A Study of Accident Experience at Michigan Trunkline Intersection Control Beacon Installations

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Chapter 1

SUMMARY OF STUDY

It has been some years since an organized before-after analysis of the accident effects associated with the installation of Intersectional Control Beacons (ICB), commonly known as flashers, has been made at Michigan Department of State Highways and Transportation (MDSHT) Trunkline Intersections where these beacons have been installed. While these devices are not expensive to install they do lay a continuing maintenance and replacement burden on highway forces, and because of their dispersed locations, their surveillance requires continuing effort. It is clear that the policy of the MDSHT is to use these devices where needed and where they are cost-effective and to avoid their use elsewhere.

This project was undertaken to take advantage of the several years of accident data available in the computer files of the MDSHT. Also, in the 1967-74 period there were several hundred ICB changes at MDSHT Trunkline Intersections therefore providing a significantly large data base of new installations.

The purpose of this study was to identify these locations, determine the overall accident response effect following their installation, and further differentiate this effect in terms of such elements as accident severity, type, frequency, as well as characteristics of the location and traffic involving such measures as ADT, rural or urban location, approach and intersection geometrics and sight distance. The final product is intended to be a revised warrant for use by MDSHT and other agencies in the state.

The main points of the analysis are that while total reduction in accident experience at 77 locations where ICB's were initially installed was not down significantly there were types of intersections at which improvement in total accident experience was recorded. There was a general overall lowering of the fraction of accidents involving injuries or fatalities (expressed as the severity ratio). A number of significant differences were found and a set of recommended warrants are described in Chapter 5.

In the following chapters the nature of the problem, the approach adopted by the research team, and the procedures followed in acquiring and analyzing data are presented in Chapters 2 and Appendix B. The results of an analysis of total accident experience at 77 intersection control beacon installations made between 1967 and 1974 are described in Chapter 3. Chapter 4 presents a comparison of the characteristics found at 8 installations where there were significant increases in accident experience following the installation of an ICB and 19 intersections where there were the most significant reductions in accident experience were found. A new set of warrants for flasher installations is recommended in Chapter 5.

Chapter 2
APPROACH

2-1 The Problem

The purpose of this research is to provide the MDSHT with an improved method of deciding when and where to install flashing beacons on the state trunkline system. The criteria used are based primarily on the principle of investing funds for this type of improvement only when it can be shown that there is a net benefit to the public by doing so and when this is clearly a better investment for MDSHT funds than are other alternatives. The second criterion is outside the range of this research but information is provided on the first which will enable the state to place this type of traffic control device in its proper place as a tool for a better highway system.

The procedure to be followed is be based on historical data from the records of the MDSHT augmented by field observations. Reviews of literature, independent analysis and discussions with MDSHT personnel are a part of the program.

The approach is based on the belief that the installation (and rejection) of intersection control beacons in the past, in response to warrants and engineering judgement, has been a response to the full range of practical dimensions of the problem. It is believed that a comprehensive review of the circumstances under which the installation decision was made provides useful guidelines for installation judgement.

Intersection control beacons (ICB) are relatively simple traffic control devices which do not have an unique right-of-way allocation function. ICB's,commonly called "flashers", are displayed so the main street directions receive a flashing yellow indication and the side streets receive a flashing red indication. They are used in addition to the other devices used at major-minor route stop sign controlled intersections. Their use is primarily to provide the additional safety associated with heightened attention to the side street by major street vehicles and a stronger indication to the side street vehicles that they must stop at this location. The results of this should be in improved safety.

These beacons are not expensive to install (as little as $500.00 has been spent) and they would appear to have no positive or negative environmental impact. Also, their impact on high-flow traffic should be minimal. Accordingly, one would expect that the analysis of the effectiveness of beacon installations would involve benefits measurable in safety terms matched against simple costs of engineering, installation and maintenance, certainly a relatively simple traffic control device evaluation procedure. Of course, inappropriate excessive use would be expected to diminish desired driver response.

Intersection Control Beacons are intended for use at intersections where conventional traffic signals are not justified but where potentially or actual high accident rates indicate a special hazard (MMUTCD, 4-E-3, 1973).

Current Michigan warrants (guidelines) for such installations (not specified in the national manual) are as follows (MMUTCD, 4-E-3):

1. Six or more accidents considered correctable by a beacon in a two-year period for rural roads (85 percentile speed greater than 40 m.p.h. or in the built-up areas

of small isolated communities).

2. For new roadways with an 85 percentile speed or speed limit greater than 40 m.p.h. and

   a. Meeting 50% or more of the traffic signal volume warrant.

   b. Stopping sight distances less than 550 feet for speeds of 40 to 55 m.p.h. and 750 feet for speed of 55 to 65 m.p.h.

These warrants have evolved from earlier standards (MMUTCD, 1963 edition). The accident value then used was four accidents over a two year period.

It is understood that Michigan has recently found conflicting results in before and after accident studies involving the installation of the ICB. These of course, are the type of accidents that are intended to be reduced by the installation of this traffic device.

2- 2 Previous Studies and Comments

There have been several previous studies of the accident effectiveness of flasher installations (see Bibliography). The research team has summarized these findings and their results are presented individually in Appendix C. In the following paragraphs their overall effect is described.

All of the studies reviewed used before-after comparisons in identifying flasher effectiveness on accident reduction. The number of sample intersections varied widely among these studies: from as few as nine intersections in Thorpe's study (1963) to the 82 Ohio intersections studied by Foody and Taylor (1967). There were also variations in the basic type of control; Tamburri's study (1968) involved eight four-way red controls among 29 investigated intersections. Five of Thorpe's nine Australian intersections were controlled by four-way yellow beacons before the installation of the flashers. The display devices used ranged from the simple overhead beacon to elaborate combinations of overhead and roadside units. Cribbins and Walton (1969) and Foody and Taylor (1967) were exclusively concerned with rural intersections.

The measurement of accident experience and the method of statistical tests also varied among these studies. Foody and Taylor used paired t-tests on the entering vehicle accident rate. After examining the number of accidents, the accident rate, the equivalent property damage only (EPDO) accidents, the EPDO accident rate, and the severity index (ratio of the number of accidents involving injuries and/or fatalities to the total) for 14 intersections in North Carolina, Cribbins and Walton used EPDO accident rate as a measure of effectiveness and applied t-tests. Chi-square tests on the number of accidents were also frequently used (e.g. Solomon, (1959). Tamburri applied chi-square tests to the number of EPDO accidents. The research team has conducted a chi-square analysis of the Cribbins-Walton data.

Overall Effects

Although the analysis of the accident data was conducted in different ways, all the studies found a general decrease in accidents following the installation of ICB's. Foody and Taylor, with the largest sample of 82 intersections, found a 53% reduction in the accident rate (a 38% decrease in total accidents). Solomon found a decrease of 26% for 50 Michigan intersections while Tamburri had a 40% reduction for 29 intersections. Cribbins and Walton found a 27% decrease for 14 intersections, and Thorpe had an average decrease of 30% for 9 intersections. In Andreassend's analysis of 25 intersections, all accidents decreased an average of 20%. Andreassend also analyzed Thorpe's results for 9 intersections and an Oregon study of 8 intersections and found reductions of 42% and 5% respectively.

Intersection control beacons were also found to reduce fatalities and injuries. Solomon found that the number of persons injured decreased by 50%. Tamburri found a general reduction in accident severity and EPDO rates. Cribbins and Walton also found a reduction in fatalities and 50% on minor and 67% in major injuries.

Intersection Type

Most of the studies found a decrease in both 3 and 4-leg intersections with a greater reduction for 3-legs. Solomon found a 32% decline in accidents at 3-leg intersections, a 21% reduction at 4-leg undivided, a 30% reduction at 4-leg divided, and a 37% reduction at 5, 6-leg and other complex configurations. Tamburri found a 31% decrease at 4-leg and a 53% decrease at 3-leg intersections. Cribbins and Walton found a 65% decrease at 3-leg and an 18% decrease for 4-leg intersections. In Foody and Taylor's study the only intersection group showing a significant reduction in accidents was the 4-leg intersection with 2 lane minor and major roads.

Some of the studies also analyzed intersections by whether or not they were channelized. Tamburri found that the accident rate reduction at 4-leg unchannelized intersections was considerably greater (38%) than at those channelized (26%). The accident rate at unchannelized intersections after the installation was still greater than the before accident rate at channelized intersections. Solomon, on the other hand, found that 4-leg channelized had a 30% reduction while 4-leg unchannelized had only a 21% reduction. Cribbins and Walton also found better results for channelized intersections. In their study there was a 47% reduction (3 per site/year) for channelized and a 24% (but not statistically significant 1.5 accidents/site/year) increase for nonchannelized intersections.

Type of Collision

Most of the studies also investigated the effect of the flasher installations on the reduction of different types of collisions. Solomon's analysis gave an 18% reduction for rear-end collisions, 32% reduction for head on, 25% reduction for sideswipe, 29% reduction for right angle and a 21% reduction for all others. Thorpe found right angle collisions reduced by 40% while Andreassend found a reduction of 29% for right angle collisions. Andreassend's analysis of Thorpe's study and an Oregon study resulted in reductions of 50% and 73% respectively. Tamburri's results indicated that multiple vehicle accidents were reduced markedly, especially right-angle broadside collisions. Cribbins and Walton's data do not detect any differences between single and multiple vehicle accidents. At 4-leg intersections rear-end accidents were reduced 46% and running off the road 70%. The ICB installation virtually eliminated the single vehicle accident at the 3-leg intersection where the vehicle on the minor leg runs through the intersection and off the road. Foody and Taylor found that there was no significant difference between various types of accidents, and concluded that ICB's were equally effective for all types.

Environmental Conditions

The studies were also concerned with the intersection control beacon's effect in regard to light and weather conditions. Solomon found that the number of accidents decreased in all weather conditions. Foody and Taylor found that there were no significant differences between reductions for daylight and night time accidents. Tamburri also found the ICB's were generally equally effective, day or night.

ADT

Two of the studies, Solomon's and Foody and Taylor's also addressed the effect of volume on the effectiveness of ICB's. In Solomon's study the intersections where ICB's were installed had an average ADT of 8,000 vehicles and there was a reduction in acc/mv (accidents per million vehicles entering the intersection) of 17%. For 16 intersections with below average ADT a reduction of 22% was calculated and for 8 intersections with above average ADT's a 10% decline was observed. Foody and Taylor found that volume did not significantly influence the reduction in accident rates. They did observe that for those intersections with an average ADT of 5,000 vehicles the reduction was .75 acc/mv for 3-leg intersections and 1.54 acc/mv for 4-leg intersections. For another group of 4-leg intersections the average ADT was 14,000 vehicles and the accident reduction was only .33 acc/mv. It therefore appears that volume should be considered when installing ICB's.

<u>Sight Distance</u>

In Tamburri's study it was stated that ICB's were used where sight distance was especially limited. Yet, Foody and Taylor's study indicated that line of sight was not a factor influencing the reduction in accidents. The Michigan Manual has a sight distance warrant.

<u>Comments</u>

There are notable discrepancies among these studies in many of their conclusions regarding the flasher's differential effects. It appears to the research team that the use of accident rates have made it impossible to directly examine and reach statistically supportable conclusions on the flasher's differential effects.

It must be remembered that the conditions prevailing at the intersections within the jurisdiction as well as the warrants used to determine the locations selected for flasher installation may strongly affect the accident experience during the after installation period. There may be explainable differences, in before-after periods, even in the same agency's intersections as a result of the different characteristics of the intersections being considered and the judgment of the engineer making the installation decision.

2-3 The Research Approach

The context of a before-after study must consider the full set of historical decisions on the installation of traffic control devices in a state such as Michigan where careful attention has been given to these devices for many years. It is clear that the set of intersections and the conditions which existed at the intersections prior to the decision to place ICB's and upon which Solomon's data are developed (1950-57) is significantly different than the conditions found to exist prior to the 1967-74 installations. Differences in the studies may very well explained by this set of circumstances For example, in the 1967-74 period very few complex multiple lane, multiple-leg intersections had flasher installations installed for the first time.

This, for example could explain the average 26% reduction in total accident experience found by Solomon in his study of the 1950 decade ICB installations in contrast with the only 4% reduction recorded in the decade centered on 1970 and reported upon in this study. The Foody-Taylor results indicate a 53% reduction for Ohio installations made in the decade centered on 1960.

Clearly this study is required to be capable of representing the effects of these temporarily changing conditions on accident experience. Also, the identification of the population of installations and sampling are of crucial importance in determining the overall effects of this device as well as in efficiently identifying the conditions where the device can be successfully installed.

A comprehensive list of potential contributing factors is developed from a literature review for the use in this study, and possible sources for information acquisition are investigated. The population for flasher installations is identified through a thorough review of MDSHT Central Traffic Files for installation years from 1967 through 1974 for which MDSHT accident data are available. The procedure and problems associated with this are described in Appendix B, Sections 1 and 2. As a result, 77 installations were identified and a decision was made to employ all of these as the sample.

As is typical in the previous studies, a before-after analysis of accident experience is selected as an adequate method in identifying the flasher effectiveness and contributing factors and further in developing warrants for flasher installation. In this study, contingency analysis of the number of before-after accidents is almost exclusively used. The use of accident rate normalized by the traffic exposure is avoided since the accident cost is not appropriately represented in this measure, and since its statistical property is less suitable for efficient and valid analysis. Kullback's information statistic is used as a test statistic for these contingency tables because of its computational ease and the theoretical firmness in its derivation.

The study consists of two stages. The first stage is concerned with the exploration of the overall effects of flasher installations, and the macroscopic examination of the interactions between the flasher effectiveness and other (particularly intersection geometric) factors. By examining the available data sources, it is recognized that most of the geometric factors examined in the previous studies can be incorporated in this stage.

The second stage employs a reduced sample set to enable an in-depth data collection and analysis of extensive factors which may be related with the flasher effectiveness. To obtain an effective sample set, it was decided to sample intersections with extreme accident experience.

It is expected that warrants for flasher installations can be obtained empirically from the macroscopic analysis of the first phase. The second phase analysis provides informal guidelines to assist the MDSHT engineer in the flasher installation decision.

The contingency analysis is also used in the second phase with a nominal representation of accident experience: significant increase or decrease in the number of accidents following the flasher installation. Fisher's exact probability is used in testing the significance of these contingency tables with relatively small number of observations.

CHAPTER III
ANALYSIS OF ACCIDENT EXPERIENCE AT 77 INTERSECTIONS

3-1 Statewide Results: 1967-74 Flasher Installations

The results presented in this chapter are based on the accident experience at all 77 MDSHT intersections where flashers were installed between 1967 and 1974 for which the various data are comparable. Appendix B describes the complex location identification and data-collection processes followed in the research. In the before-after comparison, two year periods were used because of the high variation in accident occurrence. However, to avoid possible biases in the resulting sample, no intersections were eliminated from the study because of shorter "before" or "after" periods. These are occasionally found, for example, when a traffic signal is installed less than two years after the flasher installation.

Total Accident, Severity and Type

At these locations, a total of 997 accidents were recorded in the "before" period, and 961 accidents in the "after" period, a four percent decrease (not statistically significantly different at any reasonable risk level).

Table 3-1 compares the before-after accident experience by level of accident severity (property damage only accident versus those involving injuries and/or fatalities). An important reduction of 21 percent in severe accidents can be seen following the flasher installation, as most previous studies have found. At the same time property damage accidents increased 10 percent statistically significant at the 99.5 percent level. The increase in property damage accident is close to the average growth in traffic over two year periods in this era.

TABLE 3-1

BEFORE-AFTER COMPARISON: ACCIDENT SEVERITY

	ACCIDENT SEVERITY		
Period	Property Damage Only	Injury/ Fatal	Total
Before	550	447	997
After	607	354	961
Total	1157	801	1958

(77 intersections)

2I= 12.97, P = .005

2I: Kullback's information statistic . To be used as a chi-square value.

