PB98-144611

The Safety Effects of Signalizing Intersections

FINAL REPORT

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26 November 97

Conducted for the
Michigan Department of Transportation

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1855

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle The Safety Effects of Signalizing Intersections		5. Report Date November 1997 6. Performing Organization Code
7. Author(s) Richard W. Lyles, Stephanie Rossi, and Stephanie Tumey		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Civil and Environmental Engineering Michigan State University East Lansing, Michigan 48824-1226		10. Work Unit No. 11. Contract or Grant No. MDOT-94-1521-D
12. Sponsoring Agency Name and Address Michigan Department of Transportation 425 West Ottawa Street Lansing, Michigan 48993		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The study was directed to the evaluation of the safety effects of signalizing previously unsignalized intersections on state trunklines in Michigan. An initial set of ~350 intersections which had been signalized between January 1986 and December 1992 was provided by the Michigan Department of Transportation (MDOT). Data describing both the physical characteristics of these intersections and the motor vehicle crashes that had occurred at them were then acquired and merged. For the analysis, the intersections were initially separated into one of several types: 4-way, 3-way, crossover, driveway, and ramp-end. The emphasis was on the first two types and the last was eliminated because of crash location problems. The analysis primarily consisted of comparison of before-and-after crash statistics. The most-notable results (based on 2-year before-and-after-signalization analysis periods) included the following: while crash frequencies generally (but not always) increased, there was variation by type of intersection and other variables (e.g., geographic location); there was a very clear shift from angle to rear-end crashes; there was some shift toward less severe crashes although relative distributional shifts were offset by increases in crash frequency in some instances; and, while some factors (e.g., geographic area) affected the results, others (e.g., time of day, day of week) did not.

17. Key Words signalization, safety effects, crash type, crash severity, crash frequency		18. Distribution Statement	
19. Security Classification (this report) Unclassified	20. Security Classification (this page) Unclassified	21. No. of Pages	22. Price

ACKNOWLEDGMENT

The authors wish to acknowledge the support for this research which came from the Michigan Department of Transportation (MDOT). They also wish to express their appreciation to the MDOT professional staff who provided data and other background materials and who showed great patience throughout the project. Among them, the following were especially helpful and understanding: Dale Lighthizer, Tom Rathbun, and John Saller.

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1. Introduction and Problem Statement

The primary reasons for installing traffic signals are to control conflicting traffic movements and assign right of way. At the same time, it has long been argued that installing traffic signals (or other intersection traffic control devices) will sometimes result in the increase of certain types of crashes while others decrease. However, even though raw frequencies may increase, signalization is also hopefully accompanied by a reduction in the severity of crashes. For example, installing a signal may result in additional rear-end collisions while decreasing some types of angle crashes. Indeed, these were generally found to be among the results noted in earlier studies of signal installations in Michigan. It is clear (e.g., from the *Michigan Manual of Uniform Traffic Control Devices*) that there are a variety of reasons (warrants) for introducing signals to the intersection environment (i.e., from those related to vehicular volumes to crash experience and delay).

1.1. Problem Statement

The principal question of interest to the Michigan Department of Transportation (MDOT) was: What are the safety-related effects of moving from STOP-controlled to signalized operation at intersections on state trunklines in Michigan? As noted above, the conventional wisdom regarding signalization of intersections is that while absolute numbers of crashes may increase, severity is likely to decrease. One project task was to review the published literature to determine if past history in Michigan and elsewhere supports this assertion.

Originally, the research effort was also to include some examination of tradeoffs among safety effects, the actual cost of signal installation and maintenance, and operational effects such as delay. However, site selection and, especially, data collection developed into tasks which were far more time consuming than had been anticipated—far more resources had to be invested in data collection than planned. Thus, the research plan was modified—while the principal question regarding the safety effects of signalization was addressed, the secondary tradeoff issues were not.

The sites were identified by MDOT and included all trunkline intersections which were upgraded from STOP- to signal-control between January 1986 and December 1992. The classification of sites turned out to be fairly straightforward: 4-way, 3-way, driveway, cross-over, and ramp-end intersections. Of those, 4-way and 3-way intersections were studied extensively while driveway and cross-over intersections were examined at a more general level. Ramp-end intersections were formally eliminated from the study although a separate report will be made available at a later date.

1.2. Project Outcomes

This final report provides MDOT with important information for making decisions regarding intersection signalization. Basically, the conventional wisdom is validated. A very brief overview of the results of the safety analysis is provided below while far more detail is provided in chapters 4 and 5.

Total crashes for all intersections were generally observed to increase as a result of signalization although increases in the mean number of crashes were not statistically significant. Indeed, there was substantial variation in the numbers of crashes per intersection. The variation results from numerous factors (some which can be addressed and some not) and supports the notion that for any given intersection, an increase or decrease in the number of crashes would be difficult to predict, at least without more complex analysis. In some situations, decreases in the number of crashes at a specific site are certainly possible.

For all intersection types, the shifts in **crash type** were as expected *a priori*—that is, angle crashes decreased while rear-end crashes increased. This shift was most always observed and generally fairly dramatic. However, this shift also varies considerably based upon different conditions. This variation notwithstanding, this result is clearly the most reliable. This shift was evident for all types of intersections and, to the extent it could be examined, in all types of situations.

While there were increases in crash frequency, there was generally an offsetting trend in **crash severity** from more to less severe crashes. This trend was most notable for 4-way intersections and more modest for other types. However, it should be noted that in some instances, the net increase in crashes serves to offset some of the shifting among severity categories (e.g., while there may be *relatively* fewer "B-injury" crashes, the *absolute* number of "B-injury" crashes may still be higher (as a result of the overall increase in crash frequency).

As a result of this project, the Michigan Department of Transportation will be better able to assess the likely safety impacts resulting from signalization of previously unsignalized intersections. In addition, materials generated as a result of this project will be of assistance in explaining those impacts in a variety of forums.

2. Literature Review

The primary purpose of installing traffic signals at intersections is to promote efficient traffic operations while assigning the appropriate right of way and safely controlling conflicting traffic movements. While the overall purpose of this study is the assessment of the safety-related impacts of installing signals at a set of intersections on state trunklines in Michigan, the purpose of the literature review was more broadly defined as describing what is known about the effects of signalization from previous experience in Michigan and elsewhere. In this context, it is instructive to review the literature regarding the signalization of typical STOP-controlled intersections as well as at least some other related topics such as signalized diamond interchanges and the removal of unwarranted signals—the idea being that such related findings might provide insight to the specific problem at hand.

The literature review is, in turn, addressed to the warrants that are used for signal installation, the safety effects of signalization, and signal removal and other related issues.

2.1. Warrants and Warrant-Related Research

According to the Manual of Uniform Traffic Control Devices (MUTCD), a highway traffic signal will operate to the advantage or disadvantage of the vehicles and persons controlled (FHWA 1988). The number of warrants has varied over time from, for example, eleven in the 1988 MUTCD to the seven proposed in 1993. Both sets are presented here since many of the studies to be examined were based on intersections which were signalized under the "old" warrants. In any event, the warrants should be used as guides in determining the need for traffic control signals rather than absolute criteria. Therefore, before installation takes place, the intersection and all its characteristics must be taken into account with a thorough engineering study of the roadway and traffic conditions. The traffic studies must be used to determine what type of installation is necessary, if any.

According to the MUTCD, comprehensive engineering studies should precede the installation of a signal and include the investigation of the appropriate warrants. These studies are necessary to determine the need for the signal, type of signal, timing program, and signal design. Some of the suggested data included: traffic counts, turning movements, pedestrian volumes, the eighty-fifth percentile speed, a diagram of the physical layout, a collision diagram, distribution of gaps, vehicle-seconds of vehicle, and pedestrian delay time (FHWA 1988). Data suggested to be acquired for evaluations using the 1993 warrants include: the number of vehicles entering an intersection in each hour per approach during twelve consecutive hours of an average day, vehicular volume for each traffic movement from each approach, classified by vehicle type during each fifteen minute period of the morning and afternoon peak hour of travel at the intersection, pedestrian volume counts on each crosswalk during the same periods of vehicle counts and during hours of highest pedestrian volumes, eighty-fifth percentile speed on uncontrolled approaches to location, diagram showing details of physical layout, and a collision diagram showing crashes by type (FHWA 1993). Some other data collection items for a more precise description of the intersection include: vehicle seconds delay per approach, the number and distribution of gaps in traffic on major street, eighty-fifth percentile speed on controlled approaches, and pedestrian delay time for at least two 30-minute peak pedestrian delay periods on an average day (FHWA 1993).

The eleven warrants defined in the 1988 MUTCD are described below. (These warrants are the relevant ones for many of the studies discussed later and provided at least some of the basis for signalizing many of the intersections included in this study.)

Warrant One: Minimum Vehicular Volume. The volume of intersection traffic is the principal reason for traffic signal installation. The warrant is satisfied when for each of any eight hours of an average day (a weekday representing traffic volumes normally and repeatedly found at the location) the traffic volumes in the table below exist on the major street and on the higher-volume minor-street approach to the intersection.

Minimum vehicular volumes:

number of lanes each approach		vehicles per hour major street both approaches	vehicles per hour high volume minor single approach
major street	minor street		
1	1	500	150
2+	1	600	150
2+	2+	600	200
1	2+	500	200

Warrant Two: Interruption of Continuous Traffic. This applies to traffic conditions where the traffic volume on a major street is so heavy that traffic on a minor intersecting street experiences long delays before entering the flow of the major streets traffic volume.

Minimum vehicular volumes:

number of lanes each approach		vehicles per hour major street both approaches	vehicles per hour high volume minor single approach
major street	minor street		
1	1	750	75
2+	1	900	75
2+	2+	900	100
1	2+	750	100

Warrant Three: Minimum Pedestrian Volume. If the pedestrian traffic is one hundred or more for any five hours in a day or one hundred and ninety in one hour then a signal is warranted. There shall also be less than sixty gaps per hour in the traffic stream of adequate length for pedestrians to cross during the same period.

<u>Warrant Four</u>: School Crossings. A signal may be warranted at an established school crossing in relation to the size of the pedestrian groups crossing the intersection along with the adequacy of gaps in the vehicular stream. A minimum of at least fifty children should be utilizing the crossing before applying this warrant. Less restrictive measures should also be considered before installing a traffic signal.

Safe Gap: T = 3 + (width of street/401) + F
where F = (number of children per group-1/5) (2)

<u>Warrant Five</u>: Progressive Movement. This is for an intersection that may not qualify otherwise for a signal such as a one-way street with few signals which do not provide the necessary degree of vehicle platooning and speed control or a two-way street which adjacent signals do not provide the necessary degree of platooning or speed control and proposed adjacent signals could constitute a progressive signal system. Signal spacing must be more than one thousand feet apart in addition to an area study should indicate that a minimum of two hundred vehicles per hour for each eight hour period benefit from a gap produced by a signal installed under this warrant.

<u>Warrant Six</u>: Accident Experience. This is met when all of the following apply: lesser remedies were unsuccessful, five or more accidents (crashes) occurred in one year which could have been prevented due to the installation of a traffic signal, there exists a vehicular and pedestrian volume eighty percent or greater than specified in warrants one, two and three, and lastly the signal will not seriously disrupt the traffic flow.

<u>Warrant Seven</u>: Systems. This is to encourage concentration and organization of traffic flow networks. This warrant is applicable when the common intersection of two or more major routes has a total existing or immediately projected entering volume of at least 1,00 vehicles during the peak hour of a typical weekday and has five-year projected traffic volumes which meet one or more of warrants 1,2,8,9 and/or 11 during an average weekday or has a total existing or immediately projected entering volume of at least 1,00 vehicles for each of any five hours of a Saturday and/or Sunday. A major route has one or more of the following characteristics: it is part of the street or highway system the serves a principal network for through traffic flow, a highway out side of, entering or traversing a city and/or it appears a major route in an official plan.

<u>Warrant Eight</u>: Combination of Warrants. No single warrant is satisfied but warrants one and two must be met by eighty percent of MUTCD standards.

Warrant Nine: Four-Hour Volumes. This is satisfied when each of any four hours of an average day the plotted points representing vehicles per hour on the major street and the corresponding vehicles per hour on the higher volume minor street approach all fall above the curves shown in MUTCD for the existing combination of approach lanes.

Warrant Ten: Peak-Hour Delay. The traffic volumes are such during peak hours that traffic entering the major street from the minor street suffers undue delays due to excessive traffic on the intersecting street. The total peak hour delay must exceed four hours, the side street approach must be 100vph per one lane or 150vph per two lanes and the total entering volume for the intersection during the hour equals or exceeds 800vph.

Warrant Eleven: Peak-Hour Volume. In this warrant the traffic volumes are also such during peak hours that traffic entering the major street from the minor street suffers undue delays due to excessive traffic on the intersecting street. This warrant is satisfied when the plotted point representing the vehicles per hour on the major street and corresponding vehicle per hour of the higher volume minor street approach for one hour of an average day falls above the curve for the existing combination of approach lanes.

Past research has been directed to the examination of the effectiveness of traffic control device warrants due to averse changes in traffic conditions at newly signalized intersections. The question of safety in relation to crashes is raised by the MUTCD in the "accident" warrant which states "a traffic signal is warranted when five or more crashes susceptible to correction have occurred in a twelve month period" (MUTCD). Baldwin (1966) noted that the manual was directing engineers to respond to conflict rather than to anticipate it, i.e., there was no warrant which is forward looking. As time has passed and the need arisen, the warrants have been modified to reflect research findings and practice regarding signal installation. Researchers have raised questions regarding the effectiveness of the warrant system along with questions concerning the effectiveness of individual warrants.

