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A COST-EFFECTIVENESS EVALUATION OF A DIGITAL COMPUTERIZED TRAFFIC SIGNAL SYSTEM

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JIM CLYDE LEE

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A COST-EFFECTIVENESS EVALUATION

OF A DIGITAL COMPUTERIZED TRAFFIC SIGNAL SYSTEM

APPROVED BY

DISSERTATION COMMITTEE

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Abstract

In this dissertation a digital computerized traffic signal system controlling 133 intersections in Amarillo, Texas is evaluated. The evaluation is performed in the form of a before-after study which compares the number of stops, amount of delay and number of accidents occurring in the period prior to as well as after installation of the computer traffic signal system. The stop and delay data are obtained with travel time and studies using the average car method. The stop delay and accident data are summarized for the individual studies of the section. This includes both a downtown grid section and a series of arterials. Several different methods of control which were used prior to installation of the computerized system are discussed and compared with the new system. An analysis is also included estimating the reduction in air pollutants as a result of the improved traffic operation.

The main objective of this research is to compare the reduction and road user cost in the form of reduced stops and delay with the increased cost of installation and operation of the computerized traffic signal system. This cost effectiveness operation is performed using both a benefit cost ratio and a rate of return method of analysis.

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INTRODUCTION

Numerous cities across the country and around the world have installed or are in the process of installing a digital computer controlled traffic signal system. Although results of these installations have been favorable, there has been a limited amount of evaluation. Pignataro (1, p. 374)* states that there is a "definite trend" toward these systems. Due to the relatively large capital and operating expenses of such systems it is believed that a cost effectiveness evaluation would be in order. It is the purpose of this research to measure the effectiveness of the system and to relate the cost of the system to the benefits the motorists derive from its operation.

Most cities which have installed computer controlled signal systems have engaged in some degree of system evaluation. Table 1 summarizes the results of some of these system evaluations as listed by Stockfish (2). These data are results of traffic operation before and after the installation of the computerized signal system.

Although these and other system evaluations indicate improvement, notably lacking is a comparison of the cost of the system with the

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*See References

TABLE 1

OPERATIONAL IMPROVEMENTS OF SELECTED SYSTEMS

City	Number of Intersections	Percent Reduction			
		Delay	Stops	Accidents	Travel Time
Toronto	864	20	53	13	44
San Jose	59	12	7	NA	NA
Wichita Falls	77	18	8	9	NA
New York	433	30	30	NA	20-40
West London	100	18	NA	18	9

value to the motorists in terms of reduced cost due to reduced travel time, fewer stops, fewer speed change cycles, etc.

A recent publication, Traffic Control Systems Handbook, (3, p. 612) reports costs of selected urban street traffic control systems as shown in Table 2.

In examining this table, the reader will find a wide range in system costs even when the number of intersections interfaced with the computer is considered. The main reason for this apparent discrepancy is the varying scope of the different projects. Some of the projects provided for all new local intersection equipment (poles, arms, signal heads and local controllers) while others required only the installation of the computer and peripheral equipment. Another factor in the wide variation in cost is the availability of conduit for communication of the computer to the local intersections. If existing conduit is available, a significant savings in the contract price can be realized. If conduit is not available, the contract may provide for aerial communication or leased telephone lines both of which result in a lower initial cost than the installation of underground conduit. Additionally, an initial savings might be realized by utilizing either time-division or frequency-division multiplexing both of which reduce the number of pairs of communication cable required for a given number of intersections.

The idea of a cost-effectiveness evaluation of improvements has been proposed for some time, notably by Winfrey (4). Its primary use has been in the evaluation of alternatives of construction and reconstruction of roadway facilities. This has been used in a limited way in the field of traffic control. Dudek and McCasland (5) utilized a cost-effectiveness

TABLE 2

INSTALLATION COSTS OF SELECTED SYSTEMS

City	Date of Bid	Number of Intersections	Number of Detectors	System Bid Cost (in Dollars)
Charlotte, N.C.		174	55	$1,250,000
Baltimore, Md.		900	1000	3,900,000
Oklahoma City, Okla.		33		133,572
Shreveport, La.		256	500	762,000
L.A. County, So. Bay		111		645,000
Denver, Colo.		320		550,000
Atlanta, Ga.		12		169,000
Savannah, Ga.		97	101	758,000
Albany, Ga.		60	60	670,000
Raleigh, N.C.		154		661,000
Pasadena, Tex.		63	75	145,820
Phoenix, Ariz.	1973	253	175	785,000
Lansing, Mich.	1974	150	155	649,000
Tucson, Ariz.	1974			528,000
Amarillo, Texas	1974	133	94	1,751,723
Greensboro, N.C.	1973	159	227	
Columbus, Ohio		92	230	
Laredo, Texas	1973	65	40	

evaluation of alternatives of freeway merging control. In this study four levels of ramp merging control were evaluated. The implementation cost of each level was compared with the savings to the motorists in an attempt to optimize the effectiveness of ramp control with regard to its cost.

Another consideration in studies of improved signal systems should be the fuel savings that would be associated with the improvement. A test conducted at the General Motors Research Laboratory (6) showed that travel time per unit distance was the single most important factor in explaining the variability of fuel consumption. A method of computing the reduction in fuel savings has been developed to measure traffic engineering improvements in New York State (7). In the New York State method the additional fuel requirements are computed for idling while stopped and making additional stops as presented by Claffey in NCHRP Report 111 (8). The same type of analysis can be performed using the fuel consumption data for excess idling and stops presented by Winfrey (4).

The subject of this research is a new computer controlled traffic signal system which was installed in Amarillo, Texas in 1975 (9). One hundred and thirty-three intersections were originally placed under computer control (Figure 1). These intersections vary from being a part of a tightly formed central business district grid network to those that comprise arterial street systems. Both one-way and two-way streets are involved. Figure 1 depicts the signal system with its seven sections. Generally, a section is a group of intersections which were coordinated by some type of master controller prior to installation of the computer.

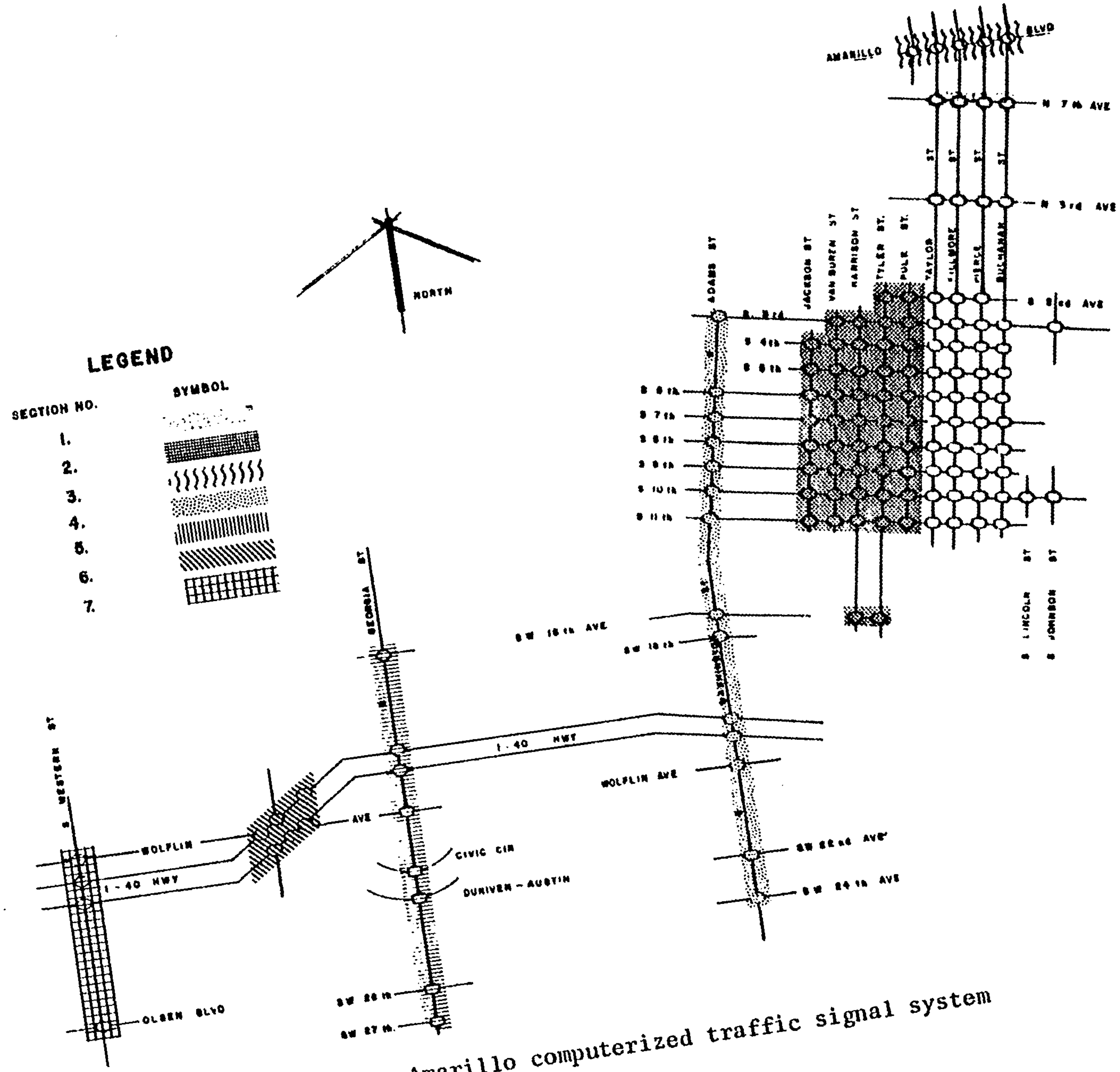


Fig. 1 - Amarillo computerized traffic signal system

Additionally, a section consists of intersections which should always be coordinated with each other, but would not necessarily need to be coordinated with those of another section.

Although other types of signal systems were considered for Amarillo, the decision was made to install a computerized system. One of the reasons for this decision was the flexibility afforded by the computerized system. It would allow an unlimited number of different timing patterns to be utilized. A second reason was the availability of a large amount of surveillance data that are provided at the control center from the detectors in the street. A third reason for deciding on a computer system was its ability to interface with a wide variety of local intersection controllers which was considered to be important both with the initial installation as well as in future expansion of the system.

In comparison with other systems (Table 2) the Amarillo system appears more costly. Table 3 lists a breakdown of the principal cost items in the Amarillo system. The first item that will be observed is the extremely high cost of cable and conduit. This is discussed in Chapter II. Additionally, new poles, heads and local controllers were installed at many of the intersections, thereby raising the cost.

Prior to installation of the computerized signal system there were several different interconnected systems in operation. What became Section 1 in the computer system was controlled by the Automatic Signal Company's PR System. The PR is an analog system which can vary splits, offsets and cycle lengths based on varying traffic demands. Although it affords flexibility in providing different traffic signal patterns for

TABLE 3

COST OF PRINCIPAL ITEMS

Item	Cost
Cable and conduit	$1,250,000
Poles, heads and local controllers	$ 450,000
Computer and peripheral equipment	$ 250,000

different conditions there were some problems encountered in trying to maintain good signal progression. Most of these problems were the result of the inability to obtain precise settings on the dials which controlled splits and offsets. The only way the desired split and offset could be accurately set was by using a stop watch. This created problems when it was necessary to change out a controller for maintenance. Since the dials did not afford precise timing the replacement controller may not have had the proper settings even though the technician would set it to the specified dial settings.

Section 2 was a Crouse-Hinds Trafflex System. This system worked quite well considering its age in excess of twenty years at the time of replacement. The system in Amarillo had the ability to vary cycle lengths but was limited to one split for each intersection. The cycle length was varied by increasing or decreasing the voltage on the secondary or "braking" coil which would allow the dial to turn at different speeds. The lower the secondary coil voltage, the faster the dial would turn which would therefore provide a short cycle length. The problem with this method of operation is the inability to precisely control the clearance intervals. For example, a five per cent clearance interval would give a yellow time of 2.25 seconds with a 45 second cycle and 4.5 seconds with a 90 second cycle.

Prior to placing it under computer control, Section 3 was also a PR system as described for Section 1. The system seemed to work somewhat better in this situation where the technician only had five signals to coordinate.

The north portion of Section 4 (3rd through 15th Street) was a trafflex system prior to computerization. The two intersections at I-40 and Washington along with Wolflin and Washington were controlled by a three dial electromechanical system. The two intersections of Washington at South 22nd and South 24th Avenues were independent semi-actuated controllers.

Sections 5 and 7 were three-dial electromechanical systems prior to being placed under computer control. These three-dial systems remained as back-ups after computerization.

CHAPTER II

DESCRIPTION OF COMPUTERIZED SIGNAL SYSTEM

Hardware

The majority of the local intersection controllers in the system are electromechanical fixed time controllers which, when under computer control, have the cam stacks ratcheted by the computer. This type of control requires the computer to stop the dial at the controller, via a pair of wires, and then issue advance pulses over a second pair of wires. A third pair of wires is required to return the A phase green status to the computer. There are 600 pairs of wire coming into the central computer room. There are several alternatives which could have been used to reduce the extremely large expense associated with this much conduit and cable. The possibility of leased telephone lines was rejected because of the large continuing expense of rental plus the lack of control over the reliability of telephone company wires. Multiplexing was rejected because it was thought to be inadequately proven from a dependability standpoint at the time the plans were prepared in 1973. Additionally, multiplexing would necessitate additional equipment for the traffic signal technicians to maintain.

Software

The software package the Amarillo system utilizes has four primary modes of operation. They are time of day, manual, static and dynamic. The time of day mode, of course, is the calling for a certain timing pattern to be implemented in a certain section at a certain time. Manual pattern selection is available whereby the operator calls a certain pattern up via the teletype. The static and dynamic modes are of a responsive nature and utilize traffic volume data from the system detectors to select a pattern. At the time the after data were collected all sections of the system were being operated in the time of day mode.

The software package also has the provision for critical intersection control (CIC) operation. This feature allows certain intersections to be designated as critical intersections and permits the splits to be varied by the computer based on demand on each phase. The intersection is still constrained to operate with the same cycle length as the rest of its section. The main disadvantage of this type of operation is that there must be at least one detector for each phase of operation.

Generally two sections of the system will be operating independently with no concern for progression between sections. There are numerous cases, however, where it is desirable to have progressive movement between two adjacent sections. This can be done by locking one section (a satellite section) to another (a key section) either manually or automatically. The automatic locking is implemented in the responsive modes when the cycle lengths of the key section and the satellite section come within a specified amount of each other (usually 5 to 10 seconds). This happens as long as locking is permitted by the operator at that particular time.

The timing patterns which were implemented with the new system were obtained by using either the PASSAR II or SIGOP programs. Both of these are computer signal optimization programs. The SIGOP program was used in the downtown area (Sections 1 and 2) in that it was designed for use in a grid system. The PASSAR II program, being designed as an arterial optimization program was used on Sections 3 through 7.

Based on traffic volume counts it was found that, generally speaking, there were four different traffic demand characteristics during the day. These were found to be the morning (AM) peak, the noon peak, the afternoon (PM) peak and the off peak period. For the morning peak period a pattern was developed which favored inbound traffic. The noon peak required a pattern which did not favor any particular direction but provided a longer cycle length than necessary for the off peak periods to accomodate the heavier volume of traffic. The afternoon peak had the highest volume of traffic of the day and, therefore, required the longest cycle length. Also, it provided preferential movement in the outbound direction. The off peak pattern had the shortest cycle length and was designed to move traffic in all directions as much as possible. In all cases the streets with the higher volumes were favored in the development of traffic signal patterns.

CHAPTER III

EXPERIMENTAL DESIGN, DATA COLLECTION AND ANALYSIS METHODOLOGY

Experimental Design

The basic research question addresses itself to the ways and the extent to which a computer controlled traffic signal system improves traffic operations. This will be determined by investigating the effect the computerized signal system has on the following variables:

1. The number of stops.
2. The amount of vehicle delay.
3. The number of accidents.
4. The motor vehicle operating cost.

One possible way to study or investigate the effect of these parameters is to formulate the following questions:

Research Question 1 - Has the number of stops required by drivers been reduced by the installation of the computerized signal system?

Research Question 2 - Has there been a decrease in vehicle delay associated with the system?

Research Question 3 - Has there been a reduction in the number of accidents on the streets comprising the new signal system since its installation?

Research Question 4 - Does the reduction in Motor Vehicle operational cost due to reduced stops and delay exceed the capital and operating cost of the system?

With regard to these research questions it is hypothesized that:

1. The installation of the system will result in a reduction in the number of stops required.
2. The new system will result in a reduction in vehicle delay.
3. There will be a reduction in accidents on the streets that are controlled by the signal system.
4. There will be a reduction in vehicle operating cost due to the installation of the signal system which will exceed the capital and operating cost of the system. It is proposed this be evaluated on an equivalent uniform annual cost basis with a ten year life of the signal system.

Each of these hypotheses may be stated statistically as follows:

Null Hypothesis	Alternate Hypothesis
1. $S_A = S_B$	1. $S_A < S_B$
2. $D_A = D_B$	2. $D_A < D_B$
3. $A_A = A_B$	3. $A_A < A_B$
4. $C_B - C_A < C_S$	4. $C_B - C_A > C_S$

where, S_A = the number of stops required on the section of the system in question and for the time period being studied after installation of the computerized signal system.

S_B = the number of stops required on the section of the system in question and for the time period being studied before the installation of the computerized signal system.

