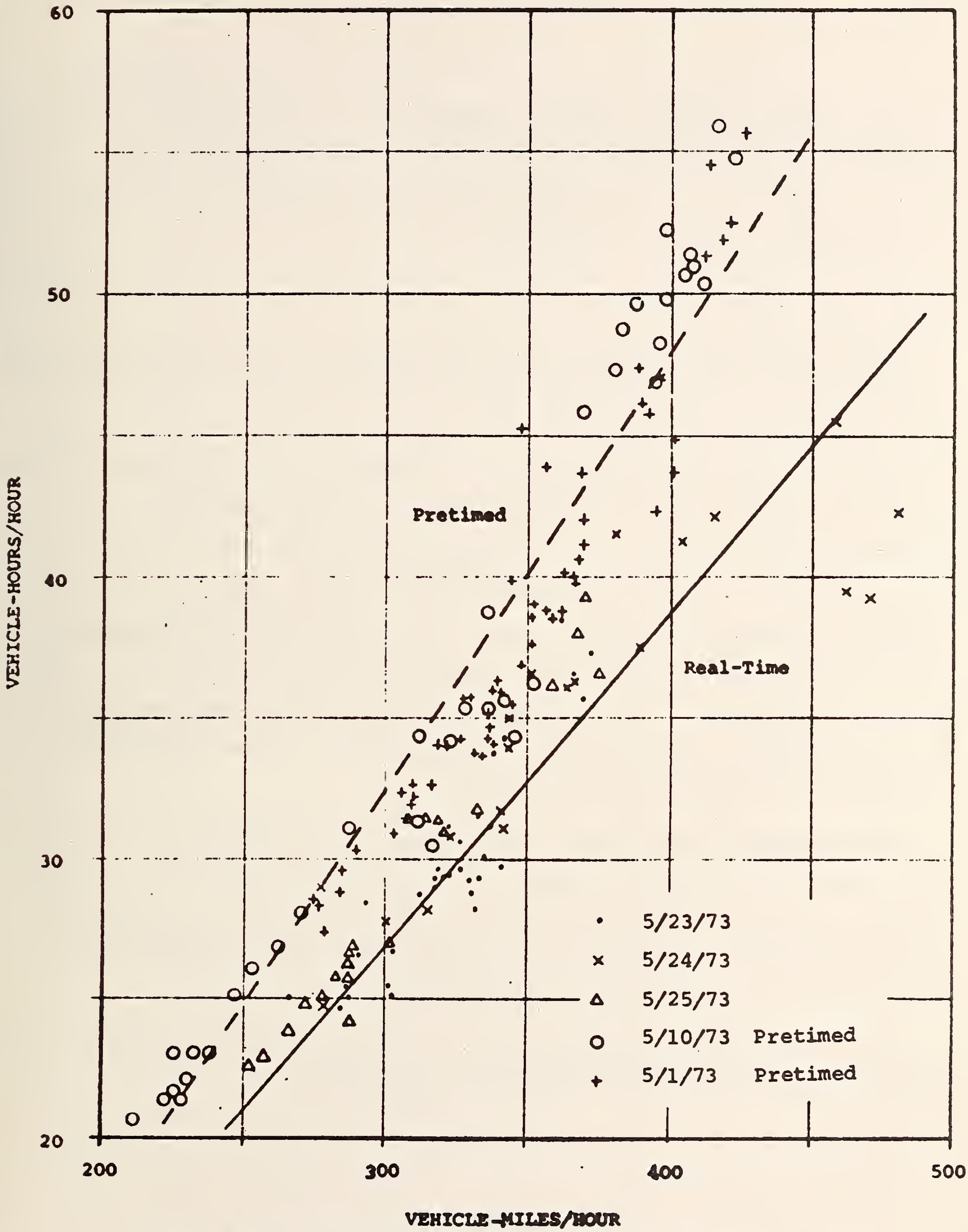

Figure 5.21 Vehicle-Hours/Hour versus Vehicle-Miles/Hour

From this figure, it can be concluded that the average percent reduction in travel time is about 16 percent -- a very significant improvement in operational performance for the real-time system over the pretimed system. This implies a reduction in delay in the order of 30 percent. (Refer to Section 4.2)

5.13 SOME SIGNAL TIMING STATISTICS

Some signal timing parameter statistics obtained from the data collected by the computerized system are presented in this section. This data was collected using the full detector set. Figure 5.22 shows the time variation of cycle length over a typical day. The distribution of cycle lengths for this particular day is shown in Figure 5.23. The 47-second cycle shows two values. There are 40 observations between 0718 and 1840. There were a total of 79 observations from 0718 to 0015.

Figure 5.24 shows the time variation of Phase A at a ramp intersection. Figure 5.25 shows the time variation for Phase B, and Figure 5.26 the time variation for Phase C. It is noted that Phase A serves the two-way arterial movements. Phase B serves the off-ramps. Phase C serves the protected left-turns into the on-ramps.

The distributions of Phase A lengths are shown in Figure 5.27 for the day, excluding the night off-peak, and for the night off-peak. The data for the first distribution covered by the lengths equal to, or greater than, 47 seconds. Consequently, the data had to be normalized to one value, which was selected to be 47 seconds.

Figure 5.28 shows corresponding distributions for Phase B. Figure 5.29 shows the corresponding distributions for Phase C.