In 1981, Clement stated that he believed the warrants based on approach volumes such as warrants one and two needed to be modified and modernized. He stated that, "In fact the approach volumes do not reflect the need for signalization, rather the conflicting traffic volumes within the intersection itself do" (Clement 1981). The argument was that if traffic is light and there are sufficient gaps in the traffic, a signal may not be necessary even if the traffic signal warrants based on approach warrants have been met.

The more recent modifications of the 1988 warrants is, for the most part, a condensation of the eleven warrants to seven. The actual text of the warrants have changed for easier use and understanding although the actual numerical criteria within the warrants have not been altered. Former warrants 1,2, and 8 have been combined into Warrant 1. Warrants 10 and 11 now make up Warrant 3. Warrants 9 is now warrant 2 and warrant 3 is now 4.

The previous warrant (4) regarding school crossings has been moved to Section 7D.4 of the manual and finally warrant 5 and 7 have revised titles (FHWA 1993).

The new language of the MUTCD indicates that a signal should not be installed unless an engineering study indicates it should, at least one or more of the warrants are met, the signal will not seriously disrupt the traffic flow, and solid engineering judgment is used (FHWA 1993). The following is an abridged description list of the 1993 version of the signal warrants (for tabular values, reference is made to the earlier version of the warrants on page 3-2).

> **Warrant One**: **Eight-Hour Vehicular Volume.** Condition A: applies where the volume intersecting traffic is the principal reason for consideration of the traffic control signal installation. Condition B: applies when traffic volumes on a major street are so heavy that traffic on a minor intersection street suffers excessive delay or hazard upon entering or crossing the major street.
>
> **Warrant Two**: **Four-Hour Vehicular Volume.** The four-hour vehicular volume warrant conditions are intended for application where the volume of the intersection traffic is the principal reason for consideration of traffic control installation.
>
> **Warrant Three**: **Peak Hour.** This warrant is for use at intersections where traffic conditions are such that for a minimum of one hour of an average day the minor-street traffic suffers undue delay in entering or crossing the major street.
>
> **Warrant Four**: **Pedestrian Volume.** To be applied where the traffic volume on a major street is so heavy that pedestrians suffer excessive delay or hazard in crossing the major street.
>
> **Warrant Five**: **Coordinated System.** Progressive movement in a coordinated system requires a traffic control signal installed at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.
>
> **Warrant Six**: **Accident Experience.** Applies where the severity and frequency of accidents (crashes) are the principal reasons for considering the installation of a traffic control signal.
>
> **Warrant Seven**: **Roadway Network.** This warrant applies to when the justification to install the signal is to encourage concentration and organization of traffic flow on a roadway network.

2.2. Safety Effects of Signal Installation

The safety effects of traffic signal installation have long been in question. One of the earliest studies was done in 1953 by McMonagle who questioned the safety-related effects of moving from stop-controlled to signalized operation. McMonagle analyzed case histories from Michigan's signalization experience by reviewing documents regarding the relationship between traffic signals and intersection crashes. He came to the conclusion that signal installation must be properly warranted and installation methods must be improved to avoid crashes and negative travel pattern changes. While at the time of this study traffic warrants did not exist as they do today, his study still has relevance regarding the negative effects of installing a traffic signal and has often been cited by later researchers.

Datta and Dutta (1989) did work similar to McMonagle's. Their study was directed to an analysis of the safety effects at intersections with newly-installed traffic signals. Datta and Dutta used before-and-after approach to examine crashes at signalized intersections, ramps, and crossovers to evaluate the change in crash characteristics resulting from signal installation. They analyzed 155 intersections where signals had been installed between 1978 and 1983 and examined the total number of crashes at the intersections as well as the types of crashes and injuries. The comparison between various intersections showed that properly installed signals reduced total injury and right-angle crashes at intersections and ramp locations while rear-end and head-on collisions increased. Datta and Dutta noted that the results of their study of newly signalized intersections compared favorably with past studies with respect to the number of crashes at the intersection as well as the types of crashes and injuries (Datta and Dutta 1990). While there were some questions about details of the Datta and Dutta study (see Mercer 1988), many other studies have been conducted along the same line using a before-and-after approach.

By using before and after (signalization) crash histories, one can determine the change the signal has had on the intersection and what it might be in similar intersections. Many researchers have tried to determine the impact a new signal will have on categorized motor vehicle crash occurrences within an intersection. For example, from a review of before-and-after crash studies of newly-signalized intersections, Clyde notes that "traffic signals are not safety devices, but rather a means of assigning right-of-way" (Clyde 1964). Clyde believed traffic signals required the driver to stop, which he felt was an unnatural action when the driver is not expecting to have to stop therefore increasing the chances of the driver causing a crash. Goldblatt and King attempted to determine the impact a new signal has on categorized vehicle crash occurrences. They examined 30 intersections in Virginia and found that when the number of right-angle crashes at a unsignalized intersection is low, the installation of a signal could cause as increase in the total number of crashes (Goldblatt and King 1975).

Hakkert and Mahalel conducted a study of 34 intersections with recently installed traffic signals in Israel. The authors found that the installation of the traffic signals did not have a uniform effect. Intersections with more than five crashes per year generally experienced a reduction of crashes while intersections with less then two crashes per year generally experienced an increase (Hakkert and Mahalel 1978). This is similar to Goldblatt and King's 1975 study results insofar as intersections with a small number of crashes before signalization tend to experience more crashes after signalization. The opposite is believed to be true when there is a larger number of crashes occurring at the intersection prior to signal installation. Similarly, Baldwin (1966) also noted in his study in New York City that where there have been a large number of crashes, a signal usually reduces the frequency. Intersections with relatively moderate crash frequency experience little change while those with a relatively low crash frequency will normally experience an increase.

More recently, Vey (1933) also found similar results when he analyzed approximately 600 intersections in the United States with newly installed traffic signals. He concluded that after signals were installed at intersections with three or less crashes per year, the crash frequency increased 39-70%; after a signal was installed at intersections with three or more crashes per year, crashes were reduced 19-49% (Vey 1933). According to the research it also seems to hold true that intersections with low traffic volumes tend to experience fewer crashes but if a signal is installed which is not necessary, even though the warrants have been met, crash numbers tend to increase. In 1959 Solomon examined intersections with low traffic volumes to determine what the safety implications of installing traffic signals would be. Solomon's results revealed that an increase in crashes occurs at intersections with low traffic volumes such as those with less than 20,000 average daily trips (Solomon 1959).

It would also appear that signalization tends to reduce certain types of crashes (e.g., angle crashes) while increasing other types (e.g., rear-end crashes). From the previous studies it also appears that the decrease in angle crashes is sometimes not great enough to offset the increase in rear-end crashes therefore actually showing an overall increase in crashes at some intersections. Schoene and Michael examined intersections with low crash frequencies to determine the safety implications of traffic signal installation in 1968. Their results showed that if there are fewer than five right-angle crashes per year prior to signalization, the increased number of rear-end crashes is usually large enough to offset the small decrease in the right-angle crashes after signalization (Schoene and Michael 1968). Many of the studies have shown that signal installation can either help increase traffic safety or it can cause more traffic conflicts. As Baldwin stated "One must first ask will installing the signal improve traffic conditions, or will results be worse?" (Baldwin 1955).

Yiu-kuen Lau and May developed injury-crash-prediction models for signalized intersections in order to estimate the rate of crashes that will occur at signalized intersections in California (Yiu-kuen Lau and May 1988). This study was developed using the data base from the Traffic Accident Surveillance and Analysis System (TASAS). The models include factors such as traffic intensity, percentage of cross street traffic, intersection type, number of lanes on main and side streets, and left-turn arrangements. A rural versus urban differentiation was not been found to be significant. For this study injuries included all injuries from slight to severe. Three models were developed to predict crashes and were based on traffic intensity, intersection characteristics, and information that includes individual crash histories (Yiu-kuen Lau and May 1988). These models can be useful in determining crash forecasts at signalized intersections.

The basic conclusion that can be drawn from the work to date is that intersections should be thoroughly analyzed before signals are installed—crash savings (or costs) are related to a variety of factors that go beyond just signalization *per se*. It should be determined if the intersection is better suited for stop sign or for signal control. It should be clear that the warrants are met, and even then intersection should be monitored after the signal is installed to analyze its effectiveness. Neudorff stated that improved crash experiences occur at newly signalized intersections with large traffic volumes, a high crash frequency, and a geometrically complex intersection with five or more approaches although these types of intersections are not as common (Neudorff 1978). Similarly Knox and Warden contend that if the warrants are correctly followed, traffic signals probably provide the strictest, although most costly method of intersection control (Knox and Waldron 1972).

2.3. Signal Removal

In some instances it may become necessary to remove traffic signals that were never warranted to begin with or where the warranting conditions have changed. Traffic signals provide the maximum intersection control to regulate traffic flow. It is possible that unwarranted traffic signals may be installed in many communities due to neighborhood or other political pressure or a lack of transportation engineering knowledge. These same reasons also make it difficult to remove the signal.

Signal warrant reviews and updates need to take place at intersections were signalization appears questionable. Intersections where there is excessive delay or high crash rates should be reexamined to ensure that the warrants which originally indicated that the signal was needed are still valid. For example, a warranted signal which was installed to ensure safety for pedestrians at a school crossing may later be a candidate for removal if the school is no longer in operation or if the use has changed dramatically. Other reasons for a valid removal include excessive delays in traffic flow or projected traffic volumes which are never reached. It is also worth mentioning that the operation and maintenance of the signal itself is much more costly than the placement of STOP signs. According to a study conducted in 1981, a signal may consume over $500 of electricity a year and maintenance cost have been recorded as high as $3550 a year (unknown 1981). If the signal is not necessary, it is in the best interest of the community to have it removed or not installed in the first place due to unnecessary costs.

Nuedorff indicated that after traffic signals were removed from intersections which no longer needed them, the number of crashes generally decreased (Neudorff 1978). It is possible that the removal of an unnecessary signal can actually reduce the number of crashes that occur at an intersection. Instead of an increase in right-angle crashes there was a significant decrease after the signal was removed but the study did not determine that there will be a significant decrease in crashes at low volume previously signalized intersections. On the other hand, the authors of a 1981 study noted that while the overall number of crashes was not found to change significantly following signal removal, the type of crash did. Following conversion from signal to two-way stop control, the number of rear-end crashes tended to decrease by nearly fifty percent, while the number of right angle crashes was found to increase by approximately the same proportion (Unknown 1981).

2.4. Diamond Interchanges

In addition to traditional isolated intersections, intersections at diamond interchanges can also be signalized and experience related safety effects. Diamond interchanges are commonly used in Texas and in the western United States in both urban and rural areas as a means to transfer freeway traffic to and from the surface street system. Diamond interchanges are typically shaped like a diamond although there are many variations such as compressed and stacked diamond interchanges. The basic shape consists of a T-shape intersection with a major road crossing over a freeway. Diamond interchanges either have stop signs or traffic signals to control traffic. Often stop signs are found to be adequate but as traffic volumes increase sometimes it is necessary to replace the stop signs with signals (Oliver 1987).

There has been little research done involving signalization at diamond interchanges (Oliver 1987). Like isolated intersections, signals at diamond interchanges are based on MUTCD warrants. These warrants are based on traffic volumes at isolated intersections therefore they may not adequately reflect the characteristics at diamond interchanges nor are they sensitive to the traffic patterns between two intersections at a diamond interchange. The study conducted by Oliver compared all-way stop signs with traffic signals at different sites in Texas (Oliver 1987). The results revealed that a discriminating traffic volume at diamond interchanges exists, beyond which traffic signal control is better than stop control in terms of a combined performance of queue and travel speed. Diamond interchanges operate much differently than isolated intersections therefore diamond interchanges should have separate criteria regarding effective warrants (Oliver 1987).

2.5. Conclusion

Based on the results of the review of previous work, it is clear that there is some variation in the safety-related impacts of signalization. Notwithstanding that variation, there are some recurring themes. Many of the studies have shown that the signal installation guidelines set by MUTCD are not guarantees that signalization is the most effective control for a particular intersection. Different intersections surrounded by different land uses will normally require individual study. For example, rural intersections should probably be treated differently than urban and intersections at diamond interchanges. Variations in traffic volumes, prevailing speeds, and surrounding land uses are all likely to be important factors involved in determining the appropriateness of the installation of a traffic signal. Some intersections will need to be reevaluated over time to determine if the signal control installed at the intersection is still warranted. It is possible that the signal may no longer be warranted or necessary due to the dynamic patterns of land usage and the transportation system surrounding the intersection.

Traffic signals have been regarded as the strictest form of traffic control and the most effective control when appropriately used. After a traffic signal is installed it has been noted that there is often little change in the total number of crashes at the intersection. There typically is an increase in the number of rear-end crashes at the intersection while at the same time there is a decrease in the number of angle crashes. It is also been noted that there is an increase in the number of crashes at intersections with low crash frequencies and a decrease in crash frequency at intersections with many crashes. These basic results were found to be fairly consistent over time. This is interesting since warrants have been modified in the MUTCD but the effects of signalization are no more or less consistent

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3. Data Collection, Data Issues, and Research Approach

The approach taken in this research was relatively straightforward. A set of recently-signalized intersections was identified by MDOT, and the safety effects of installing the signals at these intersections were evaluated in a before-after (signalization) study. While the study was conceptually quite simple, the execution was deceptively difficult. The study approach and the problems encountered (insofar as they are useful to discuss) are described below.