D_A = the number of seconds of delay incurred on the section of the system in question and for the time period being studied after installation of the computerized traffic signal system.

D_B = the number of seconds of delay incurred on the section of the system in question and for the time period being studied before installation of the computerized traffic signal system.

A_A = average annual number of accidents in the signal system in the after period.

A_B = average annual number of accidents in the signal system in the before period.

C_B = the vehicle operating cost of driving on the system prior to installation of the computerized signal system for all vehicles during all time periods for one year.

C_A = the same vehicle operating cost as above after installation of the computerized traffic signal system.

C_S = the equivalent uniform annual cost of the capital and operating expense of the system assuming a ten year life.

The data for this study were based on travel time runs on each section of roadway that was put under computer control. These runs were made utilizing the "average car" method. They consist of runs prior to as well as after installation of the computerized traffic signal system. Each street had six runs in the before period and six runs in the after period, as recommended in the Traffic Control System Handbook (3, p. 578).

There were runs for each of the following time periods: morning peak, noon peak, evening peak and off peak. The Traffic Control System Handbook suggests six runs in the peak period and six runs in the off peak period. In this study, however, it is believed there should be separate runs in each of the three previously mentioned peaks as well as the off peak primarily because there will be separate timing patterns for each peak period when under computer control. The only way that this can satisfactorily be taken into account is by making a separate study during each period.

The travel time runs were conducted using the "average car" technique. In this procedure the "vehicle travels according to the driver's judgement of the average speed of the traffic stream" (10, p. 100). "Tests of this method have shown excellent correlation with actual average travel time" (11, p. 427).

Using the travel time data the number of stops and amount of stopped time delay during each of the time periods mentioned were computed. These values were determined for both the period prior to as well as after placing the signals under computer control and were statistically compared. The motorists' operating cost (moc) was then computed as follows:

$$moc = (s)(c_s)(v) + (d)(c_d)(v)$$

where, s = number of stops per vehicle

c_s = cost per stop

v = annual volume

d = stopped time delay per vehicle

c_d = cost per vehicle second of delay

Appropriate cost figures for stops and delay and the total cost to the motorists before placing the system under computer control can be determined.

This analysis was repeated to obtain the motorists' operating cost after placing the system under computer control. The difference between the operating cost to the motorists in the before and after period can then be computed and compared with the equivalent uniform annual cost of the capital and operating expenses of the computerized signal system.

In a study such as this where the data collection for the two situations is done with a considerable time lapse it is not expected that traffic volumes would remain constant. The changes in traffic volumes should be small enough to assume the same volumes for both the before and after period. The alternative to this would be to attempt to measure the traffic volumes during each time period (AM Peak, Noon Peak, PM Peak and Off Peak) for both the before and after periods. This would introduce more error into the analysis than using the same volume for both the before and after period because the traffic volumes that were used were typical daily volumes on each particular street. They were not true average daily traffic (ADT) values in that the only way true ADT values could be obtained would be to count the total yearly volume on the street and divide by 365 days per year. Since this is not practical, weekday traffic volume was used. If another typical weekday volume was used for the after period, the daily and monthly variations that would occur might introduce more error than would be avoided by using new counts in the after period. It is reasonable to assume that there is a slight increase in volumes annually. For this reason any reductions observed in stops, delay, accidents or motorists' operating cost would be somewhat on the conservative side.

Research Question 1

The travel time data consist of six runs along each street during each of the time periods previously described. The average number of stops for the six runs during each time period for each street was computed. Repeating this process for all time periods gives the total number of stops in an average day on that particular street. In a similar manner the total number of stops was calculated for an average day after the new signal system was operational. The first null hypothesis, $S_A = S_B$ may now be statistically evaluated with the alternate hypothesis being $S_A < S_B$. This can be done using the student's t-distribution significance test (12, p. 136). This will be a one tailed test with a 0.05 significance level which will be performed separately for each time period of each street and then for a total average day for each street.

A comparison of the grand total number of stops for the entire system in the before and after periods can be made by utilizing the chi square test (12, p. 205). In this test the number of stops in the before period would be entered as the expected values while those in the after period for each street would make up the observed values. This chi square evaluation would be made at the 0.05 significance level.

Additionally a t-test may be used to evaluate the number of stops in the after period with respect to the number of stops in the before period for the entire system.

Research Question 2

This test will be similar to the one in Research Question 1 except that the quantity being measured will be the number of seconds of stopped-time delay. The number of seconds stopped will be measured for each of the six runs on each street. An average number of seconds of stopped-time delay will then be computed for each street during each time period by dividing the total number of seconds of stopped-time delay for the six runs by six. This average number of vehicle-seconds of delay per vehicle during each time period when multiplied by the number of vehicles on the street during that time period will give the total amount of delay on that street during that time period.

The null hypothesis of $D_A = D_B$ may now be evaluated with the alternate hypothesis of $D_A < D_B$ where D_A = the number of vehicle seconds of stopped time delay in the six runs in the after period and D_B = the number of vehicle-seconds of stopped-time delay in the six runs in the before period. This evaluation can be made with a one-tailed t-test at a 0.05 significance level for the entire system.

Research Question 3

In this test the number of accidents on the streets comprising the signal system in the before versus the after period will be compared. The before period is the three year period from January 1, 1972 through December 31, 1974. The after period is January 1, 1976 through December 31, 1978. The calendar year 1975 is excluded from comparison because the installation of the signal system was underway during most of that year. The significance test which is appropriate when there is a three year before and a three year after time period is the Poisson test (13, p. 47). When it is necessary to analyze data consisting of large numbers the Poisson test, as performed by Gerlough (14, p. 50) becomes quite cumbersome and may be approximated by the formula:

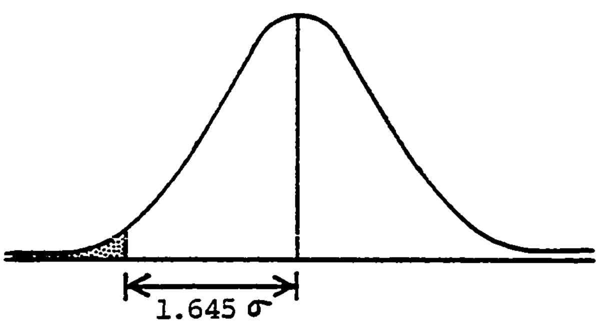
$$(B - A) > 1.654 \sqrt{M}$$

where B = number of accidents in the before period

A = number of accidents in the after period

M = mean number of accidents

This formula is based on the fact that the mean is equal to the variance for the Poisson distribution (15, p. 107). The standard deviation is therefore the square root of the mean ($\sqrt{M}$). In order to have one-tailed significance at the 0.05 significance level the difference in the accidents in the two periods must be greater than 1.645 times the standard deviation (i.e. 1.645 $\sqrt{M}$). This is graphically depicted in Figure 2.



$B-A > 1.645\sqrt{M}$ for significance at 0.05 level

Fig. 2 - Significance test for reduction in accidents

Research Question 4

The answer to this question is the basic goal of this research project. It draws from the answers to Research Questions 1, 2 and 3. It will be measured in terms of an equivalent uniform annual cost of motorists operating on the streets having computerized control with the equivalent uniform annual cost of the previous system. Any reduction of equivalent uniform annual motorists' operating cost will be compared with the difference in equivalent uniform annual capital and operating cost of the new versus the old signal systems. This analysis will utilize the vehicle operating cost data of Winfrey (4) and the more up to date (1975) cost data published by AASHTO (17).

CHAPTER IV

ANALYSIS OF RESEARCH QUESTIONS

Research Question 1

The first research question which compares the number of stops in the before period with the after period on each street was conducted using the Student's t-test. Table 4 shows the number of stops during the before and after periods on a typical street (Adams) in the northbound direction during the AM Peak. Table 5 shows the same information summarized by section.

This t-test is performed with paired variates, one in the before period and one in the after. The t-distribution in this instance is defined (12, p. 146) by:

$$t = \frac{\bar{D} - m_d}{S_{\bar{d}}}$$

where, $\bar{D}$ = mean of the differences between each before and after pair in the sample

m_d = difference in the population mean

$S_{\bar{d}}$ = best estimate of standard deviation of mean of population differences

or

TABLE 4

ADAMS STREET-NORTHBOUND AM PEAK

Run Number	No. Stops Before	No. Stops After	Difference (D) Before-After
1	2	0	2
2	1	0	1
3	1	0	1
4	1	1	0
5	1	0	1
6	1	0	1
			$\Sigma D = 6$
$n = 6$			$\bar{D} = 1$

TABLE 5

BEFORE-AFTER COMPARISON OF STOPS AND DELAY IN SIX TRAVEL TIME RUNS DURING EACH TIME PERIOD

Section	Stops (Number) / Delay (Vehicle-Seconds)														
	AM Peak			Noon Peak			PM Peak			Off Peak			Total		
	Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change	Before	After	Change
1 and 2	375*	318	-57	496	250	-246	382	320	-62	378	363	-15	1631	1251	-380
	5961	6281	+320	5436	3870	-1566	6676	7115	+439	7876	3953	-3923	25949	21219	-4730
3	7	0	-7	3	1	-2	7	13	+6	0	0	0	17	14	-3
	17	0	-17	8	2	-6	81	89	+8	0	0	0	106	91	-15
4	17	9	-8	26	20	-6	31	38	+7	12	12	0	86	79	-7
	113	73	-40	239	335	+96	560	776	+216	181	219	+38	1093	1403	+310
5	24	2	-22	34	14	-20	31	19	-12	25	5	-20	114	40	-74
	430	9	-421	818	411	-407	1071	159	-912	355	32	-323	2674	611	-2063
7	9	0	-9	-	-	-	7	9	+2	6	7	+1	22	16	-6
	152	0	-152	-	-	-	186	61	-125	177	52	-125	515	113	-402

*The numerator represents stops (number) and the denominator represents delay (vehicle-seconds).

$$S_{\bar{d}} = \frac{S_d}{\sqrt{n}}; \quad S_d = \sqrt{\frac{\Sigma(D - \bar{D})^2}{n - 1}}$$

where, S_d = best estimate of standard deviation of population differences

n = sample size

$$S_d = \sqrt{\frac{(1)^2 + 0 + 0 + (-1)^2 + 0 + 0}{5}} = \sqrt{.4}$$

$$S_{\bar{d}} = \frac{S_d}{\sqrt{n}} = \frac{\sqrt{.4}}{\sqrt{6}} = \sqrt{.0667} = .258$$

$$t = \frac{\bar{D} - 0}{S_{\bar{d}}} = \frac{1}{.258} = 3.88$$

Using five degrees of freedom (N - 1) the table value for $t_{.05}$ = 2.015. Since the calculated t-value of 3.88 is greater than 2.015, it falls in the rejection area as shown in Figure 3. For this reason the null hypothesis of $S_A = S_B$ is rejected and the alternate hypothesis of $S_A < S_B$ is accepted. In a similar manner the null hypothesis of $S_A = S_B$ was evaluated for each street in each direction during each time period. These calculations are shown in Appendix C.

A t-test was also used to evaluate the total number of stops on all streets during all time periods. This was performed by computing the difference between the total number of stops in the six runs in the before period with the number of stops in the six runs in the after period for each time period of each street in each direction. For example, in the northbound direction on Adams during the AM peak there were seven stops recorded in the six runs in the before period and one stop in the six runs in the after period. The difference in these two values is 6. This procedure is repeated for all streets in all time periods for the

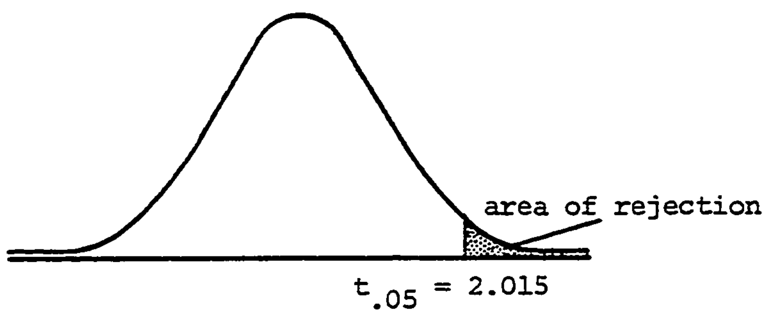


Fig. 3 - Significance test for reduction in stops

entire system. The mean of all the differences is then computed. The t-test can then be applied in the same manner as for the individual street and time periods as described previously. The calculation of this t-test is shown in Appendix D.

The total number of stops before and after during each time period on each street was computed by multiplying the volume during each period by the number of stops per vehicle during each period. These values were summed for each section to give the total number of stops per day on each section in both the before and after period. The number of stops per day in each section was then summed to give the total number of stops per day on the entire system both for the period prior to the installation of the computerized traffic signal system as well as after its installation. This permits the comparison of the stops in the system considering the volume of traffic on the various streets rather than simply comparing the number of stops in a fixed number of runs down a particular street. The total number of stops in the after period was subtracted from the number of stops in the before period to obtain the reduction in the total number of stops that could be expected on an average day of operation of the computerized traffic signal system. The reduction was then expressed in the form of a percentage reduction and the comparison is shown in Table 6.

A chi square analysis is also presented comparing the number of stops in the before versus the after period of all streets in all time periods in total. As in the t-test for the entire system the purpose of this analysis is to compare statistically the number of stops for the entire system in the before period with the after period. This analysis is shown in Appendix E.

TABLE 6

STOP AND DELAY COMPARISON BY SECTION

Section	Stops/Day				Delay (Veh-Hr/Day)			
	Before	After	Change		Before	After	Change	
			Number	Per Cent			Number	Per Cent
1 and 2	290,687	235,420	-55,267	-19.0	1,335.9	892.4	-443.5	-33.2
3	2,232	2,417	+185	+8.3	4.1	4.5	+0.4	+0.9
4	16,890	15,166	-1,724	-10.2	64.6	74.5	+9.9	+15.3
5	35,901	10,648	-25,253	-70.3	200.1	31.3	-168.8	+84.4
7	8,374	8,327	-47	-0.6	60.1	16.4	-43.7	-72.7
Total	354,084	271,978	82,106	-23.2	1,664.8	1,019.1	-645.7	-38.8

Research Question 2

In a manner similar to that used in Research Question 1 the vehicle-seconds of delay in the before and after periods was compared using the t-test. This analysis is performed in Appendix G with a summary presented in Table 5. The total number of vehicle-hours of delay in each time period on each street was then obtained in both the before and after periods by multiplying the delay per vehicle by the volume during the time period. Again, this value was summed to obtain the number of vehicle-hours of delay on each section during each time period and for the entire day for both the before and after periods. It was then, summed for all sections to give the total system delay per day in both the before and after periods. The percentage reduction in delay was then computed for the entire day.

Research Question 3

Table 7 shows the number of accidents by year on each section of the city where the computerized traffic signal system was installed. Since the signal system was installed in 1975, that particular year was excluded from the comparison of accidents. The average annual number of accidents on the entire system in the before period (1972-1974) was 1216. The average annual number of accidents in the after period (1976-1978) is 1139. This would be a reduction of an average of 77 accidents per year in the after period which on the basis of an average annual number of accidents of 1216 yields a 6.3 per cent reduction. This is a significant reduction in accidents at the 0.05 significance level using the

TABLE 7

YEARLY ACCIDENTS BY SECTION

Year	Section						
	1 & 2	3	4	5	6	7	Total
1972	747	52	151	103	15	100	
1973	784	68	177	98	21	104	
1974	737	78	163	134	27	89	
Σ 72,73,74	2268	198	491	335	63	293	3648
1976	704	95	163	139	29	123	
1977	643	99	162	143	38	108	
1978	530	85	130	113	31	83	
Σ 76,77,78	1877	279	455	395	98	314	3418
Percent Change	-17.2	+40.9	-7.3	+17.9	+55.6	+7.2	-6.3

Poisson distribution significance test for accidents. A further summary of accidents in the two periods is shown in Table 8. As can be observed, the downtown area (sections 1 and 2) is the only one to realize a significant reduction in accidents and in fact realized such a decrease in accident it was largely responsible for the significant accident reduction for the entire system.

There are two items that must be considered in this accident analysis. The first is that although certain sections show an increase in the number of accidents, they are areas that have had a general increase in traffic volumes. It is not unreasonable to assume these increases in accidents to be generally proportional to the increased traffic volumes therefore resulting in similar accident rates for the two periods. The second is that although the Poisson distribution test reveals a significant accident reduction in the after period, the conclusion may not be drawn that the reduction is due to the new signal system.

Another item that could partially account for the accident reduction is the selective traffic enforcement program (STEP) that was initiated at generally the same time period as the new signal system. In this particular program the State of Texas subsidized the City for the salary of off-duty policemen to increase enforcement of traffic laws at particular locations that have an accident problem.