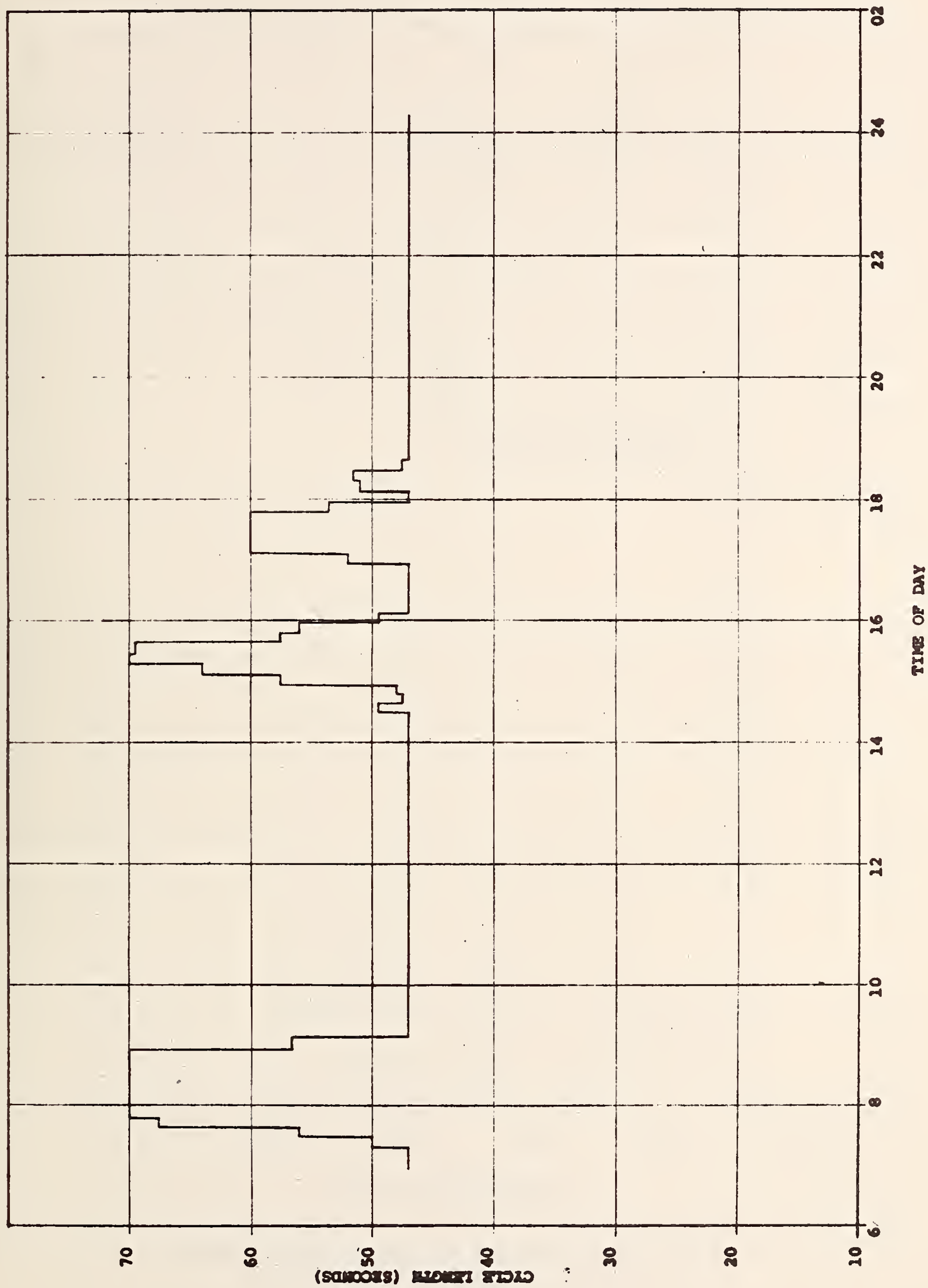

Figure 5.22 Time Variation of Cycle Length

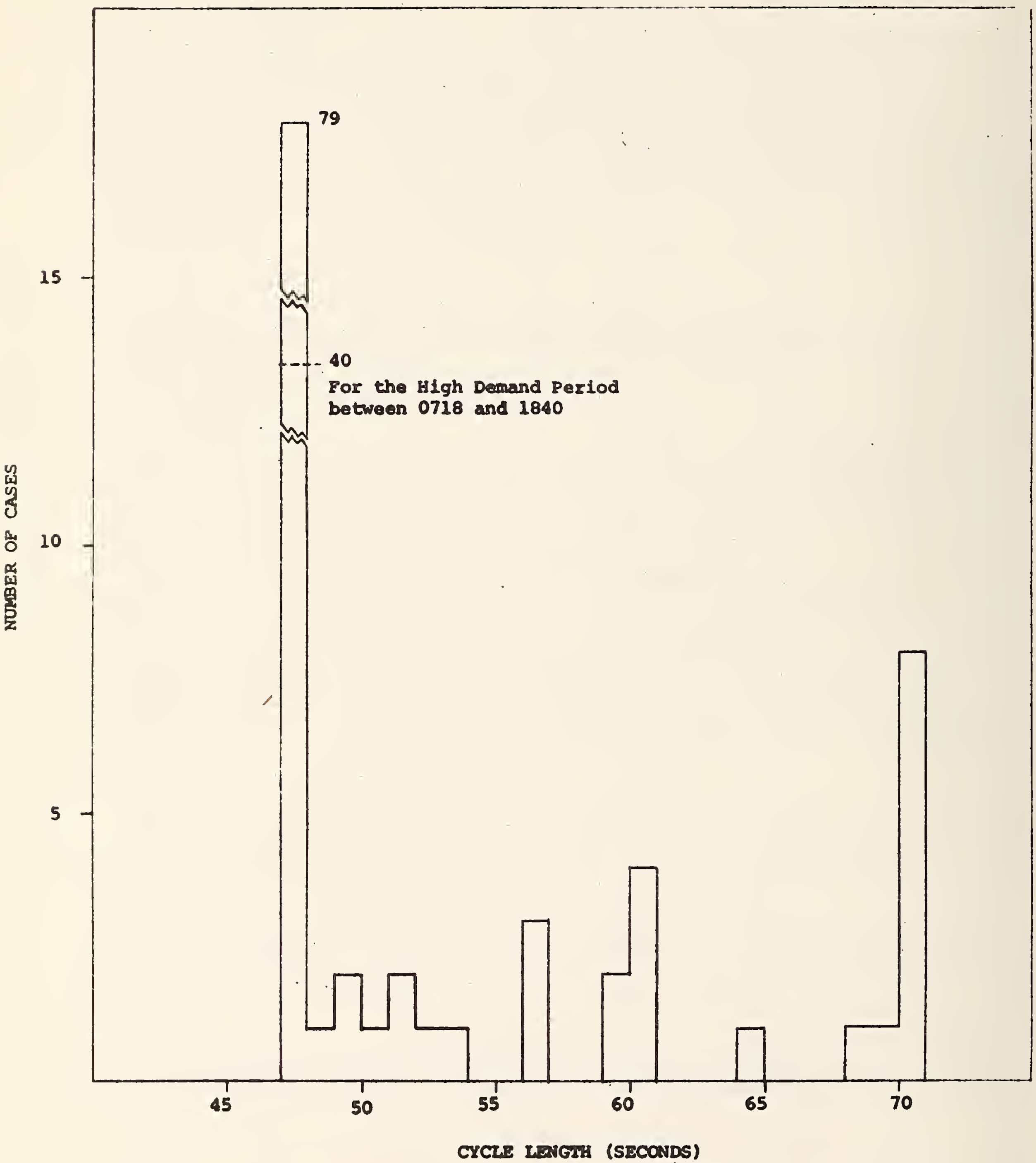

Figure 5.23 Distribution of Cycle Length

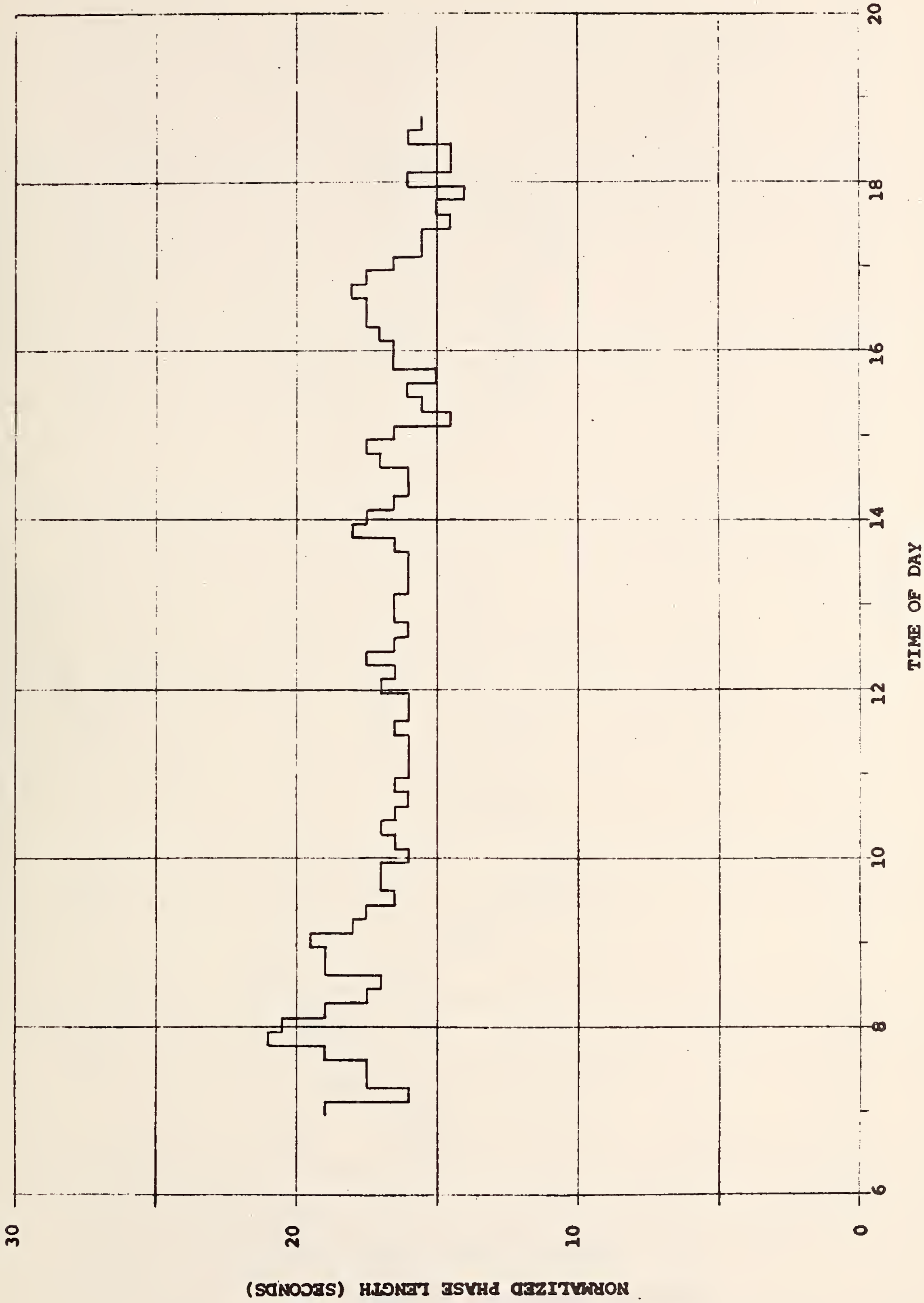

Figure 5.24 Time Variation of Phase A at a Ramp Intersection

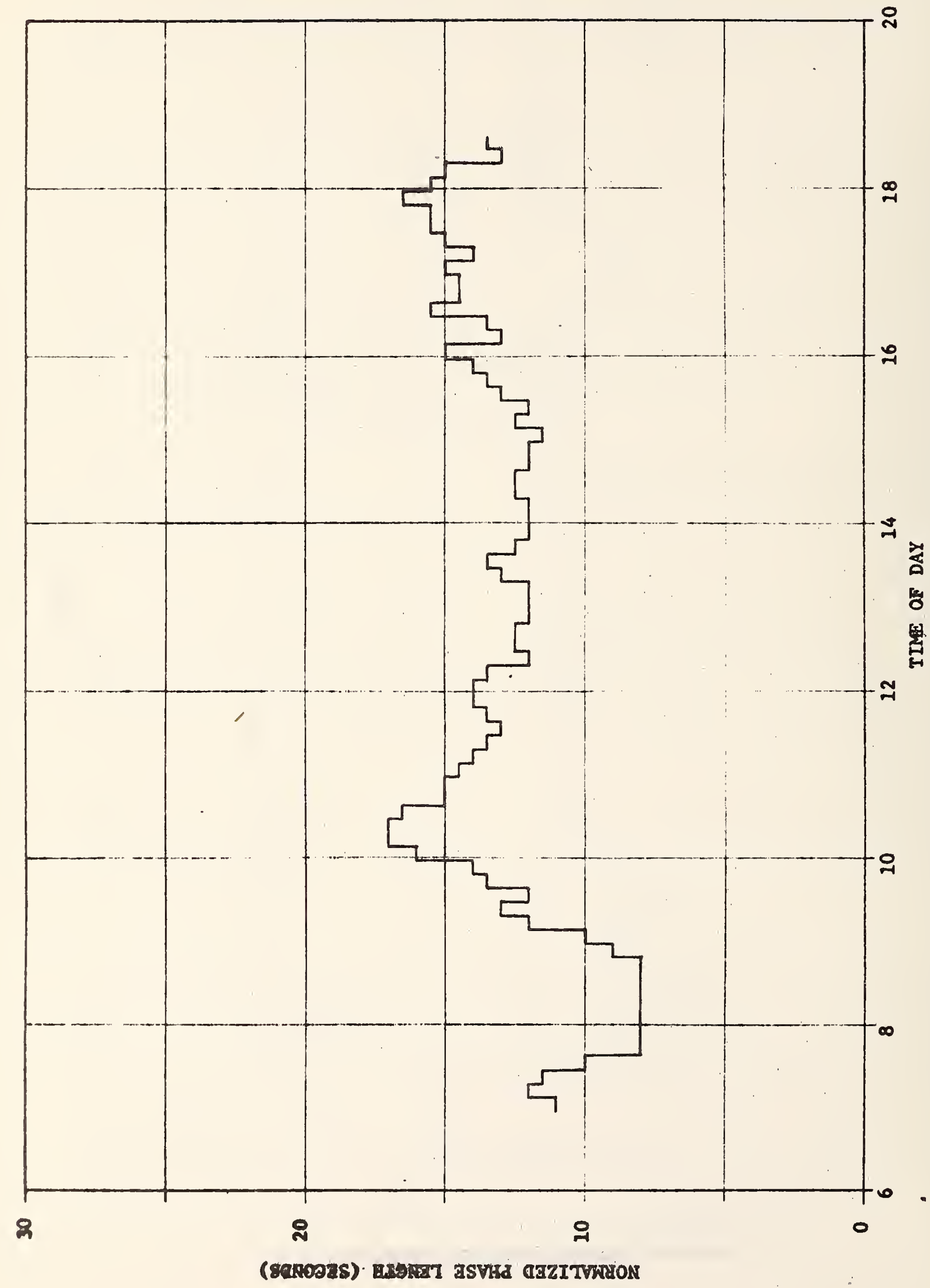

Figure 5.25 Time Variation of Phase B at a Ramp Intersection

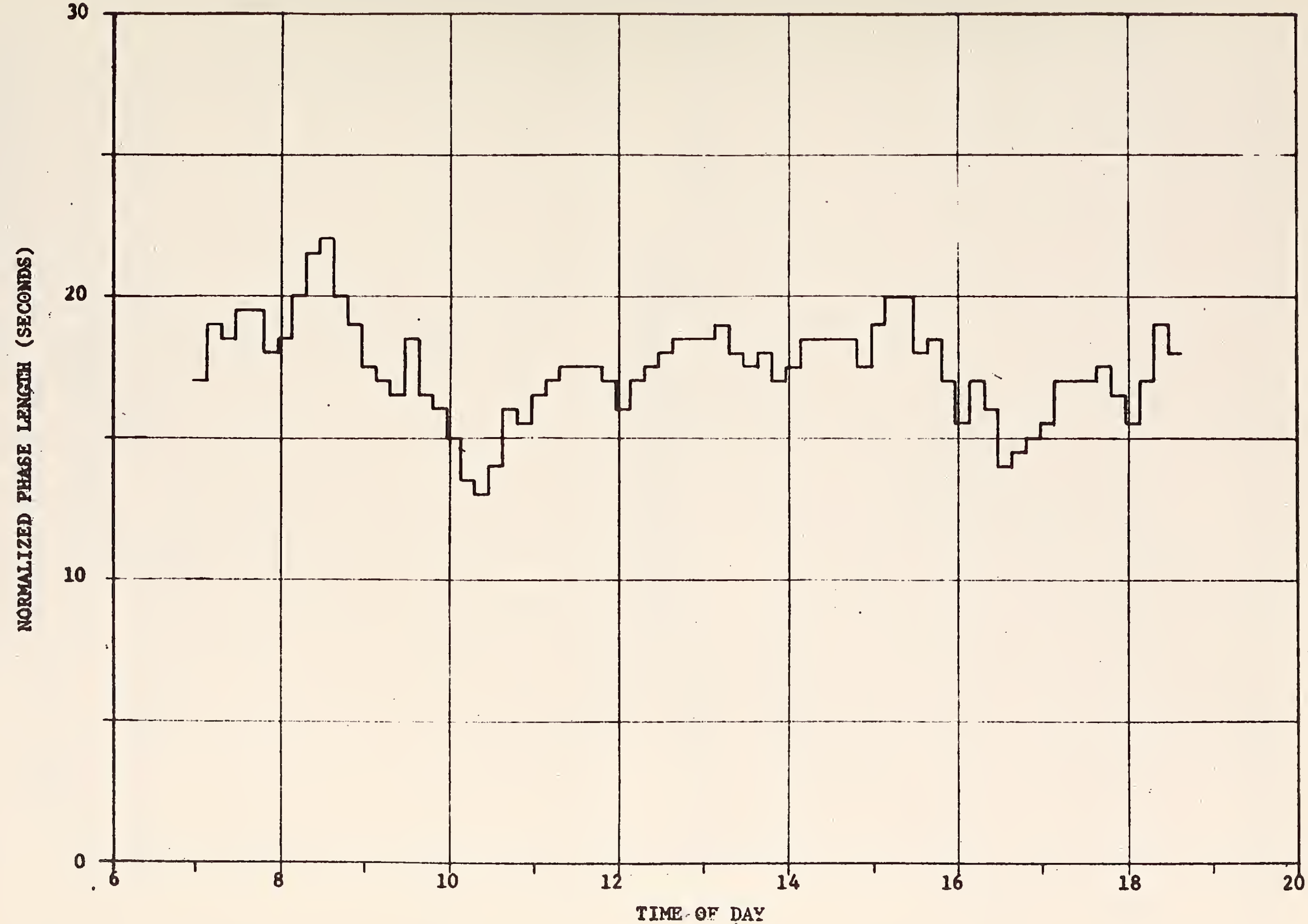

Figure 5.26 Time Variation of Phase C at a Ramp Intersection