Table 3-2 shows the number of accidents classified into six common types: angle, left-turn, rear-end, other multi-vehicle, single-vehicle, and others. There is no clear indication that any of these types of accident is disproportionally reduced by the flasher installation. This is quite contradictory to previous findings, (Andreassend (1970), and Tamburri (1968)). This result suggest that the current MDSHT practice of regarding the number of angle accidents as particularly correctable by the flasher may not be appropriate as a basis for the engineering judgement used in flasher installation decisions.

TABLE 3-2

BEFORE-AFTER COMPARISON: ACCIDENT TYPE

ACCIDENT TYPE

Period	Angle	Left Turn	Rear End	Other Multi-Vehicle	Single Vehicle	Other	Total
Before	428	138	156	146	97	32	997
After	422	114	164	141	90	30	961
Total	850	252	320	287	187	62	1958

(77 intersections)

2I= 2.28, P = .15

Since the type of accident has been viewed as important in warranting the installation of ICB devices the severity by type of accident was developed and is presented in Table 3-3. There is a large difference in severity by accident type ranging from over 60 percent of the accidents involving injuries for angle collision accidents before the flasher installation to less than 20 percent for "other" accidents (two classes) following installation of the flashers there was still a large difference by type.

Specifically, the most significant findings are described below .

For angle accidents the reduction in severity moved almost 1/4 of this type of accident from the personnal injury-fatality class to the property damage (PD) only class, a highly significant result as is seen in the following tabulation.

	Personal Injury Accidents	
	Number	Percent
Before	258	60.3%
After	197	46.7%

Both rear end and single vehicle personal injury accidents were reduced substantially as shown below.

	Rear End		Single Vehicle	
	Number	Percent	Number	Percent
Before	56	35.9%	40	41.2%
After	43	26.2%	28	31.1%

TABLE 3-3

ACCIDENT TYPE AND SEVERITY

Accident Type	Before PD	Before Injury/ Fatal	After PD	After Injury/ Fatal	Total
Angle	170	258	225	197	850
Left-turn	80	58	68	46	252
Rear-end	100	56	121	43	320
Single Vehicle	57	40	62	28	187
Other multi-vehicle	114	32	104	37	287
Other	29	3	25	5	62
Total	550	447	607	354	1958

PD: Property Damage accidents

This result is significant at the 10 percent level for rear end accidents and while not statistically significant is encouraging for single vehicle accidents.

Taken as a group, these three accident types have the following injury record.

	Number	Percentage
Before	354	52.0%
After	268	39.6%

It is clear that these installations have been particularly effective in reducing the severity of these three accident types but not their number. Other kinds of accidents recorded a small and insignificant decrease in numbers and no change in relative severity.

Environmental Condition

Table 3-4 presents the before-after comparison by natural light condition. A 14 percent reduction in night-time accidents coupled with a 6 percent increase in day-time accidents are seen. This effect is significant at the 95 percent level. This gives additional statistical support to Solomon's Michigan findings.

Analyses were further conducted on the flasher installations' differential effects on accident frequency by weather and roadway surface conditions (see Appendix Table A-3-1). There was no support for the effects previously reported by Solomon (1959).

TABLE 3-4

BEFORE-AFTER COMPARISON: LIGHT CONDITIONS

	LIGHT CONDITION		
Period	Daylight	Dusk/ Dark	Total*
Before	651	306	957
After	688	262	950
Total	1339	568	1907

(77 intersections)

$2I = 4.41$, $P = .04$

* Not including accidents with light condition unknown

Effect of Intersection Geometrics

Data obtained from the engineering drawing accompany the MDSHT work authorization form, or from the MDSHT sufficiency rating were examined for their impact on flasher effectiveness. In Table 3-5, the intersections are classified into two types: the first type involves major roadways with two lanes, and the second those with more than two lanes. A 19 percent reduction in the number of accidents at two-lane intersections, and a 12 percent increase at wider intersections can be seen (significant at the 99.5 percent level).

TABLE 3-5

BEFORE-AFTER COMPARISON: APPROACH WIDTH

NO. OF LANES

Period	Two Lanes*	More Than Two Lanes**	Total
Before	508	489	997
After	412	549	961
Total	920	1038	1958
(No. of Intersections)	(51)	(26)	(77)

$2I = 12.84$, $P < .005$
* $2I = 10.04$, $P < .005$
** $2I = 3.47$, $P = .07$

*,** Kullback's statistic for each column treated as a one dimensional contingency table

Some previous studies have found associations between the number of intersection legs and before-after accident experience. Table 3-6 shows this study's reuslts. There was a 21 percent increase at the 19 three-leg intersections (all "T" type) and a 10 percent decrease at the 57 four-leg intersections (significant at the 99 percent level). These results are quite different from previous findings, many of which indicated that more (not necessarily significant) reduction in accidents occurred at three-leg intersections (Solomon, Cribbins, Walton). When the table is reduced to a two-by-two table by omitting the one five-leg intersection we conclude that the flasher is more effective at the last decade's four-leg intersections in Michigan (significant at the 99.5 percent level).

The differences in accident severity for the three-leg and four-leg intersections, are presented in Table 3-7. From the table for the three-leg intersections, it can be seen that the 21 percent increase is entirely in property damage accidents, and the severity index, the fraction of accidents with injuries or fatalities, is reduced from .392 to .313. The interaction in this table is significant at the 90 percent level. A reduction in the severity index from .465 to .390 is seen for the four-leg intersections (significant at the 99.5 percent level). It should be noted that the before-period severity index for the four-leg intersections is 19 percent higher than for the three-leg intersections, and is reduced after the flasher installation to the "before" level for three-leg intersections. The reduction in the severity index is practically the same for these two types of intersections.

TABLE 3-6

BEFORE-AFTER COMPARISON: NUMBER OF APPROACH LEGS

	NUMBER OF APPROACH LEGS			
	3-Legs	4-Legs	5-Legs	Total
Before	217	770	10	997
After	262	694	5	961
Total	479	1464	15	1958
	(19)	(57)	(1)	(77)

2I = 9.22, P = .01

*2I = 7.69, P = .006

( ): Number of Intersections

* One 5-Leg intersection excluded

TABLE 3-7

BEFORE-AFTER ACCIDENT SEVERITY: NUMBER OF INTERSECTION LEGS

ACCIDENT SEVERITY

3-Leg Intersections

Period	PD	Injury/ Fatal	Total	Severity Index
Before	132	85	217	.392
After	180	82	262	.313
Total	312	167	479	

(19 Intersections)

2I = 3.23, P = .07

4-Leg Intersections

Period	PD	Injury/ Fatal	Total	Severity Index
Before	412	358	770	.465
After	423	271	694	.390
Total	835	629	1464	

(20 Intersections)

2I = 8.27, P $<$.005

Table 3-8 shows the accident type changes for the respective intersection classes. For three-leg intersections, there was a 53 percent increase in angle accidents but no other type responded strongly (significant at the 75 percent level). In a reduced two-by-two table (angle vs. all other multi-vehicle accident types), the interaction is significant at the 90 percent level. The relative increase in the number of single vehicle accidents is almost the same as the increase in the total accidents, contrary to Tamburri's findings.

The lower part of Table 3-8 shows that there is no difference in the accident type frequencies before and after the flasher installation at four-leg intersections. The extremely low value of the test statistic, .92, is not significant at any level. Again the present result contradicts those of Tamburri.

Other tentative findings associated with the intersection geometrics include: a more significant severity reduction at unchannelized intersections (intersections without turning lanes or flares, but possibly with improved large radius curb cuts at the corners, Appendix Table A-3-2) similar to Cribben and Watson's finding, but contrary to that of Tamburri; more severity reduction at intersections with divided major roadways (Table A-3-3); and more significant severity reductions at right angle intersections (Table A-3-4). Two of the above intersection types (unchannelized and right angle) also have a reduction in the total number of accidents itself (see Appendix Table A-3-5). However,

TABLE 3-8

BEFORE-AFTER ACCIDENT-TYPE FREQUENCIES: NUMBER OF INTERSECTION LEGS

ACCIDENT TYPE

3-Leg Intersections

Period	Angle	Left Turn	Rear End	Other Multi-Vehicle	Single Vehicle	Other	Total
Before	59	28	49	47	29	5	217
After	90	24	61	46	35	6	262
Total	149	52	110	93	64	11	479

(19 Intersections)

2I = 4.55, P = .5

4-Leg Intersections

Period	Angle	Left Turn	Rear End	Other Multi-Vehicle	Single Vehicle	Other	Total
Before	366	106	106	98	67	27	770
After	328	90	102	95	55	24	694
Total	694	196	208	193	122	51	1464

(57 Intersections)

2I = .92, P = .95

none of these reductions is significant at the 95 percent level. The differential effect of skewness on the total number of accidents is very small.

Rural-Urban Differences

The effect of roadside area type was examined employing the MDSHT TVM urban/rural classification (Table 3-9). At 53 rural intersections, the number of accidents was significantly reduced by 16 percent, but at urban area intersections it increased by 12 percent after the flasher installation (statistically significant at the 90 percent level). Severity was more significantly reduced in urban areas, from a severity index of 0.440 to 0.339, a 23 percent reduction in the expected fraction of injury/fatality accidents. The lesser 12 percent severity ratio reduction in the rural area is also significant at the 90 percent level.

Further Investigation of Approach Width Effect

Intuitively, the magnitude of complexity in judging the acceptability of a gap by the minor-road driver stopped at the intersection should increase as the number of major-road lanes increases. A flasher does not provide any additional help in this judgment, although it warns the major-road driver about the possibility of a minor-road driver accepting a small gap. Thus, at intersections where gap judgment is difficult, the flasher's effect may be less than at other intersections. The results on the interaction of the number of lanes and before-after accident experience (Table 3-5) supports this hypothesis. This subsection further explores the effect of major-road width on flasher effectiveness.

TABLE 3-9

BEFORE-AFTER ACCIDENT SEVERITY: AREA TYPE

ACCIDENT SEVERITY

Urban Areas

Period	PD	Injury/ Fatal	Total	Severity Index
Before	249	196	445	.440
After	329	169	498	.339
Total	578	365	943	

(24 intersections)

2I=10.12, $P < .005$

Rural Areas

Period	PD	Injury/ Fatal	Total	Severity Index
Before	301	251	552	.455
After	278	185	463	.400
Total	579	436	1015	

(53 intersections)

2I= 3.12, P = .08

Table 3-10 shows the before-after accident-type differences at 51 two-lane intersections. Again, there is no indication that the flasher reduces any particular type of accident unusually. Although the angle accidents show a 30 percent reduction, this is not significantly different from the reduction recorded by the other types.

In Table 3-11 changes in accident severity are tabulated for both the two-lane intersections and wider intersections, respectively. It is noted that the severity reduction at two-lane intersections is not as significant as that associated with wider intersections. On the other hand, at intersections with more than two lanes, the number of injury/fatality accidents is reduced by 12 percent in spite of the 12 percent increase in total number of accidents.

The above relationship between the total number of accidents and accident severity is similar to those found for the urban-rural area type. As will be seen later, the area type and the number of lanes are highly correlated, and because of the nature of MDSHT improvements, the separation of the effects of these two factors is not possible.

3-2 Predictability of After Installation Accident Experience from ADT and Accident Data

Figures 3-1 through 3-3 exhibit a measure of the before-after accident experience at 72 intersections against the total number

TABLE 3-10

BEFORE-AFTER ACCIDENT TYPE FREQUENCIES: TWO-LANE MAJOR-ROAD INTERSECTIONS

	ACCIDENT TYPE						
Period	Angle	Left Turn	Rear End	Other Multi-Vehicle	Single Vehicle	Other	Total
Before	207	78	69	87	53	14	508
After	146	59	75	72	43	17	412
Total	353	137	144	159	96	31	920

(51 intersections)

2I= 6.21, P = .7

TABLE 3-11

BEFORE-AFTER ACCIDENT SEVERITY: NUMBER OF MAJOR-ROAD LANES

Two Lanes

	ACCIDENT SEVERITY			
Period	PD	Injury/ Fatal	Total	Severity Index
Before	283	225	508	.443
After	255	157	412	.381
Total	538	382	920	

(51 intersections)

2I= 3.59, P = .06

More than Two Lanes

Period	PD	Injury/ Fatal	Total	Severity Index
Before	267	222	489	.454
After	352	197	549	.359
Total	619	419	1038	

(26 intersections)