3.1. Identification of Intersections to be Evaluated

MDOT identified an initial set of about 350 intersections which had been signalized in the last several years (1986-1992). These included numerous types (e.g., simple 4-way, simple 3-way) of intersections with a considerable amount of variation even within a given type (e.g., actuated versus non-actuated signals, protected versus permitted phasing). The intersections did have the common characteristic of being on the state trunkline system although the intersecting streets/roads were often non-trunkline. It should be noted that not all of these intersections are valid sites for this study—many were eliminated for a variety of different reasons (e.g., some were "upgradings" where the intersection was already signalized and the signal was being modified in some significant way). The initial list of intersections is provided in appendix 3-1.

3.2. Available Data

The data available for this study primarily consisted of information from the (paper) "spot" files maintained by MDOT for each signal location (i.e., a signalized intersection is a "spot") and crash records. Other data were available from MDOT's computerized intersection features file.

The crash records were based on the crash master file maintained and/or managed by the Michigan State Police and MDOT. The crash data actually used in this project were from the MDOT trunkline crash file, updated to 1995. These data are in a "short" form relative to the available crash data master (103 versus 252 or more characters in the record). The short-form data were used because they are updated to a consistent location frame of reference. This was necessary so that crashes could be matched to the appropriate intersections using the MDOT referencing system (and use of the long-form did not permit such accurate matching). The crash data that were used in this project were from the years 1985 through 1995.

For this project, a new intersection characteristics file was constructed, primarily by hand, from data available from MDOT's "spot" files. For example, intersection geometric features, traffic volumes, type of signal, and other descriptive features were coded into this file. These data allowed the intersections to be grouped by, for example, physical characteristics for the analysis—e.g., simple 3-way intersections could be separated out. The data in this file were obtained by manually reviewing the spot files for all of the relevant intersections, transferring information onto coding sheets, and then transferring that information into a computerized spreadsheet.

The primary use of MDOT's intersection features file was in merging the intersection characteristics information obtained from the spot files (and the resultant spreadsheet) with the crash data.

3.3. Merged Data Files

The intersection characteristics and crash files are separate and at different "levels"—that is, the unit of observation for the former is the intersection itself while in the latter it is a crash. It was necessary to merge these two files to undertake the planned analysis. The observations in the merged file are crashes—however, in almost all instances the results are aggregated to the intersection (or intersection type) level.

Based on the location data included in the intersection files, the crash data file could be entered and all relevant crashes retrieved. For example, assume that an intersection exists on control section X at milepoint Y. Code was written so that an intersection's area of influence was defined as that location plus or minus Z distance up- and down-stream of the intersection. That code provided a screen through which all trunkline crashes were passed. The crashes that were "caught" in the screen can be attributed to the specific intersections (defined by their area of influence) that caught them. Crashes that occurred within 45m (150') of the intersection on the cross street are automatically assigned to the intersection and would also be "caught." For the initial construction of the file used for analysis, 150m (500') was used as the largest possible area of analysis. Most analysis is, however, reported for an influence area of 150' which is the definition most-often used by MDOT.

As noted above, in the actual file on which the analysis was done, a single observation is a crash. Each crash carried with it, as part of its record, the description of the intersection at which it occurred. This file (as well as the other files created for this project) is available to MDOT.

3.4. The Temporal Dimension

The final issue with the data concerns the point in time that the intersection was signalized and the identification of before and after periods. From the spot files it is not at all clear when the traffic signal was actually "turned on"—that is, while there is a general record of when the signalization project was done, there is nothing that says that the signal actually started operating on a specific date. The best indication of this time is the "last action date" which is available. Thus, that date was used in the analysis as an indication of when the signal was actually in operation. To account for the unknown time difference between that recorded date and the "real" date, a 30-day window on either side of that date was used to discard some crash data (since it was not necessarily known that a crash within this time period really should be in the "before" or the "after" period).

The use of the window described above may have some effect on the results of the analysis. If there are some crashes that occur because the signal "surprises" a driver who is familiar with the site in its unsignalized operation, they will not be included in any analysis that was done where the data in the window are discarded.

It should also be noted that the real time specifications of before and after windows vary by signal installation. That is, for example, a two-year before period for intersection X is different from the two-year before period for intersection Y (unless both intersections were signalized at the same time).

3.5. Data Issues

The construction and merging of the various files used in this project was extremely labor intensive and there were many mis-steps along the way. If MDOT is interested in tracking long-term trends for signalized (and potentially other) intersections, an automated file should be developed which is consistent with other MDOT-generated/maintained data. That is, materials contained in the spot files should be routinely entered into a computerized file which has location and identifying information which is consistent with other files (e.g., the crash file). Similarly, consistent information should be collected and checked for each intersection.

A related issue is the lack of complete, consistent traffic volume information. Traffic volume data were not necessarily available or consistent from site to site. Before and after (signalization) volume data were virtually non-existent. Thus, for example, before and after crash rate determinations that are made here are somewhat crude. While collection of such data on a comprehensive statewide basis would almost certainly be cost-prohibitive, it may be appropriate (if interest warrants it) to consider such a program on the basis of a scientifically-determined sample.

Finally, there are also some questions regarding the accuracy of different data. Traffic volume data are typically from one-day counts that may be seasonally affected and are not necessarily from a similar time period as the sometimes-available 24-hour machine counts. It was also not clear when/if different actions occurred in the intersection—for example, were "new signal" signs used (and when were they put up/taken down), when was the signal actually operational.

3.6. The Research Approach

The original approach that was planned was to compare and contrast the characteristics, frequencies, and rates of crashes that occurred before and after signalization of various intersections. These changes, if any, were also to be compared with any changes that might have occurred at a set of unsignalized, "control" intersections. It turned out that the identification of a set of control (untreated) intersections was prohibitive (due to data availability and resources) so that was not done.

The fundamental comparisons that were to be made included the number and rates of crashes that occur as well as the character and severity of those crashes (e.g., does the distribution of crashes by type and/or severity change with signalization). In order to do this, a before-and-after approach to the analysis was taken.

3.6.1. Intersection Types

There is a large variance in defining types of intersections. While the "typical" intersection is perceived as being between two, 2-way streets, there are almost endless variations. For example, an intersection between two, 2-way, 2-lane streets/road is different from an intersection between two, 2-way, 4-lane streets/roads and whether the signal is actuated or not adds another level of "definition." Given that at some level each of the intersections on the original list from MDOT is unique, some characteristics will be ignored in the aggregation into a "type." The fundamental types of intersections (found on the initial list) defined for this project are presented and discussed below.

Standard 4-way intersections are those formed by the intersection of two streets/roads. There were 106 of these on the initial list. Of these, 85 were determined to be "simple" and useable 4-way intersections—that is, they are the intersections of two, 2-way streets/roads and are not missing extensive data or have other significant (e.g., locational) problems. This group of intersections is probably perceived as being "most typical."

Standard 3-way intersections are the next simplest intersection—these are basic "T" intersections. Of the 57 3-way intersections on the initial list, 36 were "simple" intersections of two, 2-way roads and useable.

Much of the analysis reported later was done on these first two types of intersections.

Ramp-end intersections, which occur when a ramp from a limited-access highway intersects with a surface street/road, account for an additional 35 intersections on the initial list. Defining the location of these intersections in terms of control sections and milepoints was quite difficult as crashes on the ramps are assigned to the highway mainline. Thus, another approach to location determination was necessary. While this information was provided by MDOT, this problem was not resolved until late in the project and these intersections will not be analyzed in any detail here. It should be noted that a separate effort (outside of the current project and this report) will be undertaken to investigate the safety effects at these intersections. It is not expected that signalization at this type of intersection will result in drastically different outcomes than at standard 3- and 4-way intersections.

Driveway intersections are those typically associated with large new developments (e.g., a shopping mall). These signals are typically installed when the development is opened to the public. In most instances, during the "before" period there was no intersection present—thus, a before-and-after comparison for the effects of signalization can be undertaken only with extreme caution.

Crossover intersections accounted for 28 of the original intersections. Crossovers have been studied in the past under a separate contract with MDOT and, in addition, there is considerable site-to-site variation in how crossovers function (e.g., number and placement of the signals themselves). Given the relatively small sample size, the existence of the prior study devoted to crossovers, and the variance within the type, only very general analysis was done on this group.

Service drive intersections constitute the final type. The service drives constitute another very specific kind of intersection (i.e., along freeways) and, in this instance, were almost all associated with one freeway in the Detroit area. For this reason (and because these intersections are, once again, so different from standard 3- and 4-way intersections), this type was excluded from further analysis.

3.6.2. Other Important Intersection Characteristics

There are other important characteristics of intersections that can be used to further define sub-categories of "type." As noted previously, these include things like the type of signalization, geometry, and so forth. The issue that arises in defining sub-types is one of sample size—e.g., there may be only one or two 3-way intersections formed by one 2-way, 2-lane and one 2-way, 4-lane road. Generalizations become impossible to make with such small samples. The effects of such characteristics are developed and discussed, as possible, in the context of the analysis presented later.

3.6.3. Measures of Safety Effects and Research Hypotheses

The principal measures of the safety effects of signalizing intersections have been mentioned previously. They are defined in more detail here and are used in the analysis that follows.

Crash frequency is a fundamental measure of "what happens" when a signal is installed—did the number of crashes increase, decrease, or stay the same as a result? However, crash frequency can be somewhat misleading if not taken in the context of the traffic volumes that are present. If the traffic volumes experienced at a site are the same during the before and after periods, then comparisons of frequencies are more appropriate.

Crash type distribution is another measure of the results of signalization. The relevant comparison here is whether the distribution of crash shifts—e.g., is there a higher proportion of rear-end crashes after signalization. Crash type changes might be an effect of signalization even if there is no change in the number of crashes.

Crash rate is another safety measure which, in essence, "adjusts" crash frequency for some measure of traffic volume. A comparison of crash rates, for example, would allow intersections which experience significantly different traffic to be compared. A major problem in using crash rates is the lack of dependable and consistent traffic volume data (e.g., virtually no intersections had before and after volume data available).

Crash severity is a measure of how serious crashes are. In this instance, each crash is classified according to its most serious outcome. For example, an crash that resulted in property damage only (PDO) would be classified as a PDO whereas one which included both property damage and an "A" injury would be classified as an "A-injury" crash. The shift in the distribution of crashes by severity would be relevant for comparison.

The research hypotheses that were pursued are structured around the measures just described. In a formal sense, the hypothesis could be stated as, for example:

H_O: signalization did not result in a change in crash frequency
H_1: signalization did result in a change in crash frequency

While the hypotheses are generally not so formally stated in the analysis which follows, they are implicitly of this form.

4. Analysis and Results

The analysis of the data for the several signalized intersections proceeded according to the general outline presented in the last chapter. The presentation and discussion of the results of that analysis is generally divided according to the type of intersection (e.g., 4-way) being considered. This is preceded by a consideration of some statewide background trends in crashes. In the concluding part of this section, results from the different types of intersections are compared and contrasted. A note on statistical testing is appropriate at the outset. In general, the results of the statistical testing that was done are not explicitly shown in the text that follows. When statistical testing was done, the results are generally reported with the criterion that was invoked being a significance of 0.05.

4.1. Background Trends in Statewide Crashes

One of the problems in determining the effects of signalization in terms of crash frequencies for time-based before and after windows defined around the actual time of signalization is that there may be some natural background variation in crash frequencies. For example, if traffic volumes and/or vehicle-miles of travel are generally increasing over time, it would be expected that the number of crashes would generally be increasing as well. Thus, the effects of some intervention (e.g., signalization) would have to be tempered by a consideration of the background trend. If, for example, the general frequency of crashes at intersections is increasing by 3%/year, then for signalization to have resulted in an *increase* in frequency, the increase would have to exceed 3%/year. Contrarily, if the crash frequency for the newly signalized intersections was not shown to increase at all (0% change) then, relative to the statewide trends, this would represent a decrease in real terms. To that end, statewide crash trends were analyzed.

It is also important to remember that in 1992, the statewide crash reporting form (the UD-10) was significantly changed. Thus, any changes in, for example, crash type distributions that occur around this time have to be evaluated with reference to those that were induced by the change in form and those that occur for other reasons.

The top part of table 4-1, which contains some general crash statistics over the period from 1985 to 1995, can be used to illustrate both of the above points. First, the total number of crashes (crash frequencies), the bottom line in the first section, is seen to vary fairly substantially on an annual basis. The total number of crashes increases annually from 1985 to 1989; then decreases for 1990, 1991, and 1992; and finally increases in 1993, 1994, and 1995. The crash figures for 1992 and after may be slightly low since unlocated trunkline crashes are allocated as non-trunkline crashes resulting in the 1992 and later counts being approximately 2 to 5% low (according to MDOT sources).