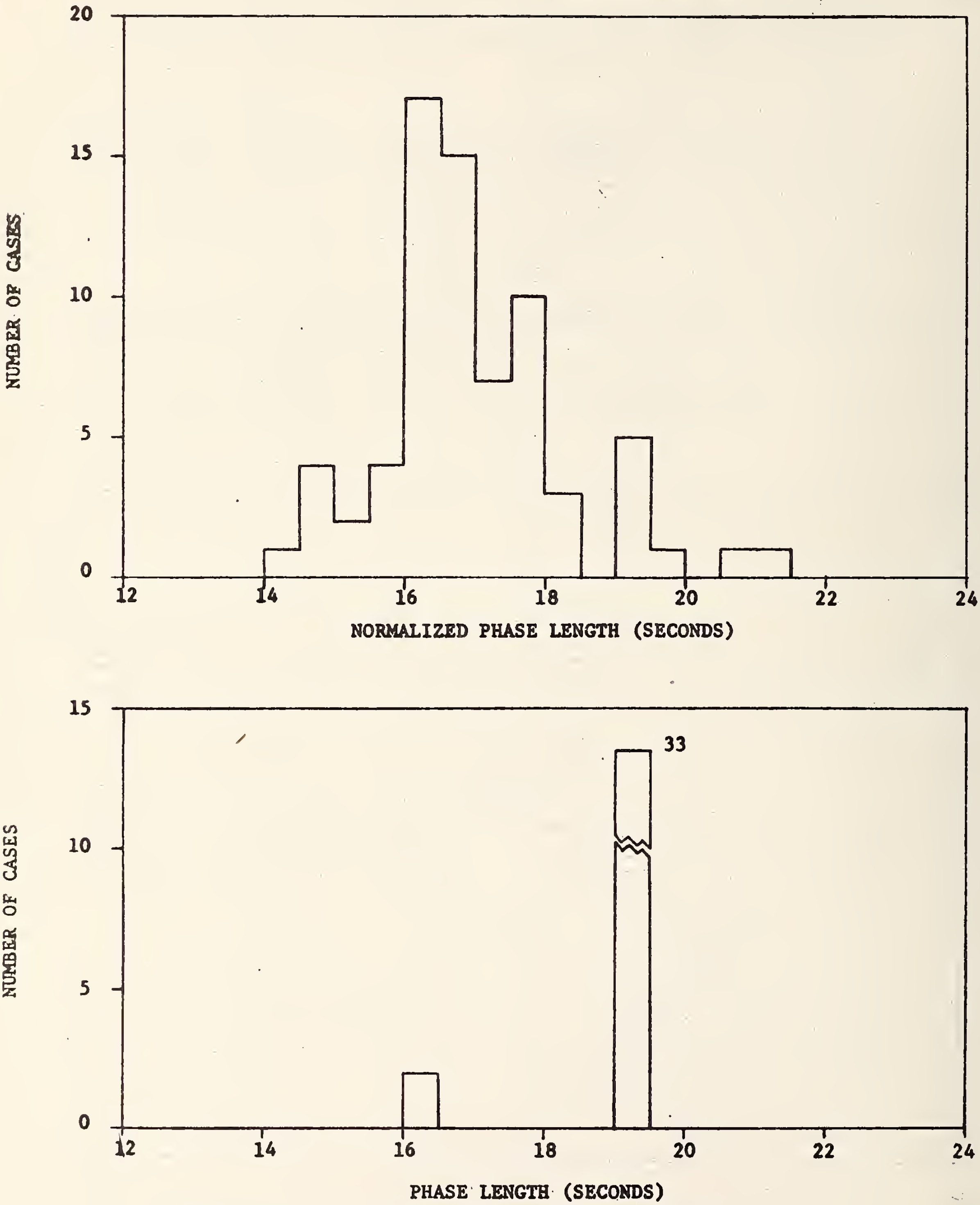

Figure 5.27 Distribution of Phase A Length.
Top Graph Excludes the Night Off-peak and is Normalized to 47 Seconds. Bottom Graph is for the Night Off-peak (Constant 47 Second Cycle) for the Period 18:30 - 00:15.

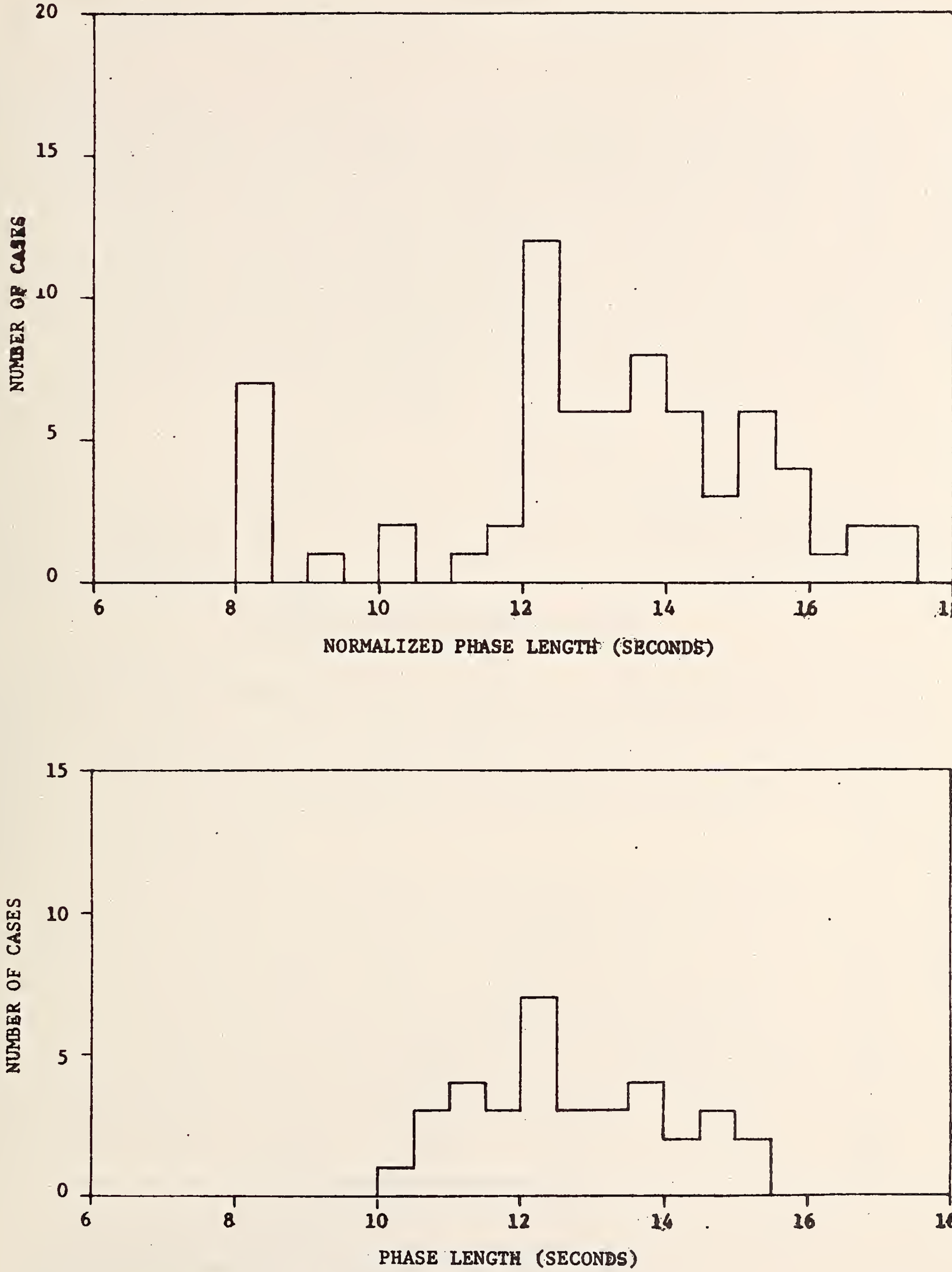

Figure 5.28 Distribution of Phase B Length.
Top Graph Excludes the Night Off-peak and is Normalized to 47 Seconds. Bottom Graph is for the Night Off-peak (Constant 47 Second Cycle) for the Period 18:30 - 00:15.

