THE EFFECTS OF INTERSECTION TRAFFIC CONTROLS UPON LEFT TURN-SIGNALLING BEHAVIOR

RESEARCH REPORT

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Engineering Department of Texas A&M University

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Results were obtained from the analysis of data which indicated that several definite relationships exist between left turn-signalling behavior and type of intersection traffic control.

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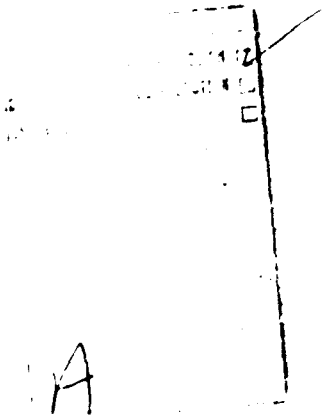

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CHAPTER I

INTRODUCTION

Each year millions of drivers of motor vehicles are involved in traffic accidents, resulting in a tremendous loss of human and economic resources (Accident Facts, 1969). For this reason, driver behavior on the highway is of critical importance for those concerned with traffic safety, possibly as important as efficient highway design, good vehicle design, and effective traffic regulation. This study was designed to provide some knowledge of one aspect of driver behavior; the effects of traffic controls upon turn-signalling behavior of motor vehicle operators.

The objective of this investigation was to determine which type of intersection traffic control was most effective in the encouragement of the use of proper left turn signals. For this purpose, three types of intersection traffic control were chosen for study. Two-way stop, four-way stop, and signal controlled intersections were selected for comparison of their effects upon the frequency of use and the distance of employment of left turn signals given by motorists performing such turns. Observations of signalling behavior were made at twenty-five intersections with traffic controls representative of the distinct types selected for study.

Legal aspects associated with signalling for a left turn and a literature survey referencing pertinent solutions to similar problems

involving turn-signalling behavior are contained in Chapter II. The method of approach to the problem and the techniques employed in determining the type of intersection traffic control most effective in eliciting proper left turns are presented in Chapter III, while Chapter IV is devoted to the findings of the investigation. A summary of the results of the study and the conclusions drawn from this information are presented in Chapter V.

CHAPTER II

LITERATURE SURVEY

Legal Background

The intersections under study were located in the cities of Texarkana, Bryan, and College Station, Texas. Therefore the investigation of legal responsibility concerning the use of left turn signals was primarily confined to sections of the Texas Motor Vehicle Laws. Section 65a of the Motor Vehicle Laws states that the driver of a vehicle intending to turn left at an intersection must do so as follows: "Approach for a left turn shall be made in . . . the right half of the roadway nearest the center line . . . and after entering the intersection the left turn shall be made so as to leave the intersection to the right of the center line being entered." It further declares in Section 68 "No person shall so turn any vehicle without giving an appropriate signal . . . in the event any other traffic may be effected by such movement . . . . A signal of intention to turn . . . left when required shall be given continuously during not less than the last one hundred (100) feet traveled by the vehicle before turning" (Texas Motor Vehicle Laws, 1969).

These sections of the Texas Motor Vehicle Laws are in complete agreement with the national Uniform Vehicle Code, sections 11-601 and 11-604 (Uniform Vehicle Code, 1962). It should be noted that a turn signal is required by law only when the turning maneuver may affect

other traffic. The use of the signal is for information only. It does not assure the turning vehicle the right-of-way, though in certain situations signalling may result in some manner of courteous response from other drivers.

Survey of the Literature

Early exploratory research justified the use of turn-signalling behavior as an area of driver behavior worthy of intensive study. The results of previous studies (Burch, Nangle, and Trumbo, 1958) and (Rockwell and Treiterer, 1968) revealed that signalling behavior could be measured in a reliable manner. It was found from these investigations that behavior was related to a number of situational characteristics (such as type of intersection and direction of turn) in ways that were neither insignificant nor obvious.

While the earlier of the two studies was primarily an exploratory one, designed to provide insight into the signalling behavior of the driver; both investigations sought to determine the limitation of turn signals as a means of intervehicular communication. Primarily two underlying assumptions constituted the basis for research in both studies. The first assumption was that different environmental or situational conditions will evoke different frequencies of signalling. Secondly, it was assumed that frequency of turn-signalling at a given location will be influenced by characteristics of the driver-vehicle unit.