A gross measure of intersection crash trends is also seen in table 4-1. The classification that is shown (middle section of table), the distribution of crashes by "highway area type" (a relatively crude indication of where on the road system an crash occurred), illustrates both the trend in intersection crashes as well as potential effects of the form change. The percentage of crashes

Table 4-1. Crash information by "area type"

	crash frequencies by year										
area type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
interchange	13736	12938	13000	13880	12990	12180	10665	25700	28364	30737	32767
intersection	69862	72819	72719	73019	73069	67759	62730	56065	57628	59760	61334
non-intersect/interchange	56349	58655	59882	63809	68132	63400	59347	39661	43677	47991	51602
non-motorized vehicle	n/a	n/a	n/a	n/a	n/a	n/a	n/a	612	381	315	337
total accidents	139947	144412	145601	150708	154191	143339	132742	122038	130050	138803	146040

	crash distribution (%) by year										
area type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
interchange	9.82%	8.96%	8.93%	9.21%	8.42%	8.50%	8.03%	21.06%	21.81%	22.14%	22.44%
intersection	49.92%	50.42%	49.94%	48.45%	47.39%	47.27%	47.26%	45.94%	44.31%	43.05%	42.00%
non-intersect/interchange	40.26%	40.62%	41.13%	42.34%	44.19%	44.23%	44.71%	32.50%	33.58%	34.57%	35.33%
non-motorized vehicle	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.50%	0.29%	0.23%	0.23%

	% change from previous year by year										
area type	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
interchange	n/a	-5.81%	0.48%	6.77%	-6.41%	-6.24%	-12.44%	140.98%	10.37%	8.37%	6.60%
intersection	n/a	4.23%	-0.14%	0.41%	0.07%	-7.27%	-7.42%	-10.62%	2.79%	3.70%	2.63%
non-intersect/interchange	n/a	4.09%	2.09%	6.56%	6.77%	-6.95%	-6.39%	-33.17%	10.13%	9.88%	7.52%
non-motorized vehicle	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	-37.75%	-17.32%	6.98%

that occurred at intersections versus interchanges, non-interchange/non-intersection, and non-motor vehicle is seen to be just under 50% in 1985, risen slightly (50.4%) in 1986 and then steadily declined through 1995. The drop between 1991 and 1992 is only slightly greater than other years. While the proportion of all crashes that occurred at intersections is decreasing, the actual numbers of crashes occurring at intersections (referring back to the top section of the table) varies considerably—there are significant yearly decreases from 1989 to 1990, from 1990 to 1991, and from 1991 to 1992; then increases from 1992 to 1993, from 1993 to 1994 and from 1994 to 1995. The lowest number of intersection crashes, 56,065, occurs in 1992 while the highest numbers occur during 1986-1989 when the yearly totals are all 72-73,000.

The changes in the other two primary crash categories shown in table 4-1 (interchange, non-interchange/non-intersection) vary considerably. While interchange crashes account for 8-10% of the crashes from 1985 to 1991, this percentage jumps to 21-22% for 1992-1995 (with a similar, off-setting, change in the non-interchange/non-intersection crashes)—this is a form-related change.

Finally, the bottom portion of table 4-1 is an illustration of the year-to-year percent change in the general crash types. For example, there is an approximate 4% **increase** in intersection crash frequency from 1985 to 1986. This is followed by **very small changes** (<1%) over the next three years, substantially larger **decreases** from 1989 to 1990 (7%), 1990 to 1991 (7%), and 1991 to 1992 (11%). Conversely, the last three years (1992-93, 1993-94, and 1994-95) in the period studied showed **increases** of 3%, 4%, and 3%. The reasons for this variation in intersection crash frequency are not known. Moreover, 1992 crashes are suspected by MDOT to have been under-counted due, in part, to the form changes.

These variations are also illustrated in figures 4-1 and 4-2 which serve to highlight the year-to-year variations and the changes in the highway area type distributions, respectively. The latter is especially useful for seeing the changes presumable resulting from the form change in 1992.

The root causes for the variations in number of crashes, number of intersection crashes, and the changes in the proportion of all crashes that occur in intersections are unknown (with the exception of the form-related changes). The lack of explicitly-known (versus conjectural) causes notwithstanding, these numbers serve to illustrate the extent of the background variation which must be considered when other signalization-related effects are discussed later.

4.2. Intersection Area of Influence

Another issue that needs to be resolved before extensive before-and-after analysis can be done involves defining the area of influence of the intersection—which crashes are and are not attributable to the intersection (and its signalization).

MDOT generally defines the area of influence of an intersection as 45m (150')—crashes occurring within that distance are assumed to be related to the intersection. Obviously, the area of influence can extend further back than 45m (150') under some conditions. The 45m (150') distance translates to a queue length of 6-9 vehicles depending on the assumption made for

Figure 4-1. Crash location by area type (#)

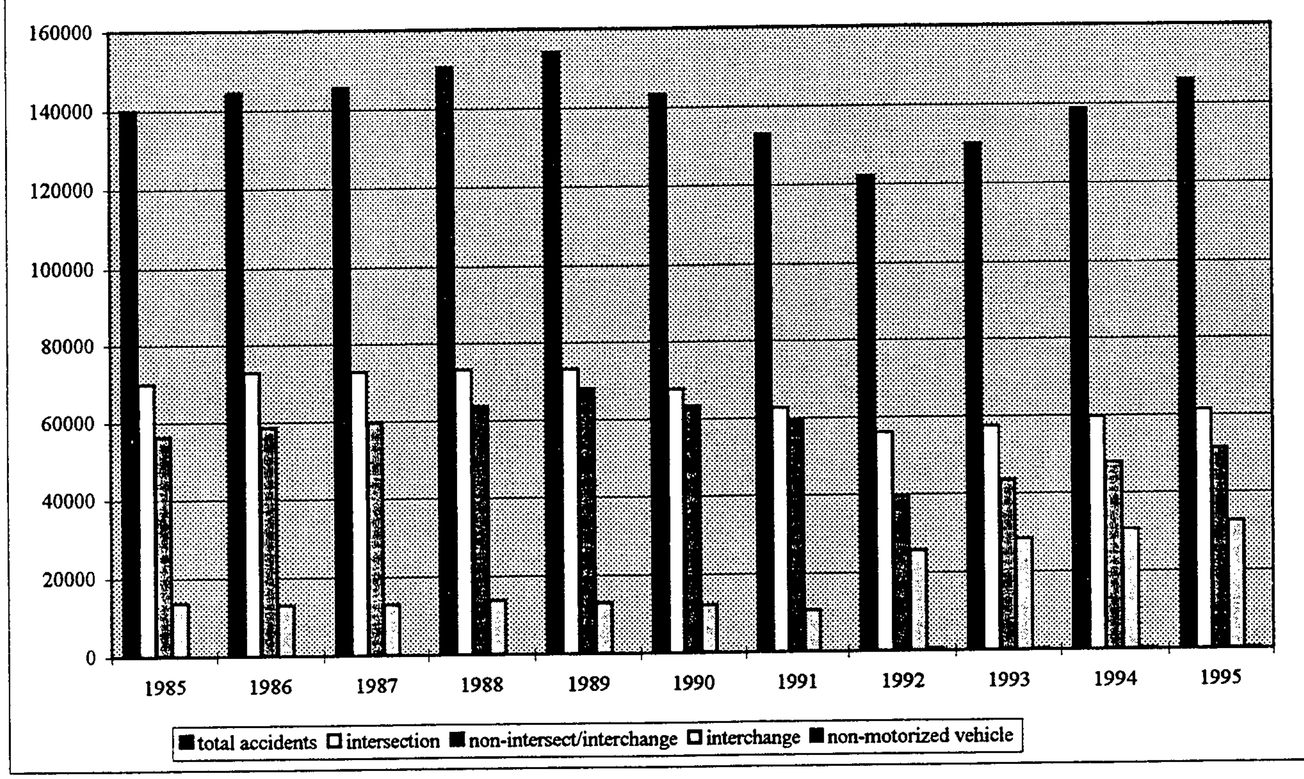
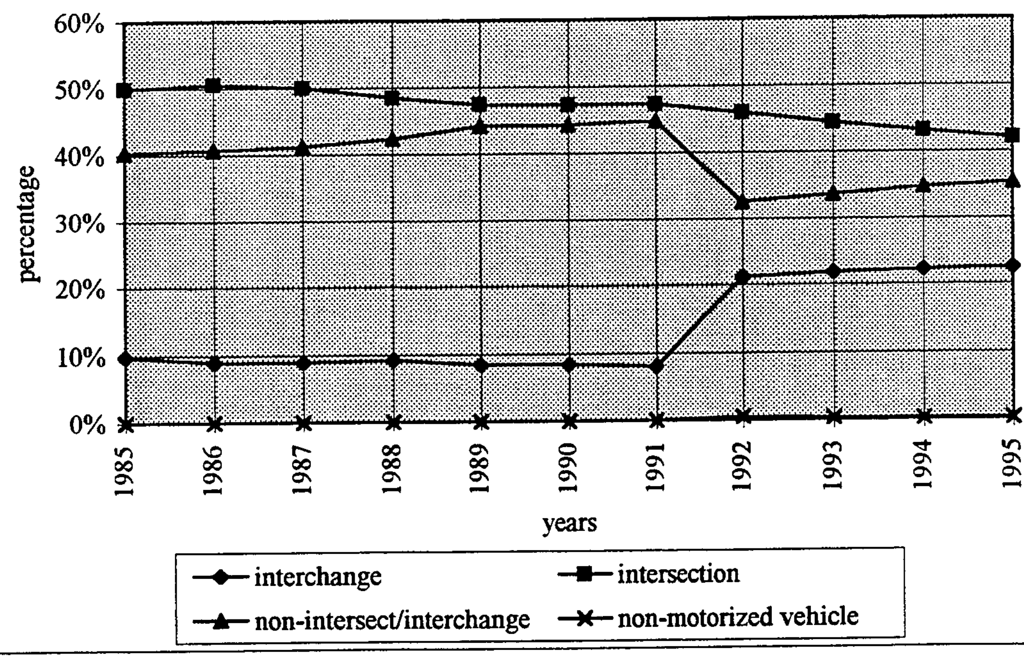


Figure 4-2. Crash location by area type (%)



vehicle spacing. A scenario of a rear-end collision that occurs more than 45m (150') from the intersection, but at the end of a queue caused by a signal, is fairly realistic. For that reason, "intersection" crashes may be declared by an investigating officer in such an instance. At the same time, 45m (150') is used to attribute side-road (non-trunkline) crashes to the intersection with the state trunkline.

On the other hand, as the distance from the intersection increases, the likelihood of crash occurring that was **not** intersection-related increases—for example, it may occur because of someone turning in to or out of a driveway or passing another vehicle. Clearly there is a trade-off: with a larger area of influence: it is more likely that all crashes correctly attributed to the intersection would be captured; conversely, it is also more likely that more crashes that are not correctly attributed to the intersection operation will also be captured.

To this end, three different distances from the intersection were used to define the area of influence: 45, 75, 150m (150, 250, and 500 feet, respectively). (Notwithstanding that intersecting local, non-trunkline streets and roads always had, by definition, a 45m [150'] influence area.) The idea was to undertake analysis and see if there were significant differences in the analysis and to determine whether a "best" distance could be determined. Basically, the finding was that when before-after crash statistics were compared, it was found that there were basic shifts in the type of crashes that were occurring (e.g., more rear-end, fewer right-angle) and that this shift was evident at all three distances. However, the magnitude of the difference in the shift was somewhat more subtle at greater distances from the intersection. Thus, it was decided to define the area of influence as within 45m (150') of the intersection. Any important crash shifts will be evident at this distance, and it is consistent with both the general definition that MDOT uses as well as results reported in the literature.

4.3. Definition of Before and After Time Window

Similar to the question of how far the area of influence of the intersection extends in terms of distance, there is a question of the length of time period over which the effects of signalization should be measured. As before there are tradeoffs in defining the appropriate time period. For example, it could be argued that the time period before and after should be as long as possible, say five years. Problems with long time windows include the effects of simple background trends (e.g., increasing traffic volumes) which may tend to overpower the effects of signalization; major improvements elsewhere in the system changing the traffic routing/flow patterns; and significant changes in development in the vicinity of the intersections. On the other hand, shorter time windows are hampered by the so-called novelty effect of the new signal; the effects of differential signing (e.g., "new signal ahead"); relatively low numbers of crashes occurring; and, in the case of the current work, not knowing when the signal was actually put into operation. While the novelty effect is arguably something that **should** be measured in the analysis, measuring this effect is significantly hampered by the lack of knowledge of when the signal was actually put into regular operation.

Table 4-2 shows the results of a general analysis of 169 intersections (an early version of the final data base that was used for this project) where the effects of the time-window definition are shown. Basically, the shorter-term effects of signalization tend to be more striking. If same-length before and after periods are compared with one another, it is noted that there are always more crashes in the after period than in the comparable before period. That notwithstanding, it should also be noted that in some of the "shorter" periods (e.g., 30 and 60 days), there is, on average, less than two crashes per intersection—i.e., sample size is quite small. Notwithstanding these findings, it should also be noted that the 30-day window is subject to unknown error with respect to when the signal was actually put into operation (i.e., some after-crashes may have actually occurred in the "true" before period or vice versa).

Table 4-2. Percent changes in total crashes by time period

time period (days)	number of crashes before signalization	number of crashes after signalization	percent change after signalization	incremental % change after signalization
30	97	168	73.20%	n/a
60	211	314	48.82%	19.05%
90	318	485	52.52%	20.38%
180	671	874	30.25%	7.42%
365	1325	1640	23.77%	12.81%
730	2588	3061	18.28%	9.63%
730	2377	2747	15.57%	n/a

Note: last row excludes crashes within 30 days of assumed date when signal was activated

Plots of crash frequency versus time window length (not shown) show that there is a fairly distinctive linear trend for both before and after periods. That is, as the time window increases in length, the number of crashes that occurred increases linearly.