It is interesting to examine the percentage of accidents that occur on the streets controlled by the signal system compared to the total number of accidents in the city. These data are shown in Table 9 and point out that system accidents varied from a high 19.9 percent of total accidents in 1974 to a low of 15.2 percent of total accidents in 1978. In the before period (1972-1974) accidents occuring on the streets which

TABLE 8

SIGNIFICANCE TESTS OF ACCIDENT REDUCTION

	Section							
	1 & 2	3	4	5	6	7	Total System	Total City
Average Before (1972-1974)	756	66	164	112	21	98	1216	6597
Average After (1976-1978)	626	93	152	132	33	105	1139	6879
Difference	-130	+27	-12	+20	+12	+7	-77	+282
Significant Reduction at 0.05 Level	Yes	—	No	—	—	—	Yes	—
Significant Increase at 0.05 Level	—	Yes	—	Yes	Yes	No	—	Yes

TABLE 9

ACCIDENT SUMMARY

Year	Section						Total		Per Cent Accidents on System to Total City
	1 & 2	3	4	5	6	7	Systems	City	
1972	747	52	151	103	15	100	1168	6244	18.7
1973	784	68	177	98	21	104	1252	6693	18.7
1974	737	78	163	134	27	89	1228	6855	19.9
1975	745	91	171	147	15	109	1278	6877	18.6
1976	704	95	163	139	29	123	1253	7044	17.9
1977	643	99	162	143	38	108	1193	7211	16.5
1978	530	85	130	113	31	83	972	6382	15.2

were to be controlled by the signal system comprised 18.4 percent of the total accidents in the city. In the after period (1976-1978) this figure had dropped to 16.6 percent. This reduction in the percent of total city accidents that occur in the signal system tends to support the hypothesis that the reduction in accidents was due to the signal system rather than the STEP program since it would be expected that the STEP program would reduce accidents more equally throughout the city. It is possible, however, that a disproportionately large portion of the emphasis of the STEP program was on the same streets that were placed under computer control therefore partially accounting for the reduction on those streets.

Research Question 4 - Basic Considerations

In answer to this research question, the annual motorists' operating cost was computed for the system for both the period before as well as after installation of the computerized traffic signal system. This was done by computing the total cost of the stops and vehicle delay to the motorists. The cost of the vehicle delay is computed by summing the excess idling cost brought about by the stopped time delay with the time value of the delay to the motorists. The actual cost of driving through the system at a constant speed was not included since it is the same for both periods and eventually cancels itself out of the analysis.

In order to obtain the cost of stops and delay it was assumed that there were 10 percent trucks and a cost value for trucks was obtained by averaging the cost values of single unit and 40 kip trucks. This figure is not inconsistent with the values obtained in manual counts on the streets in the system. The only alternative to this assumption would be to collect the actual percentage of trucks on each street on the system. This would be a very difficult procedure and would not substantially improve the accuracy of the results since very minor changes would be expected in the percentage of trucks in the two periods. It was also assumed that the stops were for 25 miles per hour with the vehicle returning to that speed after the stop.

Research Question 4 - Quantification

The calculation of the motorists' operating costs on the system in the two time periods is shown in Appendix I. The annual cost in the before period was found to be $2,254,283 and in the after period was calculated at $1,624,849. The difference in these two values ($629,434) is therefore the calculated annual cost savings to the motorists with the new system.

The cost values ($6.96 per 1000 stops for passenger cars, etc.) are taken from Winfrey (4, p. 688, 700, 723). The $1.00 per vehicle hour is the minimum value of the range of $1.00 - $4.00 per vehicle-hour given by Winfrey (4, p. 269).

The total cost of the project was $1,958,000 (18). Assuming a ten year life of the installation the equivalent uniform annual cost of the required capital expenditure (assuming 8 percent interest) is $291,800.

A benefit-cost analysis may be performed by comparing the benefits derived in the form of reduced motorists' operating costs per year to the annual cost of the system. In order to do this the increased maintenance and operating cost of the computerized signal system must be included. The increased maintenance cost is due to the highly technical and specialized nature of a digital computer and its peripheral equipment. Maintenance of this type of equipment is beyond the scope of the capabilities of a typical city's traffic signal shop. Additionally in order to fully utilize such a system extra effort in developing signal timing patterns is required by the city's staff. The total increased cost of maintenance and operating support is estimated to be $40,000 per year. Using these figures the benefit-cost ratio of the system in question may be computed as follows:

$$B - C = \frac{\text{Reduced Annual Motorists' Operating Costs}}{\text{EUAC for Installation + Increased Maintenance and Operating Cost}}$$

$$B - C = \frac{\$629,434}{\$291,800 + \$40,000} = \frac{\$629,434}{\$331,800}$$

$$B - C = 1.90$$

Although the assumption of a ten year life is valid for the digital computer itself and its peripheral equipment, it is not valid for the rest of the system equipment. The conduit and cable installation which comprised a large portion of the project cost ($1,250,000) would have a useful life of approximately 30 years. The traffic signal poles, heads and local controllers which would have a useful life of approximately 20 years represented an investment of approximately $450,000. The remaining $258,000 of the total project cost represents the cost of the computer and peripheral equipment. As previously stated, the estimate of a ten year life is reasonable for that portion of the project. Using these values for useful life, the equivalent uniform annual cost for the project is $194,124. These calculations are shown in Appendix I.

Using this value for the equivalent uniform annual cost of the installation and the same values for reduced motorists' operating costs and increased maintenance and operating costs the benefit-cost ratio can be computed.

$$B - C = \frac{\text{Reduced Annual Motorists' Operating Costs}}{\text{EUAC for Installation + Increased Maintenance and Operating Cost}}$$

$$B - C = \frac{\$629,434}{\$194,124 + \$40,000} = \frac{\$629,434}{\$234,124}$$

$$B - C = 2.69$$

One shortcoming of the preceding analysis is that it is based on cost figures presented by Winfrey (4) in his book published in 1969. Since the system being evaluated was installed in 1975 the vehicle operating cost data are well out of date. A 1978 publication by AASHTO (17) provides vehicle operating cost data for a 1975 base year. Repeating the preceding analysis using the AASHTO cost figure (17, p. 132, 133, 134, 171, 17) yields motorists' operating costs in the before and after periods respectively of $2,452,362 and $1,823,823.

In this analysis the figure of $0.21 per traveler-hour is reccommended by AASHTO for time savings of zero to five minutes on average trips. Additionally on an average of trip purposes a value of 1.56 adults per vehicle is recommended (17, p. 17).

Therefore, it is observed that although different values are used in the AASHTO publication from the Winfrey book, the end result is almost identical ($628,539 verses $629,434). A benefit-cost analysis will not be performed on the figures obtained using the AASHTO values since the results would be almost identical to those previously done.

Another method of analyzing the economics of the improvement is the internal rate of return analysis (19, p. 267). In this method the benefits are related to the costs not in the form of a ratio, but rather in the form of an annual percentage return on the investment over the life of the improvement. Again using a ten year life of the system the annual rate of return as computed in Appendix I is 27.4%.

Another important consideration in the analysis of a project such as this is the effect the new signal system has on fuel consumption and air pollution. Appendix J contains the calculations that reveal a reduction in gasoline consumption of approximately 1200 gallons per year with the installation of the new signal system. This is based on the figures of 0.58 gallons consumed per vehicle-hour of idling and 0.01 gallons consumed per vehicle-stop. Both of these figures are presented by Claffey (8).

Appendix K is the calculation of the reduction in air polution that might be expected from the more efficient vehicle operation associates with the new signal system. It reveals an approximate reduction in hydrocarbons (HC) emitted of 6.4 pounds per year and a reduction in carbon monoxide (CO) of approximately 1588 pounds per year. These figures were calculated in the manner recommended by Curry and Anderson (20, p. 38).

CHAPTER V

RESULTS

In consideration of the four basic Research Questions that were posed in Chapter II it is appropriate that an examination of the results of the analysis of Chapter IV be made.

Research Question 1

It is observed by examining the results of the t-test in Appendix C some of the streets during some of the time periods realized a significant reduction in the number of stops while others did not and in fact realized an apparent increase in the number of stops. The increase in the number of stops on some streets during some time periods is not surprising and in fact may be necessary to some extent in order to improve the operation of the streets and/or directions carrying the higher volumes. The timing patterns which were placed in the computer (those in the after period) were totally new patterns that were obtained using computer programs that optimize traffic signal timing patterns. When installing a new signal timing pattern in an area that previously had a progressive system it is expected that certain directions and/or streets would have an increase in the number of stops per travel time run in order that there could be a reduction in the number of stops on those streets and/or directions with higher volumes. This, of course, would result in a reduction in the total number of stops on the system.

The answer to Research Question 1 lies in the analysis of the total number of stops in the entire system considering all time periods and directions. This analysis reveals a reduction in the number of stops in the after period that is significant at the 0.001 level. The implication of this analysis is that it can be stated that the number of stops in the after period (under computer control) is less than in the before period with a one in one thousand chance of committing a type I error (12, p. 126). As shown in Figure 4, the calculated t-value of 5.47 is well into the rejection region which leads to rejection of the null hypothesis. In the interest of statistical accuracy it should be stated that the $t_{.001}$ value of 3.373 would actually give a 0.0005 significance level since the analysis is a one-tailed test and the 0.001 portion of the area under the curve is the area under both tails of the curve.

Therefore, the response to research question number one is that the number of stops required by drivers has been reduced with the installation of the computer controlled traffic signal system.

Research Question 2

As in the analysis of Research Question 1 the most powerful test for this question is the t-test. As in the analysis for the number of stops a t-test could be performed on the individual streets however there is such a wide range of values the results would be of very little meaning. A t-test analysis on vehicle-seconds of

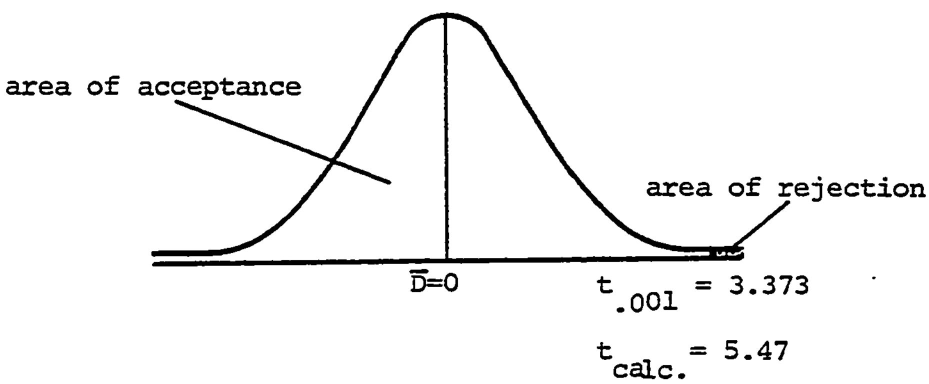


Fig. 4 - t-test of reduction of stops in the entire system

delay for the entire system is meaningful and was performed (Appendix G). Examining the null hypothesis that the delay in the after period is equal to the delay in the before period ($D_A = D_B$) against the alternate hypothesis that the delay in the after period is less than the delay in the before period ($D_A < D_B$) the t value is computed to be 2.87. This infers that the delay in the after period is significantly less than the delay in the before period at the 0.01 significance level (Figure 5).

Research Question 3

As was pointed out in Chapter IV there was a significant reduction in the number of accidents in the after period (1976-1978) when compared to the before period (1972-1974). It was also pointed out that there were other factors present which could have at least partially accounted for the reduction in accidents (e.g. selective traffic enforcement program). That the percentage of accidents on the system compared to the total number of accidents in the city decreased from 18.4 percent before to 16.6 percent after supports the conclusion that there was in fact an accident reduction due to the installation of the computerized traffic signal system and associated local intersection hardware.

The reduction in accidents could be the result of several factors. First, better progression on a street should result in fewer rear-end collisions. This is due to the fact that if the number of stops is reduced the likelihood of a rear-end collision is also reduced. Second, the timing with the new system is more precise. This is of particular

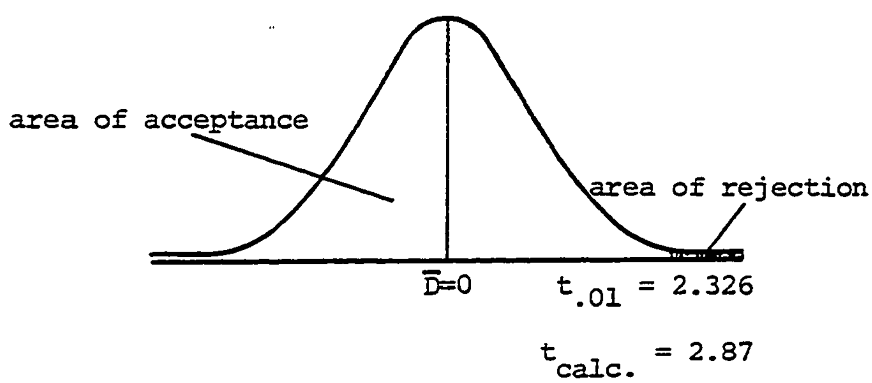


Fig. 5 - t-test analysis on H_o: $D_A = D_B$ with H_A: $D_A < D_B$

importance with the clearance intervals which is too short could lead to right angle and rear-end collisions. The possibility of short clearance intervals particularly with the Trafflex system was discussed in Chapter I.

A third, and a very important possibility for the reduction of accidents with the new system, is the installation of new mast arms and signal heads where they were necessary. This is particularly important where the old heads might have been difficult for the motorists to see. Certainly a motorist must be able to see a traffic control device before being expected to observe it. Most of the signal poles and heads in the downtown area (Sections 1 and 2) were replaced with more visible mast arm supported signal heads. That this portion of the system realized the largest decrease in accidents supports this as being the primary reason for the reduction in accidents.

Research Question 4

As shown in Chapter III, the benefit-cost ratio for the project was computed to be 1.9 based on a ten year life of the system. Using the following useful life for the various components of the system the benefit-cost ratio was calculated to be 2.7.

Item	Useful Life
Conduit and Cable	30 years
Poles, Heads, Controllers	20 years
Computer & Peripheral Equipment	10 years

Using a rate of return analysis and a 10 year system life the investment in the digital computerized traffic signal system yielded a 27.4 per cent return in the form of reduced motorists' operating costs.

It is interesting to compare the analysis using cost data from Winfrey (4) which is a 1969 reference with that using cost data from AASHTO (17) which was published in 1978. Table 10 summarizes this comparison. Comparison of Winfrey and AASHTO cost figures derived from computing for an average of trip purpose (1.56 $\frac{\text{Adults}}{\text{Vehicle}}$) and a time savings of 0-5 minutes on an average trip purposes ($0.21 per traveler hour).

Summary of Results

Table 11 is a summary of each of the four research questions posed in this study. It can be observed that stops, delay, and accidents were significantly reduced. The system resulted in a benefit-cost ratio of 2.7 and yielded a 27.4 per cent rate of return.

The operating costs are higher in the 1978 AASHTO (17) publication than the 1969 Winfrey book (4) for passenger cars as would be expected with increases in fuel, oil, maintenance and capital cost of vehicles. In the total cost analysis however this increase is offset by the much lower excess passenger travel time value recommended by AASHTO. Although Winfrey does not specify an exact value for passenger car travel time he does give a range of $1.00 to $4.00 per car-hour (4, p. 269). The AASHTO publication has values more similar to this for higher time savings. For example, if a higher time savings (over 15 minutes) is to be realized on an average of trip purposes, the AASHTO value would be

TABLE 10

COMPARISON OF MOTORISTS OPERATING COSTS

	Winfrey	AASHTO
Cost per 1000 Stops - 4 kip Passenger Car	6.96	11.25
Cost per 1000 Stops - 12 kip Truck	17.65	26.50
Cost per 1000 Stops - 50 kip (Winfrey) & 54 kip (AASHTO) Truck	74.75	91.04
Excess Idling Cost-Dollars/1000 Hours - 4 kip	114.86	312.64
Excess Idling Cost-Dollars/1000 Hours - 12 kip	200.03	277.44
Excess Idling Cost-Dollars/1000 Hours - 50 kip (54 kip)	196.28	193.07
Excess Travel Time Cost-Dollars/Veh-Hr.	$1.00-$4.00	$0.33

TABLE 11

IMPACT OF AMARILLO COMPUTERIZED SIGNAL SYSTEM

Factor	Change	Significance
Stops	-23%	Yes
Delay	-39%	Yes
Accidents	- 6%	Yes
Annual User costs	-$629,434	N.A.

($3.90 per Traveler-Hour)$(1.56 \frac{\text{Adult}}{\text{Vehicle}})$ = $6.08 per vehicle-hour. (17, p. 17). Even with these differences the final result of the two methods is very similar and yields a similar payoff of the capital investment.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This study evaluated the impact on traffic operations of a computerized traffic signal system in Amarillo, Texas (population 150,000). The system consists of 133 intersections in seven sections controlled by a digital computer. On the basis of data collected and evaluated over an extended period of time the following conclusions were drawn:

1. There was an improvement in the traffic operation of the streets that were controlled by the computerized traffic signal system. The total number of stops which were made by all motorists driving on the streets placed under computer control was reduced by 23 percent. The number of vehicle-seconds of delay while stopped at the traffic signal was reduced by 39 percent. There was also a 6 percent reduction in the number of accidents in the three year period after installation of the computerized system as compared to the three year before period.
2. The improvement in stops and delay results in a reduction in annual motorists operating cost of approximately $629,434.

3. The reduction in motorists' operating costs whem compared to the equivalent uniform annual cost of the system resulted in a benefit-cost ratio of 2.7 and a rate of return of 27.4 percent.

4. The capital cost of the computerized traffic signal system was larger than for other traffic signal control strategies.

5. The maintenance of the computer and peripheral equipment is very complicated and cannot normally be handled by the cities' maintenance staff. This normally means a contract with a computer maintenance firm at a cost of $20,000 to $40,000 per year.

6. The successful utilization of such a system normally requires one full-time operator.

7. The tremendous capabilities provided by a digital computerized traffic signal system must be largely utilized in order to justify the system. This means constantly improving the traffic flow by trying new patterns and using the information the computer obtains from detectors (e.g., stops and delay) to control a new pattern to an old one.