As for the results of the two investigations, similar conclusions were reached regarding the effects of the type of intersection, direction of turn, and sex of the driver upon signalling behavior. It was

concluded that: (a) turn-signalling behavior was influenced significantly by the type of intersection, (b) female drivers generally signalled more frequently than did male drivers, and (c) generally left turns were signalled more frequently than right turns. Yet contradictory conclusions were drawn concerning the presence of other vehicles and the signalling behavior of such vehicles. The study of (Branch, Nangle, and Trumbo, 1958) suggested that turn-signalling was not related to the presence of other traffic, or the signalling behavior of preceding vehicles. To the contrary, the study of (Rockwell and Treiterer, 1968) supported the following: (a) the presence of preceding turning vehicles reduces signalling frequencies, (b) signalling by preceding vehicles increases the signalling frequencies of the following vehicles, and (c) single vehicles signal more than vehicles traveling in the middle of platoons.

Also, additional findings (Rockwell and Treiterer, 1968) which were not included in the earlier research were: (a) drivers of commercial vehicles signal less than drivers of passenger vehicles, (b) the presence of passengers appeared to increase frequency of signals, and (c) drivers of new vehicles signal more than drivers of older vehicles.

The similar findings concerning the effects of type of intersection upon signalling behavior are more important in regards to this study. The conclusion was drawn that signalling behavior appeared to be sensitive in relation to intersection and road characteristics; yet the determination of the relative importance of various intersection characteristics required more study. No in-depth study was made in

either of the previously sited investigations as to the comparison of effectiveness of specific methods of intersection traffic control upon the eliciting of proper signalling as prescribed by law.

Therefore, unlike the previously mentioned studies, it was the purpose of this investigation to examine in greater detail the effects of selected types of intersection control upon left turn-signalling behavior --- specifically, the effect upon the encouragement of use of proper left turn signals as prescribed by law. The method of approach to the problem of obtaining quantified measures of the abilities of intersection controls to elicit proper signalling is presented in the following chapter.

CHAPTER III

METHOD

General Procedure

Signalling behavior was observed at selected two-way stop, four-way stop, and signal controlled intersections from late April to mid-July, 1970. A total of 5,427 observations were made at twenty-five intersections chosen as test sites. All data was taken manually, in good weather, and under both night and daytime conditions. Observations were made as to whether a driver signalled or failed to signal his intention to turn left, as well as the distance at which the signal was initially given. Distances were recorded in increments of twenty feet up to 100 feet from the intersection.

Sample Size

Work sampling techniques were employed in determining an adequate sample size needed to give sufficient accuracy of results. A 95 percent confidence level and a desired relative accuracy of ± 2.5 percent were selected as criteria to be used in specifying sample size. Together with this criteria, the percentage of signalling occurrence was used to determine the required number of observations. Since each of the three systems of intersection traffic control elicited a particular signalling frequency, a differently sized sample was taken for each type of intersection. These three samples comprised the total number

of observations recorded during this investigation. A further discussion of work sampling techniques used in this study is presented in Appendix 1.

Observation Sites

Test sites were selected on the basis of the method of traffic control employed at the intersection. Nine two-way stop, eight four-way stop, and eight signal controlled intersections were chosen for observation. Each of the three types of intersection were standardized in a manner that a reliable comparison as to the effect of traffic controls upon signalling behavior could be made. For purposes of this investigation, the types of intersections selected for study were standardized as follows:

Two-way stop. The two-way stop intersection consisted of two paved, two-lane roadways meeting approximately at right angles to each other; one of which was controlled by stop signs properly located, whereas traffic control devices were omitted from the other roadway. Both roadways were free of any road markings (other than center line markings) and visual obstructions located thirty-five feet or less from the center lines of the intersecting roadways.

Four-way stop. The four-way stop intersection was comprised of two paved, two-lane roadways meeting approximately at right angles to each other, controlled by a system of four-way stop signs properly located and supplemented by stop line and center line markings; but with no other means of traffic control. The intersection was free of any visual obstructions located thirty-five feet or less from the center lines of the intersecting roadways.

Signal controlled. A signal controlled intersection consisted of two paved roadways meeting approximately at right angles to each other, controlled by a pre-timed traffic signal having three lenses only — red, yellow, and green — supplemented by stop line and center line markings. The intersection was free of any other traffic control devices and markings, as well as visual obstructions thirty-five feet or less from the center lines of the intersecting roadways.

Typical two-way stop, four-way stop, and signal controlled intersections observed in this investigation are depicted in Figures 1, 2, and 3 respectively.