It was decided to use longer crash windows for this project, one of which excluded crashes occurring around the time of the signalization. The latter prohibits making inferences about the novelty (or newness) effect but comments about that effect, at least using the data available here, would be problematic anyway. Use of the larger time windows also allows more stratification of crashes (since sample size is larger). For example, analysis may be done on more than one factor at a time. In the end, 180-day and 2-year time windows were used for the analysis. The 2-year window excludes 30-day signalization implementation periods on both sides of the assumed signal-in-actual-operation date.

A final cautionary note is that the analysis done for this project was done in the aggregate (i.e., all intersections in a given group were lumped together). Thus, for example, a two-year before-after window for intersection S_1 might be 1991-92 (before) and 1993-94 (after) whereas the window for another intersection, S_2, in the same group might be 1988-89 (before) and 1990-91 (after). In the analysis that was done, all before data for all intersections in the group were grouped together as were all after data. This complicates any attempt to make adjustments for background trends:

for example, the background trend for intersection S_1 is that, statewide, intersection crashes increased while for S_2, they decreased (see table 4-1 for trends).

4.4. Analysis of 4-Way Intersection Crashes

The analysis that was done for 4-way intersections was somewhat more extensive than that for other types. The reasons for this include: 4-way intersections are considered to be most typical; 4-way intersections are probably best understood with respect to operation; and several levels of analysis were done with 4-ways to determine which were most illuminating with respect to understanding what's happening from an crash perspective.

It should be remembered that the 4-way intersections considered here are "basic"—that is they are simple intersections of two 2-way streets. While intersections with turning lanes and other simple geometric variations are included, any geometrically or operationally "odd" 4-way intersections are excluded (e.g., intersections of two one-way streets were excluded even though the intersection would have four legs). There was a total of 91 4-way intersections used in the analysis.

4.4.1. 4-Way Intersections: Total Crashes and Crash Type Distribution

The most fundamental information about these intersections includes the number and type of crashes that occurred before and after signalization. This information is shown in table 4-3 for two time windows: 180 days (with no exclusion of a signal implementation period) and two years (with exclusion of the implementation period). It should be noted that the sample size for the two time periods varies: for 180 days, there were 91 intersections; for 2 years, there were 80.

Table 4-3. 4-way intersections: before-and-after comparison of crash type 45m (150') from signal for 180 days and 2 years

		180 days		2 years	
crash type		**before**	**after**	**before**	**after**
rear-end	count	121	193	468	734
	percentage	29.30%	40.46%	28.98%	43.33%
right-angle	count	172	122	659	368
	percentage	41.65%	25.58%	40.80%	21.72%
head-on/left-turn	count	35	47	152	213
	percentage	8.47%	9.85%	9.41%	12.57%
other	count	85	115	336	379
	percentage	20.58%	24.11%	20.80%	22.37%
total	count	413	477	1615	1694

The first thing that should be noted from the numbers noted in the table is that for the 180-day period, an increase of about 15% in the number of crashes was observed. Over the longer 2-year time period, the increase was somewhat less striking, about 5%. Given the overall trends in intersection crashes (see table 4-1 and figure 4-1 and accompanying discussion in section 4.1), it appears that signalization resulted in an increase in crash frequency. For example, examining table 4-1, if **all** 4-way intersection signalizations had occurred in the last four years of the overall analysis period (the only period of steadily increasing numbers of intersection crashes), an increase of about 6% in intersection crashes would have been expected as a background trend. Any other 4-year window results in a lower rate of increase or a decrease as a background trend. Indeed the change in intersection crashes over the entire analysis period (1985 to 1995) is a reduction from 69,862 to 61,334, a net decrease of 12% (this figure obscures the fact that there were, however, increases to over 73,000 during the period). On the other hand, the average number of crashes/intersection for the 2-year analysis period increased by almost one—from 20.2 to just over 21, a difference which was not statistically significant. Interestingly, for the 180-day analysis period, the average increase in crashes is about the same (0.89, from 5.0 to 5.89).

Of primary interest is the distribution of crashes by type. The distributions shown in table 4-3 are based on the crash types defined in the crash data files but several types are aggregated into the four key types shown in order to highlight the changes attributable to signalization. Over both the short (180 days) and long (2 years) term, a significant shift between crash types is noted: rear-end crashes increase by 10-12% (of the total) while right-angle crashes decrease 11-14%. The other categories shift by significantly smaller percentages. These distributions, it should be noted, are unaffected by any background trends in raw frequencies. Thus, it can be concluded that signalization resulted in clear shifts in the type of crashes occurring at intersections—from angle-type crashes to rear-end and with a lesser increase in head-on/left-turn crashes. This is consistent with other research reported in chapter 2.

A more detailed presentation on crash types is provided in table 4-4 which shows all of the crash types that are differentiated in the MDOT/MSP crash files. The same trends are noted as had been observed in table 4-3.

4.4.2. 4-Way Intersections: Crash Severity

Crash severity changes that may result from signalization are also of interest. In this instance, each crash is classified according to its most serious outcome. That is, if an crash resulted in some property damage, an "A" injury, and a "B" injury, the crash would be classed as a "A-injury" crash which is the worst outcome. The five crash severity categories that are used here are: fatal; A (incapacitating injury), B (non-incapacitating injury), C (possible injury), and PDO (property-damage-only). The before-and-after distributions of crashes by severity for 180-day and 2-year windows are shown in table 4-5.

While the number of fatalities is fairly low in general (and fatalities are relatively rare events in general), it is seen that there were fewer fatalities after signalization for both time windows. More importantly, however, is the general distributional shift from more severe to less severe crash outcomes. For both time windows, there is decrease in fatalities, a decrease in A crashes, a decrease in B crashes, and increases in C and PDO crashes. These percentage changes are driven by absolute decreases in the numbers of fatal and A crashes for both time windows, an increase for the 180-day period and a decrease for the 2-year period for B crashes, and increases in C and PDO crashes for both time windows. Thus, in spite of overall increases in the total

Table 4-4. 4-way intersections: before-and-after comparison of detailed crash types 45m (150') from signal for 180 days and 2 years

crash types		180 days before	180 days after	2 years before	2 years after
misc 1-vehicle	count	4	5	10	22
	percentage	0.97%	1.05%	0.62%	1.30%
overturn	count	1	1	10	4
	percentage	0.24%	0.21%	0.62%	0.24%
w/parked vehicle	count	3	2	12	7
	percentage	0.73%	0.42%	0.74%	0.41%
backing	count	2	10	18	28
	percentage	0.48%	2.10%	1.11%	1.65%
parking	count	2	1	4	6
	percentage	0.48%	0.21%	0.25%	0.35%
pedestrian	count	2	2	6	6
	percentage	0.48%	0.42%	0.37%	0.35%
fixed object	count	16	23	68	56
	percentage	3.87%	4.82%	4.21%	3.31%
other object	count	5	0	4	3
	percentage	1.21%	0.00%	0.25%	0.18%
animal	count	1	3	13	17
	percentage	0.24%	0.63%	0.80%	1.00%
bicycle	count	3	4	8	15
	percentage	0.73%	0.84%	0.50%	0.89%
head-on	count	5	1	23	11
	percentage	1.21%	0.21%	1.42%	0.65%
angle-straight	count	115	88	435	259
	percentage	27.85%	18.45%	26.93%	15.29%
rear-end	count	109	178	405	695
	percentage	26.39%	37.32%	25.08%	41.03%
angle-turn	count	57	34	224	109
	percentage	13.80%	7.13%	13.87%	6.43%
side-swipe/same	count	4	3	5	29
	percentage	0.97%	0.63%	0.31%	1.71%
rear-end/left-turn	count	8	4	40	10
	percentage	1.94%	0.84%	2.48%	0.59%
rear-end/right-turn	count	4	11	23	29
	percentage	0.97%	2.31%	1.42%	1.71%
other driveway	count	6	8	32	33
	percentage	1.45%	1.68%	1.98%	1.95%
angle at driveway	count	5	10	42	41
	percentage	1.21%	2.10%	2.60%	2.42%
rear-end/driveway	count	17	27	62	70
	percentage	4.12%	5.66%	3.84%	4.13%
side-swipe/opp	count	8	9	11	21
	percentage	1.94%	1.89%	0.68%	1.24%
head-on/left-turn	count	35	47	152	213
	percentage	8.47%	9.85%	9.41%	12.57%
daul left-turn	count	1	2	5	3
	percentage	0.24%	0.42%	0.31%	0.18%
dual right-turn	count	0	4	3	7
	percentage	0.00%	0.84%	0.19%	0.41%
total	count	413	477	1615	1694

numbers of crashes between the before and after time periods, the severity of those crashes was somewhat lower.

Table 4-5. 4-way intersections: before-and-after comparison of crash severity 45 m (150') from signal for 180 days and 2 years

		180 days		2 years	
crash severity		**before**	**after**	**before**	**after**
PDO	count	276	316	1085	1134
	percentage	66.83%	66.25%	67.18%	66.94%
C-injury	count	68	96	262	329
	percentage	16.46%	20.13%	16.22%	19.42%
B-injury	count	38	42	152	146
	percentage	9.20%	8.81%	9.41%	8.62%
A-injury	count	28	22	110	82
	percentage	6.78%	4.61%	6.81%	4.84%
fatal	count	3	1	6	3
	percentage	0.73%	0.21%	0.37%	0.18%
total	count	413	477	1615	1694

4.4.3. 4-Way Intersections: Ambient Light, Time of Day, and Day of Week

Several other factors were also examined through cross-tabulations. Ambient light was defined using the standard UD-10 code (i.e., daylight, dawn or dusk, dark w/street lights, dark w/no street lights, and unknown). It should be noted that no attempt was made to verify the values of that code by using actual time of day and month—the codes were taken at face value. For ambient light there were generally only modest before-after differences in the distributions (not shown). For example, using the 2-year window, the percentage of crashes occurring during daylight hours decreased from 75.4 to 75.1%. Some of the other shifts were somewhat more notable but they were not necessarily consistent between the 180-day and 2-year time windows, and the differences were attributed to general variance.

Similarly, the before and after hour-by-hour distribution of crashes was also examined. Distributional shifts in this instance were limited to generally much less than 1% (with a maximum of about 3% in one instance). Again, these shifts seem quite insignificant and seem likely to be a result of natural variation. It is marginally interesting to note that the highest percentages of intersection crashes (both before and after signalization) occurred after 12:00 noon and before 6:00 PM. The maximum percentage for an hour (in the 12:00-6:00 block) was on the order of 12% and the minimum was about 6%. The highest hour not within this time block was 7:00-8:00 AM where the percentage was around 5% (and the adjoining hours were much less) and 6:00-8:00 PM where the hourly percentages were 5-6%. Over 50% of the intersection crashes occurred in the six-hour period from noon until the end of the evening rush hour.

Finally, before and after crash distributions by day of the week were also investigated. Once again, there does not appear to be much difference that is attributable to signalizing the intersections. Generally speaking, weekdays account for a somewhat greater percentage of the crashes than weekends—if crashes occurred randomly by day (i.e., 14+% each day), it would be expected that the two weekend days would account for about 29% while the statistics show that they account for something on the order of 20-24%. Fridays account for the greatest percentage of intersection crashes, generally 16-21%, and there appears to have been a slight decrease in that percentage between the before and after periods (about 4% using the 180-day time window, about 2% using the 2-year window). Again, this relatively small decrease may be due to natural variation. If there is an effect, signalization seems to have "smoothed out" the distribution over the week (each day accounted for a more equal amount).

Notwithstanding the minor effects that have been noted, signalization effects on these three variables appear to be relatively uninteresting and are not discussed further (i.e., for other intersection types) in any detail.

4.4.4. 4-Way Intersections: Crash Type and Other Factors

In addition to the general examination of crash type that was discussed in section 4.4.1., the crashes were also broken down into type-based groups (i.e., head-on/left-turn, right-angle, rear-end, and other) and re-examined with respect to severity, contributing circumstances, time of day, light conditions, weather, and day of week. That is, for example, all the rear-end crashes were broken out and the before-after comparison was examined with respect to the other variables just noted. In addition, both the 180-day and 2-year windows were also examined.

4.4.4.1. Level of Severity by Before/After for Different Crash Types

The general shift toward more, but less severe crashes noted above was broken down by crash type. For different types of crashes, the shifts in severity were noticeably different. The discussion that follows is based upon the comparison of 2-year before/after windows, unless otherwise noted.

Rear-End Crashes

There were large absolute and relative increases in rear-end crashes when before and after periods are compared (468 to 734, 29 to 43%). Examining only the rear-end crashes, there is a shift in severity as well: PDOs, while increasing in number (358 to 520) account for a lower percentage (77 versus 71%, respectively) of all rear-end crashes. The C crashes increased in both absolute (75 to 171) and relative (16 to 23%) terms while both B and A crashes increased in absolute terms but decreased relatively. Thus, the severity-related changes in rear-end crashes were mixed: while rear-end crashes generally increased in number there was a shift toward minor injury crashes. That is, category C increased both absolutely and relatively, while PDOs and other injury categories decreased relatively, they all increased in an absolute sense. There were no fatal rear-end crashes reported in either the before or the after period.

Right-Angle Crashes

Unlike rear-end crashes where there were notable changes in both the numbers and severity of crashes, the severity distribution of right-angle crashes remained fairly constant. The biggest relative shift was that PDO crashes decreased from 58 to 55%. This relative decrease was offset by minor increases in all but the fatal crash category. In absolute terms, there was a large overall before-after decrease in right-angle crashes (see table 4-3b) and in each severity category.