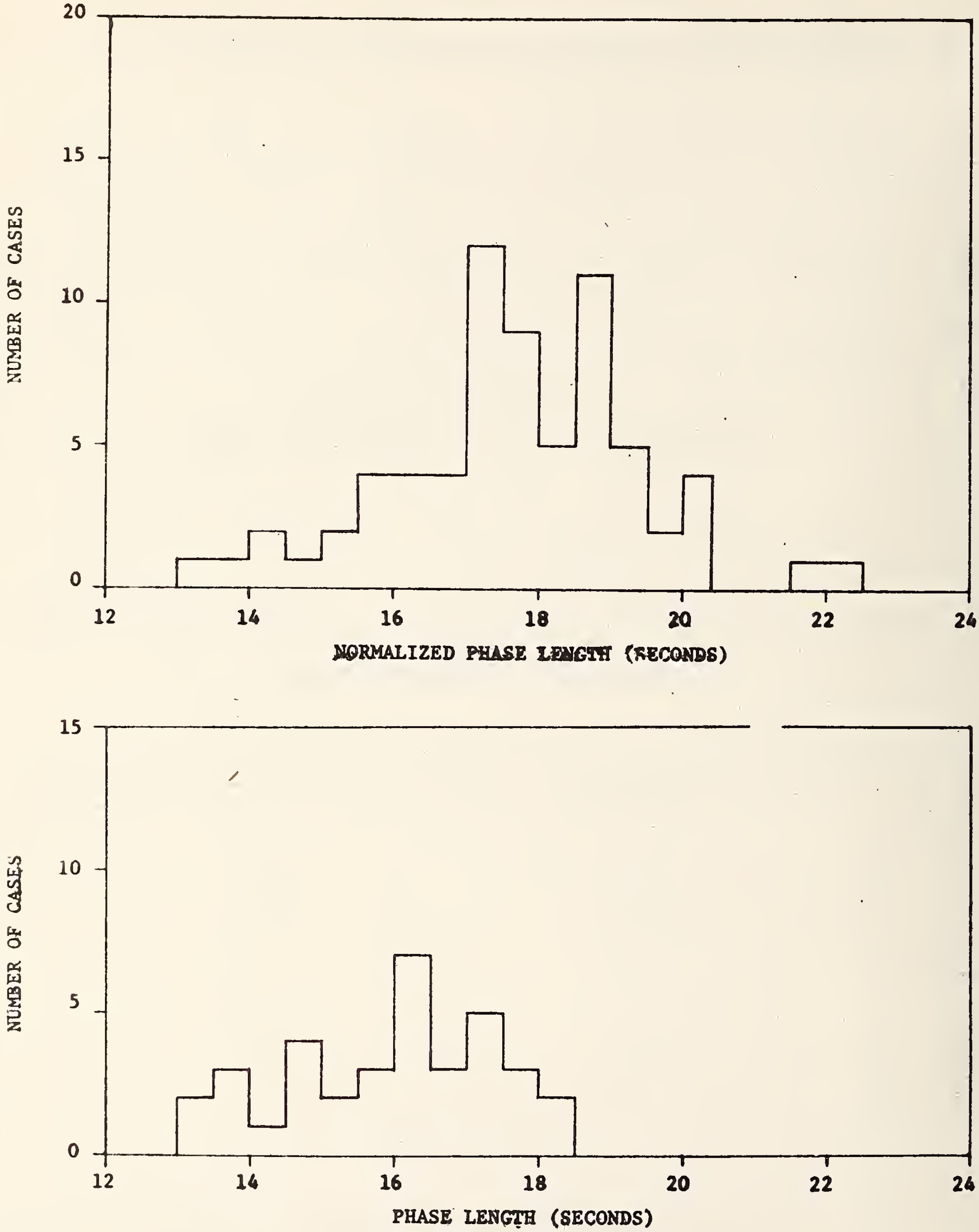

Figure 5.29 Distribution of Phase C Length
Top Graph Excludes the Night Off-peak and is Normalized to 47 Seconds. Bottom Graph is for the Night Off-peak (Constant 47 Second Cycle) for the Period 18:30 - 00:15

6. CONCLUSIONS

The computerized traffic control system that was successfully developed and implemented, as part of this project, at the Western Avenue Interchange of the Santa Monica Freeway was extensively tested over a period of several months. The main thrust of this testing period was to evaluate the operational performance of the computerized system. The preferred field operational configuration had to be identified. The existing tuned three-dial pretimed system was used as the baseline system for final evaluation.

Some of the early tests were directed to the identification of the preferred long-term period to employ for changing signal timing parameters. A 10-minute long-term period was determined to provide the preferred operational performance.

A field configuration of 18 detectors was determined to be sufficient to provide substantially improved operational performance for the computerized system. In fact, it was demonstrated that this minimun configuration, which monitors the major traffic movements, provided essentially the same operational performance as the fully-instrumented, 49-detector, research configuration.

System operational performance was measured using two methods: (1) instrumented test-cars and (2) the surveillance system of the computerized system. A test-car survey, which is a well-accepted method of evaluating operational performance, was conducted while the interchange site was operated in both pretimed and computer control. Several test-runs were made over selected routes for three time periods: AM peak, noon offpeak, and PM peak. Substantial reductions in travel time, stop time, number of stops, and number of brake applications were obtained for the computer-controlled system with respect to the pretimed system. For example, reductions of up to 15 percent in travel time and 30 percent in the number of stops were indicated.

The results obtained from the surveillance network of the computerized system were in general agreement with those from the test-car survey. The convenience of the computerized system made possible a broader type of survey. The results from this survey show that, conservatively, 18,000 vehicle-seconds of delay per hour can be saved through computerized control of the system. This value is derived from Figures 5.3 and 5.4, when it can be noted that the delay reduction per 10-minute period ranges from 3,000 to 4,000 vehicle-seconds. The 18,000 figure is obtained by using the lowest figure and multiplying by six to obtain the vehicle-seconds of delay savings per hour.

This delay savings value amounts to a reduction of approximately 120 vehicle-hours of delay per day, or (using 250 work days in a year)

$$(120 \text{ veh.-hrs./day})\ (250 \text{ days/yr.}) = 30{,}000 \text{ veh.-hrs./yr. savings in delay}$$

Further, from the test-car study, it is indicated that an average reduction of half a stop per vehicle is obtained under computer control. From the measured data, it is estimated that approximately 100,000 vehicles are measured by the system over a day. Assuming two monitored sections per test-car route, then

$$(100{,}000 \text{ veh./day})\ (1/2)\ (0.5 \text{ stops/veh.}) = 25{,}000 \text{ stops/day}$$

It has been further estimated that one stop is equivalent to a penalty of four seconds of delay* (a driver would just as soon experience an additional four seconds of delay rather than come to a full stop), then

$$(25{,}000 \text{ stops/day})\ (4 \text{ sec./stop})\ \left(\frac{250}{3600}\right) = 7{,}000 \text{ veh.-hrs./yr.}$$

* Personal communication from R. Allsop and J. Wardrop.

These computations give a total estimated saving in delay of

$30{,}000 + 7{,}000 = 37{,}000$ vehicle-hours/year.

Assuming a cost of $2.50 for one hour of travel time saving, then the estimated savings by operating a computer-controlled diamond interchange is

$(37{,}000)\ (\$2.50) \cong \$92{,}250$/year.

This is a conservative estimate, which is enhanced when the remaining days of the year are taken into account.

The cost of installing a computerized traffic control system at a diamond interchange is estimated to have the following cost breakdown:

Intersections (4) site preparation	$ 8,000	-	$11,000
Conduit, cable, and installation	14,000	-	17,000
Loop detectors and installation	7,000	-	8,000
Controller interfaces (4)	2,000	-	8,000
Minicomputer with 8k of core	9,000	-	10,000
Traffic control interface unit, cabinet, wiring, and installation	12,000	-	15,000
Use of computer peripherels (proportioned over 5-10 sites)	2,000	-	4,000
Checkout and integration	6,000	-	10,000
Total	$60,000	-	$83,000
Contingencies	6,000	-	8,000
Total	$66,000	-	$91,000

The estimated installation cost is noted to range from $66,000 to $91,000.

Hence, the implementation of a computerized traffic control system could pay for itself in less than one year. Furthermore, there is a net improvement, not only in the reduction of delay, but also in smoother flow of traffic and in the reduction of traffic backups that can produce aggravated congestion conditions at the interchange, on the surface street, and on the freeway off-ramp. Computerized control of diamond interchanges has been shown to be practical and viable.

APPENDIX A

TEST-CAR TRAVEL TIME SUMMARY DATA

TABLE A-1

TEST-CAR TRAVEL TIME SUMMARY DATA

AM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.537	.274	12
3-28-73	We	1.569	.275	21
3-30-73	Fr	1.900	.740	25
4-2-73	Mo	1.563	.328	18
4-4-73	We	1.648	.267	24
4-9-73	Mo	1.467	.363	21
Total		1.631	.393	121

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.170	.349	10
4-16-73	Mo	0.943	.377	15
4-18-73	We	1.092	.470	18
4-25-73	We	0.967	.314	15
4-27-73*	Fr	1.145	.332	22
Total		1.065	.370	80

*Construction under way

TABLE A-2

TEST-CAR TRAVEL TIME SUMMARY DATA

AM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.505	.187	13
3-28-73	We	1.345	.405	25
3-30-73	Fr	1.160	.485	25
4-2-73	Mo	1.208	.445	18
4-4-73	We	1.515	.410	23
4-9-73	Mo	1.115	.320	21
Total		1.298	.391	125

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.302	.109	11
4-16-73	Mo	1.315	.502	16
4-18-73	We	1.186	.227	18
4-25-73	We	1.386	.283	14
4-27-73*	Fr	1.266	.390	18
Total		1.284	.316	77

*Construction under way

TABLE A-3

TEST-CAR TRAVEL TIME SUMMARY DATA

AM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.116	.560	12
3-28-73	We	2.072	.505	24
3-30-73	Fr	2.050	.797	23
4-2-73	Mo	1.778	.615	18
4-4-73	We	1.945	.430	21
4-9-73	Mo	1.749	.338	21
Total		1.948	.541	119

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.890	.298	11
4-16-73	Mo	1.699	.515	15
4-18-73	We	2.103	.373	15
4-25-73	We	1.875	.410	11
4-27-73*	Fr	1.929	.262	13
Total		1.900	.377	65

*Construction under way

TABLE A-4

TEST-CAR TRAVEL TIME SUMMARY DATA

AM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.432	.257	12
3-28-73	We	1.440	.383	24
3-30-73	Fr	1.360	.275	23
4-2-73	Mo	1.645	.347	18
4-4-73	We	1.605	.455	22
4-9-73	Mo	1.602	.395	21
Total		1.513	.360	120

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.613	.240	13
4-16-73	Mo	1.545	.639	13
4-18-73	We	1.627	.502	13
4-25-73	We	1.579	.504	12
4-27-73*	Fr	1.429	.343	7
Total		1.571	.455	58

*Partial data exclusion for 4/27 because of road construction affecting Routes 4 and 6.