Statistical Analysis

The influence of traffic controls upon turn-signalling was evaluated by conducting an analysis of variance to test the hypothesis that the means of the signalling frequencies for each of the types of intersection control were equal. The testing of this hypothesis was accomplished by comparing the variance among the means of the three types of intersections with the variance of signalling frequencies of the twenty-five individual intersections within the specific types. The rationale was that if the variance among the means of the three specific types of intersections was significantly greater than the variance within the individual intersections, the added variance must be due to real differences among the types of intersections, rather than to chance factors. The statistical significance among the means was called "highly significant," "significant," or "not significant" as the significance level was found to be less than 0.01, less than 0.05, or greater than

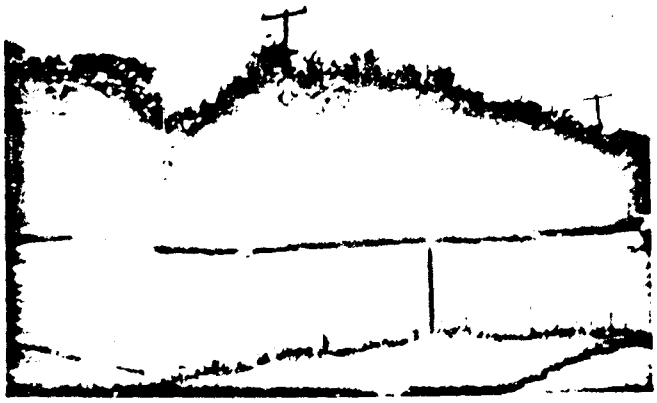

FIGURE 1. TWO-WAY STOP INTERSECTION

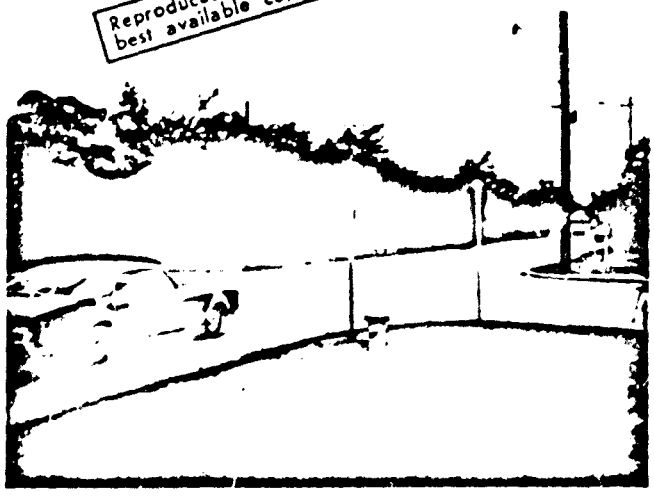

FIGURE 2. FOUR-WAY STOP INTERSECTION

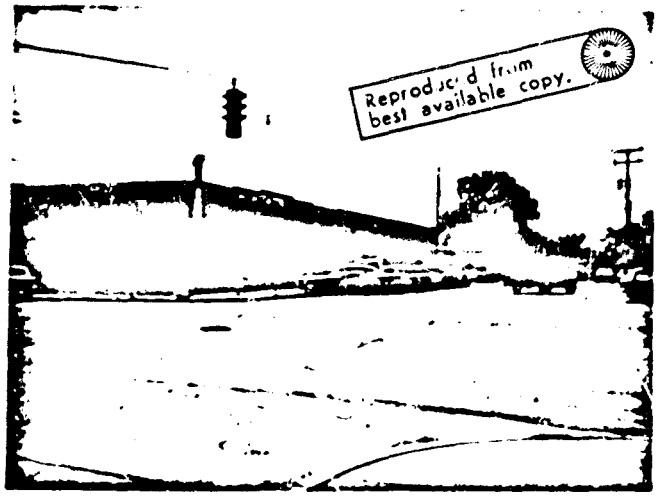

FIGURE 3. SIGNAL CONTROLLED INTERSECTION

0.05, respectively. Chi square tests were performed to substantiate the results of the analysis of variance. Analysis procedures and calculations are presented in Appendix 2.

The mean distances, of the three types of intersections, at which drivers initially signalled their intention to turn were compared to the standard distance of 100 feet prescribed in the Motor Vehicle Laws by applying the t-test using a level of significance of 0.05. Results of the analyses are presented in the succeeding chapter.

CHAPTER IV

RESULTS

Data gathered from the field observations were analyzed to determine the effects of type of intersection traffic control upon turn-signalling behavior of motor vehicle operators.