8. The improvements from the installation of the system can result only when the city understands and accepts the responsibility of providing funds for initial cost, maintenance and operating cost as a total package. If this is not realized, the installation will be of minimal benefit in which case other types of control systems such as fixed time multi-dial systems operated in a time of day mode or

arterial street systems with background coordination units should be explored. It should be pointed out, though, that the costs savings to the motorists are based on vehicle operating costs which are approximately ten years out of date. This leads to a conservative estimate of the benefit-cost ratio. With the rapid increase in gasoline and other vehicle expenses as well as the relative decline in computer equipment, systems which might not have resulted in a favorable benefit-cost ratio a few years ago might now be more cost effective. Consequently, such systems are becoming more feasible for the smaller cities than they have been in the past.

9. The companies that provide these systems should strive to make them simpler for the operator to input data and make changes to encourage a fuller utilization of the capabilities.

The above conclusions lead to the formulation of recommendations for further study which should consider the cost and effectiveness of other types of systems. For example, systems with other methods of communication (multiplexing, leased telephone lines, laser beam transmission, etc), which have a significantly lower initial cost, could be evaluated. Similarly, it would be worthwhile to evaluate computer systems with the processors at remote field locations controlling the intersections and transmitting the surveilliance data back to the central processor.

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APPENDIX A

TRAVEL TIME DATA

TABLE A.1

NUMBER OF STOPS IN SIX RUNS

	AM Peak		Noon Peak		PM Peak		Off-Peak	
	Before	After	Before	After	Before	After	Before	After
Adams								
NB	7	1	9	5	10	19	I.D.*	I.D.
SB	6	0	9	13	9	8	10	12
Amar. Blvd.								
EB	5	0	2	0	5	12	0	0
WB	2	0	1	1	2	1	0	0
Buchanan								
NB	13	5	7	6	12	2	7	4
Fillmore								
NB	7	5	14	1	9	4	7	7
Pierce								
SB	6	6	13	5	19	7	8	9
Taylor								
SB	13	3	14	1	16	64	13	10
Polk								
NB	17	11	19	32	24	15	22	25
SB	25	22	26	22	29	21	25	25
Tyler								
NB	16	12	12	11	12	9	21	7
Harrison								
SB	18	10	14	11	17	7	21	1
Van Buren								
NB	17	1	17	2	15	18	27	23
Jackson								
SB	10	26	10	18	2	12	17	13

TABLE A.1 (Continued)

	AM Peak		Noon Peak		PM Peak		Off-Peak	
	Before	After	Before	After	Before	After	Before	After
3rd								
EB	10	16	22	13	22	20	19	15
WB	18	17	12	14	20	14	18	15
6th								
EB	30	28	33	30	25	30	34	33
WB	16	19	18	0	18	27	17	11
7th								
EB	21	16	25	9	32	17	25	7
8th								
WB	23	15	20	7	21	11	25	11
9th								
EB	28	23	27	18	26	22	24	5
10th								
EB	35	35	36	29	24	20	34	43
WB	34	25	20	6	26	24	19	5
11th								
EB	18	23	7	15	13	26	13	19
Washington								
NB	4	5	6	2	11	11	1	0
SB	0	3	2	0	1	0	1	0
Georgia								
NB	15	0	20	13	17	14	15	0
SB	9	2	14	1	14	5	10	5
Western								
NB	5	0	I.D.	I.D.	2	4	4	6
SB	4	0	I.D.	I.D.	5	5	2	1

* Insufficient Data

TABLE A.2

NUMBER OF SECONDS OF DELAY IN 6 RUNS

	AM Peak		Noon Peak		PM Peak		Off-Peak	
	Before	After	Before	After	Before	After	Before	After
Adams								
NB	29	21	87	80	217	375	I.D.*	I.D.
SB	63	0	87	250	153	111	128	219
Amar. Blvd.								
EB	14	0	5	0	74	87	0	0
WB	3	0	3	2	7	2	0	0
Buchanan								
NB	263	143	145	139	252	8	116	141
Fillmore								
NB	181	96	210	34	154	21	222	122
Pierce								
SB	114	52	221	57	327	36	69	137
Taylor								
SB	198	87	260	28	484	187	134	99
Polk								
NB	229	151	297	509	322	355	473	240
SB	358	406	500	281	443	426	341	340
Tyler								
NB	43	147	75	220	50	109	64	107
Harrison								
SB	158	37	120	242	234	71	174	2
Van Buren								
NB	116	4	90	49	148	188	96	46
Jackson								
SB	143	448	106	87	10	183	65	25

TABLE A.2 (Continued)

	AM Peak		Noon Peak		PM Peak		Off-Peak	
	Before	After	Before	After	Before	After	Before	After
3rd								
EB	160	380	204	95	247	665	255	231
WB	269	533	155	77	284	424	283	138
6th								
EB	599	604	562	654	495	632	840	636
WB	346	325	357	0	401	577	445	284
7th								
EB	219	242	329	44	566	561	204	171
8th								
WB	519	419	388	82	441	226	473	97
9th								
EB	220	345	339	602	267	657	550	53
10th								
EB	743	639	716	475	611	463	1007	744
WB	541	534	284	61	705	601	360	110
11th								
EB	542	689	78	134	235	725	105	230
Washington								
NB	21	26	15	5	181	290	34	0
SB	0	26	50	0	9	0	19	0
Georgia								
NB	254	0	534	340	563	123	162	0
SB	176	9	284	71	508	36	193	32
Western								
NB	108	0	I.D.	I.D.	76	22	141	46
SB	44	0	I.D.	I.D.	110	39	36	6

* Insufficient Data

APPENDIX B

COMPUTATION OF STOPS PER DAY

TABLE B.1

COMPUTATION OF STOPS PER DAY IN BEFORE AND AFTER PERIODS

Street	Volume				Before								After							
					Stops/Vehicle				Stops/Day				Stops/Vehicle				Stops/Day			
	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak
Adams NB	1200	700	650	5900	1.167	1.500	1.667	-	1400	1050	1084	-	0.167	0.833	3.167	-	200	583	2059	-
Adams SB	200	500	950	3700	1.000	1.500	1.500	1.667	200	750	1425	6168	0	2.167	1.333	2.000	0	1084	1266	7400
Amar. Blvd. EB	650	750	1100	8100	0.833	0.333	0.833	0	541	250	916	0	0	0	2.000	0	0	0	2200	0
Amar. Blvd. WB	550	550	750	5900	0.333	0.167	0.333	0	183	92	250	0	0	0.167	0.167	0	0	92	125	0
Buchanan	1700	1100	1800	6400	2.167	1.167	2.000	1.167	3684	1284	3600	7469	0.833	1.000	0.333	0.667	1416	1100	600	4269
Fillmore	1050	950	950	9750	1.167	2.333	1.500	1.167	1225	2216	1425	11,378	0.833	0.167	0.667	1.167	875	159	634	11,378
Pierce	600	950	1600	8850	1.000	7.167	3.167	1.333	600	2059	5067	11,797	1.000	0.833	1.167	1.500	600	791	1867	13,327
Taylor	650	950	1600	8450	2.167	2.333	2.667	2.167	1409	2216	4267	18,311	0.500	0.167	2.333	1.667	325	109	3733	14,086
Polk NB	150	300	400	1150	2.833	3.167	4.000	3.667	425	950	1600	4217	1.833	5.333	2.500	4.167	275	1600	1000	4792
Polk SB	150	300	400	1150	4.167	4.333	4.833	4.167	625	1300	1933	4792	3.667	3.667	3.400	4.167	550	1100	1400	4792
Tyler	150	250	200	3100	2.667	2.000	2.000	3.500	400	500	400	10,050	2.000	1.833	1.500	1.167	300	458	300	3617
Harrison	300	500	1100	3000	3.000	2.333	2.833	3.500	900	1167	3116	10,500	1.667	1.833	1.167	0.167	500	917	1283	501
Van Buren	200	100	100	1000	2.833	2.833	2.500	4.500	567	283	250	4500	0.167	0.333	3.000	3.833	33	33	30	3833
Jackson	100	350	650	2600	1.667	1.667	0.333	2.833	167	583	216	7366	4.333	3.000	2.000	2.167	433	1050	1300	5634
3rd EB	350	400	450	2900	1.167	3.667	3.667	3.167	409	1467	1650	9184	2.667	2.167	3.333	2.500	933	867	1500	7250
3rd WB	350	400	500	3000	3.000	2.000	3.333	3.000	1050	800	1667	9000	2.833	2.333	2.333	2.500	992	933	1167	7500

TABLE B.1 (Continued)

	Before												After								
	Volume				Stops/Vehicle				Stops/Day				Stops/Vehicle				Stops/Day			
Street	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak
6th EB	200	150	300	1150	5.000	5.500	4.167	5.667	100	825	1250	6517	4.667	5.000	5.000	5.500	933	750	1500	6325
6th WB	300	600	500	4900	2.667	3.000	3.000	2.833	800	1800	1500	13,882	3.167	0	4.500	1.833	950	0	2250	8982
7th EB	400	500	650	3550	3.500	4.167	5.333	4.167	1400	2084	3466	14,793	2.667	1.500	2.833	1.167	1067	750	1841	4143
8th WB	750	450	650	3550	3.833	3.333	3.500	4.167	2875	1500	2275	14,793	2.500	1.167	1.833	1.833	1875	525	1191	6507
9th EB	150	150	200	1500	4.667	4.500	4.333	4.000	700	675	867	6000	3.833	3.000	3.667	0.833	575	450	733	1250
10th EB	200	250	350	2200	5.833	6.000	4.000	5.667	1167	1500	1400	12,467	5.833	4.833	3.333	7.167	1167	1208	1167	15,767
10th WB	550	750	1050	6050	5.667	3.333	4.333	3.167	3117	2500	4550	19,160	4.167	1.000	4.000	0.833	2292	750	4200	5040
11th EB	200	250	400	1900	3.000	1.167	2.167	2.167	600	292	867	4117	3.833	2.500	4.333	3.167	767	625	1733	6017
Washington NB	650	500	650	4900	0.667	1.000	1.833	0.167	434	500	1191	818	0.833	0.333	1.833	0	541	167	1191	0
Washington SB	1350	900	950	8450	0	0.333	0.167	0.167	0	300	159	1411	0.500	0	0	0	675	0	0	0
Georgia NB	550	700	1000	6600	2.500	3.333	2.833	2.500	1375	2333	2833	16,500	0	2.167	2.333	0	0	1517	2333	0
Georgia SB	250	800	1200	6700	1.500	2.333	2.333	1.667	375	1866	2800	7819	0.333	0.167	0.833	0.833	83	134	1000	5581
Western NB	550	600	750	5550	0.833	-	0.333	0.667	458	-	250	3669	0	-	0.667	1.000	0	-	500	5550
Western SB	550	750	1100	8150	0.667	-	0.833	0.333	367	-	916	2714	0	-	0.833	0.167	0	-	916	1361

TABLE B.2

COMPILATION OF STOPS PER DAY BY SECTION AND FOR TOTAL SYSTEM IN BEFORE AND AFTER PERIODS*

	Before				After			
	Stops/Day				Stops/Day			
Street	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak
Sections 1 & 2								
Buchanan	3684	1284	3600	7464	1416	1100	600	4269
Fillmore	1225	2216	1425	11,378	815	159	634	11,378
Pierce	600	2059	5061	11,741	600	741	1867	13,275
Taylor	1404	2216	4267	18,311	325	109	3733	14,086
Polk NB	425	950	1600	4217	275	1600	1000	4742
Polk SB	625	1300	1433	4792	550	1100	1400	4792
Tyler	400	500	400	10,850	300	458	300	3617
Harrison	900	1167	3116	10,500	500	917	1283	501
Van Buren	567	283	250	4500	33	33	30	3833
Jackson	167	583	216	7366	433	1050	1300	5634
3rd EB	408	1467	1650	9184	933	867	1500	7250
3rd WB	1050	800	1667	9000	992	933	1167	7500
6th EB	100	825	1250	6517	933	750	1500	6325
6th WB	800	1800	1500	13,882	950	0	2250	8982
7th EB	1400	2084	3466	14,793	1067	750	1841	4143
8th	2875	1500	2275	14,745	1875	525	1191	6507
9th	700	675	867	6000	575	450	733	1250
10th EB	1167	1500	1400	12,467	1167	1208	1167	15,767
10th WB	3117	2500	4550	19,168	2292	750	4200	5040
11th EB	600	292	867	4117	767	625	1733	6017
Σ Section 1 & 2	22,219	26,001	41,366	201,101	16,858	14,175	29,429	174,958

TABLE B.2 (Continued)

	Before				After			
	Stops/Day				Stops/Day			
Street	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak
Section 3								
Amar Blvd. EB	541	250	916	0	0	0	2200	0
Amar Blvd. WB	183	92	250	0	0	92	125	0
Σ Section 3	724	342	1166	0	0	92	2325	0
Section 4								
Adams NB	1400	1050	1084	-	200	583	2059	-
Adams SB	200	750	1425	6168	0	1084	1266	7400
Washington NB	434	500	1191	818	541	167	1191	0
Washington SB	0	300	159	1411	675	0	0	0
Σ Section 4	2034	2600	3859	8397	1416	1834	4516	7400
Section 5								
Georgia NB	1375	2333	2833	16,500	0	1517	2333	0
Georgia SB	375	1866	2800	7819	83	134	1000	5581
Σ Section 5	1150	4199	5633	24,319	83	1651	3333	5581
Section 7								
Western NB	458	-	250	3669	0	-	500	5550
Western SB	367	-	916	2714	0	-	916	1361
Σ Section 7	825	-	1166	6383	0	-	1416	6911

*TOTAL SYSTEM $\frac{\text{Stops}}{\text{Day}}$:

BEFORE - 354,084 AFTER - 271,978

$$\text{TOTAL SYSTEM REDUCTION IN STOPS} = \frac{354{,}084 - 271{,}978}{354{,}084} = 23.2\%$$

APPENDIX C

t-TEST ANALYSIS OF REDUCTION IN NUMBER OF STOPS BY INDIVIDUAL STREET AND DIRECTION

TABLE C.1

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND ADAMS STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	2	0	2	H_o: M_d=0 (One tailed test) $\bar{D} = 1$
	2	1	0	1	$S_d = \sqrt{0.4}$
	3	1	0	1	$S_{\bar{d}} = \sqrt{.0667} = .258$; $t = \frac{\bar{D}-0}{S_{\bar{d}}} = \frac{1}{.258} = 3.88$
	4	1	1	0	$v = 5$
	5	1	0	1	$t_{.05} = 2.015$
	6	1	0	1	∴ Reject H_o
Noon Peak	1	0	1	-1	SD = 4
	2	3	2	1	$\bar{D} = .667$
	3	1	0	1	$S_d = \sqrt{1.0667}$
	4	1	1	0	$S_{\bar{d}} = \frac{\sqrt{1.0667}}{\sqrt{6}} = \sqrt{.1778} = .4216$
	5	2	0	2	$t = \frac{.667-0}{.4216} = 1.58$; $t_{0.5} = 2.015$
	6	2	1	1	∴ Accept H_o
PM Peak	1	1	2	-1	
	2	1	3	-2	$\bar{D} = -1.5$
	3	2	5	-3	$S_{\bar{d}} = .4281$
	4	2	3	-1	$t = \frac{1.5}{.4281} = 3.50$
	5	1	3	-2	∴ Reject H_o
	6	3	3	0	
Off Peak					INCOMPLETE

TABLE C.2

tTEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND ADAMS STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	1	0	1	$\bar{D} = 1$
	2	1	0	1	$S_d = 0$
	3	1	0	1	$s_{\bar{d}} = 0$
	4	1	0	1	$t = \frac{1-0}{0} = \infty > t_{.05}$ (2.015)
	5	1	0	1	∴ Reject H_o
	6	1	0	1	
Noon Peak	1	3	2	1	$\bar{D} = -.6667$ Accept H_o
	2	1	2	-1	
	3	1	2	-1	
	4	1	2	-1	
	5	2	2	0	
	6	1	3	-2	
PM Peak	1	2	1	1	$\bar{D} = .16667$ Accept H_o
	2	0	1	-1	
	3	2	3	-1	
	4	0	1	-1	
	5	2	1	1	
	6	3	1	2	
Off Peak	1	2	2	0	$\bar{D} = -.3333$ Accept H_o
	2	3	2	1	
	3	2	2	0	
	4	1	2	-1	
	5	1	2	-1	
	6	1	2	-1	

TABLE C.3

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND 10th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak					INCOMPLETE
Noon Peak	1	4	4	0	$\bar{D} = 1.16$
	2	7	5	2	$S_{\bar{d}} = .477$
	3	7	4	3	$t = 2.44 > t_{.05}$ (2.015)
	4	7	6	1	∴ Reject H_o
	5	5	5	0	
	6	6	5	1	
PM Peak	1	6	3	3	$\bar{D} = .667$
	2	4	4	0	$S_{\bar{d}} = .494$
	3	3	3	0	$t = 1.348 < t_{.05}$ (2.015)
	4	4	4	0	∴ Accept H_o
	5	3	3	0	
	6	4	3	1	
Off Peak					INCOMPLETE