Perhaps most notable is that right-angle crashes account for all fatal crashes in the study. Moreover, this number decreased from 6 to 3 between the before and after periods. While fatal crashes are relatively rare events and the decrease could be simply a statistical anomaly, it is nonetheless noteworthy that all the fatal crashes were this type. It does appear that the decrease in the number of fatal crashes is most likely due to the general decrease in this type of crash.

Head-On/Left-Turn and Other Crashes

The other two crash types that were studied in detail were head-on/left-turn and (all) "other" crashes. While there were almost across-the-board absolute increases in each severity category for both of these types of crashes, the severity distribution did not change markedly. For both types, the PDO percentage varied by about 1% or less and there was some shifting among the personal injury categories—the largest change being a 3.6% increase in B head-on/left-turn crashes.

4.4.4.2. Crash Type by Before/After for Different Levels of Severity

The relationship between type of crash and the severity of those crashes can also be looked at "the other way around." In the last section cross-tabulations of level of severity by before/after for different crash types was examined. In this section cross-tabulations of crash type by before/after for different levels of severity will be examined. Table 4-6 is an illustration. Each section of the table shows a cross-tabulation of crash type by before/after for a different level of severity (PDO, C, B, and A). Fatal crashes are discussed separately.

PDO Crashes

As noted earlier, the absolute number of PDO crashes increased between the before and after periods from 1085 to 1134 (49 crashes, about 5%). While head-on/left-turn and "other" crash types increased only marginally (in both absolute and relative terms), there was a relatively large shift between rear-end and right-angle crashes. Rear-end crashes increased dramatically while right-angles decreased similarly.

C-Injury Crashes

While the increase in number of C crashes (262 to 329) was somewhat higher than that for PDOs (67 versus 49), the percentage increase was substantial, almost 26%. "Other" crash

Table 4-6. 4-way intersections: before-and-after comparison of severity and crash types 45m (150') from signal for 2 years

		PDOs		C-injuries		B-injuries		A-injuries	
crash type		**before**	**after**	**before**	**after**	**before**	**after**	**before**	**after**
rear-end	count	358	520	75	171	25	32	10	11
	percentage	33.00%	45.86%	28.63%	51.98%	16.45%	21.92%	9.09%	13.41%
right-angle	count	384	202	127	75	82	54	60	34
	percentage	35.39%	17.81%	48.47%	22.80%	53.95%	36.99%	54.55%	41.46%
head-on/left-turn	count	91	125	23	38	16	30	22	20
	percentage	8.39%	11.02%	8.78%	11.55%	10.53%	20.55%	20.00%	24.39%
other	count	252	287	37	45	29	30	18	17
	percentage	23.23%	25.31%	14.12%	13.68%	19.08%	20.55%	16.36%	20.73%
total	count	1085	1134	262	329	152	146	110	82

types accounted for a considerably lower proportion although it was fairly constant as it was for head-on/left-turn crashes. Again the large shift was from right-angle (large absolute and relative declines) to rear-end crashes (large absolute and relative increases).

B-Injury Crashes

B-injury crashes actually declined by almost 4%, from 152 to 146. Interestingly, the shifts among crash types was somewhat different than for other crash severity categories. Rear-end crashes showed only marginal absolute and relative increases; right-angles decreased somewhat more strikingly; and "others" held steady. The other difference was head-on/left-turn crashes which accounted for absolute and relative increases in B crashes.

A-Injury Crashes

The final category shown in the table is A-injury crashes which showed the largest overall decrease in crashes (110 to 82) in spite of being the smallest category (other than fatals). Once again, there were increases in rear-end crashes in both absolute and relative terms, decreases in right-angle crashes and modest relative increases in head-on/left-turn and "other" crashes.

Fatal Crashes

Fatal crashes are not shown in the table because there are so few, and all of which were right-angle crashes. There was a decrease of three fatal crashes (6 to 3) between the before and after periods. As noted earlier, all fatal crashes (both before and after) were associated with some sort of turning movement. Examination of other characteristics of these crashes showed the following: only one of the crashes (during the after period) was associated with DUIL or drug use as a contributing circumstance while one had "none" (before) as a contributing circumstance while 7 (5 before, 2 after) had "other;" two of the after crashes occurred in the 1:00-2:00 AM time period while one occurred in the 6:00-7:00 PM period whereas the "before" crashes were scattered throughout the afternoon and evening (1 during 11:00AM-noon, 1 during 4:00-5:00 PM, 2 during 5:00-6:00 PM, 1 during 6:00-7:00 PM, and 1 during 9:00-10:00 PM); all 6 "before" occurred during daylight or dawn/dusk hours while all 3 "after" occurred during dark conditions; with exception of 1 after crash which occurred in the rain, all others occurred when it was clear/cloudy; and, finally, the before crashes were distributed during the week 1 on Sunday, 1 on Tuesday, 2 on Thursday, and 1 each on Friday and Saturday while the after crashes occurred on Tuesday (1) and Saturday (2). Given the small number of fatal crashes that do occur, not much insight is gained on how the signalization affects these crashes although it is interesting to note that they were all angle crashes; and these sorts of crashes typically decrease as a result of signalization.

Summary and Discussion

The results arrayed in table 4-6 clearly shows that there was an overall increase in PDO and C crashes and some offsetting decreases in B and A crashes (plus the decrease in fatal crashes not shown in the table). Generally speaking, the differences in the type of crashes show up in the shift from angle to rear-end crashes. There are significantly more of the latter and fewer of the former. The increases in the overall crash numbers are attributable primarily to the additional rear-end crashes with more modest contributions from head-on/left-turn and "other" crash types. Right-angle crashes decrease in absolute and relative terms for all severity classes.

4.4.4.3. Contributing Circumstances, Time of Day, Light Conditions, Weather, Day of Week and Crash Type

Contributing circumstances, time of day, light conditions, weather, and day of week were also considered with respect to crash type. For the most part, none of these factors were interesting—that is, there were few distributional changes that might be attributable to the signal installation. Some observations regarding each type of crash follows.

For "other" crashes, it was noted that there was a decrease (both in absolute, 15 crashes, and relative, six percentage points, terms) in crashes after dark where there were no street lights present. On the other hand, crashes occurring under clear or cloudy conditions increased (in absolute and relative terms).

Head-on/left-turn crashes increased in both absolute and relative terms in dark/no-street-light conditions and snowy conditions while decreasing in relative terms for clear/cloudy conditions.

For right-angle crashes there were fewer distributional variations with the most notable being an absolute and relative decrease in daylight crashes which was offset, in a proportional sense, by increases in the percentages of nighttime crashes. Variations due to weather conditions were slight although there were significant reductions in absolute terms.

Finally, for rear-end crashes, there were only minor changes in the distributions of any of these factors.

4.4.5. 4-Way Intersections: Type of Signal Installed

There were two basic classifications of the signals that were installed: fixed timing and actuated. The same types of variables and issues were examined for each type of signal. The fundamental issue that is being addressed is whether the type of signal that is being installed results in any differential effects with respect to the crash statistics that have been examined. For this analysis, the 91 original intersections were broken down into 10 actuated signal sites and 81 fixed-time sites although this was further reduced to 9 and 70 for the 2-year analysis period.

4.4.5.1. Signal Type and Crash Type

While the general trends in distributional shifts that were discussed earlier were also apparent here (e.g., an absolute and relative increase in rear-end crashes as a result of signalization), there were some basic differences between the distribution of crashes by type for the two different types of signal. For example, rear-end crashes accounted for 30% (439) of the before crashes and 44% (687) of the after crashes for fixed timing sites while, for actuated signal sites, rear-end crashes accounted for only 19% (27) of before crashes and 35% (42) of the after crashes. These distributions are shown in table 4-7. The largest part of the differences between the two types of sites is accounted for in the differences between rear-end and right-angle crashes. In general, fixed-timing sites had proportionately fewer right-angle crashes and more rear-end crashes. The differences were especially noticeable during the before period. The higher percentage of right-angle crashes at actuated signal sites may well be explained by more equal and possibly higher volumes being experienced at those sites both before and after signalization.

Table 4-7 also indicates that there are some other fundamental differences between fixed and actuated signal sites. For fixed-time sites, there was an absolute increase in the number of crashes (in addition to the distributional shifts just noted) which resulted in a mean increase of 0.76 (although this is not statistically significant). On the other hand, for actuated sites, there was an absolute decrease in crashes and a sizable, but statistically insignificant, mean decrease (4.22). There were, however, only nine actuated sites.

Table 4-7. 4-way intersections: before-and-after comparison of crash type by timing type 45m (150') from signal for 2 years

		fixed		actuated	
crash type		**before**	**after**	**before**	**after**
rear-end	count	439	687	27	42
	percentage	30.13%	44.24%	18.49%	35.00%
right-angle	count	582	336	75	27
	percentage	39.95%	21.64%	51.37%	22.50%
head-on/left-turn	count	132	189	19	23
	percentage	9.06%	12.17%	13.01%	19.17%
other	count	304	341	25	28
	percentage	20.86%	21.96%	17.12%	23.33%
total	count	1457	1553	146	120

4.4.5.2. Signal Type and Severity

The general trend noted earlier of typically more crashes but with less severity is also in evidence for both types of signals. For fixed-time signals, there are absolutely and relatively fewer A crashes, about the same number but relatively fewer B crashes, absolutely and relatively more C crashes, and relatively the same percentage but a greater number of PDO crashes. For actuated-signal sites, C crashes "collect" absolutely and relatively more crashes than the other categories. Crashes at actuated-signal sites are, in general, more likely to be more severe than those at fixed-time signal sites, notwithstanding the fact that all fatal crashes were at fixed-time sites. These results are summarized in table 4-8.

Table 4-8. 4-way intersections: before-and-after comparison of crash severity by type of signal timing 45 m (150') signal for 2 years

		fixed		actuated	
crash severity		**before**	**after**	**before**	**after**
PDO	count	984	1045	90	75
	percentage	67.54%	67.29%	61.64%	62.50%
C-injury	count	241	298	20	27
	percentage	16.54%	19.19%	13.70%	22.50%
B-injury	count	133	131	19	12
	percentage	9.13%	8.44%	13.01%	10.00%
A-injury	count	93	76	17	6
	percentage	6.38%	4.89%	11.64%	5.00%
fatal	count	6	3	0	0
	percentage	0.41%	0.19%	0.00%	0.00%
total	count	1457	1553	146	120

4.4.5.3. Signal Type and Other Variables

Several other variables (detailed crash type, contributing circumstances, time of day, light condition, weather condition, and day of week) were also examined with respect to differences that might be attributable to the type of signal that was installed. While most of these effects were not dissimilar from those already noted, there were a couple of notable exceptions.

For light conditions, there were very minor differences in the before-after distribution of crashes occurring under different light conditions for fixed-time signal sites (a maximum difference of about one percentage point). However, for actuated signal sites, there were some notable before-after changes. For example, the percentage of crashes that occurred during daylight conditions decreased from 77 to 68% and dark/street lights present increased by about the same amount (10 to 19%). There is no ready explanation for this shift—i.e., why the installation of one type of signal would make a difference in the distribution of crashes by light condition.

A similar outcome was noted when weather conditions (at the time of the crash) were considered. There was little change in the distributions for fixed-time sites but significant shifts at actuated signal sites. The latter consisted of a decrease during clear or cloudy conditions (82 to 70%) with an offsetting increase for rainy conditions (10 to 22%).

4.4.6. 4-Way Intersections: Geographic Area

Another classification that was investigated was a rough definition of "where" the signalized intersections were located. This definition was based on the general character of the county where the signal was installed: metro, mixed, and rural. Metropolitan counties were those such as Wayne which has a primarily urban, very-built-up character. Mixed counties are those such as Ingham which contains a significant amount of urban development (Lansing in this case) but also significant suburban and rural areas. Rural counties are those where there is no principal urban center. The breakdown of the original 91 intersections into the three groups just defined was: metro, 15; mixed, 63; and rural, 14. (For the 2-year analysis period, these numbers were further reduced to 14, 53, and 13, respectively.)

Although the definitions of the three geographic area types are crude, the results were, nonetheless, interesting. While the mixed category represented the most sites, there was a reasonable distribution among the three categories. While the trend of more crashes in the after period that was noted earlier is still evident, the percentage change in total crashes varied by area: in rural areas, the increase was almost 9% (208 to 226); in mixed areas, the increase was about 5% (1136 to 1187); and for metro areas, the increase was the lowest, almost 4% (271 to 281). While this could easily be explained by changes in traffic volumes and so forth, it could also be argued that the signals in more rural-oriented areas would typically result in the most (unexpected) change to traffic patterns and, hence, be more likely to result in a higher increase in traffic crashes. There is no way to prove this contention, but it seems a logical explanation.

The mean number of crashes also varies by geographic type. The before-and-after mean values were: rural-16 to 16.1; mixed-21.4 to 22; and metro-19.4 to 18.7. The mean decrease in metro being an artifact of a change in sample size. None of the differences was statistically significant.

While the general tendencies in the shifts among crash types is the same as reported earlier, there are differences for the different areas and are shown in table 4-9. For the rural sites, the percentages of rear-end crashes increase only 5% with signalization while for the mixed areas the increase is about 15% and for metro areas, about 20%. This is accompanied, and largely offset, by decreases in right-angle crash percentages: the rural decrease is 6%, mixed is 21%, and metro is 17%. Depending on the type of area in which signalization occurs, somewhat different crash shifts could be expected. In general, the shifts are much more pronounced in more suburban and/or urban areas.