TABLE A-5

TEST-CAR TRAVEL TIME SUMMARY DATA

AM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.789	.410	14
3-28-73	We	1.897	.434	30
3-30-73	Fr	2.020	.459	28
4-2-73	Mo	1.634	.407	24
4-4-73	We	1.838	.367	27
4-9-73	Mo	1.748	.332	28
Total		1.830	.401	151

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.641	.362	19
4-16-73	Mo	1.507	.340	20
4-18-73	We	1.441	.323	24
4-25-73	We	1.559	.340	20
4-27-73*	Fr	1.657	.389	21
Total		1.556	.350	104

*Construction under way

TABLE A-6

TEST-CAR TRAVEL TIME SUMMARY DATA

AM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.400	.599	14
3-28-73	We	2.083	.473	29
3-30-73	Fr	2.400	.619	28
4-2-73	Mo	1.995	.362	24
4-4-73	We	2.560	.475	23
4-9-73	Mo	2.214	.381	27
Total		2.260	.478	145

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.869	.344	18
4-16-73	Mo	1.793	.361	22
4-18-73	We	2.028	.262	19
4-25-73	We	2.089	.321	19
4-27-73*	Fr	2.228	.579	5
Total		1.957	.339	83

*Partial data exclusion for 4/27 because of road construction affecting Routes 4 and 6.

TABLE A-7

TEST-CAR TRAVEL TIME SUMMARY DATA

NOON OFFPEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.653	.296	17
3-21-73	We	1.694	.343	22
3-26-73	Mo	1.532	.469	16
3-27-73	Tu	1.552	.339	17
3-29-73	Th	1.253	.233	15
Total		1.552	.337	87

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.403	.294	13
4-13-73	Fr	1.417	.337	18
4-17-73 *	Tu	1.265	.300	16
4-20-73 **	Fr	1.279	.291	17
4-23-73 *	Mo	1.080	.315	15
Total		1.290	.308	79

*Construction under way
**Easter Weekend

TABLE A-8

TEST-CAR TRAVEL TIME SUMMARY DATA

NOON OFFPEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.026	.345	18
3-21-73	We	0.959	.383	22
3-26-73	Mo	0.869	.292	18
3-27-73	Tu	0.800	.191	16
3-29-73	Th	0.912	.273	15
Total		0.924	.304	89

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.431	.251	13
4-13-73	Fr	1.333	.262	18
4-17-73*	Tu	1.217	.310	18
4-20-73**	Fr	1.322	.306	18
4-23-73*	Mo	1.373	.348	15
Total		1.328	.296	82

*Construction under way
**Easter Weekend

TABLE A-9

TEST-CAR TRAVEL TIME SUMMARY DATA

NOON OFFPEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.433	.354	18
3-21-73	We	1.633	.381	19
3-26-73	Mo	1.443	.442	18
3-27-73	Tu	1.541	.390	15
3-29-73	Th	1.610	.473	15
Total		1.530	.406	85

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.794	.300	12
4-13-73	Fr	1.962	.354	17
4-17-73*	Tu	1.981	.330	18
4-20-73**	Fr	1.769	.522	14
4-23-73*	Mo	1.854	.441	15
Total		1.883	.388	76

*Construction under way

**Easter Weekend

TABLE A-10

TEST-CAR TRAVEL TIME SUMMARY DATA

NOON OFFPEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.710	.445	18
3-21-73	We	1.473	.408	20
3-26-73	Mo	1.432	.394	18
3-27-73	Tu	1.596	.402	18
3-29-73	Th	1.583	.452	15
Total		1.556	.419	89

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.105	.351	12
4-13-73	Fr	1.552	.346	17
4-17-73*	Tu			
4-20-73**	Fr	1.548	.394	15
4-23-73*	Mo			
Total		1.429	.364	44

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.

**Easter Weekend

TABLE A-11

TEST-CAR TRAVEL TIME SUMMARY DATA

NOON OFFPEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	2.220	.420	20
3-21-73	We	1.822	.495	23
3-26-73	Mo	2.009	.294	24
3-27-73	Tu	1.698	.405	24
3-29-73	Th	1.801	.387	19
Total		1.904	.399	110

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.397	.310	15
4-13-73	Fr	1.742	.379	21
4-17-73*	Tu	1.672	.387	21
4-20-73**	Fr	1.548	.336	24
4-23-73*	Mo	1.576	.252	20
Total		1.597	.335	101

*Construction under way
**Easter Weekend

TABLE A-12

TEST-CAR TRAVEL TIME SUMMARY DATA

NOON OFFPEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.967	.456	21
3-21-73	We	1.777	.387	25
3-26-73	Mo	1.781	.355	24
3-27-73	Tu	1.797	.380	24
3-29-73	Th	1.777	.544	19
Total		1.817	.418	113

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.982	.296	15
4-13-73	Fr	2.030	.467	23
4-17-73*	Tu			
4-20-73**	Fr	2.132	.336	18
4-23-73*	Mo			
Total		2.049	.379	56

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.
**Easter Weekend

TABLE A-13

TEST-CAR TRAVEL TIME SUMMARY DATA

PM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	1.522	.343	21
3-22-73	Th	1.743	.347	22
4-3-73	Tu	1.785	.431	16
4-5-73	Th	1.621	.473	21
Total		1.661	.396	80

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	1.718	.442	15
4-19-73	Th	1.812	.552	16
4-24-73	Tu	1.465	.344	15
4-26-73	Th	1.319	.281	18
Total		1.570	.401	64

TABLE A-14

TEST-CAR TRAVEL TIME SUMMARY DATA

PM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	1.589	.383	21
3-22-73	Th	1.595	.335	25
4-3-73	Tu	1.555	.148	16
4-5-73	Th	1.344	.322	22
Total		1.520	.308	84

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	1.794	.408	15
4-19-73	Th	1.761	.368	15
4-24-73	Tu	1.630	.316	13
4-26-73	Th	1.506	.207	14
Total		1.677	.327	57

TABLE A-15

TEST-CAR TRAVEL TIME SUMMARY DATA

PM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	1.755	.443	20
3-22-73	Th	1.823	.420	22
4-3-73	Tu	2.015	.407	15
4-5-73	Th	1.937	.419	21
Total		1.873	.423	78

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.030	.454	15
4-19-73	Th	2.049	.492	14
4-24-73	Tu	1.481	.250	15
4-26-73	Th	1.556	.304	18
Total		1.764	.370	62

TABLE A-16

TEST-CAR TRAVEL TIME SUMMARY DATA

PM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.043	.659	23
3-22-73	Th	2.665	.650	23
4-3-73	Tu	2.366	.781	15
4-5-73	Th	2.247	.442	21
Total		2.329	.623	82

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	1.484	.650	15
4-19-73	Th	1.727	.343	15
4-24-73	Tu	1.678	.327	12
4-26-73	Th	1.446	.354	18
Total		1.572	.420	60

TABLE A-17

TEST-CAR TRAVEL TIME SUMMARY DATA

PM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.363	.395	27
3-22-73	Th	2.151	.418	30
4-3-73	Tu	2.374	.326	18
4-5-73	Th	2.066	.508	27
Total		2.224	.420	102

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	1.732	.236	17
4-19-73	Th	2.096	.397	16
4-24-73	Tu	1.696	.320	15
4-26-73	Th	1.866	.296	22
Total		1.850	.310	70

TABLE A-18

TEST-CAR TRAVEL TIME SUMMARY DATA

PM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.645	.691	26
3-22-73	Th	2.404	.472	27
4-3-73	Tu	2.491	.595	16
4-5-73	Th	2.205	.314	26
Total		2.430	.509	95

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.315	.375	16
4-19-73	Th	2.334	.292	14
4-24-73	Tu	2.098	.317	16
4-26-73	Th	2.013	.346	22
Total		2.170	.335	68

APPENDIX B

TEST-CAR STOP TIME SUMMARY DATA

TABLE B-1

TEST-CAR STOP TIME SUMMARY DATA

AM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	0.681	.255	11
3-28-73	We	0.686	.220	21
3-30-73	Fr	1.081	.522	24
4-2-73	Mo	0.771	.316	18
4-4-73	We	0.773	.221	22
4-9-73	Mo	0.658	.250	21
Total		0.791	.306	117

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	0.355	.261	10
4-16-73	Mo	0.258	.308	15
4-18-73	We	0.352	.312	18
4-25-73	We	0.253	.242	15
4-27-73*	Fr	0.338	.262	22
Total		0.312	.278	80

*Construction under way

TABLE B-2

TEST-CAR STOP TIME SUMMARY DATA

AM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	0.516	.174	13
3-28-73	We	0.400	.324	25
3-30-73	Fr	0.306	.348	22
4-2-73	Mo	0.336	.316	18
4-4-73	We	0.558	.276	21
4-9-73	Mo	0.159	.216	21
Total		0.371	.284	120

COMPUTER CONTROL

Date		Average	σ	Sample Size
4-12-73	Th	0.464	.393	12
4-16-73	Mo	0.413	.242	16
4-18-73	We	0.293	.174	18
4-25-73	We	0.390	.238	15
4-27-73*	Fr	0.383	.328	19
Total		0.382	.269	80

* Construction under way

TABLE B-3

TEST-CAR STOP TIME SUMMARY DATA

AM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.034	.478	9
3-28-73	We	0.900	.421	24
3-30-73	Fr	0.902	.598	22
4-2-73	Mo	0.700	.492	18
4-4-73	We	0.694	.356	20
4-9-73	Mo	0.653	.290	21
Total		0.798	.435	114

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	0.816	.278	11
4-16-73	Mo	0.677	.338	15
4-18-73	We	0.952	.339	12
4-25-73	We	0.778	.339	11
4-27-73*	Fr	0.741	.284	14
Total		0.785	.316	63

*Construction under way

TABLE B-4

TEST-CAR STOP TIME SUMMARY DATA

AM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	0.521	.152	10
3-28-73	We	0.618	.322	24
3-30-73	Fr	0.524	.255	23
4-2-73	Mo	0.741	.277	18
4-4-73	We	0.663	.215	20
4-9-73	Mo	0.635	.331	21
Total		0.621	.270	116

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	0.845	.398	14
4-16-73	Mo	0.700	.477	13
4-18-73	We	0.806	.501	12
4-25-73	We	0.752	.447	12
4-27-73*	Fr	0.632	.303	8
Total		0.757	.433	59

*NOTE: Partial data exclusion for 4/27 because of road construction affecting Routes 4 and 6.