2I= 9.72, $P < .005$

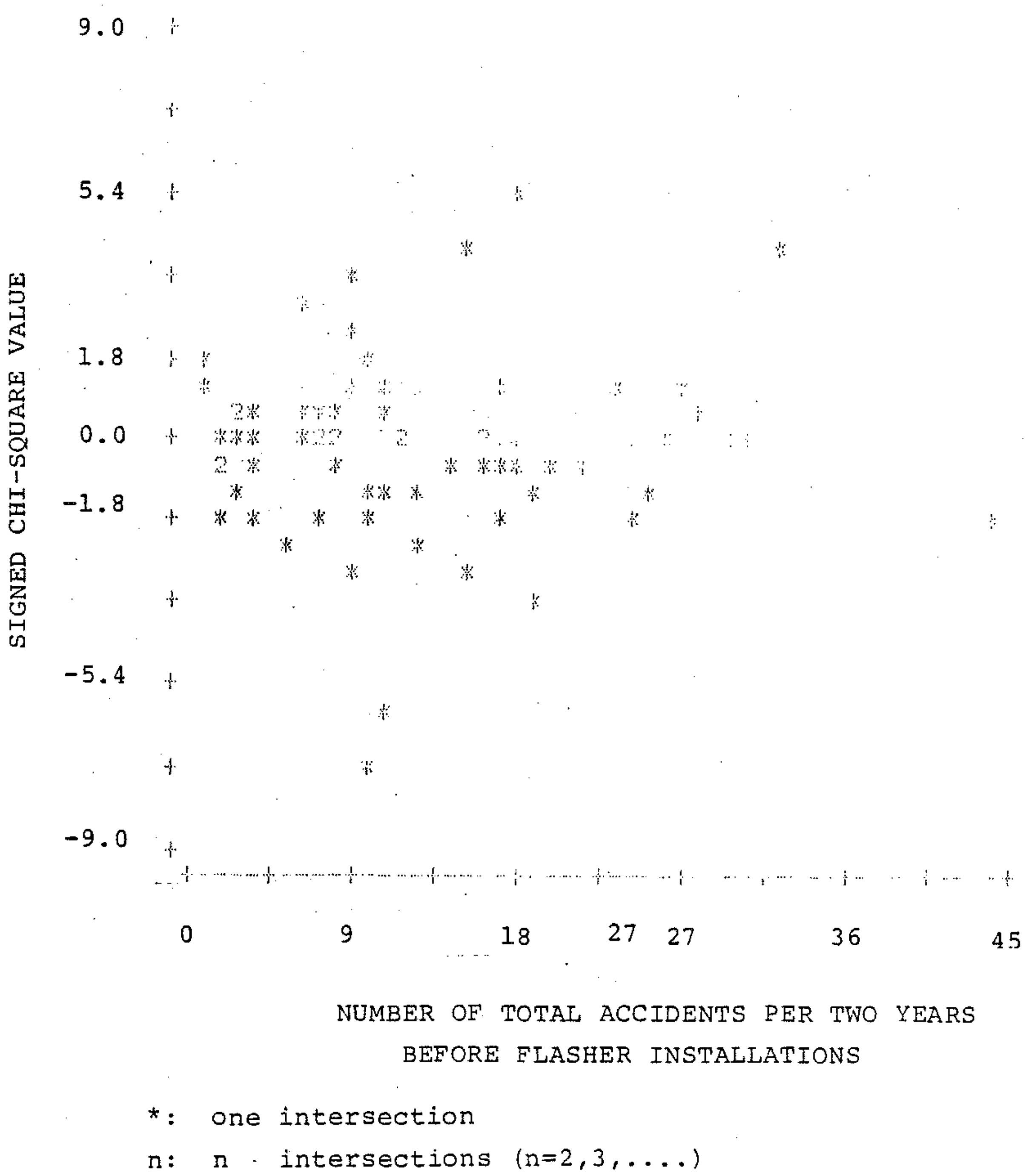

FIGURE 3-1 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY ACCIDENT EXPERIENCE BEFORE FLASHER INSTALLATION

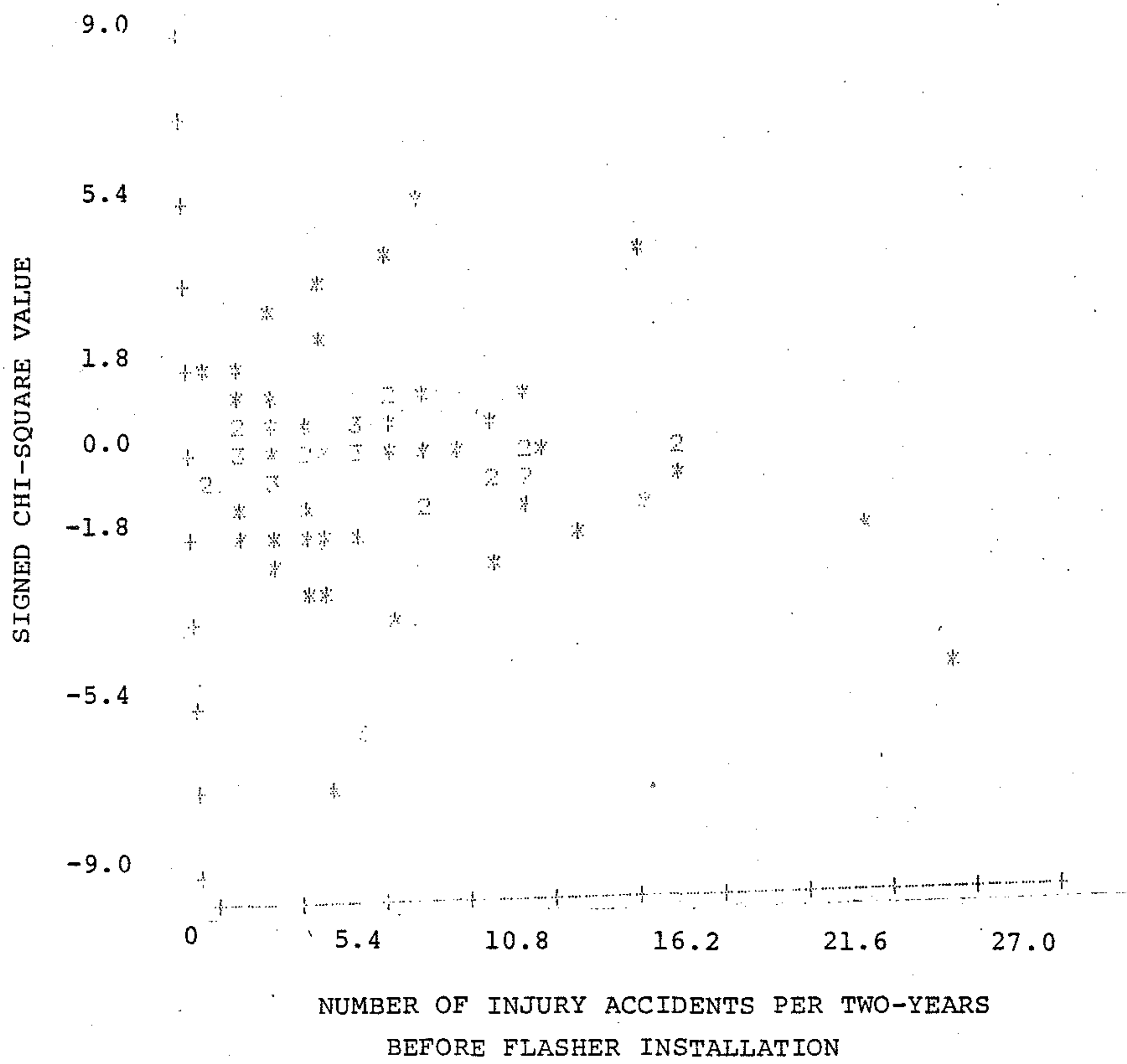

FIGURE 3-2 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY INJURY ACCIDENT EXPERIENCE BEFORE FLASHER INSTALLATION

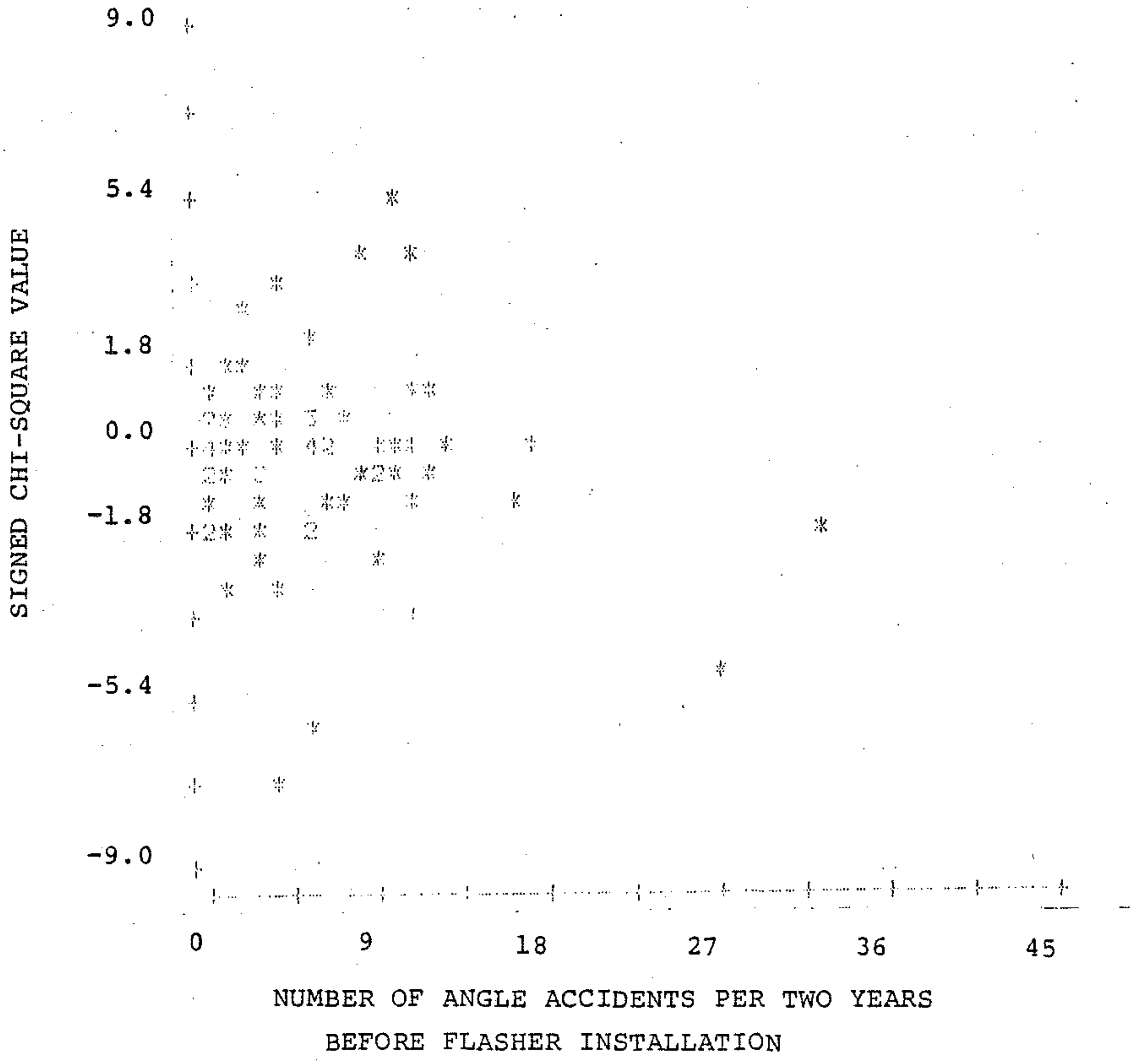

FIGURE 3-3 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY ANGLE ACCIDENT EXPERIENCE BEFORE FLASHER INSTALLATION

of accidents in the two-year before period, injury accidents, and right-angle accidents, respectively. Five intersections where the accident data were available only for a one-year before-period are excluded. The accident experience is represented by a signed chi-square value for the before-after difference in the total number of accidents for each intersection. When the number of accidents decreased after the flasher installation, a negative sign is attached to the chi-square value. These signed chi-square values are plotted along the vertical axis of these three figures.

In these figures, no clear relationship can be seen relating the accident experience in the "before" period to the significance or direction of accident change after the flasher installation.

From Figure 3-3, it can be seen that the number of right-angle accidents can hardly serve as a basis of judgment for the flasher installation decision. Within the range from 0 to 15 accidents in two years, the bulk of the experience, there is no tendency relating the number of right-angle accidents to the signed chi-square values as measures of before-after accident experience. There are a few intersections with more than 15 before-period accidents for which the tendency toward reduction is notable. This tendency can also be found in Figure 3-2 for the number of injury accidents.

The effect of ADT is plotted in Figure 3-4, again employing the signed chi-square values in representing the before-after accident experience. The value of the correlation coefficient the ADT increases, accidents tend to decrease less after the flasher installation. HOwever, this associate is not strong.

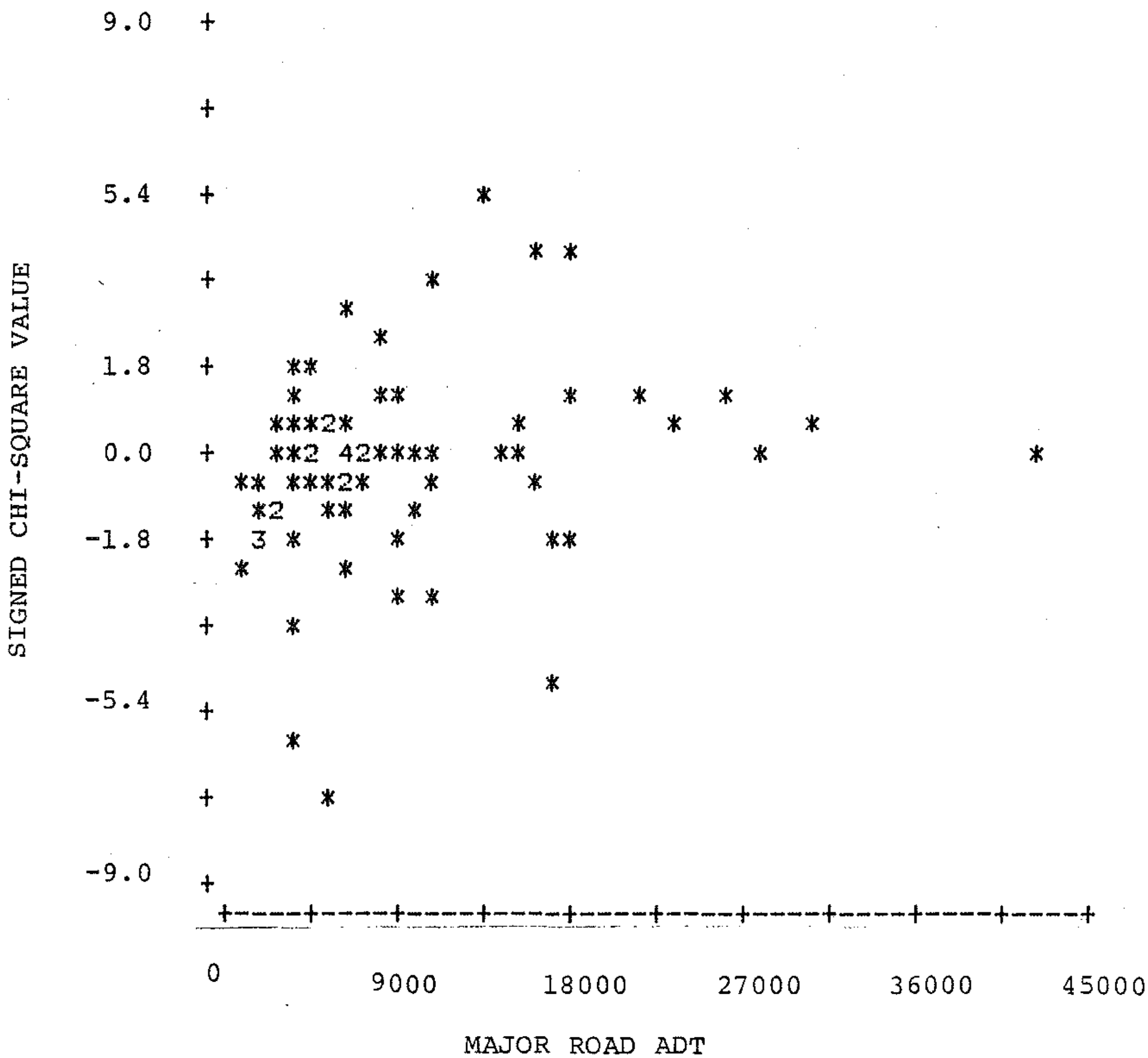

FIGURE 3-4 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY MAJOR ROAD ADT

For the intersections for which traffic flow data were available, signed chi-squares are plotted against the minor-major road traffic ratio as well as the total left-turn traffic total inbound intersection traffic ratio in Appendix Figures A-3-1 and A-3-2. Again no clear relationship is found.

Figures 3-5 through 3-7 present the signed chi-square value against: total accident rate, injury/fatality accident rate and right-angle accident rate, respectively. All accident rates are normalized by major-road ADT to accidents per million inbound-vehicles (MIV). In these figures, the most significant accident increases (positive large signed chi-square values) are found at the lower accident rates. No significant increase (at the 75 percent level) is observed when the MIV accident rate exceeds 3.4 total accidents, 1.2 injury accidents and 1.2 angle accidents per MIV. When the accident rate is lower than the above values, there is no clear relation between the before-period accident rate and before-after accident experience.

As simple correlation coefficients with the signed chi-square values, the total accident rate, injury accident rate and angle accident rate have values of -0.31, -0.27, and -0.25, respectively. In practice, there is little difference among these three measures in predicting the consequences of flasher installation. Further these three measures are highly intercorrelated (see Table 3-11, in next section).