Table 1 presents field data taken at the twenty-five test sites selected to represent the methods of intersection control being investigated. The data includes the total number of vehicles making left turns, the number signalling or non-signalling, and the percent of vehicles which signal a left turn movement.

An analysis of variance was performed to compare the means of the turn-signalling frequency of the three systems of intersection control, the results of which are given in Table 2. From this analysis it was concluded that signal controlled intersections tend to elicit a significantly greater use of left turn signals than do either two-way stop or four-way stop intersections. It was also concluded that two-way stop and four-way stop intersections do not differ significantly ($P>0.05$) in the eliciting of left turn signals. A further comparison was made as to the effects of method of intersection control upon the distance at which drivers initially signal an intention to turn left. Table 3 gives the percentages of the total signals given for each particular range as observed at each of the three types of intersections.

TABLE 1

TURN-SIGNALLING FREQUENCIES AND PERCENTAGES AT TEST SITES

Intersection	Total left turns	Signal used	No signal used		%Sig.
TWO-WAY					
1	192	108	84		56.21
2	272	169	103		62.13
3	184	127	57		69.02
4	200	128	72		64.00
5	210	121	89		57.61
6	206	136	70		65.53
7	224	138	86		61.60
8	228	142	86		62.28
9	240	169	71		70.41
total	1956	1238	718	**avg.**	63.29
FOUR-WAY					
1	233	136	97		58.37
2	226	138	88		61.06
3	221	143	78		64.70
4	229	166	63		72.48
5	217	154	63		70.96
6	219	138	81		63.01
7	245	170	75		69.38
8	208	142	66		68.26
total	1798	1187	611	**avg.**	66.02
SIGNAL					
1	227	182	45		80.17
2	209	163	46		77.99
3	246	179	67		72.76
4	232	142	91		60.78
5	211	143	68		67.77
6	195	148	47		75.89
7	206	164	42		79.62
8	147	112	35		76.19
total	1673	1232	441	**avg.**	73.89

TABLE 2

STATISTICAL COMPARISON OF TURN-SIGNALLING FREQUENCIES

METHODS OF CONTROL	SIGNAL CONTROLLED	TWO-WAY STOP	FOUR-WAY STOP
SIGNAL CONTROLLED	———	0.01	0.05
TWO-WAY STOP	0.01	———	NS*
FOUR-WAY STOP	0.05	NS*	———

* Not significant at the 0.05 level

It was concluded that no significant difference ($P > 0.05$) existed among the effects of the three systems of intersection traffic control upon the distance at which drivers initially signal their intention to turn left.

Also, it was found that the mean signalling distances of the three types of intersections were significantly less ($P > 0.05$) than the standard distance of 100 feet set forth in the Texas Motor Vehicle Laws. A discussion as to the findings of this investigation is included in Chapter V.

TABLE 3

SIGNALLING DISTANCES

DISTANCES	SIGNAL CONTROLLED	TWO-WAY STOP	FOUR-WAY STOP
0-20 feet	20.4% *	22.9%	24.1%
20-40 feet	16.0%	17.1%	17.3%
40-60 feet	14.5%	9.5%	10.1%
60-80 feet	10.9%	8.9%	8.8%
80-100 feet	11.1%	12.4%	14.5%
over 100 feet	27.1%	29.2%	25.2%

* percentage of the total number of signals given for the particular intersection

CHAPTER V

SUMMARY

The objective of this research was to investigate the use of turn signals at urban intersections. More specifically, the study was designed to provide some knowledge as to the effects of type of intersection upon left turn-signalling behavior of motor vehicle operators. Results were obtained from the analysis of data which indicated the following relationships between left turn-signalling behavior and type of intersection traffic control:

1. Signal controlled intersections elicit a significantly greater signalling frequency than do two-way stop and four-way stop intersections.

2. Two-way stop and four-way stop intersections do not differ significantly in their effects upon signalling frequencies of left turns.

3. No significant difference exist among the effects of two-way stop, four-way stop, and signal controlled intersections upon the distance at which drivers initially signal their intention to turn left.

4. The mean signalling distances of the three types of intersections were significantly less than the standard distance of 100 feet prescribed by the Texas Motor Vehicle Laws.

It was further determined from the 5,427 observations made at the various test sites, that a signal of intention to turn left was given

for approximately 68 percent of the observed turns; yet only slightly more than one-fifth of those signals were given for a distance of at least 100 feet as set forth by law.