TABLE B-5

TEST-CAR STOP TIME SUMMARY DATA

AM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	0.396	.265	13
3-28-73	We	0.551	.288	30
3-30-73	Fr	0.590	.322	27
4-2-73	Mo	0.403	.285	24
4-4-73	We	0.500	.236	26
4-9-73	Mo	0.433	.259	28
Total		0.489	.277	148

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	0.381	.306	19
4-16-73	Mo	0.256	.268	20
4-18-73	We	0.238	.222	24
4-25-73	We	0.303	.264	20
4-27-73*	Fr	0.371	.256	21
Total		0.307	.261	104

*Construction under way

TABLE B-6

TEST-CAR STOP TIME SUMMARY DATA

AM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	0.678	.452	12
3-28-73	We	0.582	.358	29
3-30-73	Fr	0.739	.392	27
4-2-73	Mo	0.488	.277	24
4-4-73	We	0.878	.341	22
4-9-73	Mo	0.643	.304	27
Total		0.662	.346	141

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	0.532	.281	19
4-16-73	Mo	0.458	.237	21
4-18-73	We	0.638	.218	20
4-25-73	We	0.639	.226	19
4-27-73*	Fr	0.473	.122	3
Total		0.561	.236	82

* NOTE: Partial data exclusion for 4/27 because of road construction affecting Routes 4 and 6.

TABLE B-7

TEST-CAR STOP TIME SUMMARY DATA

NOON OFF-PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.718	.238	14
3-21-73	We	0.603	.391	20
3-26-73	Mo	0.716	.346	16
3-27-73	Tu	0.663	.283	18
3-29-73	Th	0.455	.180	15
Total		0.630	.295	83

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.501	.203	13
4-13-73	Fr	0.562	.270	17
4-17-73*	Tu	0.429	.248	16
4-20-73**	Fr	0.447	.248	13
4-23-73*	Mo	0.300	.270	15
Total		0.449	.249	74

*Construction under way
**Easter Weekend

TABLE B-8

TEST-CAR STOP TIME SUMMARY DATA

NOON OFF-PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.055	.144	15
3-21-73	We	0.042	.122	21
3-26-73	Mo	0.082	.201	18
3-27-73	Tu	0.027	.103	15
3-29-73	Th	0.091	.202	15
Total		0.059	.154	84

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.427	.282	13
4-13-73	Fr	0.369	.214	18
4-17-73*	Tu	0.298	.210	18
4-20-73**	Fr	0.362	.210	15
4-23-73*	Mo	0.446	.232	15
Total		0.375	.227	79

*Construction under way
**Easter Weekend

TABLE B-9

TEST-CAR STOP TIME SUMMARY DATA

NOON OFF-PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.282	.291	13
3-21-73	We	0.450	.341	19
3-26-73	Mo	0.436	.432	18
3-27-73	Tu	0.483	.267	15
3-29-73	Th	0.556	.401	15
Total		0.446	.351	80

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.702	.244	12
4-13-73	Fr	0.850	.251	16
4-17-73*	Tu	0.887	.488	18
4-20-73**	Fr	0.583	.327	9
4-23-73*	Mo	0.769	.329	15
Total		0.782	.337	70

*Construction under way
**Easter Weekend

TABLE B-10

TEST-CAR STOP TIME SUMMARY DATA

NOON OFF-PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.801	.391	15
3-21-73	We	0.567	.361	20
3-26-73	Mo	0.565	.350	18
3-27-73	Tu	0.748	.433	18
3-29-73	Th	0.691	.356	15
Total		0.667	.378	86

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.275	.287	12
4-13-73	Fr	0.661	.316	17
4-17-73*				
4-20-73**	Fr	0.568	.252	9
4-23-73*	Mo			
Total		0.517	.292	38

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.

**Easter Weekend

TABLE B-11

TEST-CAR STOP TIME SUMMARY DATA

NOON OFF-PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.640	.300	18
3-21-73	We	0.432	.331	24
3-26-73	Mo	0.549	.193	24
3-27-73	Tu	0.397	.301	22
3-29-73	Th	0.438	.318	19
Total		0.487	.286	107

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.157	.150	15
4-13-73	Fr	0.369	.267	21
4-17-73*	Tu	0.307	.238	21
4-20-73**	Fr	0.260	.209	20
4-23-73*	Mo	0.284	.157	20
Total		0.283	.208	97

*Construction under way
**Easter Weekend

TABLE B-12

TEST-CAR STOP TIME SUMMARY DATA

NOON OFF-PEAK
Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.249	.241	18
3-21-73	We	0.283	.254	26
3-26-73	Mo	0.338	.261	24
3-27-73	Tu	0.317	.237	24
3-29-73	Th	0.317	.355	18
Total		0.302	.266	110

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.555	.292	15
4-13-73	Fr	0.610	.334	23
4-17-73*	Tu			
4-20-73**	Fr	0.568	.302	14
4-23-73*	Mo			
Total		0.583	.313	52

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.
**Easter Weekend

TABLE B-13

TEST-CAR STOP TIME SUMMARY DATA

PM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	0.536	.271	18
3-22-73	Th	0.729	.272	19
4-3-73	Tu	0.766	.247	15
4-5-73	Th	0.629	.329	22
Total		0.660	.284	74

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	0.791	.352	14
4-19-73	Th	0.781	.403	14
4-24-73	Tu	0.636	.323	15
4-26-73	Th	0.480	.227	17
Total		0.662	.321	60

TABLE B-14

TEST-CAR STOP TIME SUMMARY DATA

PM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	0.479	.313	18
3-22-73	Th	0.497	.189	22
4-3-73	Tu	0.451	.176	16
4-5-73	Th	0.274	.231	22
Total		0.421	.227	78

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	0.659	.316	15
4-19-73	Th	0.679	.338	15
4-24-73	Tu	0.618	.272	13
4-26-73	Th	0.436	.169	14
Total		0.600	.275	57

TABLE B-15

TEST-CAR STOP TIME SUMMARY DATA

PM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	0.533	.385	16
3-22-73	Th	0.699	.371	20
4-3-73	Tu	0.857	.352	15
4-5-73	Th	0.823	.345	21
Total		0.731	.363	72

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	0.873	.343	15
4-19-73	Th	0.937	.454	13
4-24-73	Tu	0.487	.231	14
4-26-73	Th	0.528	.251	18
Total		0.693	.313	60

TABLE B-16

TEST-CAR STOP TIME SUMMARY DATA

PM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	0.847	.480	17
3-22-73	Th	1.529	.517	19
4-3-73	Tu	1.179	.467	14
4-5-73	Th	1.138	.350	20
Total		1.182	.450	70

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	0.555	.572	15
4-19-73	Th	0.773	.267	15
4-24-73	Tu	0.657	.228	12
4-26-73	Th	0.559	.326	18
Total		0.631	.353	60

TABLE B-17

TEST-CAR STOP TIME SUMMARY DATA

PM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	0.816	.299	24
3-22-73	Th	0.745	.373	26
4-3-73	Tu	0.801	.296	19
4-5-73	Th	0.508	.393	27
Total		0.707	.345	96

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	0.349	.241	18
4-19-73	Th	0.525	.224	16
4-24-73	Tu	0.353	.243	15
4-24-73	Th	0.425	.236	19
Total		0.412	.236	68

TABLE B-18

TEST-CAR STOP TIME SUMMARY DATA

PM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	0.963	.557	23
3-22-73	Th	0.762	.281	24
4-3-73	Tu	0.894	.405	17
4-5-73	Th	0.632	.279	26
Total		0.801	.374	90

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	0.678	.290	16
4-19-73	Th	0.725	.291	14
4-24-73	Tu	0.516	.304	16
4-26-73	Th	0.497	.226	21
Total		0.592	.273	67

APPENDIX C

TEST-CAR NUMBER OF STOPS SUMMARY DATA

TABLE C-1

TEST-CAR NUMBER OF STOPS SUMMARY DATA

AM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.3	1.960	12
3-28-73	We	2.2	.995	21
3-30-73	Fr	2.6	.902	22
4-2-73	Mo	1.7	.694	18
4-4-73	We	2.1	.869	23
4-9-73	Mo	1.7	.913	21
Total		2.1	.975	117

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.2	.919	10
4-16-73	Mo	0.9	1.125	15
4-18-73	We	1.2	.924	18
4-25-73	We	0.7	.594	15
4-27-73*	Fr	1.1	.854	21
Total		1.0	.880	79

*Construction under way

TABLE C-2

TEST-CAR NUMBER OF STOPS SUMMARY DATA

AM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.6	.900	12
3-28-73	We	1.3	1.129	24
3-30-73	Fr	0.8	.853	22
4-2-73	Mo	1.2	.943	18
4-4-73	We	2.1	1.593	23
4-9-73	Mo	0.9	.889	21
Total		1.307	1.074	120

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.4	1.240	12
4-16-73	Mo	1.1	.719	16
4-18-73	We	1.2	.647	18
4-25-73	We	1.3	.704	15
4-27-73*	Fr	1.0	.686	18
Total		1.183	.771	79

*Construction under way

TABLE C-3

TEST-CAR NUMBER OF STOPS SUMMARY DATA

AM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.6	1.165	12
3-28-73	We	2.4	1.135	24
3-30-73	Fr	2.7	1.900	21
4-2-73	Fr	2.3	1.879	18
4-4-73	We	2.4	1.093	22
4-9-73	Mo	2.0	.894	21
Total		2.4	1.337	118

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.8	.874	11
4-16-73	Mo	1.9	1.580	15
4-18-73	We	2.4	1.165	12
4-25-73	We	1.9	1.136	11
4-27-73*	Fr	1.8	.801	13
Total		2.0	1.132	62

*Construction under way

TABLE C-4

TEST-CAR NUMBER OF STOPS SUMMARY DATA

AM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.8	1.193	12
3-28-73	We	1.7	.955	24
3-30-73	Fr	1.7	1.009	23
4-2-73	Mo	2.2	.618	18
4-4-73	We	2.6	1.221	22
4-9-73	Mo	2.3	1.231	21
Total		2.1	1.036	120

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.1	.376	13
4-16-73	Mo	2.3	.947	13
4-18-73	We	2.4	.961	13
4-25-73	We	2.1	.835	12
4-27-73*	Fr	2.1	.378	7
Total		2.2	.730	58

*Construction under way

TABLE C-5

TEST-CAR NUMBER OF STOPS SUMMARY DATA

AM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	1.6	.632	15
3-28-73	We	1.9	.960	30
3-30-73	Fr	2.4	1.420	28
4-2-73	Mo	1.8	1.641	24
4-4-73	We	2.1	1.086	28
4-9-73	Mo	1.5	.882	28
Total		1.9	1.128	153

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.6	1.017	19
4-16-73	Mo	1.4	1.095	20
4-18-73	We	1.0	.751	24
4-25-73	We	1.2	.910	20
4-27-73*	Fr	1.2	.625	21
Total		1.3	.870	104

*Construction under way

TABLE C-6

TEST-CAR NUMBER OF STOPS SUMMARY DATA

AM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	3.4	2.678	14
3-28-73	We	2.1	1.721	30
3-30-73	Fr	2.7	1.520	25
4-2-73	Mo	2.0	1.197	24
4-4-73	We	3.3	1.864	23
4-9-73	Mo	2.1	1.423	27
Total		2.5	1.658	143