It should be noted here that neither the signed chi-square values nor accident rates directly represent the before-after

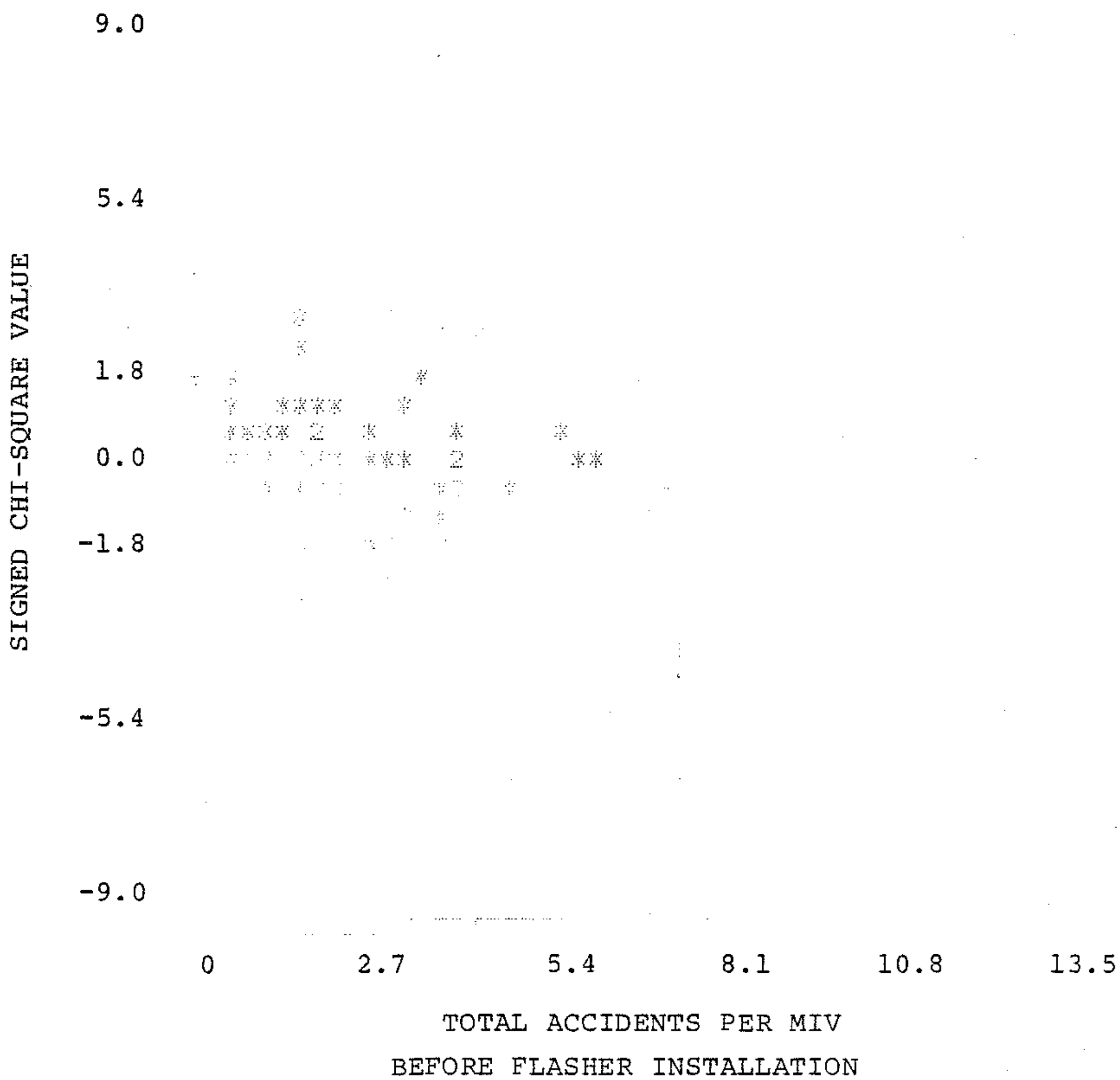

FIGURE 3-5 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY TOTAL - ACCIDENT RATE BEFORE FLASHER INSTALLATION

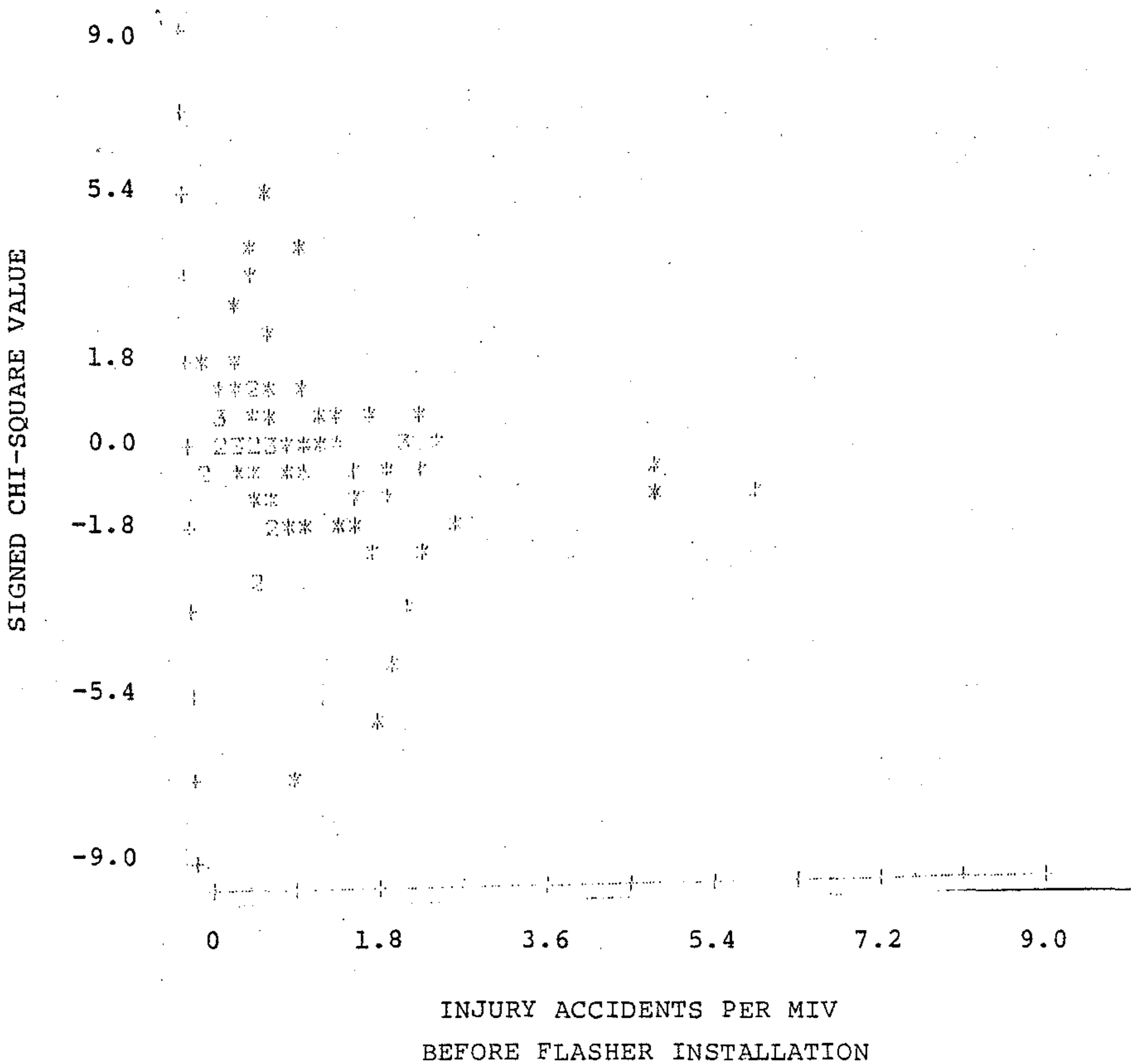

FIGURE 3-6 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY INJURY ACCIDENT RATE BEFORE FLASHER INSTALLATION

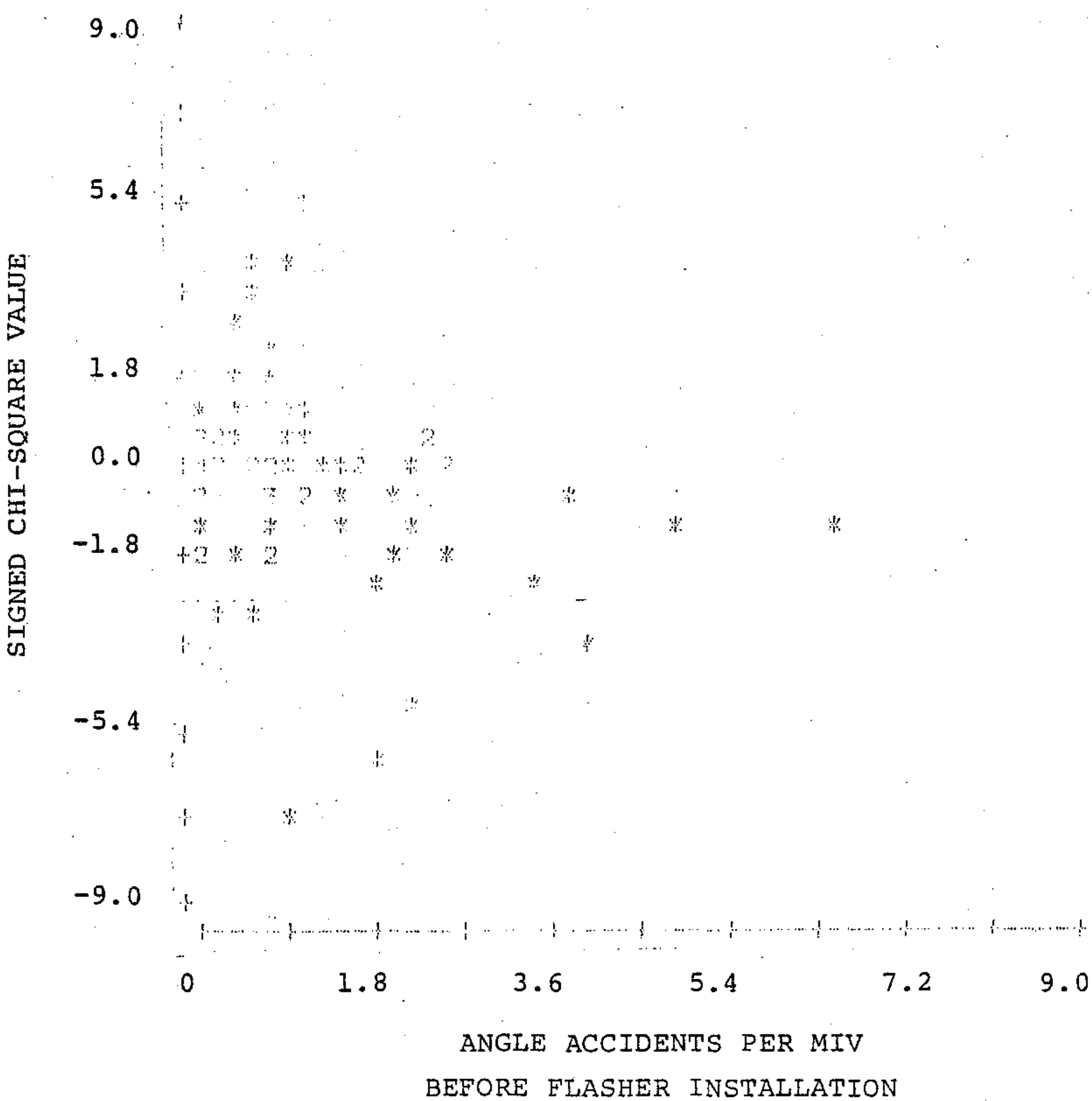

FIGURE 3-7 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY ANGLE - ACCIDENT RATE BEFORE FLASHER INSTALLATION

accident cost difference. Thus in cases where priorities have to be assessed among several candidates for flasher installation, the total number of accidents and severity must also be considered.

Both major-road ADT and accident data are easily retrievable from existing MDSHT data systems. Although high variations in accident experience exist, the critical accident rates presented above can be used to assist the engineering judgement process in the flasher installation decision.

3-3 Correlation among Accident, Traffic and Roadway Factors

Table 3-12 presents a correlation matrix involving the major-road ADT, before-after ADT ratio, three measures of before-period accident rate, (total, injury-fatality and angle) major-road width (two lanes, and more than two lanes), urban-rural area type and number of legs for 72 intersections with complete ADT data. The last three variables have already been shown to be very strongly associated with the before-after experience.

The anticipated high intercorrelations among the major-road width, area type and ADT are noted. The signs of these coefficients indicate a positive association between road width and ADT and more two-lane roadways and lower ADT in rural areas. In fact, among the 77 intersections studied, there are only five rural intersections which have major approaches wider than two lanes, and three urban intersections with two-lane major approaches. Further, among these five rural intersections, there are only three with undivided roadways.

Because of these intercorrelations (or, un alanced improvement experience) and limited sample size, the analysis here cannot separate the independent effect of each factor. Therefore, care

TABLE 3-12

CORRELATIONS AMONG ACCIDENT, TRAFFIC AND ROADWAY FACTORS

	Severity Index	Accident Rate	Injury Acc. Rate	Angle Acc. Rate	ADT	ADT Ratio	Approach Width	Area Type	Number of Legs
Accident Rate	.110	1.0							
Injury Accident Rate	.394	.909	1.0						
Angle Accident Rate	.286	.901	.923	1.0					
ADT	.089	-.386	-.324	-.277	1.0				
ADT Ratio	.051	-.199	-.118	-.136	.085	1.0			
Approach Width*	.206	-.280	-.216	-.152	.723	.088	1.0		
Area Type**	-.100	.320	.268	.204	-.700	-.186	-.774	1.0	
Number of Legs	.323	.358	.310	.313	-.149	.057	-.236	.150	1.0

* Two Lane = 0, More than two lane = 1 (72 intersections)

** Urban = 0, Rural = 1

Critical value at the 95 percent level = .232

should be taken in the application of the findings presented in this report to two-lane major-road intersections in urban areas with low ADT.

Other interesting points are the decrease in accident rate with increasing ADT, increased severity with a higher right-angle accident rate (both significant at the 95 percent level), a higher accident rate at rural intersections than in urban areas, a lower accident rate at intersections with more lanes and, of course, high intercorrelations among the three accident rates.

The ratio of the after-period major-road ADT to the before-period ADT, a measure of the change in traffic exposure, can be directly related to the before-after accident experience. The signed chi-square is plotted against this ADT ratio in Appendix Figure A-3-3. In fact, the correlation coefficient between this ratio and the signed chi-square is +0.22, (significant at the 95 percent level) but less when compared with those between the signed chi-square and accident rates, approach width, and area type.

It can be seen that except for a few extreme cases, the range of the ratios is small, and that the relation is not strong. More importantly, the correlation matrix shows that this ratio is not strongly correlated with other factors. Although this study avoided the normalization of the number of accidents by the traffic exposure, it is not likely that this normalization changes the results obtained.

3-4 Summary

The tabulations presented in this chapter support the conclusion that the entire set of 77 1967-1974 flasher installations as a whole did not cause a reduction in the total number of accidents, but reduced accident severity significantly. Among the types of accident examined, substantial reductions in severity were found for angle, rear-end, and single-vehicle accidents.

An important reduction in the total number of accidents was found at installations on two-lane trunkline intersections as well as at four-leg intersections. At the same time, a reduction in the number of accidents at rural intersections was found. Reductions in severity were recorded at urban intersections, at intersections with major approaches wider than two lanes, at divided intersections, and at right-angle intersections.

There was an indication of greater night-time accident reduction. There was no indication of a differential flasher effect on accident type. This was also found when accident type differences were analyzed for two-lane major-road intersections and four-leg intersections where the most significant accident reductions were observed.

By observations of the relations between the before-after accident experience and before-period accident experience, accident rate, and ADT, it was found that no significant accident increases occurred when the before-period accident rates exceeded values of 3.4 total accidents per MIV, 1.2 injury accidents per MIV, and 1.2 angle accidents per MIV. This relation may be used as a crude guideline in flasher installation judgment. On the other hand no support was found for using the number of angle accidents as a criterion in the decision.

CHAPTER IV
ANALYSIS OF 26 INTERSECTIONS WITH EXTREME ACCIDENT CHANGE EXPERIENCE

Among the basic 77 intersections, the 27 intersections with significant (at the 75 percent level) changes in the total number of accidents following the flasher installation were selected for further detailed investigation. The analysis in this chapter primarily uses information available from the MDSHT data system, mostly from the photolog. Thus the information required to apply the results to other intersections can be readily developed by the MDSHT.

4-1 Overview of the 27 Intersections

Among these 27 intersections, 8 had increases in the total number of accidents in the after-period, and 19 showed decreases in the total number of accidents. Table 4-1 summarizes the accident experience by severity level. The total number of accidents observed at these intersections in the four-year study period was 694, among which accidents at the increased-accident intersections accounted for 41 percent. The averages of total numbers of accidents in the two-year before period are 12.5 for the 8 intersections with increased accidents, and 14.3 for the other 19 intersections. These averages increased 86 percent to 23.2 for those intersections which had more accidents and decreased 49 percent to an average of 7.2 at those with better experience.

A significant reduction in accident severity is found for the intersections with reduced number of accidents, a more than 25 percent improvement. On the other hand, no improvement in accident severity was found for the other intersections.