Additional research will be required to determine the effects of more complex systems of intersection traffic control upon driver behavior. Also further research is needed to investigate the extent to which various situational or environmental factors interact.

APPENDIXES

APPENDIX 1

Work Sampling

A sample taken at random from a large group tends to have the same pattern of distribution as the large group or population. If a sample is large enough, the characteristics of the sample will differ but little from the characteristics of the population. Work sampling is one technique used to determine an adequate sample size, such that the sample will exhibit the characteristics of the parent population. The formula given here is customarily used for determining the number of observations for work sampling studies.

$$Sp = k\sqrt{p(1-p)/N} \qquad A.1.1$$

This formula assumes that the binomial distribution is a reasonable qpproximation of the true condition (Barnes, 1957). Equation A.1.1 may be similarly expressed as follows:

$$N = k^2 (1-p)/S^2p \qquad A.1.2$$

where S = desired accuracy

p = percentage of occurrence of an activity

k = confidence level expressed in sigma limits

N = number of random observations

Values of S and k are selected based on such governing criteria as desired accuracy of results, economics, risks involved, etc.; whereas, a value of p (the percentage of occurrence of an activity) can be

initially estimated by taking a small sample and determining p from that sample. Later, as more data or samples are obtained, the estimate of p can be corrected.

For purposes of this study, a sample size was determined based on a modification of Equation A.1.2. The discussion of this modification is beyond the scope of this paper, but the interested reader may refer to the text Work Sampling by Ralph M. Barnes for a detailed discussion of the subject.

APPENDIX 2

Statistical Analyses

Analyses of variance were used to test the hypothesis that the mean signalling frequencies of the three types of intersection were equal. The purpose of the analyses was to compare the effectiveness of the methods of intersection traffic control in the eliciting of proper left turn signals given by motorists performing such turns. An excellent discussion of the mechanics of an analysis of variance can be found in the text Engineering Statistics by Albert H. Bowker and Gerald J. Lieberman.

Tables A1, A2, A3 and A4 present the results of the analyses of variances.

TABLE A1

COMPARISON OF TWO-WAY STOP, FOUR-WAY STOP, AND SIGNAL CONTROLLED INTERSECTIONS

Sum of Squares Due to	Value of SS	Degrees of Freedom	Mean Square
SS Total	1156.1	24	
SS Between	504.4	2	252.2
SS Within	651.7	22	29.62

$F = 252.2 / 29.62 = 8.51$

Hypothesis: The mean signalling frequencies of two-way stop, four-way stop, and signal controlled intersections are equal.

$F = 8.51 > F_{.01} = 5.73$. Reject the hypothesis

TABLE A2

COMPARISON OF TWO-WAY STOP AND SIGNAL CONTROLLED INTERSECTIONS

Sum of Squares Due to	Value of SS	Degrees of Freedom	Mean Square
SS Total	960.3	16	
SS Between	484.7	1	484.7
SS Within	475.6	15	31.67

$F = 484.7 / 31.67 = 15.3$

Hypothesis: The mean signalling frequencies of two-way stop and signal controlled intersections are equal.

$F = 15.3 > F_{.01} = 8.68$ Reject the hypothesis

TABLE A3

COMPARISON OF FOUR-WAY STOP AND SIGNAL CONTROLLED INTERSECTIONS

Sum of Squares Due to	Value of SS	Degrees of Freedom	Mean Square
SS Total	732.7	15	
SS Between	247.7	1	247.7
SS Within	485.0	14	34.64

$F = 247.7 / 34.64 = 7.15$

Hypothesis: The mean signalling frequencies of four-way stop and signal controlled intersections are equal.

$F = 7.15 > F_{.05} = 4.60$ Reject the hypothesis

TABLE A4

COMPARISON OF TWO-WAY STOP AND FOUR-WAY STOP INTERSECTIONS

Sum of Squares Due to	Value of SS	Degrees of Freedom	Mean Square
SS Total	376.8	16	
SS Between	34.0	1	34.0
SS Within	342.8	15	22.85

$F = 34.0 / 22.85 = 1.49$

Hypothesis: The mean signalling frequencies of two-way stop and four-way stop intersections are equal.

$F = 1.49 < F_{.05} = 4.54$ Do not reject hypothesis

Chi square tests were performed to substantiate the results of the analyses of variance. It was found that the results of the chi square tests were in complete agreement with those obtained in the analyses of variance. The results of the chi square tests are given in Tables A5, A6, and A7. Reference may be made to the text Statistical Analysis by Edward C. Bryant in order that the chi square test (as it applies to the comparison of frequencies) might be better understood.