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	1.5	.924	18
4-16-73	Mo	1.8	1.097	22
4-18-73	We	1.9	1.276	20
4-25-73	We	1.8	1.032	19
4-27-73*	Fr	2.0	1.000	5
Total		1.8	1.082	84

*Construction under way

TABLE C-7

TEST-CAR NUMBER OF STOPS SUMMARY DATA

NOON OFF-PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	2.2	.809	17
3-21-73	We	2.4	1.314	20
3-26-73	Mo	1.8	.775	16
3-27-73	Tu	2.1	.832	18
3-29-73	Th	1.7	.816	15
Total		2.06	.926	86

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.5	.660	13
4-13-73	Fr	1.9	1.056	18
4-17-73	Tu	1.4	.512	16
4-20-73**	Fr	1.3	.588	17
4-23-73*	Mo	1.1	1.060	15
Total		1.48	.781	79

*Construction under way
**Easter Weekend

TABLE C-8

TEST-CAR NUMBER OF STOPS SUMMARY DATA

NOON OFF-PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	0.3	.588	17
3-21-73	We	0.3	.646	21
3-26-73	Mo	0.2	.548	18
3-27-73	Tu	0.1	.500	16
3-29-73	Th	0.2	.561	15
Total		0.225	.572	87

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.7	.927	13
4-13-73	Fr	1.6	.840	18
4-17-73	Tu	1.2	.809	17
4-20-73**	Fr	1.3	.826	18
4-23-73*	Mo	1.6	.816	15
Total		1.465	.840	81

*Construction under way
**Easter Weekend

TABLE C-9

TEST-CAR NUMBER OF STOPS SUMMARY DATA

NOON OFF-PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.7	.840	18
3-21-73	We	1.8	.958	19
3-26-73	Mo	1.2	.878	18
3-27-73	Tu	1.8	.862	15
3-29-73	Th	1.4	1.089	14
Total		1.58	.920	84

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.9	.668	12
4-13-73	Fr	2.2	.856	16
4-17-73	Tu	1.8	1.122	14
4-20-73**	Fr	1.6	1.008	14
4-23-73*	Mo	1.7	.743	15
Total		1.87	.883	71

*Construction under way
**Easter Weekend

TABLE C-10

TEST-CAR NUMBER OF STOPS SUMMARY DATA

NOON OFF-PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	2.3	.985	17
3-21-73	We	2.4	1.040	20
3-26-73	Mo	2.3	1.018	18
3-27-73	Tu	2.5	.924	18
3-29-73	Th	2.6	1.158	14
Total		2.41	1.020	87

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	1.1	.793	12
4-13-73	Fr	2.2	.911	16
4-17-73*	Tu			
4-20-73**	Fr	1.6	.497	14
4-23-73*	Mo			
Total		1.69	.739	42

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.
**Easter Weekend

TABLE C-11

TEST-CAR NUMBER OF STOPS SUMMARY DATA

NOON OFF-PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	2.4	1.037	23
3-21-73	We	2.0	1.118	25
3-26-73	Mo	2.4	.974	24
3-27-73	Tu	1.5	1.163	23
3-29-73	Th	1.9	1.089	20
Total		2.05	1.076	115

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	0.9	.640	15
4-13-73	Fr	1.4	.956	20
4-17-73	Tu	1.7	.995	21
4-20-73**	Fr	1.2	1.062	24
4-23-73*	Mo	1.3	.761	20
Total		1.3	.903	100

*Construction under way
**Easter Weekend

TABLE C-12

TEST-CAR NUMBER OF STOPS SUMMARY DATA

NOON OFF-PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	2.1	1.320	22
3-21-73	We	1.3	1.087	26
3-26-73	Mo	1.2	.917	24
3-27-73	Tu	1.5	1.062	24
3-29-73	Th	1.5	1.357	20
Total		1.51	1.137	116

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.1	1.027	14
4-13-73	Fr	2.0	1.186	23
4-17-73	Tu			
4-20-73**	Fr	1.6	.840	18
4-23-73*	Mo			
Total		1.89	1.032	55

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.
**Easter Weekend

TABLE C-13

TEST-CAR NUMBER OF STOPS SUMMARY DATA

PM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	1.8	1.044	21
3-22-73	Th	2.3	.767	22
4-3-73	Tu	2.3	.724	15
4-5-73	Th	2.3	1.017	21
Total		2.2	.899	79

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	We	2.4	1.284	13
4-19-73	Th	2.5	1.345	14
4-24-73	Tu	2.0	.845	15
4-26-73	Th	1.6	1.115	17
Total		2.1	1.138	59

TABLE C-14

TEST-CAR NUMBER OF STOPS SUMMARY DATA

PM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	1.7	.966	21
3-22-73	Th	1.7	.980	25
4-3-73	Tu	2.0	.894	16
4-5-73	Th	1.4	.921	21
Total		1.782	.945	83

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.3	.816	15
4-19-73	Th	2.3	1.047	15
4-24-73	Tu	1.8	.689	13
4-26-73	Th	2.3	1.151	14
Total		2.186	.930	57

TABLE C-15

TEST-CAR NUMBER OF STOPS SUMMARY DATA

PM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.2	.933	20
3-22-73	Th	2.4	1.121	23
4-3-73	Tu	3.1	1.506	15
4-5-73	Th	2.0	.921	21
Total		2.4	1.093	79

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.8	1.373	15
4-19-73	Th	2.2	1.193	12
4-24-73	Tu	1.5	.640	15
4-26-73	Th	1.3	.594	18
Total		1.9	.920	60

TABLE C-16

TEST-CAR NUMBER OF STOPS SUMMARY DATA

PM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.9	1.231	22
3-22-73	Th	4.9	2.410	23
4-3-73	Tu	3.0	1.528	13
4-5-73	Th	3.6	1.630	21
Total		3.68	1.729	79

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	1.9	1.512	14
4-19-73	Th	2.9	1.125	15
4-24-73	Tu	2.5	.850	10
4-26-73	Th	2.9	1.114	18
Total		2.35	1.168	57

TABLE C-17

TEST-CAR NUMBER OF STOPS SUMMARY DATA

PM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.7	1.031	27
3-22-73	Th	2.6	1.194	30
4-3-73	Tu	2.5	.697	19
4-5-73	Th	2.0	1.201	28
Total		2.45	1.063	104

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	1.3	.471	18
4-19-73	Th	2.1	1.663	16
4-24-73	Tu	1.2	.802	14
4-26-73	Th	1.6	.995	20
Total		1.56	.974	68

TABLE C-18

TEST-CAR NUMBER OF STOPS SUMMARY DATA

PM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	3.7	1.458	26
3-22-73	Th	2.9	1.386	28
4-3-73	Tu	3.2	1.682	16
4-5-73	Th	2.9	1.354	26
Total		3.2	1.446	96

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.6	1.056	15
4-19-73	Th	2.6	1.284	14
4-24-73	Tu	1.8	.689	13
4-26-73	Th	2.0	1.026	21
Total		2.25	1.020	63

APPENDIX D

TEST-CAR BRAKE APPLICATION SUMMARY DATA

TABLE D-1

TEST-CAR BRAKE APPLICATION SUMMARY DATA

AM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.8	2.048	9
3-28-73	We	2.8	.995	21
3-30-73	Fr	3.6	1.554	24
4-2-73	Mo	2.7	1.113	15
4-4-73	We	3.0	.999	22
4-9-73	Mo	2.4	1.076	21
Total		2.9	1.231	112

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.2	1.032	10
4-16-73	Mo	1.7	.447	16
4-18-73	Fr	2.1	.832	18
4-25-73	We	2.0	.926	15
4-27-73*	Fr	2.2	1.200	17
Total		2.0	.878	76

*Construction under way

TABLE D-2

TEST-CAR BRAKE APPLICATION SUMMARY DATA

AM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.2	.972	9
3-28-73	We	2.6	1.083	25
3-30-73	Fr	2.5	1.057	22
4-2-73	Mo	2.3	1.496	15
4-4-73	We	2.7	1.112	23
4-9-73	Mo	2.9	1.276	21
Total		2.6	1.164	115

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.4	.669	12
4-16-73	Mo	2.2	1.276	16
4-18-73	We	1.8	.563	17
4-25-73	We	2.4	.910	15
4-27-73*	Fr	2.3	.970	18
Total		2.2	.886	78

*Construction under way

TABLE D-3

TEST-CAR BRAKE APPLICATION SUMMARY DATA

AM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	3.7	1.323	9
3-28-73	We	3.3	1.113	24
3-30-73	Fr	3.7	1.488	21
4-2-73	Mo	3.2	1.656	15
4-4-73	We	4.4	2.013	22
4-9-73	Mo	2.7	.966	21
Total		3.5	1.422	112

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.9	.301	11
4-16-73	Mo	3.3	1.326	14
4-18-73	We	3.5	1.036	11
4-25-73	We	3.7	1.421	11
4-27-73*		2.9	.701	11
Total		3.[illegible]	.976	58

*Construction under way

TABLE D-4

TEST-CAR BRAKE APPLICATION SUMMARY DATA

AM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.7	1.225	9
3-28-73	We	2.5	.780	24
3-30-73	Fr	2.2	1.193	23
4-2-73	Mo	2.6	.828	15
4-4-73	We	3.1	1.457	22
4-9-73	Mo	3.0	1.431	21
Total		2.7	1.155	114

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.1	.863	13
4-16-73	Mo	2.3	1.032	13
4-18-73	We	2.4	.669	12
4-25-73	We	2.4	.669	12
4-27-73*	Fr	2.2	.408	6
Total		2.3	.770	56

*Partial data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.

TABLE D-5

TEST-CAR BRAKE APPLICATION SUMMARY DATA

AM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	2.9	1.045	11
3-28-73	We	2.8	1.095	30
3-30-73	Fr	3.4	1.863	27
4-2-73	Mo	2.9	1.889	20
4-4-73	We	3.0	1.388	28
4-9-73	Mo	2.6	1.497	27
Total		2.9	1.480	143

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.2	.959	19
4-16-73	Mo	2.3	1.455	20
4-18-73	We	1.9	.796	24
4-25-73	We	2.1	1.461	20
4-27-73*	Fr	2.5	1.400	21
Total		2.2	1.202	104

*Construction under way

TABLE D-6

TEST-CAR BRAKE APPLICATION SUMMARY DATA

AM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-20-73	Tu	6.0	2.683	11
3-28-73	We	3.3	1.461	29
3-30-73	Fr	3.9	1.846	25
4-2-73	Mo	3.6	1.569	20
4-4-73	We	5.3	3.202	21
4-9-73	Mo	3.8	1.494	24
Total		4.1	1.942	130

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-12-73	Th	2.3	.752	18
4-16-73	Mo	2.3	1.359	22
4-18-73	We	2.5	1.645	19
4-25-73	We	2.8	1.425	19
4-27-73*	Fr	2.0	1.155	4
Total		2.4	1.297	82

*Partial data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.