TABLE 4-1

BEFORE-AFTER ACCIDENT SEVERITY:

INTERSECTIONS WITH EXTREME ACCIDENT CHANGE EXPERIENCE

ACCIDENT SIGNIFICANTLY REDUCED INTERSECTIONS

	ACCIDENT SEVERITY			
Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	148	123	271	.454
After	92	45	137	.328
Total	240	168	408	

(19 intersections)

2I= 5.99, P = .02

ACCIDENT SIGNIFICANTLY INCREASED INTERSECTIONS

	ACCIDENT SEVERITY			
Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	62	38	100	.380
After	112	74	186	.398
Total	174	112	286	

(8 intersections)

2I= 0.08, P = .9

An important finding is that the severity index in the before period is 20 percent higher for the intersections with reduced accidents. This suggests that accident severity may be employed as a good predictor of the intersections where accidents may decrease after the flasher installation.

Table 4-2 compares the before-after accident type differences. There is a significant difference in type at the 75 percent level at the reduced frequency intersections. The much more than proportional reduction in the left-turn accidents is the main contributor to this result. Again, no evidence is found to support the belief that angle accidents are particularly reducible by flashers. The table for the increased-accident intersections shows no change in the accident type frequencies between the before-after periods.

4-2 Roadway, Roadside and Traffic Factors

Utilizing the MDSHT photolog system and other information sources, many factors believed to characterize the major road (MDSHT trunkline) approaches to 26 intersections were collected (photolog data were not available for one of the 27 intersections). For this data collection procedure, see Appendix B, Section 4. The reduced data set involved variables listed in Table 4-3 with a classification into approach geometrics, intersection geometrics, sight conditions, traffic control elements, and roadside development. The remainder of this chapter presents the principal findings based on analysis of these variables. The analysis are based on comparisons between the number of intersections with increased versus those with decreased accident experience.

TABLE 4-2

BEFORE-AFTER ACCIDENT-TYPE FREQUENCIES:
INTERSECTIONS WITH EXTREME ACCIDENT CHANGE EXPERIENCE

ACCIDENT SIGNIFICANTLY REDUCED INTERSECTIONS

	ACCIDENT TYPE						
Period	Angle	Left Turn	Rear End	Other Multi-Vehicle	Single Vehicle	Other	Total
Before	124	34	39	31	32	11	271
After	71	7	26	16	13	4	137
Total	195	41	65	47	45	15	408

(19 intersections)

2I= 8.28, P = .15

ACCIDENT SIGNIFICANTLY INCREASED INTERSECTIONS

	ACCIDENT TYPE						
Period	Angle	Left Turn	Rear End	Other Multi-Vehicle	Single Vehicle	Other	Total
Before	43	11	15	16	9	6	100
After	90	26	27	21	10	12	186
T0tal	133	37	42	37	19	18	286

(8 intersections)

2I= 3.24, P = .7

TABLE 4-3

VARIABLES EMPLOYED IN THE ANALYSIS

APPROACH GEOMETRICS

No. of Lanes*
Roadway Type (Divided, Undivided)*
Vertical Alignment at the Intersection
Horizontal Alignment at the Intersection
No. of Vertical Curves
No. of Horizontal Curves
Approach Width
Passing Sight Restriction
Flasher Visibility Distance
Cross Road Visibility Distance
Flare Visibility Distance
Flasher Sight Obstruction

INTERSECTION GEOMETRICS

No. of Approach Legs*
Channelization*
Skewness*
Corner Clearance
Entrance Width

TRAFFIC CONTROL ELEMENTS

Passing Restriction
Parking Restriction
Lens Size of Flasher*
Case Sign at the Intersection
Lighting at the Intersection
Speed Limit
Cross Road Guide Sign
Intersection Warning Sign
Curve Warning Sign
Pavement Edge Marking

ROADSIDE DEVELOPMENT

TVM Area Type (Urban, Rural)*
Intersection Corner Development
Environmental (Residential, Commercial, Agricultural, Vacant)

* Element also used in analysis of 77 intersections

Approach Geometrics

Number of Lanes - Table 4-4 presents the association between the number of major-road lanes (categorized as two, or more than two) and accident experience (significantly increased, or significantly decreased). This table shows that accident reduction by flashers can be found much more frequently at intersections with two-lanes on the major approaches than at wider approaches. The level of significance determined from Fisher's exact probability test is 91 percent.

Roadway Alignment - The photolog survey provided information on the number of vertical and horizontal curves along 1-mile major approaches to the intersections. Table 4-5 gives the association of the presence or absence of vertical curves and accident experience. The table strongly suggests that when the major-road approaches are flat without vertical curves, the reduction in accident experience after the flasher installation is less than on approaches with vertical curves (significance level is 93 percent). On the other hand, no significant result was obtained when there are horizontal curves along the approaches as shown in Table 4-6.

These results are compatible with an intuitive discussion on the flasher's role in conveying information presence of the intersection to major-road drivers. When the intersection is visually obstructed by vertical curves, a flasher can, because of its height, significantly increase the distance from the intersection where the driver is made aware of the intersection. However, for horizontal curves, it is likely that either the flasher is hidden by the same roadside objects which obstruct the view of

TABLE 4-4

EXTREME ACCIDENT CHANGE EXPERIENCE: LANE WIDTH

No. of Lanes	ACCIDENT EXPERIENCE Increased	Decreased	Total
Two lanes	3	14	17
More than Two lanes	5 (3)	5 (2)	10 (5)
Total	8 (6)	19 (16)	27 (22)

(27 intersections)
P_f = .09

( ) : Divided highway excluded

TABLE 4-5

EXTREME ACCIDENT CHANGE EXPERIENCE: APPROACH VERTICAL CURVES

No. of Vertical Curves	ACCIDENT EXPERIENCE Increased	Decreased	Total
None	3	1	4
Present	5	17	22
Total	8	18	26

(26 intersections)
P_f= .07

P_f: Fisher's exact probability; see note in Appendix A

TABLE 4-6

EXTREME ACCIDENT CHANGE EXPERIENCE:
INTERSECTION HORIZONTAL ALIGNMENT

	ACCIDENT EXPERIENCE		
Horizontal Alignment	Increased	Decreased	Total
Tangent	5	12	17
Curved	3	6	9
Total	8	18	26

(26 intersections)
$P_f = .59$

TABLE 4-7

EXTREME ACCIDENT CHANGE EXPERIENCE:
INTERSECTION VERTICAL ALIGNMENT

	ACCIDENT EXPERIENCE		
Vertical Alignment	Incresed	Decreased	Total
Crest	1	8	9
Other	7	10	17
Total	8	18	26

(26 intersections)
$P_f = .13$

the intersection itself, or the flasher is out of the driver's normal line of sight until getting very close to the intersection. Thus we may not expect as much of an effect on flashers along approaches with horizontal curves.

Road Alignment at the Intersection

The above discussion on the flasher's effectiveness in transmitting the information of intersection presence is further examined in Table 4-7. The table indicates that when an intersection is located at or near a vertical crest along the major road, more frequent accident reduction can be expected (significant at the 87 percent level).

Summarizing these results, it is concluded that the vertical alignment, both along the major road approaches and at the intersection, can be used as predictors of the consequences of flasher installation. The flasher is quite effective when installed at an intersection involving a crest. Use of a flasher at an intersection with sag, flat and tangent approaches appears to provide little effect.

Other Measurements of Roadway Alignment - Other than the two measurements explored above, two surrogate variables of roadway alignment were obtained from the photolog survey: percent of roadway segments within each 1-mile approach where passing is restricted, and the number of curve warning signs within the 1-mile approach. However, no strong association with accident experience was found for these variables.

Intersection Geometrics

Channelization - The same result obtained for the full set of intersections, namely that unchannelized intersections respond better to flashers than do channelized intersections can be seen in Table 4-8 (significant at the 85 percent level).

Intersection Skewness and Number of Legs - No significant association was found between the skewness of the intersection and before-after accident experience for those intersections. This result is similar to the findings for the entire accident set. The table is Appendix Table A-4-1. Also no significant result is observed at these 26 intersections regarding the number of legs (Appendix Table A-4-2).

Sight Conditions

Two measurements representing the sight condition at the intersections are analyzed here: the largest visibility distance to the flasher, and the number of vacant corners at the intersection, both obtained from the photolog. Other measurements of sight conditions, such as the visibility distance to the cross road pavement surfaces, are not used in the analysis because of small variations of these measurements.

Flasher Visibility Distance along the Major Road: In Table 4-9, the average visibility distance to the flasher for all major approaches to each intersection is used with a split into two categories at 0.3 mile sight distance. The table shows a strong association of the visibility distance and the before-after accident experience (92%). More frequent accident reduction at intersections with shorter visibility distances is clear. It should be noted here that this distance is not exactly comparable with the distance for passenger-car drivers, since the distance was measured on the photolog film, which was taken from a van-mounted camera located much higher above the road.

TABLE 4-8

EXTREME ACCIDENT CHANGE EXPERIENCE: CHANNELIZATION

Channelization	ACCIDENT EXPERIENCE Increased	Decreased	Total
No	1	8	9
Yes	7	11	18
Total	8	19	27

(27 intersections)
$P_f = .17$

TABLE 4-9

EXTREME ACCIDENT CHANGE EXPERIENCE:
FLASHER VISIBILITY DISTANCE

Flasher Visibility Distance	ACCIDENT EXPERIENCE Increased	Decreased	Total
Less than 0.3 Mile	1	9	10
Equal to or Greater than 0.3 Mile	7	9	16
Total	8	18	26

(26 intersections)
P_f = .08

TABLE 4-10

EXTREME ACCIDENT CHANGE EXPERIENCE:
NUMBER OF VACANT CORNERS

No. of Vacant Corners	ACCIDENT EXPERIENCE Increased	Decreased	Total
0	3	3	6
1	2	3	5
2	1	4	5
3	1	5	6
4	1	3	4
Total	8	18	26

(26 intersections)
$\bar{R}$ = -0.72, P = .1

This result again suggests that flashers are less effective when installed at an intersection with "good" approach alignments where the flasher can be visible from a great distance.

Corner Clearance - Among other measurements made on the corner sight and obstacle clearance, the number of vacant corners (those with adequate sight triangles) is most easily measured and the least subjective. Table 4-10 shows that as the number of vacant corners increases, accident reduction occurs more frequently. The regression correlation coefficient between the number of vacant corners and the fraction of increased accident locations is shown in the table with the significance level.

Corner Development - Four types of corner development are defined according to the land use type at the corners of each intersection: vacant, residential, residential and commercial mixed, and commercial. A contingency table is presented in Table 4-11, but no clear relationship is apparent. The high frequency of accident reduction for commercial development probably represents rural intersections with service stations at the corners. No test statistics are presented for this table since no small sample statistics can be efficiently developed for this table.

Traffic Control Elements

Regulations - The possible effect of the speed limit regulations is examined in Table 4-12, where the regulation is classified into two categories: the statewide speed limit and lower. No supportable statement can be made. This result suggests either

TABLE 4-11

EXTREME ACCIDENT CHANGE EXPERIENCE:
CORNER DEVELOPMENT

	ACCIDENT EXPERIENCE		
Corner Development	Increased	Decreased	Total
Vacant	2	4	6
Residential	3	3	6
Residential/ Commercial	1	3	4
Commercial	2	8	9
Total	8	18	26

(26 intersections)

TABLE 4-12

EXTREME ACCIDENT CHANGE EXPERIENCE: SPEED LIMIT

	ACCIDENT EXPERIENCE		
Speed Limit	Increased	Decreased	Total
Statewide	5	14	19
Other	3	5	8
Total	8	19	27

(27 intersections)
$P_f = .44$

TABLE 4-13

EXTREME ACCIDENT CHANGE EXPERIENCE: AREA TYPE

	ACCIDENT EXPERIENCE		
Area Type	Increased	Decreased	Total
Urban	5	5	10
Rural	3	14	17
Total	8	19	27

(27 intersections)
$P_f = .09$

that the urban-rural environmental factor has its own effect other than the effect of different operating speeds, or that most of the apparent effect of the area type is attributed to the correlation with the approach width.

Other regulations examined involved passing and parking restrictions at the intersection. The analysis indicated that neither of these factors contributed to a before-after accident experience difference between the two groups.

Warning and Guide Signs - The presence of an intersection warning sign and/or cross road guide sign on the major road approaches provides the same information on the intersection presence as a flasher. Considering a possible interactive effect of these signs and flashers, a contingency analysis was made. However, the results did not indicate any significant association.

In the course of the data collection, it was found that obtaining the information on the existence of warning or guide signs prior to the flasher installation was an extremely difficult task. These devices are continuously modernized, relocated, and newly installed. Further, it is likely that traffic sign improvements were made at or around the time of flasher installation. It was beyond the research team's capability to trace these changes in the signing devices chronologically. The same is true regarding such low capital improvements as minor pavement resurfacing and marking. In this sense, the analysis does not isolate the flasher's effect on accident experience, since those other factors are not held constant.

However, since these uncontrolled factors appear to have relatively small association with accident experience, the disturbance caused by these factors is considered to be minor.

Other Elements - Data were also collected on intersection safety lighting and pavement edge marking. Again no significant results were obtained.

Environment

TVM Urban-Rural Classifications - Similar to the statewide results on the pooled number of accidents, a strong association was found between TVM urban-rural classification and accident experience (Table 4-13). However, in the analysis employing the researcher's observation of roadside development, no significant result was obtained.

4-3 Summary of Field Study

Six locations in the vicinity of Flint and Lansing with extreme accident experience changes were visited to investigate their minor approach road characteristics. Brief descriptions of these intersections can be found in Appendix D.

The observations generally confirmed the findings on flasher effectiveness. The three intersections with reduced accidents have minor approaches involving vertical curves close to the intersections and these vertical curves entirely obstruct the view to the road pavements. The flasher visibility distance is satisfactory along these approaches and significantly improves the recognizability of the intersections.

The major roads also involve vertical and/or horizontal curves near or at these intersections. Accordingly, the sight to the major-road vehicles at the intersection is somewhat limited for the minor road drivers.

Two of the three intersections with increased accident experience have straight and flat (or almost flat) minor approaches. Along these approaches the flasher and traffic signs are unobstructed. This result is identical to that obtained for the major approach. Also it is noted that these minor approaches are characterized as high-type two-lane highways with good shoulder and roadside clearance.

The other increased accident intersection has a MDSHT trunkline (M-50) as one of its minor approaches. This approach has a junction with an Interstate Freeway (I-69) near the intersection, and is a high-type rural two-lane highway. An abrupt environmental change from a rural highway to an urban intersection is noted.

There is a horizontal curve with an up-grade along the same approach close to the intersection and the flasher's visibility distance is limited. As a result, the flasher is not contributing to increasing the distance where the driver recognizes the existence of a stop control. This result is consistent with the previous finding regarding the horizontal curve effect.

In summary, the survey confirms that vertical alignment along minor approaches is an important factor affecting flasher effectiveness, especially in cases where the vertical curves obstruct the view to the intersection, whereas the flasher is visible from an appropriate distance. However, it should be noted here that this conclusion is subject to reservation since two important factors, the number of major-road lanes and urban-rural environmental classification, are not controlled in these six sample locations to separate their effects.

4-4 Summary

At the 26 intersections where significant changes in the number of total accidents were observed following the flasher installation and for which data were obtainable, many factors associated with the intersections and major approaches were collected using the MDSHT photolog and other sources. In addition to generally confirming the results obtained in Chapter 3, it was found that the flasher effectiveness is strongly associated with the roadway alignment:

i. When the approach is flat, the flasher is less effective.

ii. When the intersection is located at/or near a crest vertical curve, the flasher is more effective.

iii. When the visibility distance along the major approaches is relatively short (less than 0.3 mile, or 20 sec.) the flasher is more effective.

A field survey on the minor approach characteristics for 6 of these 26 intersections confirmed points i and ii also to be true for the minor approaches. These additional results can be immediately utilized in the engineering analysis of flasher installations.

CHAPTER V

RECOMMENDATIONS

The analysis of the 77 most recent Michigan flasher installations indicates that they are not uniformly effective in reducing the total number of accidents. No overall change in the type of collision was found. However, the analysis has shown that the more severe accidents involving injuries and fatalities were significantly reduced by 21 percent in the two years following the flasher installations. During the same period there was a 10 percent increase in property damage only accidents. Except for a greater reduction in night-time accidents, no indications of differential flasher effects by the environmental weather and surface conditions were obtained.