Table 4-9. 4-way intersections: before-and-after comparison of crash type by type of area 45m (150') from signal for 2 years

		rural		mixed		metro	
crash type		**before**	**after**	**before**	**after**	**before**	**after**
rear-end	count	71	90	317	504	80	140
	percentage	34.13%	39.82%	27.90%	42.46%	29.52%	49.82%
right-angle	count	64	56	493	255	102	57
	percentage	30.77%	24.78%	43.40%	21.48%	37.64%	20.28%
head-on/left-turn	count	22	28	108	160	22	25
	percentage	10.58%	12.39%	9.51%	13.48%	8.12%	8.90%
other	count	51	52	218	268	67	59
	percentage	24.52%	23.01%	19.19%	22.58%	24.72%	21.00%
total	count	208	226	1136	1187	271	281

There are also some differences in the severity of crashes by type of geographic area. For rural sites, there is a shift from the PDO category (which accounted for 76% of all before crashes "before" signalization and decreased to 66% "after") to C (14 to 19%), B (5 to 10%), and A (4 to 5%) injury crashes. There were, however, two fatal crashes in the before period but none after. For mixed areas, the proportion of PDO crashes increased from 66 to 68% while C crashes increased (17 to 19%), B crashes decreased (10 to 8%), and A crashes decreased (8 to 5%). Fatal crashes in mixed areas decreased from 4 to 3. Finally, for metro areas, the shifts were: PDOs decreased (68 to 62%), C crashes increased (15 to 24%), and both B and A crashes decreased (10 to 9% and 10 to 5%, respectively). There were no fatalities in the metro grouping. In summary, rural sites tended to experience more serious crashes as a result of signalization, mixed areas had somewhat reduced severity, and metro areas experienced some compensating shifts (fewer PDOs but also fewer A and B-injury crashes with an increase in C crashes). The increase in severity in rural areas may be hypothesized to result from problems with generally higher speed vehicles although that was not tested in any way.

The results for the other variables that were examined (e.g., contributing circumstances, light condition) showed no other striking results.

4.4.7. 4-Way Intersections: Summary and Synthesis of the Effects of Signalization

Based on the analysis of the 4-way intersections included in this study, the following synthesis and summary of findings can be presented.

* Notwithstanding variations in the background trends in intersection crashes over the entire analysis period, it appears that signalization results in an increase in crash frequency—using a 2-year analysis before and after window, the increase was about 5%. However, the extent of the increase varies according to several factors and is difficult, if not impossible, to predict for any given site. Moreover, changes in the mean values of crashes per intersection are generally small and statistically insignificant.

* The shifts in crash type as would be expected *a priori*—that is, angle crashes decreased while rear-end crashes increased. This shift was most always observed and generally fairly dramatic. It too varies considerably based upon different conditions.

* Notwithstanding an often-observed increase in crash frequency, there is also a shift in crash severity from more severe to less severe crashes. PDO and C-injury crashes tend to increase in both absolute and relative terms while A-injury, B-injury, and fatal crashes decrease in both absolute and relative terms.

* While there does not appear to be any relationship between signalization changes and light conditions with respect to the incidence of crashes, it is interesting to note that over 50% of intersection crashes occur between noon and 6:00 PM. Otherwise, there is nothing notable with respect to signalization effects with respect to light conditions, time of day, or day of week.

* The absolute and relative increases in rear-end crashes was accompanied by a shift toward minor personal-injury (C-injury) crashes. That is, C-injury crashes accounted for a higher percentage of the crashes after signalization. However, there were absolute increases in the numbers of crashes in all severity categories.

* While the relative distribution of right-angle crashes by severity effectively remained the same, there were significant reductions in the absolute number of such crashes in all severity categories.

* Right-angle crashes accounted for all fatal crashes during both the before and after periods and decreased from six (6) to three (3) between the before and after periods.

* Differences in crash distributions are difficult to relate to the type of signal, fixed-time versus actuated, that is installed since there are differences between these two sets of sites during the before period. That is, sites where fixed-time signals are installed appear to have different crash statistics than those where actuated signals are installed. Fixed-time sites tended to have proportionately fewer right-angle and more rear-end crashes that actuated sites.

* Actuated signal sites tended to have less severe crashes than fixed-time sites although all fatal crashes were at the latter. It should be noted, however, that there were relatively few actuated sites.

* For actuated signal sites, there was a noticeable distributional shift from crashes occurring under daylight to dark/no-street lights conditions. There was also a distributional shift from clear/cloudy to rainy conditions for actuated signal sites. There is no ready explanation for this shift.

* Increases in crashes as a result of signalization appeared to be related to type of area (metro, mixed, rural) in which a signal was found. Intersections in rural areas increased the most (9%) followed by mixed areas (5%) and metro areas (4%). The changes in the mean number of crashes was not, however, statistically significant.

* The right-angle-to-rear-end shift in crash distributions also vary by type of area with rural areas experiencing less of a shift than the others.

* With respect to crash severity, rural sites tended to shift to more serious crashes while mixed areas had somewhat reduced severity and metro areas had some compensating shifts (fewer PDOs but also fewer A- and B-injury crashes). Fatal crashes occurred in rural areas (2 before) and mixed areas (4 before, 3 after).

4.5. Analysis of 3-Way Intersection Crashes

The analysis of 3-way intersections proceeded in a parallel fashion to that done for the 4-way sites. As was the case for the 4-ways, the intersections analyzed were "simple" 3-way intersections—that is, basic "T" intersections of two 2-way streets. Any other geometrically or operationally "odd" intersections were excluded. The discussion presented here is somewhat briefer as only those issues which were found to be important are discussed (the discussion of 4-ways had been somewhat more comprehensive to illustrate the breadth of the work that had been done). There was a total of 37 3-way intersections (35 for the 2-year analysis period).

4.5.1. 3-Way Intersections: Total Crashes and Crash Type Distribution

Table 4-10 shows the basic cross-tabulation of the before and after signalization crashes distributed by crash type (only the data for the 2-year window are shown). In the discussion that follows, there are references back to table 4-3 to show fundamental differences between crash type distributions at the two different types of intersections.

Table 4-10. 3-way intersections: before-and-after comparison of crash type 45m (150') from signal for 2 years

crash type		**before**	**after**
rear-end	count	334	536
	percentage	36.99%	49.49%
right-angle	count	240	147
	percentage	26.58%	13.57%
head-on/left-turn	count	42	86
	percentage	4.65%	7.94%
other	count	287	314
	percentage	31.78%	28.99%
total	count	903	1083

First, it is noted that there is again an increase in total crashes from the before to after periods—in this instance, the increase is from 903 to 1083, almost 20% and sizably more than the 5% increase noted for 4-way intersections. The mean number of crashes obviously increases as well, from about 26 to about 31, although the increase was not statistically significant. Compared to 4-way intersections, the mean number of crashes at 3-way intersections is higher for both before and after periods. The crash rates for 3-ways are, however, about the same as for the 4-ways. Thus, the differences in the mean number of crashes are likely to be simply artifacts of the traffic volumes at the 4-way versus 3-way intersections. (Other crash rates are not discussed in any detail given that before and after ADTs were not available in the data base and, hence, rate changes mirror the frequency changes).

The distributions of crashes by type are also different from the 4-ways although the shifts among crash types are somewhat similar. For the 3-way intersections, head-on/left-turn crashes comprise a smaller proportion of all crashes while the "other" crashes are substantially larger. It should be noted that with 3-way intersections the absolute number of head-on-related conflicts would, assuming equal roadway volumes, be less than for 4-way intersections (by definition). The primary shift though is still between rear-end and right-angle crashes: rear-end crashes increase in both absolute and relative terms (from 334 to 536, and from 37 to almost 50% of all crashes); and right angle crashes decrease in both absolute and relative terms (from 240 to 147, and from 27 to 14%). Right-angle crashes are the only type that shows an absolute decrease from the before to the after period.

4.5.2. 3-Way Intersections: Crash Severity

Changes in crash severity for 3-way signalization sites are shown in table 4-11 (again, only the 2-year window is illustrated). While the substantial increase of 180 crashes has already been noted, a large proportion of the increase is in PDO crashes, although the PDOs account for a slightly decreasing percentage of all crashes. The C-injury category is the only one that increases in both absolute and relative terms. While B-injury crashes increase slightly in number, the proportion decreases. A-injury crashes decrease in both relative and absolute terms while fatal crashes remain the same.

Table 4-11. 3-way intersections: before-and-after comparison of crash severity 45 m (150') from signal for 2 years

crash severity		before	after
PDO	count	646	765
	percentage	71.54%	70.64%
C-injury	count	147	208
	percentage	16.28%	19.21%
B-injury	count	70	75
	percentage	7.75%	6.93%
A-injury	count	37	32
	percentage	4.10%	2.95%
fatal	count	3	3
	percentage	0.33%	0.28%
total	count	903	1083

A comparison of the results shown here and those in table 4-5 for 4-way intersections reveals that the same general trends are evident: in absolute terms the PDO and C-injury categories account for the most of the change in absolute terms and the C category accounts for a somewhat higher percentage of crashes overall. However, whereas with the 4-way intersections there was a marginal tendency toward less severe crashes overall (A, B, and fatal crashes all decreased although C and PDO crashes increased), any severity "improvement" is more modest with C- and A-injury crashes increasing and fatal crashes remaining the same. Percentagewise, there is still, nonetheless, some improvement.

4.5.3. 3-Way Intersections: Crash Type and Other Factors

As was done for the 4-way intersections, the before and after crashes were broken down by crash type and further analysis was done. Only the data for the 2-year window are shown. In the next part of this section, crashes are grouped by type, and then examined. After that, the crashes are grouped "the other way," that is, by severity level.

4.5.3.1. Level of Severity by Before/After for Different Crash Types

The four (basic) different types of crashes are rear-end, right-angle, head-on/left-turn, and "other" and are addressed in turn.

Rear-End Crashes

For rear-end crashes, the before-after comparison shows that there are more crashes in every severity category in an absolute sense (PDOs increase from 248 to 365, Cs from 68 to 137, Bs from 17 to 28, and As from 1 to 6) and a primary shift from PDO to C-injury crashes. That is, the percentage of crashes in category C increases from 20 to 26% and is largely offset by a corresponding decrease (74 to 68%) in the percentage of PDO crashes. Thus, it seems clear that rear-end crashes generally become not only more numerous in the after period, but also somewhat more serious.

Right-Angle Crashes

Right-angle crashes, on the other hand, show decreases in all severity categories (PDOs from 165 to 100, Cs from 30 to 24, Bs from 21 to 14, As from 23 to 9, and fatal crashes from 1 to 0). On a percentage basis, there is some minor shifting from the fatal and A categories to B and C categories. Given that the numbers of crashes in the personal injury categories are relatively small, it is not clear that this really represents a significant shift in severity.

Head-On/Left-Turn Crashes

For head-on/left-turn crashes, there was an overall increase in the number of crashes, from 42 to 86, an increase of over 100%. This increase showed up, in absolute terms, in all severity categories. In relative terms, PDO crashes decreased in a relative sense (from 28 to 53 crashes, but 67 to 62%), C crashes increased in absolute terms (6 to 12) but stayed approximately the same at 14%, while B crashes increased from 4 to 13 (10 to 15%), and As increased from 4 to 8 and held relatively steady, proportionately, at about 9-10%. In general, this represents an increase in this type of crashes and a general increase in severity (although the numbers driving the distributions are small).

"Other" Crashes

Other crashes also increased in overall number (287 to 314) but here there was a clear trend, in a both absolute and relative sense, toward less severe crashes—PDO crashes increased in both absolute and relative terms while all others decreased, except for fatal crashes which increased from 2 to 3.

4.5.3.2. Crash Type by Before/After for Different Levels of Severity

Crashes were also grouped into the different severity categories and examined in more detail with regard to shifts among crash types. The crash type distributions for each severity level (except for fatal crashes) are shown in table 4-12 and discussed below. (This table is comparable to table 4-6 for 4-way intersections.)

PDO Crashes

The 18% increase in PDO crashes between the before (646) and after (765) periods varied by crash type. The largest increase was in rear-end crashes which rose from 248 to 365 and accounted for 38 and 48% of all before and after PDO crashes, respectively. There were also increases in head-on/left-turn (28 to 53) and "other" (205 to 247) crashes. On the other hand there was a decrease in right-angle PDOs (165 to 100).

C-Injury Crashes

C-injury crashes also increased (147 to 208), a greater percentage increase than was seen for PDOs, but a smaller number in absolute numbers (61 versus 119). The distribution by crash type for C crashes is somewhat similar to the PDOs but there is an even greater domination by rear-end crashes—rear-end numbers increase from 68 to 137, accounting for 46 and 66% of all C crashes during the before and after periods, respectively. Right-angle crashes decrease in absolute and relative terms, while head-on/left-turn crashes are few in number (6 and 12, accounting for 4 and 6% of the before and after crashes, respectively). Other crash types also decrease in both absolute and relative terms.

B-Injury Crashes

Compared to PDOs and C-injury crashes, there are relatively few crashes in the other severity categories. The increase in B-injury crashes is only from 70 to 75, accounting for 8 and 7% of all before and after crashes. The small numbers notwithstanding, the pattern of change with respect to crash type is similar—an increase in rear-end crashes (17 to 28), a decrease in right-angle crashes (21 to 14), an increase in head-on/left-turn crashes (4 to 13), and a decrease in "other" crashes (from 28 to 20).