TABLE D-7

TEST-CAR BRAKE APPLICATION SUMMARY DATA

NOON OFF-PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-9-73	Mo	3.3	1.849	11
3-21-73	We	2.7	.883	15
3-26-73	Mo	2.6	.885	16
3-27-73	Tu	2.8	1.060	18
3-29-73	Th	2.4	1.121	15
Total		2.7	1.115	75

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.4	.882	9
4-13-73	Fr	3.2	.718	12
4-17-73 *	Tu	2.4	.768	13
4-20-73 **	Fr	2.3	1.303	12
4-23-73 *	Mo	2.4	. 900	12
Total		2.5	.913	58

*Construction under way
**Easter Weekend

TABLE D-8

TEST-CAR BRAKE APPLICATION SUMMARY DATA

NOON OFF-PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	1.6	1.676	12
3-31-73	We	2.2	.774	15
3-26-73	Mo	2.2	1.689	18
3-27-73	Tu	1.7	.873	16
3-29-73	Th	1.7	.798	15
Total		1.9	1.159	76

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.5	1.128	11
4-13-73	Fr	2.7	1.073	12
4-17-73*	Tu	2.1	.917	14
4-20-73**	Fr	1.9	.663	14
4-23-73*	Mo	2.2	.557	12
Total		2.2	.862	63

*Construction under way
**Easter Weekend

TABLE D-9

TEST-CAR BRAKE APPLICATION SUMMARY DATA

NOON OFF-PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	3.4	1.676	12
3-21-73	We	2.5	.915	15
3-26-73	Mo	2.6	1.464	18
3-27-73	Tu	2.9	1.407	15
3-29-73	Th	2.5	1.126	15
Total		2.7	1.309	75

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.7	1.252	10
4-13-73	Fr	2.8	1.030	12
4-17-73*	Tu	2.2	.835	12
4-20-73**	Fr	2.7	1.009	11
4-23-73*	Mo	2.9	.726	12
Total		2.6	.960	57

*Construction under way
**Easter Weekend

TABLE D-10

TEST-CAR BRAKE APPLICATION SUMMARY DATA

NOON OFF-PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	3.1	1.084	12
3-21-73	We	2.6	.938	14
3-26-73	Mo	3.0	1.372	18
3-27-73	Tu	2.7	1.029	18
3-29-73	Th	3.0	1.511	15
Total		2.9	1.195	77

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.2	.751	11
4-13-73	Fr	3.2	1.401	11
4-17-73*	Tu			
4-20-73**	Fr	2.0	.816	10
4-23-73*	Mo			
Total		2.5	.995	32

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.

**Easter Weekend

TABLE D-11

TEST-CAR BRAKE APPLICATION SUMMARY DATA

NOON OFF-PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	3.2	.975	14
3-21-73	We	2.6	1.065	19
3-26-73	Mo	3.0	1.233	24
3-27-73	Tu	2.3	.885	23
3-29-73	Th	2.5	.904	19
Total		2.7	1.020	99

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.1	1.025	16
4-13-73	Fr	2.7	1.139	14
4-17-73*	Tu	2.4	1.121	17
4-20-73**	Fr	2.2	1.353	18
4-23-73*	Mo	2.8	1.527	16
Total		2.4	1.237	81

*Construction under way
**Easter Weekend

TABLE D-12

TEST-CAR BRAKE APPLICATION SUMMARY DATA

NOON OFF-PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-19-73	Mo	3.9	1.685	14
3-21-73	We	2.5	1.043	18
3-26-73	Mo	2.7	1.239	24
3-27-73	Tu	2.8	1.166	23
3-29-73	Th	3.1	2.078	19
Total		2.9	1.412	98

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-10-73	Tu	2.4	.957	16
4-13-73	Fr	2.6	1.365	16
4-17-73*	Tu			
4-20-73**	Fr	2.8	1.474	15
4-23-73*	Mo			
Total		2.6	1.261	47

*Data exclusion for 4/17 and 4/23 because of road construction affecting Routes 4 and 6.

**Easter Weekend

TABLE D-13

TEST-CAR BRAKE APPLICATION SUMMARY DATA

PM PEAK

Route 1

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.6	1.097	18
3-22-73	Th	2.9	.970	19
4-3-73	Tu	3.2	1.014	15
4-5-73	Th	3.7	1.833	21
Total		3.11	1.259	73

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	3.0	1.483	11
4-19-73	Th	3.7	1.414	9
4-24-73	Tu	2.9	1.141	14
4-26-73	Th	2.9	1.685	14
Total		3.07	1.429	48

TABLE D-14

TEST-CAR BRAKE APPLICATION SUMMARY DATA

PM PEAK

Route 2

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.3	.970	18
3-22-73	Th	2.7	1.077	22
4-3-73	Tu	3.0	1.211	16
4-5-73	Th	2.9	1.356	22
Total		2.73	1.158	78

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.6	.985	12
4-19-73	Th	2.7	.707	9
4-24-73	Tu	2.6	.768	13
4-26-73	Th	3.4	1.929	12
Total		2.83	1.115	46

TABLE D-15

TEST-CAR BRAKE APPLICATION SUMMARY DATA

PM PEAK

Route 3

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	2.8	1.125	16
3-22-73	Th	2.7	1.057	19
4-3-73	Tu	4.1	1.580	15
4-5-72	Th	3.1	1.352	21
Total		3.14	1.270	71

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	3.2	.622	12
4-19-73	Th	2.7	.886	8
4-24-73	Tu	2.5	1.125	15
4-26-73	Th	2.9	.770	14
Total		2.82	.861	49

TABLE D-16

TEST-CAR BRAKE APPLICATION SUMMARY DATA

PM PEAK

Route 4

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	3.6	1.382	18
3-22-73	Th	5.1	2.089	20
4-3-73	Tu	4.7	1.548	13
4-5-73	Th	5.0	2.720	21
Total		4.62	1.999	72

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.9	.996	12
4-19-73	Th	3.7	1.500	9
4-24-73	Tu	3.6	1.075	10
4-26-73	Th	2.6	.799	15
Total		3.14	1.047	46

TABLE D-17

TEST-CAR BRAKE APPLICATION SUMMARY DATA

PM PEAK

Route 5

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	3.7	1.517	24
3-22-73	Th	3.6	1.770	26
4-3-73	Tu	4.1	2.193	18
4-5-73	Th	3.6	1.523	27
Total		3.72	1.716	95

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	2.4	.842	14
4-19-73	Th	2.9	1.643	8
4-24-73	Tu	2.6	1.183	15
4-26-73	Th	3.0	1.323	17
Total		2.72	1.207	54

TABLE D-18

TEST-CAR BRAKE APPLICATION SUMMARY DATA

PM PEAK

Route 6

PRETIMED CONTROL				
Date		Average	σ	Sample Size
3-21-73	We	3.9	1.604	23
3-22-73	Th	3.9	1.558	24
4-3-73	Tu	5.7	2.947	18
4-5-73	Th	4.0	2.693	25
Total		4.29	2.163	90

COMPUTER CONTROL				
Date		Average	σ	Sample Size
4-11-73	We	3.8	1.625	13
4-19-73	Th	3.8	1.202	9
4-24-73	Tu	3.8	1.068	13
4-26-73	Th	3.8	1.951	19
Total		3.80	1.535	54

APPENDIX E

CALIBRATION OF PERFORMANCE STATISTICS ROUTINE FOR ESTIMATING TRAVEL TIMES

The performance statistics routine for estimating travel time and delay was calibrated using the Los Angeles Traffic Flow Analyzer. This device provides a means for measuring the number of vehicle-seconds accumulated by the vehicles using a segment of roadway during a given period of time.

The Traffic Flow Analyzer essentially consists of five accumulators: one for keeping track of elapsed clock time, one for the number of vehicles which have entered the segment, one for the number which have exited from the segment, one for the difference between the number in and the number out, and one for the accumulated vehicle-seconds (this is driven by the difference between the number of vehicles in minus the number of vehicles out).

The device has two buttons which are operated by the user of the equipment: one for vehicles entering and one for vehicles exiting. Activating the button causes the corresponding count of the number of vehicles to be incremented.

The analyzer was used to monitor traffic for a ten-minute period in a segment at the same time the statistics program was monitoring the segment. This test was repeated four times on each of two different segments. The results obtained are summarized in the table below in terms of the percentage error in estimating travel time by the Performance Statistics computer routine with respect to the traffic flow analyzer results.

	PERCENT ERROR IN MEASUREMENT	
Run No.	Segment A	Segment B
1	8.9	-4.9
2	-14.0	2.1
3	7.7	-1.9
4	5.8	-10.0
Average	2.1	-3.7
Average of A & B	-0.8	

LIST OF PROJECT REPORTS
ON
DIAMOND INTERCHANGE TRAFFIC CONTROL

1. Vol. 1., Geometric Design and Signalization Characteristics of Diamond Interchanges, J. A. Nemeczky and J. F. Torres, May 1972, PB 217527,* TM-4601/009/01.

2. Vol. 2., Design Manual for Traffic Signal Control of Diamond Interchange Complexes, P. K. Munjal, J. A. Nemeczky, J. F. Torres, June 1972, PB 217518, TM-4601/007/003.

3. Vol. 3., Program Manual for Microscopic Simulation Model of Diamond Interchange Traffic Operations, B. D. Widdice, May 1972, TM-4601/010/01.

4. Vol. 4., Program Manual for Macroscopic Simulation Model of Diamond Interchange Traffic Operations, W. H. Stone, T. E. Banks, J. A. Nemeczky, J. F. Torres, May 1972, PB 216990, TM-4601/011/01.

5. Vol. 5., Before-and-After Simulation and Field Studies of Diamond Interchange Operations, J. F. Torres, J. A. Nemeczky, P. K. Munjal, and B. D. Widdice, May 1972, PB 218138, TM-4601/005/01.

6. Vol. 6., Instrumentation Considerations for Computerized Traffic Control of a Diamond Interchange Complex, C. T. Barooshian, J. A. Nemeczky, J. F. Torres, May 1972, PB 217519, TM-4601/008/01.

7. Vol. 7., Diamond Interchange Traffic Control Interface Unit, C. T. Barooshian, July 1973, TM-4601/012/01.

8. Vol. 8., User's Guide for the Computerized Traffic Control Program, W. H. Stone, T. E. Banks, July 1973, TM-4601/013/01.

9. Vol. 9., Test and Evaluation of Computerized Traffic Control System, J. F. Torres, July 1973, TM-4601/015/01.

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12. Vol. 12., An Analysis of Diamond Interchange Signalization, P. K. Munjal, August 1970, TM-4601/001/00.

*The "PB" number is the National Technical Information Service identification number, and the "TM" number is the System Development Corporation identification number.

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14. Vol. 14., Development and Evaluation of Real-Time Control Algorithms, P. K. Munjal and Y. S. Hsu, April 1971, TM-4601/003/01.

15. Vol. 15., A Comparison of Signal Control Strategies on a Digital Computer Simulation Model, June 1971, TM-4601/006/01.

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