Significant interactions with intersection and approach geometrics showed greater accident reductions at rural two-lane major-road intersections, and at four-leg intersections compared with intersections with wider approaches and three-leg intersections, respectively. Further, in the analysis of accident experience at the 26 intersections where the extreme changes in the total number of accidents were observed, it was found that the flasher is more effective at intersections involving vertical curve sight distance and intersection locations.

The development of warrants is not possible for intersections involving multi-lane approaches because of the relatively small number of samples, and limited amount of roadway information. The following warrants for a flasher installation at two-lane highway intersections are developed and recommended.

Warrants for Two-lane Rural Highway Intersections with major road ADT less than 3500

From Figure 3-4 (Chapter III), it can be seen that the accident experience is almost always improved after the flasher installation when major road ADT is less than 3500. Warrants for these low ADT two-lane intersections are developed separately as below:

An Intersection Control Beacon installation is recommended at two-lane rural highway intersections with the major-road ADT less than 3,500, where a traffic signal is not justified, and where the total number of accidents in the two-year period is four or more, and, the number of accidents involving injuries and/or fatalities in the same period is two or more.

The expected improvement following the flasher installation is estimated as follows based on the accident experiences at 9 intersections which qualify for the above warrants:

Average Reduction in P.P.O. Accidents: 0.4 accidents/2 years

Average Reduction in Injury Accidents: 2.7 accidents/2 years

Since accident improvement is almost always expected following an flasher installation, the above warrants can be relaxed in favor of the installation, particularly when the intersection is located at or near a crest, sight condition is restricted, or when accident severity is high.

Warrants for Two-lane, Rural, Four-leg Intersections with Major Road ADT $\geq$ 3500.

An Intersection Control Beacon installation is recommended at two-lane rural four-leg intersections with the major-road ADT greater than or equal to 3500, where a traffic signal is not justified, and where the total number of accidents in the two-year period is three or more.

The warrants are based on accident experiences at 31 intersections of the above specified type. Among these, 8 experienced significant reductions in the total number of accidents, one a significant increase, 12 insignificant reductions or no changes, and 10 experienced insignificant increases following the flasher installation. The above warrants are developed observing that all intersections with significant reductions involve at least 9 accidents, and also at least 3 injury accidents in the two-year before period; on the other hand the intersection with an significant increase had one injury accident. The above critical numbers of accidents are determined in such a manner that the resulting sample average of accident improvements is maximized. Out of the 31 intersections, 21 meet the above warrants, among which 8 experienced significant accident reductions, 8 had insignificant reductions, and 5 had slight increases in terms of the total number of accidents. The number of injury accidents is almost always reduced except at two locations. The average improvement following the warranted flasher installation is:

Average Reduction in P.D.O. Accidents: 1.5 accidents/2 years

Average Reduction in Injury Accidents: 2.1 accidents/2 years

The accident improvement can be found at many installations of this class where the warrants are not met (see Table 5-1). Accordingly the warrants can be again relaxed unless the severity index is not extremely low (less than 0.25).

Warrants for Two-lane Three-leg Intersections with Major-Road ADT $\geq$ 3500

The following warrants are based on the accident experiences at 7 two-lane, three-leg intersections with major-road ADT greater than or equal to 3500. Three of these intersections are in urban areas and the warrants apply to urban intersections as well.

An Intersection Control Beacon installation is recommended at two-lane three-leg intersections with major road ADT greater than or equal to 3500, where a traffic signal is not justified, and where the total number of accidents in the two-year period is 7 or more, injury/fatal accidents in the same period is three or more, and the two-year period injury accident rate (number of injury/fatal accidents per million vehicles entering on the major road) exceeds 0.8.

The warrants are more restrictive of the installation compared with those for four-leg intersections, as would have been expected from the analysis in Chapter III. The average improvement at 2 intersections which meet these warrants is:

Average Reduction in P.D.O. Accidents: 3.5 accidents/2 years

Average Reduction in Injury Accidents: 3.0 accidents/2 years

The accident experiences following 50 installations where the above warrants categories apply are summarized in Table 5-1. The installations are classified according to their qualification for the proposed warrants, and also for the present MDSHT accident warrants (accidents susceptible for correction by the flasher are regarded as angle accidents). The proposed warrants justify more installations compared with the present ones. There is no statistical difference in overall before-after accident experiences by the qualification for the proposed and present warrants, except for the case of three-leg intersections, where clear improvements can

TABLE 5-1

ACCIDENT EXPERIENCE BY QUALIFICATIONS TO PROPOSED AND PRESENT FLASHER INSTALLATION WARRANTS

ADT < 3,500

		TOTAL ACCIDENTS			INJURY ACCIDENTS		
PROPOSED WARRANTS	NO. OF INSTALLATIONS	Before	After	Total	Before	After	Total
Met	9	74	46	120	42	18	60
Not Met	3	7	2	9	2	0	2
Total	12	81	48	129	44	18	62
CURRENT MDSHT WARRANTS							
Met	2	29	19	48	17	6	23
Not Met	10	52	29	81	27	12	39
Total	12	81	48	129	44	18	62
ADT ≥ 3,500, 4-Leg Intersections							
PROPOSED WARRANTS							
Met	21	298	223	521	139	96	235
Not Met	10	61	70	131	14	17	31
Total	31	359	293	652	153	113	266
CURRENT MDSHT WARRANTS							
Met	10	169	134	303	89	65	154
Not Met	21	190	159	349	64	48	112
Total	31	359	293	652	153	113	266
ADT ≥ 3,500, 3-Leg Intersections							
PROPOSED WARRANTS							
Met	2	14	7	21	8	2	10
Not Met	5	38	52	90	11	22	33
Total	7	52	59	111	19	24	43

TABLE 5-1 Con't.

ADT $\geq$3,500, 3-Leg Intersections

CURRENT MDSHT WARRANTS							
Met	0	-	-	-	-	-	-
Not Met	7	52	59	111	11	22	43

be found when the installation is justified by the proposed warrants. In other words, the proposed warrants performs as well or better than the present ones in distinguishing the installations which improvements can be expected.

The proposed warrants for installation can be justified by examining the cost-effectiveness of warranted installations. Table 5-2 shows this by comparing the expected benefit from accident improvements against flasher installation and maintainance costs. The cost for installation is parameterized as $5,000 and $10,000 and a conservative value of 10 years is assumed as the project life. As accident cost, an average of $480 per property damage only accident, and $5800 per injury accident is assumed. An average of 1.7 injured persons is assumed in determining the cost per injury accident. Fatal accidents are not considered in the cost effectiveness computation because of their rare occurrence and the less reliable accident occurrence estimates both from before and after installation.

<u>Other Guidelines for Flasher Installation</u>

Because of the limited population experience, installation warrants have not been developed for all combinations of the contributing factors relative to the flasher effectiveness. The following elements should be considered in the installation decision where the above sets of accident warrants do not apply or do not support installation:

i) When the severity index (fraction of accident involving personal injury or fatality) exceeds 0.45 a flasher installation is recommended.

ii) When the intersection is found on a crest, a flasher installation is recommended.

TABLE 5-2

COST EFFECTIVENESS OF INSTALLATIONS JUSTIFIED BY THE PROPOSED WARRANTS

Installation and Maintenance Cost per year	Intersection Class	Average Accident Improvement per year P.D.O.	Injury/Fatal	Average Accident Cost Reduction per year
Installation $1200 if initial investment is $5,000	ADT < 3,500	0.2	1.3	$7,600
$2,000 if initial investment is $10,000	ADT ≥ 3,500 4-Leg	0.8	1.0	$6,200
Maintenance & Operation = $300	ADT ≥ 3,500 3-Leg	1.8	1.5	$9,600

On the other hand, even when the accident-rate warrants an installation, effectiveness is minimal.

i) Where the major-road approach is flat and the flasher would be visible for 20 seconds or longer.

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APPENDIX A

APPENDIX TABLES AND FIGURES

NOTE

The significance of the interaction in the two by two contingency tables of the extreme analysis is presented by Fisher's exact probability. This probability is obtained by enumerating the probabilities that outcomes with interactions of higher magnitudes than the observation occur assuming the independence (or no interaction effect) and given the observed marginal distribution. Fisher's probability retains its validity when the sample size is extremely small and thus asymptotic tests such as chi-square test do not apply.

APPENDIX TABLE A-3-1

BEFORE-AFTER COMPARISON: WEATHER AND SURFACE CONDITIONS

WEATHER CONDITIONS

Period	Clear	Inclement	Total*
Before	789	195	984
After	759	198	957
Total	1548	393	1941

(77 intersections)

$2I = 0.23$, $P = .3$

* Not including accidents with weather condition unknown

SURFACE CONDITION

Period	Dry	Wet	Icy	Total*
Before	683	199	106	988
After	652	202	99	953
Total	1335	401	205	1941

(77 intersections)

$2I = 0.35$, $P = .15$

* Not including accidents with surface conditions unknown

APPENDIX TABLE A-3-2

BEFORE-AFTER ACCIDENT SEVERITY: CHANNELIZATION

UNCHANNELIZED INTERSECTIONS

ACCIDENT SEVERITY

Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	143	144	287	.502
After	151	89	240	.371
Total	294	233	527	

(28 intersections)

2I= 9.12, P = .01

CHANNELIZED INTERSECTIONS

ACCIDENT SEVERITY

Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	407	303	710	.427
After	456	265	721	.368
Total	863	568	1431	

(49 intersections)

2I= 5.25, P = .08

APPENDIX TABLE A-3-3

BEFORE-AFTER ACCIDENT SEVERITY: DIVIDED HIGHWAYS

UNDIVIDED INTERSECTIONS

	ACCIDENT SEVERITY			
Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	364	274	638	.429
After	362	217	579	.375
Total	726	491	1217	

(61 intersections)

2I= 3.76, P = .05

DIVIDED INTERSECTIONS

	ACCIDENT SEVERITY			
Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	186	173	359	.482
After	245	137	382	.359
Total	431	310	741	

(16 intersections)

2I=11.58, P .001

APPENDIX TABLE A-3-4

BEFORE-AFTER ACCIDENT SEVERITY: INTERSECTION SKEWNESS

RIGHT ANGLE INTERSECTIONS

ACCIDENT SEVERITY

Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Before	232	213	445	.479
After	253	147	400	.368
Total	485	360	845	

(38 intersections)

2I=10.70, P .001

SKEWED INTERSECTIONS

ACCIDENT SEVERITY

Period	P.D.O.	Injury/ Fatal	Total	Severity Index
Berfore	318	234	552	.424
After	354	207	561	.369
Total	672	441	1113	

(39 intersections)

2I= 3.50, P = .07

APPENDIX TABLE A-3-5
BEFORE-AFTER COMPARISON: CHANNELIZATION, ROADWAY TYPE, AND INTERSECTION SKEWNESS

CHANNELIZATION

Period	Unchannelized	Channelized	Total
Before	287	710	997
After	240	721	961
Total	527	1431	1958

(77 intersections)

2I= 3.62, P = .06

ROADWAY TYPE

Period	Undivided	Divided	Total
Before	638	359	997
After	579	382	961
Total	1217	741	1958

(77 intersections)

2I= 2.94, P = .09

INTERSECTION SKEWNESS

Period	Right Angle	Skewed	Total
Before	445	552	997
After	400	561	961
Total	845	1113	1958

(77 intersections)

2I= 1.82, P = .15

APPENDIX A-4-1

EXTREME ACCIDENT CHANGE EXPERIENCE: INTERSECTION SKEWNESS

	ACCIDENT EXPERIENCE			
Skewness	Significant Increases	Significant Decreases	Non-significant Changes	Total
Right Angle	5	9	24	38
Skewed	3	10	26	39
Total	8	19	50	77

(77 intersections)