Signal distances (of 100 feet or greater) at which drivers initially signal their intentions to turn left were compared by using a chi square test. The results of the comparison are given in Table A8.

A final analysis was performed, using a t-test, to compare the mean signalling distances of two-way stop, four-way stop, and signal controlled intersections with the standard distance of 100 feet prescribed in the Texas Motor Vehicle Laws. The computed mean distances and estimated standard deviations for each of the three types of intersection are listed in Table A9. The results of the t-tests are given in Table A10.

TABLE A5

A COMPARISON OF TWO-WAY STOP VS. SIGNAL CONTROLLED INTERSECTIONS

Intersection	f_o*	f_c*	$\lvert f_o-f_c\rvert -\frac{1}{2}$	$(\lvert f_o-f_c\rvert -\frac{1}{2})^2/f_c$
Two-Way Stop	1238	1331	92.5	6.42
Signal	1232	1139	92.5	7.51
	2470	2470		13.93

$x^2 = 13.93$ *

Hypothesis: The signalling distribution is in the ratio of 1956/1673.

$x^2_{.01} = 6.63$

$x^2 = 13.93 > x^2_{.01} = 6.63$ Reject the hypothesis

TABLE A6

A COMPARISON OF FOUR-WAY STOP VS. SIGNAL CONTROLLED INTERSECTIONS

Intersection	f_o*	f_c*	$\lvert f_o-f_c\rvert -\frac{1}{2}$	$(\lvert f_o-f_c\rvert -\frac{1}{2})^2/f_c$
Four-Way Stop	1187	1236	48.5	1.90
Signal	1232	1183	48.5	1.99
	2419	2419		3.89

$x^2 = 3.89$ *

Hypothesis: The signalling distribution is in the ratio of 1798/1673.

$x^2_{.05} = 3.84$

$x^2 = 3.89 > x^2_{.05} = 3.84$ Reject the hypothesis

*where f_o = observed frequency

f_c = calculated or theoretical frequency

x^2 = chi square variable

TABLE A7

A COMPARISON OF TWO-WAY STOP VS.
FOUR-WAY STOP INTERSECTIONS

Intersection	f_o*	f_c*	$\lvert f_o-f_c\rvert -\frac{1}{2}$	$(\lvert f_o-f_c\rvert -\frac{1}{2})^2/f_c$
Two-Way Stop	1238	1263	24.5	0.47
Four-Way Stop	1187	1162	24.5	0.51
	2425	2425		0.98

$x^2 = 0.98$ *

Hypothesis: The signalling distribution is in the ratio of 1956/1793.

$x^2_{.05} = 3.84$

$x^2 = 0.98 < x^2_{.05} = 3.84$ Do not reject the hypothesis

TABLE A8

COMPARISON OF SIGNAL DISTANCES OF
100 FEET OR GREATER

Intersection	f_o*	f_c*	$\lvert f_o-f_c\rvert -\frac{1}{2}$	$(\lvert f_o-f_c\rvert -\frac{1}{2})^2/f_c$
Two-Way Stop	361	336	24.9	1.84
Four-Way Stop	299	323	24.2	1.80
Signal	333	334	0.1	0.00
	993	993		3.64

$x^2 = 3.64$ *

Hypothesis: The signal distances for 100 feet or greater are in the ratio of 1238/1187/1232.

$x^2_{.05} = 3.84$

$x^2 = 3.64 < x^2_{.05} = 3.84$ Do not reject the hypothesis

*where f_o = observed frequency

f_c = calculated or theoretical frequency

x^2 = chi square variable

TABLE A9

MEAN DISTANCES AND ESTIMATED STANDARD DEVIATIONS

Intersection	Mean Distance	Standard Deviation
Two-Way Stop	41.6	29.6
Four-Way Stop	42.5	30.2
Signal	43.4	28.3
Combined	42.5	29.0

TABLE A10

COMPARISON OF MEAN DISTANCES WITH THE STANDARD DISTANCE OF 100 FEET

Hypothesis: The mean (distance) of the population is 100 feet.

	Two-Way	Four-Way	Signal	Combined
t statistic value	56.3	56.6	60.0	84.5
critical $t_{.05}$ value	1.96	1.96	1.96	1.96

Reject the hypothesis for all cases.

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