TABLE C.4

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR WESTBOUND 10th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	5	6	-1	$\bar{D} = 1.5$
	2	6	6	0	$S_{\bar{d}} = .846$
	3	5	4	1	t = 1.77 Accept H_o
	4	7	5	2	
	5	5	3	2	
	6	6	1	5	
PM Peak	1	4	1	3	$\bar{D} = 2.33$
	2	4	0	4	$S_{\bar{d}} = .714$
	3	2	3	-1	t = 3.26 Reject H_o
	4	4	1	3	
	5	4	1	3	
	6	2	0	2	
Noon Peak	1	4	4	0	$\bar{D} = .333$
	2	4	3	1	$S_{\bar{d}} = .333$
	3	4	3	1	t = 1 Accept H_o
	4	5	6	-1	
	5	5	4	1	
	6	4	4	0	
Off Peak	1	4	1	3	$\bar{D} = 2.33$
	2	3	1	2	$S_{\bar{d}} = .714$
	3	4	0	4	$t = 3.26 > t_{.05}$ (2.015)
	4	4	1	3	Reject H_o
	5	5	2	3	
	6	0	1	-1	

TABLE C.5

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND 11th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	3	4	-1	$\bar{D} = -.333$	
	2	3	4	-1	$S_{\bar{d}} = .714$	
	3	3	4	-1	$t = -.466$	Accept H_o
	4	1	4	3		
	5	2	4	-2		
	6	3	3	0		
Noon Peak	1	1	3	-2	$\bar{D} = -1.33$	
	2	1	2	-1	$S_{\bar{d}} = .333$	
	3	1	3	-2	$t = -4$	Accept H_o
	4	1	3	-2		
	5	1	2	-1		
	6	2	2	0		
PM Peak	1	3	3	0	$\bar{D} = -2.16$	
	2	2	5	-3	$S_{\bar{d}} = .477$	
	3	1	4	-3	$t = -4.539$	Accept H_o
	4	1	4	-3		
	5	3	5	-2		
	6	3	5	-2		
Off Peak	1	1	2	-1	$\bar{D} = -.833$	
	2	1	4	-3	$S_{\bar{d}} = .792$	
	3	3	3	0	$t = -1.05$	Accept H_o
	4	3	1	2		
	5	4	4	0		
	6	1	4	-3		

TABLE C.6

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND AMA BOULEVARD

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	1	0	1	$\bar{D}$ = .8333
	2	1	0	1	$S_{\bar{d}}$ = .16667
	3	1	0	1	t = 5.00 > $t_{.05}$ (2.015)
	4	0	0	0	Reject H_o
	5	1	0	1	
	6	1	0	1	
Noon Peak	1	0	0	0	$\bar{D}$ = .3333
	2	0	0	0	$S_{\bar{d}}$ = .2108
	3	1	0	1	t = 1.58 Accept H_o
	4	0	0	0	
	5	0	0	0	
	6	1	0	1	
PM Peak	1	0	2	-2	$\bar{D}$ = -1.16667
	2	2	1	1	$S_{\bar{d}}$ = .543
	3	1	2	-1	t = -2.15 Accept H_o
	4	0	3	-3	
	5	1	2	-1	
	6	1	2	-1	
Off Peak	1	0	0	0	t = 0 Accept H_o
	2	0	0	0	
	3	0	0	0	
	4	0	0	0	
	5	0	0	0	
	6	0	0	0	

TABLE C.7

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR WESTBOUND AMA BOULEVARD

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	0	0	0	$\bar{D}$ = .3333
	2	0	0	0	$S_{\bar{d}}$ = .2108
	3	0	0	0	t = 1.58 Accept H_o
	4	1	0	1	
	5	1	0	1	
	6	0	0	0	
Noon Peak	1	0	0	0	$\bar{D}$ = 0
	2	0	0	0	$S_{\bar{d}}$ = .2582
	3	0	0	0	t = 0 Accept H_o
	4	1	0	1	
	5	0	1	-1	
	6	0	0	0	
PM Peak	1	0	0	0	$\bar{D}$ = .16667
	2	0	1	-1	$S_{\bar{d}}$ = .3073
	3	1	0	1	t = .542 Accept H_o
	4	1	0	1	
	5	0	0	0	
	6	0	0	0	
Off Peak	1	0	0	0	t = 0 Accept H_o
	2	0	0	0	
	3	0	0	0	
	4	0	0	0	
	5	0	0	0	
	6	0	0	0	

TABLE C.8

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND BUCHANAN STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	4	1	3	$\bar{D} = 1.333$	
	2	3	1	2	$S_{\bar{d}} = .494$	
	3	2	0	2	$t = 2.70$	Reject H_o
	4	1	1	0		
	5	2	1	1		
	6	1	1	0		
Noon Peak	1	2	1	1	$\bar{D} = .1667$	
	2	1	1	0	$S_{\bar{d}} = .3073$	
	3	0	1	-1	$t = .542$	Accept H_o
	4	2	1	1		
	5	1	1	0		
	6	1	1	0		
PM Peak	1	1	0	1	$\bar{D} = 1.6667$	
	2	2	0	2	$S_{\bar{d}} = .558$	
	3	1	0	1	$t - 2.99$	Reject H_o
	4	4	0	4		
	5	3	1	2		
	6	1	1	0		
Off Peak	1	1	0	1	$\bar{D} = 0.5$	
	2	1	0	1	$S_{\bar{d}} = 0.619$	
	3	1	2	-1	$t = 0.808$	Accept H_o
	4	3	0	3		
	5	0	1	-1		
	6	1	1	0		

TABLE C.9

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND FILLMORE STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	3	1	2	$\bar{D}$ = 0.3333
	2	1	0	1	$S_{\bar{d}}$ = 0.494
	3	1	2	-1	t = 0.674 Accept H_o
	4	0	1	-1	
	5	1	1	0	
	6	1	0	1	
Noon Peak	1	2	0	2	$\bar{D}$ = 2.1667
	2	2	0	2	$S_{\bar{d}}$ = 0.703
	3	3	0	3	t = 3.081 Reject H_o
	4	5	0	5	
	5	1	1	0	
	6	1	0	1	
PM Peak	1	0	1	-1	$\bar{D}$ = 0.8333
	2	4	0	4	$S_{\bar{d}}$ = .703
	3	1	0	1	t = 1.185 Accept H_o
	4	1	1	0	
	t	2	1	1	
	6	1	1	0	
Off Peak	1	1	2	-1	$\bar{D}$ = 0
	2	1	0	1	$S_{\bar{d}}$ = .365
	3	1	1	0	t = 0 Accept H_o
	4	1	2	-1	
	5	1	0	1	
	6	2	2	0	

TABLE C.10

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND PIERCE STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	3	0	3	$\bar{D} = 0$
	2	0	1	-1	$S_{\bar{d}} = 0.730$
	3	0	2	-2	$t = 0$ Accept H_o
	4	1	0	1	
	5	1	1	0	
	6	1	2	-1	
Noon Peak	1	3	0	3	$\bar{D} = 1.3333$
	2	0	0	0	$S_{\bar{d}} = 0.558$
	3	1	0	1	$t = 2.390$ Reject H_o
	4	1	1	0	
	5	5	2	3	
	6	3	2	1	
PM Peak	1		1		
	2		1		
	3		1		PM Peak Data Incomplete
	4		1		
	5		2		
	6		1		
Off Peak	1	1	1	0	$\bar{D} = -0.16667$
	2	2	1	1	$S_{\bar{d}} = 0.477$
	3	1	2	-1	$t = -0.349$ Accept H_o
	4	0	2	-2	
	5	2	2	0	
	6	2	1	1	

TABLE C.11

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND TAYLOR STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	1	1	0	$\bar{D}$ = 1.66667
	2	2	0	2	$S_{\bar{d}}$ = .422
	3	2	0	2	t = 3.953 Reject H_o
	4	3	1	2	
	5	2	1	1	
	6	3	0	3	
Noon Peak	1	2	0	2	$\bar{D}$ = 2.16667
	2	2	0	2	$S_{\bar{d}}$ = 0.307
	3	2	0	2	t = 7.050 Reject H_o
	4	3	0	3	
	5	4	1	3	
	6	1	0	1	
PM Peak	1	3	2	1	$\bar{D}$ = 0.3333
	2	3	2	1	$S_{\bar{d}}$ = 0.333
	3	2	2	0	t = 1.00 Accept H_o
	4	4	4	0	
	5	2	3	-1	
	6	2	1	1	
Off Peak	1	0	1	-1	$\bar{D}$ = 0.5
	2	4	1	3	$S_{\bar{d}}$ = 0.806
	3	0	1	-1	t = 0.620 Accept H_o
	4	1	1	0	
	5	6	3	3	
	6	2	3	-1	

TABLE C.12

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND POLK STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	3	3	0	$\bar{D} = 1$
	2	4	1	3	$S_{\bar{d}} = .683$
	3	1	1	0	$t = 1.464$ Accept H_o
	4	2	1	1	
	5	5	2	3	
	6	2	3	-1	
Noon Peak	1	4	5	-1	$\bar{D} = -2.17$
	2	2	6	-4	$S_{\bar{d}} = .477$
	3	4	5	-1	$t = -4.54$ Accept H_o
	4	3	5	-2	
	5	3	6	-3	
	6	3	5	-2	
PM Peak	1	5	3	2	$\bar{D} = 1.5$ (Sto 1)
	2	3	3	0	$S_{\bar{d}} = .5$
	3	6	3	3	$t = 3$ Reject H_o
	4	2	2	0	
	5	3	1	2	
	6	5	3	2	
Off Peak	1	5	3	2	$\bar{D} = .33$
	2	5	5	0	$S_{\bar{d}} = .421$
	3	5	4	1	$t = .790$ Accept H_o
	4	3	4	-1	
	5	4	4	0	
	6	5	5	0	

TABLE C.13

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND POLK STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	6	5	1	$\bar{D} = 0.5$
	2	4	5	-1	$S_{\bar{d}} = 0.671$
	3	3	5	-2	$t = 0.745$ Accept H_o
	4	4	3	1	
	5	4	2	2	
	6	4	2	2	
Noon Peak	1	3	5	-2	$\bar{D} = 0.66667$
	2	3	3	0	$S_{\bar{d}} = 0.615$
	3	6	5	1	$t = 1.085$ Accept H_o
	4	6	4	2	
	5	5	3	2	
	6	3	2	1	
PM Peak	1	4	4	0	$\bar{D} = 1.5$
	2	6	4	2	$S_{\bar{d}} = 0.563$
	3	6	3	3	$t = 2.666$ Reject H_o
	4	3	3	0	
	5	5	4	1	
	6	6	3	3	
Off Peak	1	6	6	0	$\bar{D} = 0$
	2	4	7	-3	$S_{\bar{d}} = 0.856$
	3	6	5	1	$t = 0$ Accept H_o
	4	5	3	2	
	5	1	3	-2	
	6	3	1	2	

TABLE C.14

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND TYLER STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	3	2	1	$\bar{D}$ = .667
	2	3	3	0	$S_{\bar{d}}$ = .615
	3	4	2	2	t = 1.08 Accept H_o
	4	3	2	1	
	5	3	1	2	
	6	0	2	-2	
Noon Peak	1	2	2	0	$\bar{D}$ = .167
	2	3	3	0	$S_{\bar{d}}$ = .307
	3	2	1	1	t = .542 Accept H_o
	4	2	2	0	
	5	1	2	-1	
	6	2	1	1	
PM Peak	1		1		
	2		1		
	3		2		PM Peak Data Incomplete
	4		2		
	5		1		
	6		2		
Off Peak	1	4	0	4	$\bar{D}$ = 2.33
	2	4	1	3	$S_{\bar{d}}$ = .494
	3	2	1	1	t = 4.72 Reject H_o
	4	5	2	3	
	5	3	1	2	
	6	3	2	1	

TABLE C.15

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND HARRISON STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	3	2	1	$\bar{D}$ = 1.33	
	2	2	2	0	$S_{\bar{d}}$ = .421	
	3	3	1	2	t = 3.16	Reject H_o
	4	3	2	1		
	5	3	2	1		
	6	4	1	3		
Noon Peak	1	3	2	1	$\bar{D}$ = .5	
	2	2	3	-1	$S_{\bar{d}}$ = .428	
	3	2	1	1	t = 1.17	Accept H_o
	4	3	1	2		
	5	2	2	0		
	6	2	2	0		
PM Peak	1	3	0	3	$\bar{D}$ = 1.67	
	2	1	1	0	$S_{\bar{d}}$ = .083	
	3	3	4	-1	t = 2.08	Reject H_o
	4	2	1	1		
	5	4	1	3		
	6	4	0	4		
Off Peak	1	3	0	3	$\bar{D}$ = 3.33	
	2	4	0	4	$S_{\bar{d}}$ = .33	
	3	3	1	2	t = 1.0	Reject H_o
	4	3	0	3		
	5	4	0	4		
	6	4	0	4		

TABLE C.16

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND VAN BUREN STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	4	0	4	$\bar{D} = 2.67$
	2	2	1	1	$S_{\bar{d}} = .494$
	3	2	0	2	$t = 5.39$ Reject H_o
	4	3	0	3	
	5	2	0	2	
	6	4	0	4	
Noon Peak	1	4	0	4	$\bar{D} = 2.5$
	2	3	0	3	$S_{\bar{d}} = .619$
	3	2	0	2	$t = 4.04$ Reject H_o
	4	2	0	2	
	5	4	0	4	
	6	2	2	0	
PM Peak	1	2	4	−2	$\bar{D} = -0.5$
	2	3	3	0	$S_{\bar{d}} = .619$
	3	2	3	−1	$t = -0.808$ Accept H_o
	4	3	3	0	
	5	1	3	−2	
	6	4	2	2	
Off Peak	1	3	4	−1	$\bar{D} = 0$
	2	5	4	1	$S_{\bar{d}} = .258$
	3	3	3	0	$t = 0$ Accept H_o
	4	4	4	0	
	5	4	4	0	
	6	4	4	0	

TABLE C.17

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND JACKSON STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	2	5	-3	$\bar{D} = -2.67$
	2	2	3	-1	$S_{\bar{d}} = .557$
	3	2	5	-3	$t = -4.78$ Accept H_o
	4	1	5	-4	
	5	2	3	-1	
	6	1	5	-4	
Noon Peak	1	3	3	0	$\bar{D} = -1.33$
	2	3	3	0	$S_{\bar{d}} = .421$
	3	1	3	-2	$t = -3.16$ Accept H_o
	4	1	3	-2	
	5	1	3	-2	
	6	1	3	-2	
PM Peak	1	0	1	-1	$\bar{D} = -1.67$
	2	0	2	-2	$S_{\bar{d}} = .210$
	3	1	2	-1	$t = -7.91$ Accept H_o
	4	1	3	-2	
	5	0	2	-2	
	6	0	2	-2	
Off Peak	1	1	2	-1	$\bar{D} = .333$
	2	2	2	0	$S_{\bar{d}} = .333$
	3	3	2	1	$t = 1$ Accept H_o
	4	2	2	0	
	5	3	2	1	
	6	4	3	1	

TABLE C.18

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND WASHINGTON STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	1	1	0	$\bar{D} = -.167$
	2	0	1	-1	$S_{\bar{d}} = .307$
	3	0	1	-1	$t = -.542$ Accept H_o
	4	1	1	0	
	5	1	0	1	
	5	1	1	0	
Noon Peak	1	1	0	1	$\bar{D} = .667$
	2	1	0	1	$S_{\bar{d}} = .210$
	3	1	1	0	$t = 3.16$ Reject H_o
	4	1	1	0	
	5	1	0	1	
	6	1	0	1	
PM Peak	1	1	1	0	$\bar{D} = 0$
	2	0	2	-2	$S_{\bar{d}} = .516$
	3	3	2	1	$t = 0$ Accept H_o
	4	1	2	-1	
	5	3	2	1	
	6	3	2	1	
Off Peak	1	0	0	0	$\bar{D} = .167$
	2	0	0	0	$S_{\bar{d}} = .167$
	3	1	0	1	$t = 1$ Accept H_o
	4	0	0	0	
	5	0	0	0	
	6	0	0	0	

TABLE C.19

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND WASHINGTON STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	0	0	0	$\bar{D} = -.5$
	2	0	0	0	$S_{\bar{d}} = .223$
	3	0	1	-1	$t = -2.23$ Accept H_o
	4	0	0	0	
	5	0	1	-1	
	6	0	1	-1	
Noon Peak	1	1	0	1	$\bar{D} = .333$
	2	0	0	0	$S_{\bar{d}} = .210$
	3	0	0	0	$t = 1.58$ Accept H_o
	4	0	0	0	
	5	0	0	0	
	6	1	0	1	
PM Peak	1	0	0	0	$\bar{D} = .167$
	2	0	0	0	$S_{\bar{d}} = .167$
	3	1	0	1	$t = 1$ Accept H_o
	4	0	0	0	
	5	0	0	0	
	6	0	0	0	
Off Peak	1	0	0	0	$\bar{D} = .167$
	2	0	0	0	$S_{\bar{d}} = .167$
	3	1	0	1	$t = 1$ Accept H_o
	4	0	0	0	
	5	0	0	0	
	6	0	0	0	

TABLE C.20

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND GEORGIA STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	3	0	3	$\bar{D} = 2.5$	
	2	3	0	3	$S_{\bar{d}} = .341$	
	3	1	0	1	$t = 7.32$	Accept H_o
	4	2	0	2		
	5	3	0	3		
	6	3	0	3		
Noon Peak	1	4	2	2	$\bar{D} = 1.16$	
	2	2	3	-1	$S_{\bar{d}} = .477$	
	3	2	1	1	$t = 2.44$	Reject H_o
	4	4	2	2		
	5	4	2	2		
	6	4	3	1		
PM Peak	1	4	0	4	$\bar{D} = .5$	
	2	2	3	-1	$S_{\bar{d}} = .718$	
	3	3	3	0	$t = .695$	Accept H_o
	4	3	3	0		
	5	3	3	0		
	6	2	2	0		
Off Peak	1	2	0	2	$\bar{D} = 2.5$	
	2	4	0	4	$S_{\bar{d}} = .341$	
	3	3	0	3	$t = 7.32$	Reject H_o
	4	2	0	2		
	5	2	0	2		
	6	2	0	2		