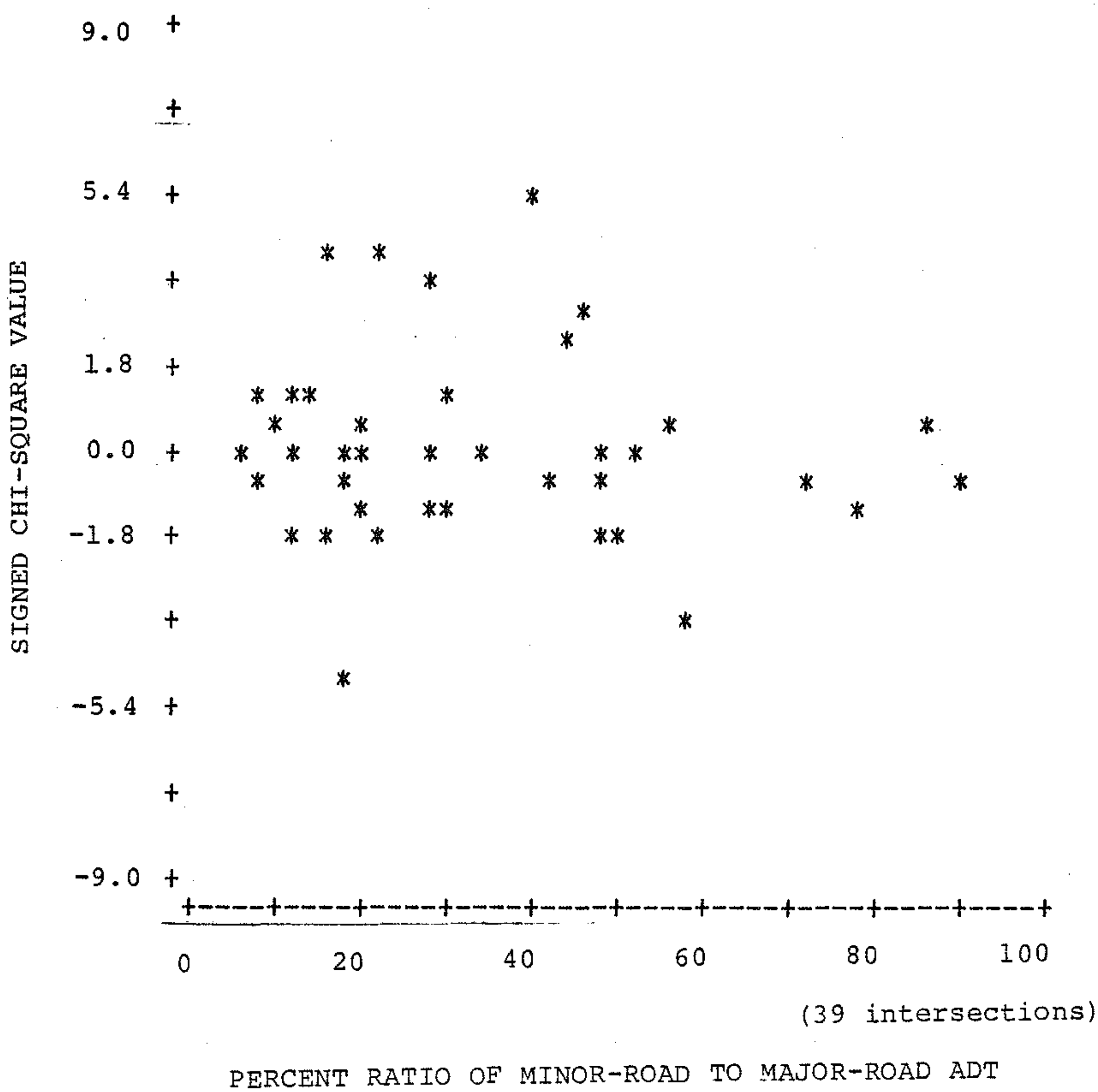
$f_p = .38$

APPENDIX A-4-2

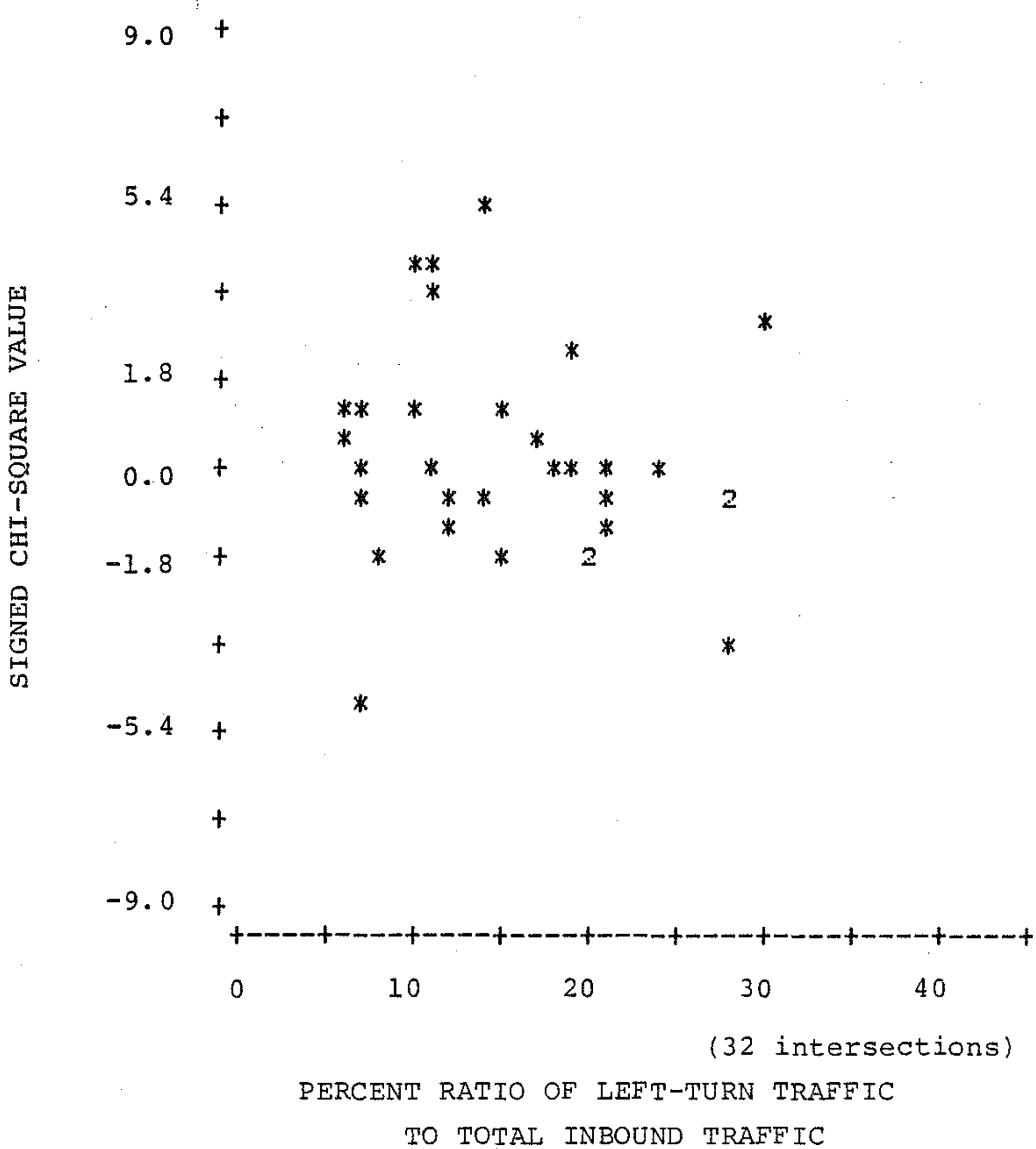
ACCIDENT EXPERIENCE: NUMBER OF APPROACH LEGS

No. of Approach Legs	ACCIDENT EXPERIENCE Significant Increases	Significant Decreases	Non-significant Changes	Total
2	0	0	4	4
3	3	3	9	15
4	5	15	37	57
5	0	1	0	1
Total	8	19	50	77

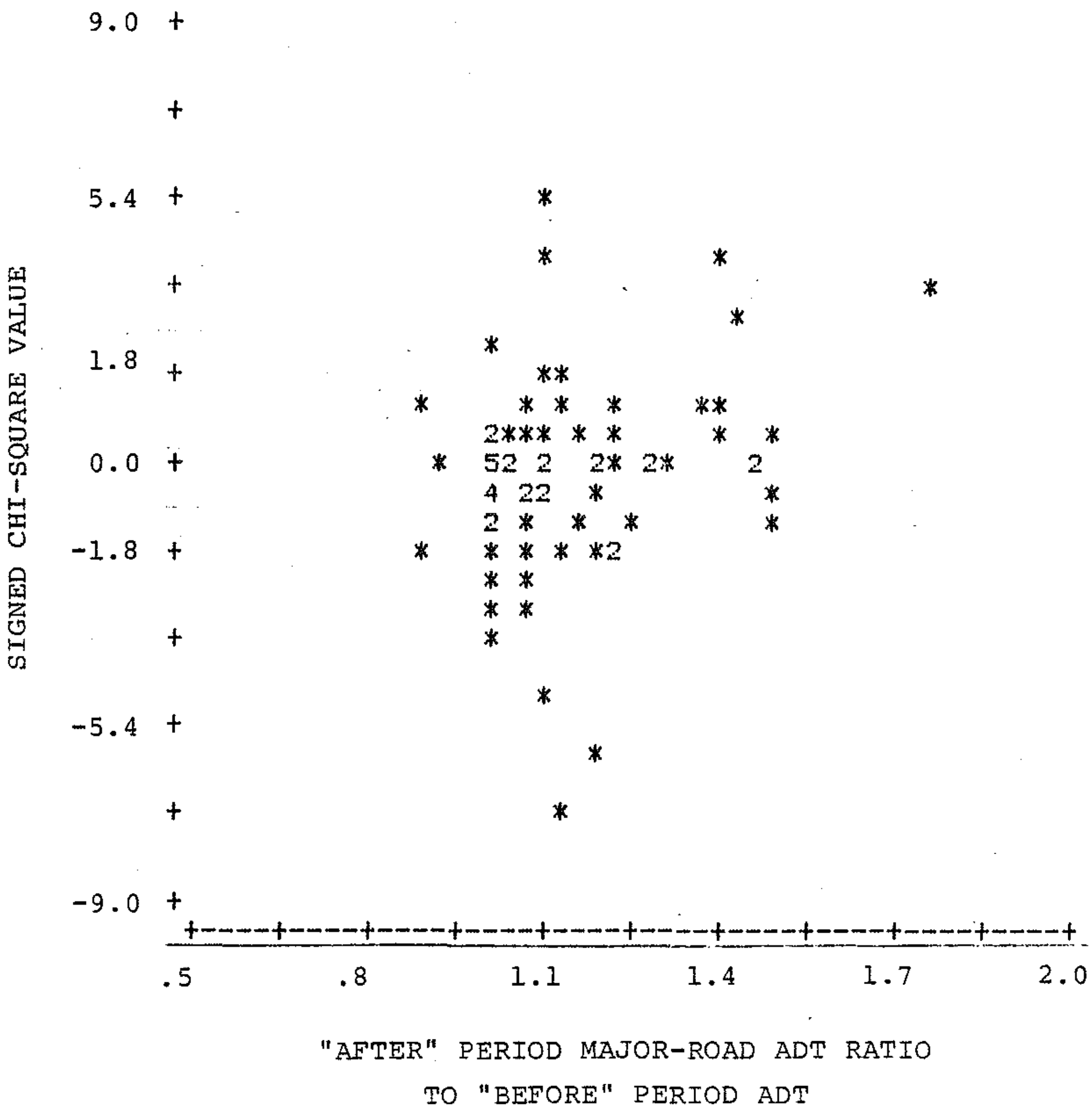
(77 intersections)



APPENDIX FIGURE A-3-1 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY MINOR-MAJOR ADT RATIO



APPENDIX FIGURE A-3-2 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY LEFT-TURN TRAFFIC RATIO



APPENDIX FIGURE A-3-3 NUMBER OF INTERSECTIONS WITH SIGNED CHI-SQUARE RESULT BY BEFORE-AFTER ADT RATIO

APPENDIX B

PROCEDURES FOR DATA COLLECTION

APPENDIX B

PROCEDURES FOR DATA COLLECTION

B-1 Spot Identification

The identification of the 1967-74 flasher installations was started using the Traffic Signal Inventory maintained by the Electronics Devices Unit, MDSHT. The Inventory contained information on the rough description of the device, cost agreement regarding the installation, modernization and maintenance, and most importantly, the data on the most recent work done on the device. By examining this list, 103 flasher locations were identified for further investigation.

The research team was aware of the possibility of obtaining a biased sample if the above locations alone were employed in the study, since these locations did not include the cases where flashers were originally installed and later replaced by traffic signals. It was believed that this type of improvement could be related to accident experience where flashers were not effective in reducing the number of accidents.

The existence of other sources of information was not immediately apparent to the research team in order to identify the locations with such an improvement history. Therefore, the Traffic Signal Inventory was further employed to make another list containing the entire work on traffic signals between 1967 and 1974. In this manner 307 additional locations were identified for further review.

The total of four hundred and some locations identified above were examined by the nature of improvement. A review was made of the work authorization forms and other documents filed at the

Traffic Central File, MDSHT. Much care was taken to confirm that no electrical control devices existed at the intersection prior to the flasher installation.

Through this review, many flasher installations which were irrelevant to this study were eliminated (e.g. flashers attached to warning signs and miscellaneous improvement and maintenance work on existing flashers). By exploring the improvement history of each signalized intersection, several locations with 1967-74 flasher installations prior to stop-and-go signals were identified. For each of these new flasher installations, its location and a brief description of the type of device and intersection geometry were recorded.

An effort was made to capture the effect of the lens size modernization (8 inch to 12 inch diameter) on accident reduction. Many flasher improvements among the 103 locations were of this type, and were installed around 1972 during a statewide program for such modernization. These locations were also recorded for accident analysis.

When the above investigation was almost completed, the research team was informed of the existence of a list of Work Authorization Forms maintained by the Electrical Device Unit. Although the task could be redundant, a decision was made to also review this list to guarantee the completeness of the list of flasher installations. Through the review on the Traffic Central File, it had been found that the Traffic Signal Inventory was not necessarily updated with the latest work authorization for each location. By reviewing the above list for all flasher-related authorizations from 1966 through 1974, it was found that there was quite a large number of new installations and modernizations which had not been identified in the review based on the Inventory. Further, some of the undated flasher improvements in the Inventory were found with their completion dates in this list. A total of 200 additional locations were identified from this list for further investigation in the Traffic Central File.

During the course of the above procedure, a problem of undated improvements was noticed by the research team. Many of them were concentrated in the Detroit Metropolitan District, where very old traffic signal installations were founded. However, it was later found that the undated works were not necessarily old. Rather, when the date of work completion was not known, the date was left blank, and the number of these undated changes was substantial.

For the purpose of the study, the date of flasher installation was crucially important in determining the before and after periods for accurate tabulation of accident experiences. For this reason, we had to discard a substantial number of locations where flasher installations were authorized during the study period, but installation dates were unknown. In this respect, the study locations comprise a sample set from the entire 1967-74 flasher installations despite the fact that 100 percent of the dated and relevant installations was included. The research team believes that unknown installation dates are not systematically related with any of the factors affecting accident experience.

As a conclusion of the entire spot identification procedure, 89 new flasher installations and 65 lens diameter modernizations were identified as the sample for before and after accident comparison.

B-2 Accident Data

Following the above identification process, accident data were retrieved from the MDSHT Accident Master File for a period from 1966 through 1976. All reported accidents that occurred within 0.04 mile of each intersection were tabulated regardless of their types or causes.

Upon examining the 11 year time series of annual accident data for each intersection, it was found that accident data for some intersections were not found for certain years.

Some of these problems were caused by changes in the MDSHT District to which the intersections were assigned or to the turnbacks of State Trunklines to a county. It was also found that accident data were not available for the City of Detroit. Therefore, several locations were discarded.

For some locations, however, it was noted that the unusual accident records were a result of changes in the MDSHT Control Section mileage logs of these intersections. Considering the importance of accurate accident tabulations in this study, a decision was made to review all intersections in the set for historical changes in mileage logs. For the locations where changes were found within the "before" or "after" study periods, accident data were manually retabulated by the research team, employing Accident Log Listing (a Michigan Accident Location Index package; a one line summary of each reported accident), maintained by the Accident Analysis Unit. Considering the time requirements for this review the lens diameter modernizations were excluded from further consideration.

In tabulating the before and after accident experiences, a two month period centered on the installation data was excluded to eliminate the transient effects of the installation work and system change on accident occurrence. The length of this period was determined by studying sample intersections to identify the transition in the accident experience after the flasher installation.

For 1967 and some of the 1968 installations, accident data were not available for the entire two year period. In this case, one year before and after periods were used.

The research team had obtained separately the state-wide total number of intersectional accident tabulations for the 1966-1976 period. Examination of these tabulations had revealed the existence of many undated accidents in 1966 and 1967, about 5 percent of the total 1966 accidents, and 1.3 percent of the 1967 accidents. Further, it was found that extremely high numbers of accidents were recorded for January and February, 1967 (28% of annual accidents in these two months) and extremely low numbers of accidents in February, 1966 (4.4% of annual accidents) and in November and December, 1967 (8.9% in two months). Some systematic errors in the Accident Master File are very strongly suspected. The research team was reluctant to eliminate the flasher installations which were affected by these unreliable accident data (1967-1969 installations) since approximately one third of the sample would have had to be discarded.

Fortunately, accident tabulations for the intersections of concern were generally available in the engineering analyses filed at the Traffic Central File. Many of these tabulations were prepared by the County Sheriff or Road Commission. Thus a decision was made to use the accident data from the Accident Master File after confirming their validity against other tabulations.

The before-after accident tabulation involved information on severity, weather, light condition, surface condition, and accident type. All classifications are based on the MDSHT and State Police codes.

During the course of accident data tabulation, several locations were eliminated from the sample for various reasons. Some were due to the unavailability of accident data. Others were due to new findings about the intersection improvement history. The reasons for eliminations are listed below.

Reasons	No. of Locations
City of Detroit (No accident data filed)	2
No accident data retrievable after the turnback to the County	2
Temporary flasher installations	3
Intersection Relocation	2
Existence of flashers prior to the investigated installation	2
Total	12

As a result, the number of new installations was reduced to 77. Among these, 8 were later replaced with traffic signals.

B-3 ADT Information

The desired traffic information for this study involved flow data for both major and minor approaches, and appropriate turn-movement counts to represent the stream conflicts at the intersection. It was also desired that ADT counts be obtained so that traffic flows for both before and after study periods could be reasonably represented.

In the spot identification procedure, the existence of intersection traffic counts was checked for each location. It was found that counts were available for only 39 intersections.

An alternative information source was the TVM (Trunkline Vehicle Mileage), which provided accurate flow counts for the roadway segments containing the intersection. Data were available from 1967 through 1975.

To the best knowledge of the research team, no organized MDSHT information source existed with regard to the traffic flow along minor (non-Trunkline) cross roads. Although the data files at the Jackson Field Office were examined for possible usage, their employment was impossible because the file organization required an inordinate amount of effort to retrieve the information, and the existence of the desired information was not assured. As a result, the study had to be conducted without any crossroad traffic information for half of the intersections.

A Note on Historical Changes in Intersection Geometrics and Traffic Control - In this type of before and after study, a chronological trace of the changes associated with each location is crucially important in obtaining fully valid conclusions. Through the review of the Traffic Central File, it was found that flasher installations were frequently accompanied with other "minor improvements", such as pavement resurfacing, parking regulation and traffic sign modification. At some of the intersections, changes in geometrics were found after the time of flasher installations.

However, it was recognized that the materials contained in Traffic Central File were not substantial enough to identify the dates during which these improvement works were conducted. In some cases it was difficult even to determine whether the recommended improvements were carried out.

With the lack of information sources which could be efficiently utilized for identifying these changes chronologically, the amount of effort required was expected to be far above what was available. Thus a decision was made to limit the detailed investigation on improvement history only to the 27 intersections with significant before and after changes in accident experiences.