TABLE C.21

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND GEORGIA STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	2	0	2	$\bar{D}$ = 1.16	
	2	2	0	2	$S_{\bar{d}}$ = .307	
	3	2	1	1	t = 3.79	Reject H_o
	4	1	0	1		
	5	1	1	0		
	6	1	0	1		
Noon Peak	1	2	0	2	$\bar{D}$ = 2.16	
	2	3	1	2	$S_{\bar{d}}$ = .307	
	3	3	0	3	t = 7.05	Reject H_o
	4	2	0	2		
	5	3	0	3		
	6	1	0	1		
PM Peak	1	2	0	2	$\bar{D}$ = 1.5	
	2	2	1	1	$S_{\bar{d}}$ = .428	
	3	3	1	2	t = 3.50	Reject H_o
	4	3	0	3		
	5	2	2	0		
	6	2	1	1		
Off Peak	1	1	1	0	$\bar{D}$ = .833	
	2	1	0	1	$S_{\bar{d}}$ = .167	
	3	2	1	1	t = 5	Reject H_o
	4	2	1	1		
	5	2	1	1		
	6	2	1	1		

TABLE C.22

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR NORTHBOUND WESTERN STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	1	0	1	$\bar{D}$ = .833
	2	0	0	0	$S_{\bar{d}}$ = .167
	3	1	0	1	t = 5 Reject H_o
	4	1	0	1	
	5	1	0	1	
	6	1	0	1	
Noon Peak	1				
	2				
	3				Noon Peak Data Incomplete
	4				
	5				
	6				
PM Peak	1	0	0	0	$\bar{D}$ = -.333
	2	0	0	0	$S_{\bar{d}}$ = .210
	3	1	1	0	t = -1.58 Accept H_o
	4	0	1	-1	
	5	1	1	0	
	6	0	1	-1	
Off Peak	1	0	1	-1	$\bar{D}$ = -.333
	2	1	1	0	$S_{\bar{d}}$ = .210
	3	1	1	0	t = -1.58 Accept H_o
	4	1	1	0	
	5	0	1	-1	
	6	1	1	0	

TABLE C.23

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR SOUTHBOUND WESTERN STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	0	0	0	$\bar{D}$ = .667
	2	1	0	1	$S_{\bar{d}}$ = .210
	3	1	0	1	t = 3.16 Reject H_o
	4	1	0	1	
	5	0	0	0	
	6	1	0	1	
Noon Peak	1				
	2				
	3				Noon Peak Data Incomplete
	4				
	5				
	6				
PM Peak	1	2	1	1	$\bar{D}$ = 0
	2	0	1	-1	$S_{\bar{d}}$ = .516
	3	2	0	2	t = 0 Accept H_o
	4	0	1	-1	
	5	1	1	0	
	6	0	1	-1	
Off Peak	1	0	0	0	$\bar{D}$ = .167
	2	1	0	1	$S_{\bar{d}}$ = .307
	3	0	0	0	t = .542 Accept H_o
	4	0	1	-1	
	5	1	0	1	
	6	0	0	0	

TABLE C.24

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND 3rd STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	2	4	-2	$\bar{D} = -1$
	2	2	3	-1	$S_{\bar{d}} = .258$
	3	2	3	-1	$t = -3.87$ Accept H_o
	4	2	3	-1	
	5	1	2	-1	
	6	1	1	0	
Noon Peak	1	2	2	0	$\bar{D} = 1.5$
	2	4	3	1	$S_{\bar{d}} = .428$
	3	4	2	2	$t = 3.50$ Reject H_o
	4	3	2	1	
	5	4	2	2	
	6	5	2	3	
PM Peak	1	5	4	1	$\bar{D} = 0$
	2	4	3	-1	$S_{\bar{d}} = .365$
	3	3	4	-1	$t = 0$ Accept H_o
	4	3	3	0	
	5	4	3	1	
	6	3	3	0	
Off Peak	1	0	2	-2	$\bar{D} = -.667$
	2	2	2	0	$S_{\bar{d}} = .333$
	3	1	2	-1	$t = -2$ Accept H_o
	4	3	3	0	
	5	2	3	-1	
	6	3	3	0	

TABLE C.25

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR WESTBOUND 3rd STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	1	2	-1	$\bar{D}$ = .167	
	2	3	3	0	$S_{\bar{d}}$ = .307	
	3	4	3	1	t = .542	Accept H_o
	4	3	3	0		
	5	4	3	1		
	6	3	3	0		
Noon Peak	1	3	3	0	$\bar{D}$ = -.5	
	2	3	2	1	$S_{\bar{d}}$ = .428	
	3	1	2	-1	t = -1.167	Accept H_o
	4	1	2	-1		
	5	1	3	-2		
	6	3	2	0		
PM Peak	1	2	3	-1	$\bar{D}$ = 1	
	2	3	3	0	$S_{\bar{d}}$ = .632	
	3	5	2	3	t = 1.58	Accept H_o
	4	4	2	2		
	5	4	2	2		
	6	2	2	0		
Off Peak	1	5	4	1	$\bar{D}$ = 2.5	
	2	3	1	2	$S_{\bar{d}}$ = .428	
	3	4	1	3	t = 5.84	Reject H_o
	4	3	1	2		
	5	5	1	4		
	6	4	1	3		

TABLE C.26

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR WESTBOUND 6th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	3	2	1	$\bar{D} = -.5$	
	2	3	5	-2	$S_{\bar{d}} = .763$	
	3	3	3	0	$t = -0.654$	Accept H_o
	4	2	5	-3		
	5	2	3	-1		
	6	3	1	2		
Noon Peak	1	3	0	3	$\bar{D} = 3$	
	2	4	0	4	$S_{\bar{d}} = .258$	
	3	3	0	3	$t = 11.62$	Reject H_o
	4	2	0	2		
	5	3	0	3		
	6	3	0	3		
PM Peak	1	3	5	-2	$\bar{D} = -1.5$	
	2	4	4	0	$S_{\bar{d}} = .428$	
	3	4	5	-1	$t = -3.50$	Accept H_o
	4	2	4	-2		
	5	2	5	-3		
	6	3	4	-1		
Off Peak	1	5	2	3	$\bar{D} = 1.5$	
	2	3	3	0	$S_{\bar{d}} = .428$	
	3	3	1	2	$t = 3.50$	Reject H_o
	4	3	2	1		
	5	3	2	1		
	6	3	1	2		

TABLE C.27

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND 6th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS	
AM Peak	1	6	5	1	$\bar{D}$ = .333	
	2	4	4	0	$S_{\bar{d}}$ = .494	
	3	5	6	-1	t = .674	Accept H_o
	4	5	4	1		
	5	5	3	2		
	6	5	6	-1		
Noon Peak	1	5	5	-	$\bar{D}$ = .5	
	2	4	5	-1	$S_{\bar{d}}$ = .428	
	3	5	5	0	t = 1.16	Accept H_o
	4	7	5	2		
	5	6	5	1		
	6	6	5	1		
PM Peak	1	4	5	-1	$\bar{D}$ = -.833	
	2	4	5	-1	$S_{\bar{d}}$ = .307	
	3	4	5	-1	t = -2.71	Accept H_o
	4	5	5	0		
	5	4	6	-2		
	6	4	4	0		
Off Peak	1	5	5	0	$\bar{D}$ = .167	
	2	6	6	0	$S_{\bar{d}}$ = .167	
	3	5	5	0	t = 1	Accept H_o
	4	6	6	0		
	5	6	6	0		
	6	6	5	1		

TABLE C.28

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND 7th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	4	3	1	$\bar{D}$ = .833
	2	5	4	1	$S_{\bar{d}}$ = .542
	3	5	2	3	t = 1.535 Accept H_o
	4	4	3	1	
	5	2	3	-1	
	6	1	1	0	
Noon Peak	1	6	1	5	$\bar{D}$ = 2.67
	2	3	2	1	$S_{\bar{d}}$ = .614
	3	4	2	2	t = 4.34 Reject H_o
	4	4	0	4	
	5	4	2	2	
	6	4	2	2	
PM Peak	1	4	2	2	$\bar{D}$ = 2.5
	2	5	3	2	$S_{\bar{d}}$ = .5
	3	5	3	2	t = 5 Reject H_o
	4	6	4	2	
	5	6	1	5	
	6	6	4	2	
Off Peak	1	4	1	3	$\bar{D}$ = 3
	2	3	1	2	$S_{\bar{d}}$ = .577
	3	3	2	1	t = 5.19 Reject H_o
	4	4	1	3	
	5	6	1	5	
	6	5	1	4	

TABLE C.29

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR WESTBOUND 8th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	5	3	2	$\bar{D}$ = 1.33
	2	5	2	3	$S_{\bar{d}}$ = .667
	3	4	3	1	t = 2 Accept H_o
	4	4	1	3	
	5	2	2	0	
	6	3	4	-1	
Noon Peak	1	1	1	0	$\bar{D}$ = 2.17
	2	5	1	4	$S_{\bar{d}}$ = .600
	3	3	2	1	t = 3.61 Reject H_o
	4	4	1	3	
	5	4	1	3	
	6	3	1	2	
PM Peak	1	2	1	1	$\bar{D}$ = 1.67
	2	4	2	2	$S_{\bar{d}}$ = .421
	3	4	1	3	t = 3.95 Reject H_o
	4	4	4	0	
	5	3	1	2	
	6	4	2	2	
Off Peak	1	6	1	5	$\bar{D}$ = 3.33
	2	5	4	1	$S_{\bar{d}}$ = .614
	3	5	2	3	t = 5.42 Reject H_o
	4	6	1	5	
	5	4	1	3	
	6	5	2	3	

TABLE C.30

t-TEST ANALYSIS OF REDUCTION IN STOPS FOR EASTBOUND 9th STREET

TIME PERIOD	RUN #	STOPS BEFORE (B)	STOPS AFTER (A)	DIFF B-A (D)	REMARKS AND CALCULATIONS
AM Peak	1	4	5	-1	$\bar{D}$ = .833
	2	6	4	2	$S_{\bar{d}}$ = .872
	3	4	5	-1	t = .955 Accept H_o
	4	4	2	2	
	5	4	5	-1	
	6	6	2	4	
Noon Peak	1	4	3	1	$\bar{D}$ = 1.5
	2	5	3	2	$S_{\bar{d}}$ = .428
	3	6	3	3	t = 3.50 Reject H_o
	4	4	3	1	
	5	5	3	2	
	6	3	3	0	
PM Peak	1	4	2	2	$\bar{D}$ = 0
	2	3	4	-1	$S_{\bar{d}}$ = .683
	3	4	5	-1	t = 0 Accept H_o
	4	7	5	-2	
	5	4	2	2	
	6	4	4	0	
Off Peak	1	4	2	2	$\bar{D}$ = 3.67
	2	6	2	4	$S_{\bar{d}}$ = .421
	3	4	1	3	t = 8.69 Reject H_o
	4	5	0	5	
	5	4	0	4	
	6	4	0	4	

APPENDIX D

t-TEST EVALUATION OF NUMBER OF STOPS
IN ENTIRE SYSTEM

TABLE D.1

t-TEST EVALUATION OF NUMBER OF STOPS IN ENTIRE SYSTEM*

Street	H_o: $S_A = S_B$ Direction	H_A: $S_A < S_B$ Period	Stops Before (B)	Stops After (A)	Diff. B − A (D)
Adams	NB	AM Peak	7	1	6
		Noon Peak	9	5	4
		PM Peak	10	19	-9
	SB	AM Peak	6	0	6
		Noon Peak	9	13	-4
		PM Peak	9	8	1
		Off Peak	10	12	-2
Amar. Blvd.	EB	AM Peak	5	0	5
		Noon Peak	2	0	2
		PM Peak	5	12	-7
		Off Peak	0	0	0
	WB	AM Peak	2	0	2
		Noon Peak	1	1	0
		PM Peak	2	1	1
		Off Peak	0	0	0
Buchanan	NB	AM Peak	13	5	8
		Noon Peak	7	6	1
		PM Peak	12	2	10
		Off Peak	7	4	3
Filmore	NB	AM Peak	7	5	2
		Noon Peak	14	1	13
		PM Peak	9	4	5
		Off Peak	7	7	0
Pierce	SB	AM Peak	6	6	0
		Noon Peak	13	5	8
		PM Peak	19	7	12
		Off Peak	8	9	-1
Taylor	SB	AM Peak	13	3	10
		Noon Peak	14	1	13
		PM Peak	16	14	2
		Off Peak	13	10	3
Polk	NB	AM Peak	17	11	6
		Noon Peak	19	32	-13
		PM Peak	24	15	9
		Off Peak	22	25	-3

TABLE D.1 (Continued)

Street	H_o: $S_A = S_B$ Direction	H_A: $S_A < S_B$ Period	Stops Before (B)	Stops After (A)	Diff. B - A (D)
Polk	SB	AM Peak	25	22	3
		Noon Peak	26	22	4
		PM Peak	29	21	8
		Off Peak	25	25	0
Tyler	NB	AM Peak	16	12	4
		Noon Peak	12	11	1
		PM Peak	12	9	3
		Off Peak	21	7	14
Harrison	SB	AM Peak	18	10	8
		Noon Peak	14	11	3
		PM Peak	17	7	10
		Off Peak	21	1	20
Van Buren	NB	AM Peak	17	1	16
		Noon Peak	17	2	15
		PM Peak	15	18	-3
		Off Peak	27	23	4
Jackson	SB	AM Peak	10	26	-16
		Noon Peak	10	18	-8
		PM Peak	2	12	-10
		Off Peak	17	13	4
Washington	NB	AM Peak	4	5	-1
		Noon Peak	6	2	4
		PM Peak	11	11	0
		Off Peak	1	0	1
	SB	AM Peak	0	3	-3
		Noon Peak	2	0	2
		PM Peak	1	0	1
		Off Peak	1	0	1
Georgia	NB	AM Peak	15	0	15
		Noon Peak	20	13	7
		PM Peak	17	14	3
		Off Peak	15	0	15
	SB	AM Peak	9	2	7
		Noon Peak	14	1	13
		PM Peak	14	5	9
		Off Peak	10	5	5

TABLE D.1 (Continued)

Street	H_O: $S_A = S_B$ Direction	H_A: $S_A < S_B$ Period	Stops Before (B)	Stops After (A)	Diff. B - A (D)
Western	NB	AM Peak	5	0	5
		PM Peak	2	4	-2
		Off Peak	4	6	-2
	SB	AM Peak	4	0	4
		PM Peak	5	5	0
		Off Peak	2	1	1
3rd	EB	AM Peak	10	16	-6
		Noon Peak	22	13	9
		PM Peak	22	20	2
		Off Peak	19	15	4
	WB	AM Peak	18	17	1
		Noon Peak	12	14	-2
		PM Peak	20	14	6
		Off Peak	18	15	3
6th	EB	AM Peak	30	28	2
		Noon Peak	33	30	3
		PM Peak	25	30	-5
		Off Peak	34	33	1
	WB	AM Peak	16	19	-3
		Noon Peak	18	0	18
		PM Peak	18	27	-9
		Off Peak	17	11	6
7th	EB	AM Peak	21	16	5
		Noon Peak	25	9	16
		PM Peak	32	17	15
		Off Peak	25	7	18
8th	WB	AM Peak	23	15	8
		Noon Peak	20	7	13
		PM Peak	21	11	10
		Off Peak	25	11	14
9th	EB	AM Peak	28	23	5
		Noon Peak	27	18	9
		PM Peak	26	22	4
		Off Peak	24	5	19
10th	EB	AM Peak	35	35	0
		Noon Peak	36	29	7
		PM Peak	24	20	4
		Off Peak	34	43	-9

TABLE D.1 (Continued)

Street	H_o: $S_A = S_B$ Direction	H_A: $S_A < S_B$ Period	Stops Before (B)	Stops After (A)	Diff. B - A (D)
10th	WB	AM Peak	34	25	9
		Noon Peak	20	6	14
		PM Peak	26	24	2
		Off Peak	19	5	14
11th	EB	AM Peak	18	23	-5
		Noon Peak	7	15	-8
		PM Peak	13	26	-13
		Off Peak	13	19	-6

*The data in this table were used in the calculation of the t-test.

For One-tail test: $t_{.05} = 1.66$ (d.f. = 115)

$t_{calc.} = 5.47 > 1.66$, ∴ Reject H_o, Accept H_A

APPENDIX E

CHI SQUARE EVALUATION OF NUMBER OF STOPS

TABLE E.1

CHI SQUARE EVALUATION OF NUMBER OF STOPS

STREET	DIRECTION	PERIOD	AFTER (OBSERVED)	BEFORE (EXPECTED)	x^2 $\frac{(A - B)^2}{B}$
Adams	NB	AM Peak	1	7	5.14
		Noon Peak	5	9	1.78
		PM Peak	19	10	8.1
	SB	AM Peak	0	6	6.0
		Noon Peak	13	9	1.78
		PM Peak	8	9	0.11
		Off Peak	12	10	0.4
Amar. Blvd.	EB	AM Peak	0	5	5.0
		Noon Peak	0	2	2.0
		PM Peak	12	5	9.8
		Off Peak	0	0	0
	WB	AM Peak	0	2	2.0
		Noon Peak	1	1	0
		PM Peak	1	2	0.5
		Off Peak	0	0	0
Buchanan	NB	AM Peak	5	13	4.92
		Noon Peak	6	7	0.14
		PM Peak	2	12	8.33
		Off Peak	4	7	1.29
Filmore	NB	AM Peak	5	7	0.57
		Noon Peak	1	14	12.07
		PM Peak	4	9	2.78
		Off Peak	7	7	0
Pierce	SB	AM Peak	6	6	0
		Noon Peak	5	13	4.92
		PM Peak	7	19	7.58
		Off Peak	9	8	0.13
Taylor	SB	AM Peak	3	13	7.69
		Noon Peak	1	14	12.07
		PM Peak	14	16	0.25
		Off Peak	10	13	0.69
Polk	NB	AM Peak	11	17	2.12
		Noon Peak	32	19	8.89
		PM Peak	15	24	3.38
		Off Peak	25	22	0.41

TABLE E.1 (Continued)

STREET	DIRECTION	PERIOD	AFTER (OBSERVED)	BEFORE (EXPECTED)	x^2 $\frac{(A-B)^2}{B}$
	SB	AM Peak	22	25	0.36
		Noon Peak	22	26	0.62
		PM Peak	21	29	2.21
		Off Peak	25	25	0.0
Tyler	NB	AM Peak	12	16	1.0
		Noon Peak	11	12	0.08
		PM Peak	9	12	0.75
		Off Peak	7	21	9.33
Harrison	SB	AM Peak	10	18	3.56
		Noon Peak	11	14	0.64
		PM Peak	7	17	5.88
		Off Peak	1	21	19.05
Van Buren	NB	AM Peak	1	17	15.06
		Noon Peak	2	17	13.24
		PM Peak	18	15	0.6
		Off Peak	23	27	0.59
Jackson	SB	AM Peak	26	10	25.6
		Noon Peak	18	10	6.4
		PM Peak	12	2	50.0
		Off Peak	13	17	0.94
Washington	NB	AM Peak	5	4	0.25
		Noon Peak	2	6	2.67
		PM Peak	11	11	0.0
		Off Peak	0	1	1.0
	SB	AM Peak	3	0	
		Noon Peak	0	2	2.0
		PM Peak	0	1	1.0
		Off Peak	0	1	1.0
Georgia	NB	AM Peak	0	15	15.0
		Noon Peak	13	20	2.45
		PM Peak	14	17	0.53
		Off Peak	0	15	15.0
	SB	AM Peak	2	9	5.44
		Noon Peak	1	14	12.07
		PM Peak	5	14	5.79
		Off Peak	5	10	2.50

TABLE E.1 (Continued)

STREET	DIRECTION	PERIOD	AFTER (OBSERVED)	BEFORE (EXPECTED)	X^2 $\frac{(A-B)^2}{B}$
Western	NB	AM Peak	0	5	5.0
		PM Peak	4	2	2.0
		Off PEak	6	4	1.0
	SB	AM Peak	0	4	4.0
		PM Peak	5	5	0.0
		Off Peak	1	2	0.5
3rd	EB	AM Peak	16	10	3.6
		Noon Peak	13	22	3.68
		PM Peak	20	22	0.18
		Off Peak	15	19	0.84
	WB	AM Peak	17	18	0.06
		Noon Peak	14	12	0.33
		PM Peak	14	20	1.80
		Off Peak	15	18	0.50
6th	EB	AM Peak	28	30	0.13
		Noon Peak	30	33	0.27
		PM Peak	30	25	1.0
		Off Peak	33	34	0.03
	WB	AM Peak	19	16	0.56
		Noon Peak	0	18	18.0
		PM Peak	27	18	4.5
		Off Peak	11	17	2.12
7th	EB	AM Peak	16	21	1.19
		Noon Peak	9	25	10.24
		PM Peak	17	32	7.03
		Off Peak	7	25	12.96
8th	WB	AM Peak	15	23	2.78
		Noon Peak	7	20	8.45
		PM Peak	11	21	4.76
		Off Peak	11	25	7.84
9th	EB	AM Peak	23	28	0.89
		Noon Peak	18	27	3.0
		PM Peak	22	26	0.62
		Off Peak	5	24	15.04
10th	EB	Noon Peak	29	36	1.36
		PM Peak	20	24	0.67
		Off Peak	43	34	2.38

TABLE E.1 (Continued)

STREET	DIRECTION	PERIOD	AFTER (OBSERVED)	BEFORE (EXPECTED)	x^2 $\frac{(A - B)^2}{B}$
10th	WB	AM Peak	25	34	2.38
		Noon Peak	6	20	9.8
		PM Peak	24	26	0.15
		Off Peak	5	19	10.32
11th	EB	AM Peak	23	18	1.39
		Noon Peak	15	7	9.14
		PM Peak	26	13	13.0
		Off Peak	19	13	2.77

$n = 116$ $\Sigma = 520.73$

APPENDIX F

COMPUTATION OF DELAY PER DAY

TABLE F.1

COMPUTATION OF DELAY PER DAY IN BEFORE AND AFTER PERIODS

STREET	VOLUME				BEFORE: DELAY/VEHICLE (SEC)				BEFORE: DELAY/DAY (VEH-HR)				AFTER: DELAY/VEHICLE (SEC)				AFTER: DELAY/DAY (VEH-HR)			
	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak
Adams NB	1200	700	650	5900	4.85	14.5	36.2	-	1.6	2.8	6.5	-	3.5	13.3	62.5	-	1.2	2.6	11.3	-
Adams SB	200	500	950	3700	10.5	14.5	25.5	21.3	0.6	2.0	6.7	21.9	0.0	41.7	18.5	36.5	0	5.8	4.9	37.5
Amar. Blvd. EB	650	750	1100	8100	2.3	0.8	12.3	0.0	0.4	0.2	3.8	0	0.0	0.0	14.5	0.0	0	0	4.5	0
Amar. Blvd. WB	550	550	750	4900	0.5	0.5	1.2	0.0	0.1	0.1	0.3	0	0.0	0.3	0.3	0.0	0	0	0.1	0
Buchanan NB	1700	1100	1800	6400	43.8	24.2	42.0	19.3	20.7	7.4	21.0	34.3	23.8	23.2	1.3	23.5	11.2	7.1	0.7	41.8
Fillmore NB	1050	950	950	9750	30.2	35.0	25.7	37.0	8.8	9.2	6.8	100.2	16.0	5.7	3.5	20.3	4.7	1.5	0.9	55.2
Pierce SB	600	950	1600	8850	19.0	36.8	54.5	11.5	3.2	9.7	24.2	28.3	8.7	0.5	6.0	22.8	1.5	2.5	2.7	56.1
Taylor SB	650	950	1600	8450	33.0	43.3	80.7	22.3	6.0	11.4	35.9	52.3	14.5	4.7	31.2	16.5	2.6	1.2	13.9	38.7
Polk NB	150	300	400	1150	38.2	49.5	53.7	78.8	1.6	4.1	6.0	25.2	25.2	84.8	59.2	40.0	1.1	7.1	6.6	12.8
Polk SB	150	300	400	1150	49.7	83.3	73.8	56.8	2.5	6.9	8.2	18.1	67.7	46.8	71.0	56.7	2.8	3.9	7.9	18.1
Tyler NB	150	250	200	3100	7.2	12.5	8.3	10.7	0.3	0.9	0.5	9.2	24.5	36.7	18.2	17.8	1.0	2.5	1.0	15.3
Harrison SB	300	500	1100	3000	26.3	20.0	39.0	29.0	2.2	2.8	11.9	24.2	6.2	40.3	11.8	0.3	0.5	5.6	3.6	0.3
Van Buren NB	200	100	100	1000	19.3	15.0	24.7	16.0	1.1	0.4	0.7	4.4	0.7	8.2	31.3	7.7	0	0.2	0.9	2.1
Jackson SB	100	350	650	2600	23.8	17.7	1.7	10.8	0.7	1.7	0.3	7.8	74.7	14.5	30.5	4.2	2.1	1.4	5.5	3.0
3rd EB	350	400	450	2900	26.7	34.0	41.2	42.5	2.6	3.8	5.2	34.2	63.3	15.8	110.8	38.5	6.2	1.8	13.9	31.0
3rd WB	350	400	500	3000	44.8	25.8	47.3	47.2	4.4	2.9	6.6	39.3	88.8	12.8	70.7	23.0	8.6	1.4	9.8	19.2

TABLE F.1 (Continued)

STREET	VOLUME				BEFORE DELAY/VEHICLE (SEC)				BEFORE DELAY/DAY (VEH-HR)				AFTER DELAY/VEHICLE (SEC)				AFTER DELAY/DAY (VEH-HR)			
	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak	AM Peak	Noon Peak	PM Peak	Off Peak
6th EB	200	150	300	1150	99.8	93.7	82.5	140.0	5.5	3.9	6.9	44.7	100.7	109.0	105.3	106.0	5.6	4.5	8.8	33.9
6th WB	300	600	500	4400	57.7	54.5	66.8	74.2	4.8	9.9	9.3	101.0	54.2	0.0	96.2	47.3	4.5	0	13.4	64.4
7th EB	400	500	650	3550	36.5	54.8	94.3	34.0	4.1	7.6	17.0	33.5	40.3	7.3	93.5	28.5	4.5	1.0	16.9	28.1
8th WB	750	450	650	3550	86.5	64.7	73.5	78.8	18.0	8.1	13.3	77.7	69.8	13.7	37.7	16.2	14.5	1.7	6.8	16.0
9th EB	150	150	200	1500	36.7	56.5	44.5	91.7	1.5	2.4	2.5	38.2	57.5	100.3	109.5	8.8	2.4	4.2	6.1	3.7
10th EB	200	250	350	2200	123.8	119.3	101.8	167.8	6.9	8.3	9.9	102.5	106.5	79.2	77.2	124.0	5.9	5.5	7.5	75.8
10th WB	500	750	1050	6050	90.2	47.3	117.5	60.0	13.8	9.9	34.3	100.8	89.0	10.2	100.2	18.3	13.6	2.1	29.2	30.8
11th EB	200	250	400	1900	90.3	13.0	39.2	17.5	5.0	0.9	4.4	9.2	114.8	22.3	120.8	38.3	6.4	1.5	13.4	20.2
Washington NB	650	500	650	4900	3.5	2.5	30.2	5.7	0.6	0.3	5.5	7.8	4.3	0.8	48.3	0.0	0.8	0.1	8.7	0
Washington SB	1350	900	950	8450	0.0	8.3	1.5	3.2	0	0.4	0.4	7.5	4.3	0.0	0.0	0.0	1.6	0	0	0
Georgia NB	500	700	1000	6600	42.3	89.0	93.8	27.0	6.5	17.3	26.1	49.5	0.0	56.7	20.5	0.0	0	11.0	5.7	0
Georgia SB	260	800	1200	6700	29.3	47.3	84.7	32.2	2.1	10.5	28.2	59.9	1.5	11.8	6.0	5.3	0.1	2.6	2.0	9.9
Western NB	500	600	750	5550	18.0	-	12.7	23.5	2.8	-	2.6	36.2	0.0	-	3.7	7.7	0	-	0.8	11.9
Western SB	500	750	1100	8150	7.3	-	18.3	6.0	1.1	-	3.8	13.6	0.0	-	6.5	1.0	0	-	1.4	2.3

TABLE F.2

COMPILATION OF DELAY PER DAY BY SECTION AND FOR TOTAL SYSTEM IN BEFORE AND AFTER PERIODS*

STREET	BEFORE DELAY/DAY					AFTER DELAY/DAY				
	AM Peak	Noon Peak	PM Peak	Off Peak	Total	AM Peak	Noon Peak	PM Peak	Off Peak	Total
Sections 1 & 2										
Buchanan	20.7	7.4	21.0	34.3		11.2	7.1	0.7	41.8	
Fillmore	8.8	9.2	6.8	100.2		4.7	1.5	0.9	55.2	
Pierce	3.2	9.7	24.2	28.3		1.5	2.5	2.7	56.1	
Taylor	6.0	11.4	35.9	52.3		2.6	1.2	13.9	38.7	
Polk NB	1.6	4.1	6.0	25.2		1.1	7.1	6.6	12.8	
Polk SB	2.5	6.9	8.2	18.1		2.8	3.9	7.9	18.1	
Tyler	0.3	0.9	0.5	9.2		1.0	2.5	1.0	15.3	
Harrison	2.2	2.8	11.9	24.2		0.5	5.6	3.6	0.3	
Van Buren	1.1	0.4	0.7	4.4		0	0.2	0.9	2.1	
Jackson	0.7	1.7	0.3	7.8		2.1	1.4	5.5	3.0	
3rd EB	2.6	3.8	5.2	34.2		6.2	1.8	13.9	31.0	
3rd WB	4.4	2.9	6.6	39.3		8.6	1.4	9.8	19.2	
6th EB	5.5	3.9	6.9	44.7		5.6	4.5	8.8	33.9	
6th WB	4.8	9.9	9.3	101.0		4.5	0	13.4	64.4	
7th	4.1	7.6	17.0	33.5		4.5	1.0	16.4	28.1	
8th	18.0	8.1	13.3	77.7		14.5	1.7	6.8	16.0	
9th	1.5	2.4	2.5	38.2		2.4	4.2	6.1	3.7	
10th EB	6.9	8.3	9.9	102.5		5.9	5.5	7.5	75.8	
10th WB	13.8	9.9	34.3	100.8		13.6	2.1	29.2	30.8	
11th EB	5.0	0.9	4.4	9.2		6.4	1.5	13.4	20.2	
	113.7	112.2	224.9	885.1	1335.9	99.7	56.7	169.5	566.5	892.4

TABLE F.2 (Continued)

STREET	BEFORE DELAY/DAY AM Peak	Noon Peak	PM Peak	Off Peak	Total	AFTER DELAY/DAY AM Peak	Noon Peak	PM Peak	Off Peak	Total
Section 3										
Amar. Blvd. EB	0.4	0.2	3.8	0		0	0	4.4	0	
Amar. Blvd. WB	0.1	0.1	0.3	0		0	0	0.1	0	
	0.5	0.3	4.1	0	4.9	0	0	4.5	0	4.5
Section 4										
Adams NB	1.6	2.8	6.5	-		1.2	2.6	11.3	-	
Adams SB	0.6	2.0	6.7	21.9		0	5.8	4.9	37.5	
Washington NB	0.6	0.3	5.5	7.8		0.8	0.1	8.7	0	
Washington SB	0	0.4	0.4	7.5		1.6	0	0	0	
	2.8	5.5	19.1	37.2	64.6	3.6	8.5	24.9	37.5	74.5
Section 5										
Georgia NB	6.5	17.3	26.1	49.5		0	11.0	5.7	0	
Georgia SB	2.1	10.5	28.2	59.9		0.1	2.6	2.0	9.9	
	8.6	27.8	54.3	109.4	200.1	0.1	13.6	7.7	9.9	31.3

TABLE F.2 (Continued)

STREET	BEFORE DELAY/DAY AM Peak	Noon Peak	PM Peak	Off Peak	Total	AFTER DELAY/DAY AM Peak	Noon Peak	PM Peak	Off Peak	Total
Section 7										
Western NB	2.8	-	2.6	36.2		0	-	0.8	11.9	
Western SB	1.1	-	3.8	13.6		0	-	1.4	2.3	
	3.9	-	6.4	49.8	1664.8	0	-	2.2	14.2	1019.1

*TOTAL SYSTEM DELAY - BEFORE - 1664.8 AFTER - 1019.1

$$\text{TOTAL SYSTEM REDUCTION IN DELAY} = \frac{1664.8 - 1019.1}{1664.8} = 38.8\%$$

APPENDIX G

t-TEST EVALUATION OF DELAY IN ENTIRE SECTION

TABLE G.1

t-TEST EVALUATION OF DELAY IN ENTIRE SYSTEM*

H_o: $D_A = D_B$ H_A: $D_A < D_B$

STREET	DIRECTION	PERIOD	DELAY BEFORE (B)	DELAY AFTER (A)	DIFFERENCE B - A (D)
Adams	NB	AM Peak	29	21	8
		Noon Peak	87	80	7
		PM Peak	217	375	-158
	SB	AM Peak	63	0	63
		Noon Peak	87	250	-163
		PM Peak	153	111	42
		Off Peak	128	219	-91
Amar. Blvd.	EB	AM Peak	14	0	14
		Noon Peak	5	0	5
		PM Peak	74	87	-13
		Off Peak	0	0	0
	WB	AM Peak	3	0	3
		Noon Peak	3	2	1
		PM Peak	7	2	5
		Off Peak	0	0	0
Buchanan	NB	AM Peak	263	143	120
		Noon Peak	145	139	6
		PM Peak	252	8	244
		Off Peak	116	141	-25
Fillmore	NB	AM Peak	181	96	85
		Noon Peak	210	34	176
		PM Peak	154	21	133
		Off Peak	222	122	100
Pierce	SB	AM Peak	114	52	62
		Noon Peak	221	57	164
		PM Peak	327	36	291
		Off Peak	69	137	-68
Taylor	SB	AM Peak	198	87	111
		Noon Peak	260	28	232
		PM Peak	484	187	297
		Off Peak	134	99	35
Polk	NB	AM Peak	229	151	78
		Noon Peak	297	509	-212
		PM Peak	322	355	-33
		Off Peak	473	240	233

TABLE G.1 (Continued)