B-4 Photolog Study

For the 27 intersections where significant changes in accident experience were found after the flasher installations, (Chapter 4), detailed information was collected employing various information sources. The MDSHT Trunkline Photolog was utilized to collect extensive information on intersection and approach geometrics, pavement markings, sight conditions, corner developments, traffic signs, and flasher and crossroad visibility.

Approach Geometrics - The horizontal and vertical geometrics along the Trunkline approaches were recorded for 1 mile approaches to the intersections. From the Photolog screen, mile posts for points of curvature and points of tangency and direction of the curves were recorded to represent the horizontal alignment. The sharpness of curves was approximated by the presence of curve warning signs and advisory speed panels.

Similarly, vertical geometrics were recorded along with the mileposts where changes in alignment occurred. The type of these changes in geometrics were recorded as, e.g. crest, sag, and upgrade to level. The apparent steepness of the grade was also noted.

Traffic Signs and Controls - Sign inventories were prepared for the one mile Trunkline approaches. Of particular concern were intersection warning and/or guide signs, no-passing zoning, parking regulations, and speed zoning.

For each traffic sign which could serve as an indication of the existence of an intersection, its type, location, approximate size, and legend (if necessary) were recorded.

Posted parking regulations at, or in the vicinity of the intersection were carefully checked. Further investigations on parking regulation were later conducted using the traffic sign inventory maintained by the Reflective Devices Unit.

No-passing zoning was recorded with its starting and ending points. Important information obtained included whether passing was prohibited at the intersection. By merging the information on approach alignment, curve warning signs, and no-passing zoning, it was possible to quantitatively capture the characteristics of the Trunkline approaches.

The speed limit transitions along the approaches to each intersection were recorded from the Photolog. Historical changes in speed limit were investigated on the authorization forms for speed zoning.

Intersection Geometrics and Markings - Although most of the information on intersection geometrics was available from the engineering drawings accompanying the Work Authorization Form, exact information on lane assignment, channelization, pavement marking and turning flares still had to be obtained from the Photolog. The information on flares provided by the shoulder pavement appeared to be important since the flare might be one of the indicators of intersection presence to the approaching driver.

Pavement Marking at the intersection was carefully recorded. Also pavement edge markings on the approach roadways were recorded.

Intersection Corner Developments - Corner developments were recorded with type of facilities (e.g. service station, restaurant). Occasionally, descriptions of the apparent visual clutter created by these facilities were recorded.

Corner sight obstructions were carefully observed. A categorical description of the degree of obstruction was used to represent the sight triangle condition at the intersection.

Flasher and Crossroad Visibility - The greatest visible distance to the flasher was determined for each approach to the intersection from the Photolog. It should be noted that the height of the Photolog movie camera was approximately 5.5 feet, much higher than the driver's eye height of a typical passenger car. Thus the visibility distance is overestimated in cases where a vertical crest obstructs the flasher.

At the same time, the greatest visible distances to crossroad pavement surfaces and turning flares if applicable were measured. It was expected that the difference between the visibility distances to the flasher and the crossroad surface or flare could be a variable representing the effectiveness of the flasher in providing drivers with information on the intersection presence.

Other Information - Of particular concern with the three-leg (T type) intersection was the existence of target arrow warning signs and obstruction delineators indicating the termination of the roadway. Roadside developments along the opposing side of this roadway, especially driveways were carefully sketched.

Safety lighting was investigated on the Photolog since the Traffic Central File did not always carry Work Authorizations on the lighting. Shoulder treatment and the presence of other major intersections were also recorded. Roadside developments were cross-classified by density (rural, suburban and urban) and land use (vacant or agricultural, residential and commercial) for each approach. When community clusters existed close to the intersection, transitions in the environment along the approaches were recorded in detail.

B-5 Minor Road Approach

The available information on the minor approaches was very limited and far less compatible with that on the major approaches. Occasionally the traffic engineering analysis before the flashers installation referred to the sight conditions from and/or geometric problems along the minor approaches. Also photographs of/or from these approaches are almost all of the accessible information sources.

An attempt was made to investigate the intersection precaution signs along the minor approaches using the Traffic Sign Inventory maintained by the Reflective Devices Unit. However, no substantial information was obtained other than the size of the stop signs, and the existence and size of the "STOP AHEAD" signs.

APPENDIX C

SUMMARIES OF PREVIOUS STUDIES

Solomon's study (1959) investigated Michigan accident experience following flasher installations at 50 locations in the 1950's. A before-after comparison with one or two year periods was made and the number of accidents was found to be reduced by an average of 26 percent, from 402 to 299, and the number of persons injured by 50 percent.

The effect of ADT was investigated at 25 intersections where counts were available. Reductions in accident and injury rates were found across the entire ADT range, but with a lesser reduction as ADT increased.

The number of accidents was apparently decreased under all weather conditions and both day and night. However, the night reduction of 33 percent was greater than during the day (20 percent). Independent analysis of Solomon's accident data by the research team indicated, however, that claimed interactions between natural night and weather conditions are not significant.

No differential effect of the flasher on type of accident was found by Solomon. Also he found no clear effect for the number of approach legs, although the percentage decrease of accidents per million vehicles (MV) entering the intersection increased with intersection complexity.

In a study for the Ohio Department of Transportation, Foody and Taylor (1967) conducted a before-after study at 82 intersections where flashers were installed between 1955 and 1960. The factors explored in this extensive study included the type of flashing device, intersection geometrics, line of sight distance, and environmental features. In comparing the before-after accident experience, student t-tests were applied to the entering vehicle accident rate difference. They observed a 53 percent reduction in accidents, a very significant result. Their other findings were that the flasher effect depends on the type of flashing devices used. They also reported an interaction between the device and intersection type. There was no overall difference in accident pattern or by light condition, but some flashing devices showed a higher reduction in night-time accidents and rear-end and angle collisions. No clear relationship between ADT and accident reduction was observed although there was a tendency that the flasher accident improvement diminished at very high ADT intersections. When the line of sight was greater, more reductions were observed.

Tamburri, et.al. (1968) used several measures of accident experience incomparing the before-after accident experience at 29 California intersections. These were the number of accidents, the entering vehicle accident rate, the number of equivalent property damage only (EPDO) accidents, the EPDO entering vehicle accident rate, and the severity index. The 29 intersections included several locations with four-way stop control.

Their findings were: the total number of accidents was reduced significantly (at the 90 percent level) at 10 intersections; severity was reduced, resulting in a 50 percent reduction in the number of EPDO accidents at these intersections; at four-leg intersections a reduction in the accident rate from 2.3 acc./million vehicles (MV) to 1.6 add/MV and a 36 percent reduction in EPDO accidents were observed; there was a remarkable reduction in multiple vehicle accidents at four-leg intersections, especially right-angle accidents, and in single vehicle accidents crossing the intersection for the stem at six 3-leg intersections; there was a greater reduction in the accident rate at four-leg unchannelized intersections than at the four-leg channelized intersections; there was a reduction in severity at unchannelized intersections, especially for night-time accidents at four-leg intersections; a greater accident reduction for 12 inch diameter lenses compared with 8 inch lenses was found.

Following these findings, Tamburri developed warrants for flasher installations at four-leg intersections. For the case when the minor to major entering traffic volume ratio did not exceed 0.5, two criteria used were, 1) four or more left-turn plus right angle accidents in one year, or 2) six or more left-turn plus angle accidents in two consecutive years.

Cribbins and Walton (1970) studied the before-after accident experience at 14 rural intersections in North Carolina employing the same measurements as Tamburri. They reported a 48 percent reduction in the EPDO rate as an overall flasher improvement factor. This was concluded to be significant at the 99 percent level by applying the student t-test. They also reported a 21 percent decrease in multiple-vehicle accidents, a 62 percent decrease in single-vehicle accidents, a 33 percent decrease in the EPDO rate at four-leg intersections, and an 88 percent decrease at three-leg intersections. Other findings included a decrease in the severity index except at channelized intersections, decreased rear-end, accident experience, fewer angle and "other" accidents except at the unchannelized intersections and an insignificant increase in the EPDO rate at unchannelized intersections.

The research team conducted a separate analysis of the Cribbins and Walton data looking at accident and severity data separately and using contingency table analysis.

Considering all data, a general reduction on the order of two accidents per year per site was found, a 27 percent reduction (significant at the 90 percent level). Considering all locations there was no discernible difference in the reduction in single-vehicle or multiple-vehicle accident experience. Flashers installed at three-leg intersections had almost a two-thirds reduction, four accidents/site/year, (95 percent).

There was also a significant effect in severity on all of the data as described below (significant 90 percent):

1. There was essentially no change in the number of property damage only accidents.
2. There was more than a 50 percent reduction in minor injuries.
3. There was almost a 2/3 reduction in the number of major injury accidents recorded at the entire set of sites.

The ten channelized intersections were compared with the four unchannelized intersections. While the ten channelized intersections had a decrease in accidents of three per year site (64 to 34), and almost 50 percent reduction, those intersections which were not channelized increased approximately 1.5 accidents per year per site to a value of almost 8. It is statistically significant at the 98 percent level that these two types of intersections are not responding similarly to the installation of the flasher.

Thorpe conducted a before-after study at nine intersections in Victoria, Australia. Five of these intersections were controlled by four-way flashing amber beacons before the flasher installation and four were two-way stops. A 30 percent reduction in total accidents were observed. He reported no significant difference in accident reduction between these two groups of intersections but there was a 40 percent reduction in right-angle accidents.

Adreeassend (1970) also evaluated 25 intersections in Victoria. The overall reduction in accidents was 45 percent and right-angle accidents were reduced by 50 percent, both reported to be significant at the 99 percent level employing the Wilcoxon test. The same order of reduction in accident severity was also reported. He observed that the greatest reduction in accidents occurred at those intersections with high initial accident frequencies, and concluded that the flasher was effective where there had been a history of two to three right-angle accidents per year, but should not be used when the volume was high enough to warrant traffic signals.

APPENDIX D

BRIEF DESCRIPTION OF SIX FIELD-STUDY INTERSECTIONS

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M-15 at Dodge Road

Sight condition problems were recognized in the engineering analysis for the flasher installation. The accidents were improved from 13 in the before period to 6.

The intersection is on a horizontal curve along the major two-lane road (M-15) and located near a crest. The flasher visibility distance is short along the major approaches. The roadside environment is rural.

The east leg (minor approach) is rolling and curved. The vertical alignment to the intersection is up-grade, and the intersection is located right beyond a crest. Accordingly, the crossroad pavement is entirely invisible until one arrives at the intersection.

The west leg has a steep rolling terrain. The stop sign appears above a crest at 0.15 mile away from the intersection. The flasher visibility distance is 0.35 mile.

The sight condition at the intersection is limited for the both minor approaches due to the curved and down-grade alignment of M-15.

M-78 (Temp. I-69) at Lake Lansing Road

M-78 is a divided expressway in a rural environment There is another flasher at Marsh Road about one mile away along M-78. Following 46 accidents in two years, the flasher was installed in 1973,resulting in a reduced number of accidents of 27 in the following two years. The traffic control at the median was altered from "yield" to "stop" at the time of flasher installation.

The intersection is on a large curve along M-78 and skewed. The corner is clear with appropriate right-of-way for clear vision.

The north approach of Lake Lansing Road goes through a residenital area with four lanes and narrows to two-lane near the intersection. This approach has a steep up-grade section close to the intersection after a four-leg intersection located at a sag (.25 mile away for the flasher). The major road pavement is visible at about 0.1 mile from the flasher.

The south leg is straight and rolling in low density rural residential area. The speed limit is 45 mph, passing is restricted in both directions and adequately marked and signed. The "stop ahead" sign is visible at 0.18 mile, but the major road pavement is yet not visible from this point. The flasher is continuously visible from about 0.25 mile. The alignment is down-grade to the intersection.

The sight condition at the intersection is good but the skewness may cause certain difficulties for the minor-road driver.

M-52 at Grand River Road

Bad geometrics along the minor road were noted int engineering analysis for the flasher installation. Advanced sign improvements, pavement resurfacing and passing flare construction took place before the flasher installation, but the dates and detail of these improvements are unknown. Considering the increased accident experience in 1972, the flasher was installed in January 1974, and resulted in a reduction from 10 to 1 accident in two year periods.

The intersection is located in a rural area. Both the major and minor roadways are two-lane. The east leg (minor road) is straight with no gravel shoulders, trees on both roadsides, and involves slight rolling. There is a short but steep up-grade right before the intersection. This significantly obstructs the view to the intersection. The flasher is visible from 0.8 mile away, a "Stop Ahead" sign from 0.5 mile, and the stop sign is visible from 0.4 mile.

The west leg involves a crest close to the intersection. This crest hides the bottom of a "Stop Ahead" warning sign. The stop sign becomes completely visible at 0.2 mile, but is not within the normal sight of a driver since it is located far to the right due to a short right turning flare with almost no taper. The approach is downgrade to the intersection . The major roadway involves rolling terrain near the intersection, and there is a crest shortly to the south from the intersection. The view of the south major leg at the intersection is limited from both minor approaches because of the vertical alignment along M-52.

M-54 (Dort Highway) at Stanley Road

The flasher was installed in May 1968 following 9 accidents in the foregoing 2 years. In the following two years 19 accidents (12 involved injuries) were observed. The intersection has four legs with five-lane major approaches and has suburban residential - commercial corner developments. Presently (October 1977) the intersection is traffic signal controlled.

The major approaches have adjacent signal controlled intersections about 0.5 mile away from the investigated intersection. The approaches have good visibility of the signal.

The high-type two-lane minor approaches (Stanley Road) are straight, with slight rolling on the east side. The speed limit is

45 mph. The west leg is installed with street lights.

From the west leg, the signal is visible all the way along the approach. The slight rolling terrain on the east leg obstructs visibility, and the visibility distance is 0.38 mile.

M-56 (Old M-21, Corunna Road) at Elm Road

The major road (M-56) has four lanes with rumbler strips at the center line. The west leg is a divided highway at 0.8 mile away from the intersection. It is presently signal controlled. The total number of accidents is increased from 18 to 35 in the two year period following the flasher installation.

The west leg is curved on the approach, and the signal head is visible at approximately 0.45 mile away from the intersection. The sight restriction is very slight. The east leg has good alignment with a signal visibility distance of 0.65 mile.

The south minor leg (Elms Road) is two-lane, straight and flat, with the speed limit of 45 mph, street lighting, and in suburban residential environments. The signal is clearly visible from a great distance (more than 1.4 miles), and the sight condition at the intersection is good.

The north leg has the similar characteristics as the south leg, except that it involves very slight rolling. The signal is visible from more than 0.9 mile away. Extremely good sight conditions along these minor approaches are noteworthy.

US-27 BR, M-50 (Cochran) at M-50 (Upland and Shepherd)

The north approach (US-27 BR) goes through Charlotte downtown area. The flasher and intersection is clearly visible from an adequate distance, and the intersection is heavily signed aling this four-lane approach.

The south leg, another major approach, is straight involving a crest close to the intersection. The flasher is visible from 0.5 mile away, but the view of the pavement of the crossroad itself is obstructed by this crest. The guide and route signs are very densely installed also along this approach, and the speed limit is 45 mph.

One of the minor approaches (west leg) apparently has light traffic generated by the local community. A four-way-stop controlled intersection exists a few blocks away from the investigated intersection. The approach is straight and the flasher is visible from 0.5 mile away.

The east leg (minor approach) is a State Trunkline, and involves a junction with I-69 about 0.75 mile away from the intersection. The approach is a high-type two-lane highway, and does not have any electric control devices for more than 10 miles from the intersection.

There is a combination of horizontal up-grade and vertical curves close to the intersection. The flasher visibility distance is short (0.25 mile) accordingly. The approach is heavily signed with route and guide signs, and these signs are visible at the same time as the flasher . The stop sign itself is hidden by these signs.

The sight at the intersection is obstructed to the right by roadside trees. Also the crest on the south leg restricts the view to the left. The accident experience at this intersection is 9 total accidents in the before period, and 17 in the after period.