STREET	DIRECTION	PERIOD	DELAY BEFORE (B)	DELAY AFTER (A)	DIFFERENCE B - A (D)
Polk	SB	AM Peak	358	406	-48
		Noon Peak	500	281	219
		PM Peak	443	426	17
		Off Peak	341	340	1
Tyler	NB	AM Peak	43	147	-104
		Noon Peak	75	220	-145
		PM Peak	50	109	-59
		Off Peak	64	107	-43
Harrison	SB	AM Peak	158	37	121
		Noon Peak	120	242	-122
		PM Peak	234	71	163
		Off Peak	174	2	172
Van Buren	NB	AM Peak	116	4	112
		Noon Peak	90	49	41
		PM Peak	148	188	-40
		Off Peak	96	46	50
3rd	EB	AM Peak	160	380	-220
		Noon Peak	204	95	109
		PM Peak	247	665	-418
		Off Peak	255	231	24
	WB	AM Peak	269	533	-264
		Noon Peak	155	77	78
		PM Peak	284	424	-140
		Off Peak	283	138	145
6th	EB	AM Peak	599	604	-5
		Noon Peak	562	654	-92
		PM Peak	495	632	-137
		Off Peak	840	636	204
	WB	AM Peak	346	325	21
		Noon Peak	357	0	357
		PM Peak	401	577	-176
		Off Peak	445	284	161
7th	EB	AM Peak	219	242	-23
		Noon Peak	329	44	285
		PM Peak	566	561	5
		Off Peak	204	171	33

TABLE G.1 (Continued)

STREET	DIRECTION	PERIOD	DELAY BEFORE (B)	DELAY AFTER (A)	DIFFERENCE B - A ($\bar{D}$)
8th	WB	AM Peak	519	419	100
		Noon Peak	388	82	306
		PM Peak	441	226	215
		Off Peak	473	97	376
9th	EB	AM Peak	220	345	-125
		Noon Peak	339	602	-263
		PM Peak	267	657	-390
		Off Peak	550	53	497
10th	EB	AM Peak	743	639	104
		Noon Peak	716	475	241
		PM Peak	611	463	148
		Off Peak	1007	744	263
	WB	AM Peak	541	534	7
		Noon Peak	284	61	223
		PM Peak	705	601	104
		Off Peak	360	110	250
11th	EB	AM Peak	542	689	-147
		Noon Peak	78	134	-56
		PM Peak	235	725	-490
		Off Peak	105	230	-125
Washington	NB	AM Peak	21	26	-5
		Noon Peak	15	5	10
		PM Peak	181	290	-109
	SB	AM Peak	0	26	-26
		Noon Peak	50	0	50
		PM Peak	9	0	9
		Off Peak	19	0	19
Georgia	NB	AM Peak	254	0	254
		Noon Peak	534	340	194
		PM Peak	563	123	440
		Off Peak	162	0	162
	SB	AM Peak	176	9	167
		Noon Peak	284	71	213
		PM Peak	508	36	472
		Off Peak	193	32	161

TABLE G.1 (Continued)

STREET	DIRECTION	PERIOD	DELAY BEFORE (B)	DELAY AFTER (A)	DIFFERENCE B - A (D)
Western	NB	AM Peak	108	0	108
		PM Peak	76	22	54
		Off Peak	141	46	95
	SB	AM Peak	44	0	44
		PM Peak	110	39	71
		Off Peak	36	6	30

*The data in this table were used in the calculation of the t-test.

$n = 117$
$B = 45.30$

$S_{\bar{d}} = 15.79$

$t = 2.87$

t_{CALC} (2.87) > $t_{.01}$ (2.33)

∴ Reject H_o

Accept H_A

$t_{.05} = 1.66$

$t_{.01} = 2.33$

APPENDIX H

t-TEST EVALUATION OF NUMBER OS STOPS BY SECTION

TABLE H.1

t-TEST EVALUATION OF NUMBER OF STOPS IN SECTIONS 1 AND 2 CALCULATIONS*

SECTION 1 AND 2

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
Buchanan	NB	AM Peak	13	5	8
		Noon Peak	7	6	1
		PM Peak	12	2	10
		Off Peak	7	4	3
Fillmore	NB	AM Peak	7	5	2
		Noon Peak	14	1	13
		PM Peak	9	4	5
		Off Peak	7	7	0
Pierce	SB	AM Peak	6	6	0
		Noon Peak	13	5	8
		PM Peak	19	7	12
		Off Peak	8	9	-1
Taylor	SB	AM Peak	13	3	10
		Noon Peak	14	1	13
		PM Peak	16	14	2
		Off Peak	13	10	3
Polk	NB	AM Peak	17	11	6
		Noon Peak	19	32	-13
		PM Peak	24	15	9
		Off Peak	22	25	-3
	SB	AM Peak	25	22	3
		Noon Peak	26	22	4
		PM Peak	29	21	8
		Off Peak	25	25	0
Tyler	NB	AM Peak	16	12	4
		Noon Peak	12	11	1
		PM Peak	12	9	3
		Off Peak	21	7	14
Harrison	SB	AM Peak	18	10	8
		Noon Peak	14	11	3
		PM Peak	17	7	10
		Off Peak	21	1	20
Van Buren	NB	AM Peak	17	1	16
		Noon Peak	17	2	15
		PM Peak	15	18	-3
		Off Peak	27	23	4

TABLE H.1 (Continued)

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
Jackson	SB	AM Peak	10	26	-16
		Noon Peak	10	18	-8
		PM Peak	2	12	-10
		Off Peak	17	13	4
3rd	EB	AM Peak	10	16	-6
		Noon Peak	22	13	9
		PM Peak	22	20	2
		Off Peak	19	15	4
	WB	AM Peak	18	17	1
		Noon Peak	12	14	-2
		PM Peak	20	14	6
		Off Peak	18	15	3
6th	EB	AM Peak	30	28	2
		Noon Peak	33	30	3
		PM Peak	25	30	-5
		Off Peak	34	33	1
	WB	AM Peak	16	19	-3
		Noon Peak	18	0	18
		PM Peak	18	27	-9
		Off Peak	17	11	6
7th	EB	AM Peak	21	16	5
		Noon Peak	25	9	16
		PM Peak	32	17	15
		Off Peak	25	7	18
8th	WB	AM Peak	23	15	8
		Noon Peak	20	7	13
		PM Peak	21	11	10
		Off Peak	25	11	14
9th	EB	AM Peak	28	23	5
		Noon Peak	27	18	9
		PM Peak	26	22	4
		Off Peak	24	5	19
10th	EB	AM Peak	35	35	0
		Noon Peak	36	29	7
		PM Peak	24	20	4
		Off Peak	34	43	-9

TABLE H.1 (Continued)

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
10th	WB	AM Peak	34	25	9
		Noon Peak	20	6	14
		PM Peak	26	24	2
		Off Peak	19	5	14
11th	EB	AM Peak	18	23	-5
		Noon Peak	7	15	-8
		PM Peak	13	26	-13
		Off Peak	13	19	-6

*The data in this table were used in the calculation of the t-test.

$n = 80$

$S_{\bar{d}} = 0.885$

$\bar{D} = 4.275$

$t = 4.83 > 1.67$

$t_{.05}(79 d.f.) = 1.67$

$\therefore$ Reject H_o

TABLE H.2

t-TEST EVALUATION OF NUMBER OF STOPS IN SECTIONS*

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
Amar. Blvd.	EB	AM Peak	5	0	5
		Noon Peak	2	0	2
		PM Peak	5	12	-7
		Off Peak	0	0	0
	WB	AM Peak	2	0	2
		Noon Peak	1	1	0
		PM Peak	2	1	1
		Off Peak	0	0	0

*$n = 8$ $S_{\bar{d}} = 1.21$

$\bar{D} = 0.375$ $t = 0.310$

$t_{CALC} = 0.310 < 1.895$ $t_{.05}(7d.f.) = 1.895$

$\therefore$ Accept H_o, Reject H_A

TABLE H.3

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
Adams	NB	AM Peak	7	1	6
		Noon Peak	9	5	4
		PM Peak	10	19	-9
	SB	AM Peak	6	0	6
		Noon Peak	9	13	-4
		PM Peak	9	8	1
		Off Peak	10	12	-2
Washington	NB	AM Peak	4	5	-1
		Noon Peak	6	2	4
		PM Peak	11	11	0
		Off Peak	1	0	1
	SB	AM Peak	0	3	-3
		Noon Peak	2	0	2
		PM Peak	1	0	1
		Off Peak	1	0	1

TABLE H.4

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
Georgia	NB	AM Peak	15	0	15
		Noon Peak	20	13	7
		PM Peak	17	14	3
		Off Peak	15	0	15
	SB	AM Peak	9	2	7
		Noon Peak	14	1	13
		PM Peak	14	5	9
		Off Peak	10	5	5

*$n = 8$ $\quad S_{\bar{d}} = 1.62$

$\bar{D} = 9.25$ $\quad t = 5.70$

$t_{.05}(7\text{d.f.}) = 1.895$

$t_{calc.} = 5.70 > 1.895$, ∴ Reject H_o, Accept H_A

TABLE H.5

STREET	DIRECTION	PERIOD	STOPS BEFORE (B)	STOPS AFTER (A)	DIFFERENCE B - A (D)
Western	NB	AM Peak	5	0	5
		PM Peak	2	4	-2
		Off Peak	4	6	-2
	SB	AM Peak	4	0	4
		PM Peak	5	5	0
		Off Peak	2	1	1

*$n = 6$ $\quad S_{\bar{d}} = 1.21$

$\bar{D} = 1.0$ $\quad t = 0.83$

$t_{.05}5\text{d.f.}) = 2.015$

$t_{CALC} = 0.83 < 2.015$, ∴ Accept H_o

APPENDIX I

CALCULATION OF VEHICLE OPERATING COSTS

The annual operating cost during the before and after period would be computed as follows:

Annual Operating Cost = Cost of Stops + Excess Idling Cost + Motorist' Excess Time Costs =

$$\left(\frac{\text{Stops}}{\text{Day}}\right)(365)\left(\frac{\text{Cost}}{\text{Stop}}\right)+\left(\frac{\text{Veh-Hr}}{\text{Day}}\right)(365)\left(\frac{\text{Cost}}{\text{Veh-Hr}}\right)+\left(\frac{\text{Veh-Hr}}{\text{Day}}\right)(365)\left(\frac{\$}{\text{Hour}}\right)$$

Using this method of analysis the excess motorists' operating cost (above the constant speed cost) in the before period is as follows:

$$C_B = \frac{(354{,}084\frac{\text{Stops}}{\text{Day}})365\frac{\text{Days}}{\text{Year}})(6.96)(.9)}{1000} + \frac{(354{,}084)(365)(58.85)(.1)}{1000}$$

$$+ \frac{(1664.8)(365)(114.86)(.9)}{1000} + \frac{(1664.8)(365)(225)(.1)}{1000}$$

$$+ (1664.8\frac{\text{Veh-Hr}}{\text{Day}})(365\frac{\text{Days}}{\text{Year}})(\$1/\text{vehicle-hour})$$

$$C_B = 809{,}563 + 760{,}581 + 62{,}815 + 13{,}672 + 607{,}652$$

$$C_B = \$2{,}254{,}283$$

In a similar manner the motorists' operating cost after installation of the computer controlled signal system is computed.

$$C_A = \frac{(271{,}978)(365)(6.96)(.9)}{1000} + \frac{(271{,}978)(365)(58.85)(.1)}{1000}$$

$$+ \frac{(1019.1)(365)(114.86)(.9)}{1000} + \frac{(1019.1)(365)(225)(.1)}{1000}$$

$$+ (1019.1)(365)(\$1/\text{vehicle-hour})$$

$C_A = 621,840 + 584,216 + 38,452 + 371,972$

$C_A = \$1,624,849$

Annual Reduction in Motorists Operating Cost =

$2,254,283 - $1,624,849 = $629,434

The equivalent uniform annual cost for the installation assuming a 10 year life and an interest rate of 8% is

EUAC = ($1,958,000)(CRF-8% - 10 yrs)

EUAC = ($1,958,000)(0.149029)

EUAC = $291,800

Assuming the cost and expected life of the components to be

Item	Cost	Life
Conduit and Cable	1,250,000	30 years
Poles, Heads and Controllers	450,000	20 years
Computer and Peripheral Equipment	250,000	10 years

EUAC = ($1,250,000)(CRF-8%-30yrs.) + ($450,000)(CRF-8%-20yrs.)

+ ($250,000)(CRF-8%-10yrs.)

EUAC = ($1,250,000)(.088827) + $450,000)(.101852) + ($250,000)

(.49029)

EUAC = $111,034 + 45,833 + 37,257

EUAC = $194,124

$$C_B = \frac{(354,084\frac{\text{Stops}}{\text{Day}})(365\frac{\text{Days}}{\text{Year}})(11.25\frac{\$}{1000\ \text{Stops}})(.9) +}{1000}$$

$$\frac{(354,084)(365)(58.77)(.1)}{1000} +$$

$$\frac{(1664\frac{\text{Veh-Hr}}{\text{Day}})(365\frac{\text{Days}}{\text{Year}})(312.64\frac{\$}{1000\ \text{hrs.}})(.9)}{1000} +$$

$$\frac{(1664)(365)(235.26)(.1)}{1000} +$$

$$(1664.8\frac{\text{Veh-Hr}}{\text{Day}})(365\frac{\text{Days}}{\text{Year}})(.21\frac{\$}{\text{Travel-Hour}})(1.56\frac{\text{Traveler}}{\text{Vehicle}})$$

$$C_B = 1,308,562 + 759,547 + 170,897 + 14,289 + 199,067$$

$$C_B = \$2,452,362$$

$$C_A = \frac{(271,978)(365)(11.25)(.9)}{1000} + \frac{(271,978)(365)(58.77)(.1)}{1000}$$

$$+ \frac{(1019.1)(365)(312.64)(.9)}{1000} + \frac{(1019.1)(365)(235.26)(.1)}{1000}$$

$$+ (1019.1)(365)(.21)(1.56)$$

$$C_A = 1,005,129 + 583,421 + 104,664 + 8751 + 121,858$$

$$C_A = \$1,823,823$$

Annual Reduction in Motorists' Operating Costs =

$2,452,362 - $1,823,823 = $628,539

$$(\text{Crf-r-10}) = \frac{\text{Savings Due to Investment}}{\text{Investment}}$$

$$(\text{Crf-r-10}) = \frac{\text{Reduced Motorists' Operating Cost} - \text{Increased Maintenance and Operating Costs}}{\text{Investment}}$$

$$(\text{Crf-r-I0}) = \frac{(\$629,434/\text{yr}) - (\$40,000/\text{yr.})}{\$1,958,000}$$

$$(\text{Crf-r-10}) = \frac{589,434}{1,958,000} = .3010$$

By interpolation

Crf-30%-10 = .323463
Crf-r%-10 = .3010
Crf-25%-10 = .280073

$$r = (\frac{.3010 - .280073}{.323463 - .280073})(.05) + .25$$

$$r = (\frac{.020927}{.04339})(.05) + .25$$

$$r = .274 = 27.4\%$$

APPENDIX J

FUEL CONSUMPTION REDUCTION WORKSHEET

1. Reduced vehicle-hour delay per year (idling):

   $(645.7 \frac{\text{vehicle-hour}}{\text{day}})\ (365 \frac{\text{day}}{\text{year}}) = \underline{235,681}$

2. Gallons consumed per vehicle-hour delay (idling):

   0.58

3. Total gallons saved by reduction of delay/year (1 x 2):

   136,695

4. Reduced vehicle stops per year:

   $(82,106 \frac{\text{stops}}{\text{day}})\ (365) = 29,968,690$

5. Gallons consumed per vehicle-stop:

   0.01

6. Total gallons saved per year by reduction of vehicle-stops (4 x 5):

   299,687

7. Total fuel saved per year, gallons (3 + 6):

   436,382 gallons

APPENDIX K

AIR POLLUTION REDUCTION WORKSHEET

1. Reduced Vehicle-Hours Delay Per Year (Idling)

$$(645.7 \frac{\text{vehicle-hour}}{\text{day}})\ (365 \frac{\text{day}}{\text{year}}) = 235{,}681$$

2. Reduced Annual HC emissions from idling (1. x .0087 $\frac{\text{lbs.}}{\text{hr}}$)

235,681 hr. of idling (.0087 $\frac{\text{lbs.}}{\text{hr}}$) = 2050 lbs.

3. Reduced HC emissions from reduced stops (from 25 mph)

$$(29{,}967 \frac{\text{thousand-stops}}{\text{yr.}})\ (.01 \frac{\text{lbs.}}{\text{thousand-stops}}) =$$

(300 $\frac{\text{lbs.}}{\text{yr}}$) HC Reduction

4. Reduced CO emissions from reduction in idling

(Reduction in idling)(CO emissions in $\frac{\text{lbs.}}{\text{vehicle-hour}}$)

$$(235{,}681 \frac{\text{vehicle-hour}}{\text{year}})\ (1.19 \frac{\text{lbs.}}{\text{vehicle-hour}}) = 280{,}460 \frac{\text{lbs.}}{\text{yr}}$$

5. Reduced CO emission from reduction in stops

$$(29{,}967 \frac{\text{thousand-stops}}{\text{year}})\ (10 \frac{\text{lbs.}}{\text{thousand-stops}}) = 299{,}670 \frac{\text{lbs.}}{\text{yr}}$$

Total Reduction From Project:

HC: 2350 $\frac{\text{lbs.}}{\text{year}}$

CO: 580,130 $\frac{\text{lbs.}}{\text{year}}$