A-Injury Crashes

The A-injury crashes are even smaller (37 and 32) but do represent a net decrease. While the numbers are small, there was an increase in rear-ends, a decrease in right-angles, an increase in hear-on/left-turns, and no change in "others." Most notable of these changes is the reduction in right-angle crashes which decreased from 23 to 9.

Table 4-12. 3-way intersections: before-and-after comparison of severity and crash types 45m (150') from signal for 2 yrs

		PDOs		C-injuries		B-injuries		A-injuries	
crash type		**before**	**after**	**before**	**after**	**before**	**after**	**before**	**after**
rear-end	count	248	365	68	137	17	28	1	6
	percentage	38.39%	47.71%	46.26%	65.87%	24.29%	37.33%	2.70%	18.75%
right-angle	count	165	100	30	24	21	14	23	9
	percentage	25.54%	13.07%	20.41%	11.54%	30.00%	18.67%	62.16%	28.13%
head-on/left-turn	count	28	53	6	12	4	13	4	8
	percentage	4.33%	6.93%	4.08%	5.77%	5.71%	17.33%	10.81%	25.00%
other	count	205	247	43	35	28	20	9	9
	percentage	31.73%	32.29%	29.25%	16.83%	40.00%	26.67%	24.32%	28.13%
total	count	646	765	147	208	70	75	37	32

Fatal Crashes

Unlike the 4-way intersections where all fatal crashes were associated with angle-turning movements, only one before crash was in the right-angle category for the 3-ways. The other five fatal crashes were in the "other" category. Four of these (2 before, 1 after) were head-on collisions and one was a pedestrian crash.

Summary and Discussion

The changes attributed to signalization for 3-way intersections are not all that dis-similar from those noted for 4-ways. Much of the increase in PDOs was from rear-end crashes in both absolute and relative terms with a decrease in right-angle crashes. There were also increases in rear-end crashes in all other severity categories. The most notable off-setting trend was the decrease in right-angle crashes, in both absolute and relative terms, in all severity categories and especially so for A-injury crashes (although the numbers were not large). Fatal crashes at 3-way intersections, while, again, a very small number were much more varied in type than they had been for 4-way intersections—whereas all fatals had been right-angle crashes, for 3-ways, this was the case for only one crash.

4.5.4. 3-Way Intersections: Type of Signal Installed

The 3-way signal installations were also examined with respect to differences in crash types, severity, and so forth, as was the case for the 4-way sites. As appropriate, references are made to the latter results which were shown in tables 4-7 and 4-8. Of the original 37 3-way intersections, six (6) had actuated signals and the remaining 31 were fixed-time.

4.5.4.1. Signal Type and Crash Type

The cross-tabulations of the crash type distribution for both (fixed and actuated) signal types are shown in table 4-13. A comparison of the two before distributions shows that there are some differences in the crash distributions in these two sets of sites prior to signal installation. While there is about the same proportion of rear-end crashes (37%) at both types, there is a significantly higher percentage of right-angle crashes (28%) at fixed-time sites versus actuated sites (19%). The compensating differences are found in the remaining two crash types—the percentages for both head-on/left-turn and "other" types are higher at the actuated sites.

For the after periods, at the fixed-time sites there is a shift to rear-end and head-on/left-turn crashes although the latter is more modest. The off-setting decrease is primarily in the right-angle category. For actuated sites, it is interesting to note that while right-angle crashes increase in number, the proportion of all crashes that this category accounts for is essentially unchanged. On the other hand, there is a significant absolute and proportional increase in the rear-end category and a corresponding decrease in "other" crashes, at least proportionately.

In general, the magnitudes of the shifts with respect to different types of signals are somewhat different than those seen for 4-way intersections although the dominance of rear-end crashes is still apparent. However, for both 3-way and 4-way intersections, it should be noted that there are fundamental differences in the crash distributions at fixed and actuated sites before the signal is installed. This is, no doubt, due to the types of sites that are chosen to have different types of signals installed.

Table 4-13. 3-way intersections: before-and-after comparison of crash type by signal type 45m (150') from signal for 2 years

		fixed		actuated	
crash type		**before**	**after**	**before**	**after**
rear-end	count	281	449	53	87
	percentage	37.02%	50.11%	36.81%	46.52%
right-angle	count	213	113	27	34
	percentage	28.06%	12.61%	18.75%	18.18%
head-on/left-turn	count	33	74	9	12
	percentage	4.35%	8.26%	6.25%	6.42%
other	count	232	260	55	54
	percentage	30.57%	29.02%	38.19%	28.88%
total	count	759	896	144	187

4.5.4.2. Signal Type and Severity

The type of signal installed was also examined with respect to severity. These results are shown in table 4-14. Again, it should be noted that there are some initial differences (i.e., in the "before" distributions) in the severity levels at the two types of sites. There are, generally speaking, more PDOs at the actuated sites. These differences notwithstanding, the results in the table shows that for fixed-time sites, there was a shift toward C-injury crashes, mostly from more severe crash categories; for actuated sites, the shifts were much more slight, on the order of only one or two percentage points (and with a relatively small sample size so that a shift of a few crashes could account for a percentage point of change).

4.5.4.3. Signal Type and Other Variables

As was the case for 4-way sites, the effects of/on several other variables were also examined although little of interest was noted. The sole exception was that for actuated signals, there was a clear shift (in proportional and absolute terms) of crashes to daylight conditions. This was primarily offset by an absolute and relative decrease in crashes occurring under dark/no-street light conditions. No similar shift was evident for fixed-time sites (in fact, for those sites, there was a relative increase in dark/no-street light crashes). For 4-way sites, the significant shifts noted here were the reverse. Again, there is no ready explanation for these changes.

Table 4-14. 3-way intersections: before-and-after crash severity by type of signal 45 m (150') from signal for 2 years

crash severity		fixed		actuated	
		before	**after**	**before**	**after**
PDO	count	538	623	108	142
	percentage	70.88%	69.53%	75.00%	75.94%
C-injury	count	127	180	20	28
	percentage	16.73%	20.09%	13.89%	14.97%
B-injury	count	62	63	8	12
	percentage	8.17%	7.03%	5.56%	6.42%
A-injury	count	30	27	7	5
	percentage	3.95%	3.01%	4.86%	2.67%
fatal	count	2	3	1	0
	percentage	0.26%	0.33%	0.69%	0.00%
total	count	759	896	144	187

4.5.5. 3-Way Intersections: Geographic Area

The definitions of the three geographic areas (rural, mixed, and metro) were provided in the earlier discussion of 4-way intersections. There were 10 metro, 25 mixed, and only four (4) rural 3-way intersections. The crash-type distribution for each of the three areas is given in table 4-15 (the comparable table for 4-way intersections is 4-9). Interestingly, the crashes in rural areas actually declined between the before and after periods while 23% increases were recorded for the other two. This is quite different from what was found for 4-way intersections where the differences were greatest for rural areas, less for mixed areas, and least for metro areas.

Table 4-15. 3-way intersections: before-and-after comparison of crash type by type of area 45m (150') from signal for 2 years

crash type		rural		mixed		metro	
		before	**after**	**before**	**after**	**before**	**after**
rear-end	count	19	36	154	272	161	228
	percentage	17.12%	33.64%	35.81%	51.22%	44.48%	51.24%
right-angle	count	35	24	123	68	82	55
	percentage	31.53%	22.43%	28.60%	12.81%	22.65%	12.36%
head-on/left-turn	count	7	11	13	19	22	56
	percentage	6.31%	10.28%	3.02%	3.58%	6.08%	12.58%
other	count	50	36	140	172	97	106
	percentage	45.05%	33.64%	32.56%	32.39%	26.80%	23.82%
total	count	111	107	430	531	362	445

The "before" crash type distributions are quite different for all areas with rear-end crashes, not surprisingly, accounting for a higher fraction of crashes from rural to mixed to metro intersections. The shifts to rear-end crashes resulting from signalization, on the other hand, are more pronounced in rural areas although the final proportion is not as high as it is for mixed and metro sites. Unlike the 4-way sites, the shift in distribution away from right-angle crashes is somewhat more consistent: a ten-point decrease for rural and metro sites, and a 16-point shift for mixed areas.

The severity distributions show that rural sites increased in severity (although overall crash frequencies actually decreased): PDOs had a twelve-point decrease while C and B categories both increased (10 to 16% and 3 to 9%, respectively) and A decreased very modestly (<one point). (See table 4-16.) For mixed areas, PDOs decrease in a relative sense as do A and B categories while the C category increases—what appears to be a sort of "wash" in terms of whether severity increased or decreased. For metro areas, the PDO proportion increases and all others decrease. So, rural areas tended to see fewer, but somewhat more serious crashes, mixed areas stayed about the same, and metro areas saw a shift toward less serious crashes. Finally, it should be noted that all but one of the fatal crashes occurred in the mixed areas.

4.5.6. 3-Way Intersections: Summary and Synthesis of the Effects of Signalization

Based on the analysis of the 37 3-way intersections included in this study, the following synthesis and summary of findings can be presented.

* Signalization appears to result in a sizeable increase in the number of crashes occurring at 3-way intersections—on the order of 20% although that figure varies under different conditions. While there is an (obvious) accompanying increase in the mean number of crashes per intersection (~5), the increase is not statistically significant.

* The primary shift in crash type is to the rear-end category where there are both absolute and relative increases. On the other hand, right-angle crashes decrease in both absolute and relative terms.

* A large percentage of the increased number of crashes is accounted for by PDO crashes although this category decreases slightly in importance in relative terms. C-injury crashes increase in both relative and absolute terms while B-injury crashes increase absolutely and decrease relatively and A-injury crashes decrease in both senses. Fatal crashes remain the same. "Improvement" in terms of crash statistics is modest, if at all.

* Rear-end crashes become not only more numerous but also somewhat more severe at these sites. They are the dominant type of crash in each severity category except fatal crashes.

* Right-angle crashes decrease in number although any shift in severity is modest.

* Head-on/left-turn crashes increase in number and there is a shift to more severe crashes. The absolute numbers are relatively small and the distributional shift is sensitive as a result.

* PDO crashes increased significantly and was dominated by rear-end crashes with lesser numbers of head-on/left-turn and other crashes.

* Fatal crashes at 3-way intersections included one angle-turn crash (before) and five "other" crashes. Four of these (2 before, 1 after) were head-on/left-turn collisions and one was a pedestrian crash.

* Sites where fixed-time versus actuated signals were installed appear to be different from each other prior to signalization (e.g., different crash type distributions during the before period). Nonetheless, there is still a basic shift to rear-end type crashes as a result of signalization at both types of site.

* At fixed-time sites, the shift in crash severity is toward C-injury crashes (from less and more serious categories, although the latter seems more dominant) while for actuated sites shifts were much more modest (slight).

* At rural sites, signalization resulted in fewer crashes while relatively significant increases were noted for mixed and metro sites.

* The shifts among crash type categories (to rear-end crashes) are more pronounced in rural areas although the shift from right-angle crashes is clear in all cases (a ten-point decrease for rural and metro sites, a 16-point shift for mixed sites).

* Rural sites saw an increase in severity (although frequencies decreased), while mixed sites had largely compensating shifts among categories for, most likely, no real change in severity, and metro sites shifted toward less serious crashes.

4.6. Analysis of Driveway Intersections

Several of the signal installations provided by MDOT were classified as "driveways" and are singled out for analysis which is separate from the 4- and 3-way intersections discussed in the previous sections. The primary difference with driveways is that these are generally sites where there may not have been a real intersection present during the "before" period—i.e., a typical situation is where a new shopping mall opens and the main entrance is signalized (although this is not necessarily the case). While this may be a typical-looking 3- or 4-way intersection after the mall opened, during the before period it may well have not existed. Moreover, depending on the location of the driveway, the character of the development which it serves, the area, and whether the intersection existed prior to signalization, there may be substantial changes in traffic volumes on the state trunkline before and after the mall opens. In addition, there were only 12 usable intersections in the initial set of intersections provided for the study (and that reduced to nine when the 2-year analysis period was considered). Thus, the attention that "driveway" intersections receives here is very broad—they are not generally comparable to other types of sites.

4.6.1. Driveway Intersections: Total Crashes and Crash Type Distribution

The total crashes and crash type distribution for driveways are shown in table 4-16. It is seen in that table that the total number of crashes increases from 122 to 189, a 55% increase. While this increase is quite large, it should be remembered that, for the most part, the crashes in the before period included many which were attributable to non-intersection locations (i.e., at least some of the "intersections" did not exist prior to signalization). However, even with the large increase in crashes and the accompanying increase in the mean number of crashes/intersection (from 13.3 to 20.6), the difference is not statistically significant.

Table 4-16. Driveway intersections: before-and-after comparison of crash type 45m (150') from signal for 2 years

crash type		before	after
rear-end	count	24	66
	percentage	19.67%	34.92%
right-angle	count	8	16
	percentage	6.56%	8.47%
head-on/left-turn	count	5	10
	percentage	4.10%	5.29%
other	count	85	97
	percentage	69.67%	51.32%
total	count	122	189

It is also noted that the "before" distribution is quite different from others that have been examined to this point. Only "rural" intersections exhibited so low a percentage of rear-end crashes in the before period. In the same vein, the "other" type of crashes dominates the distribution. The rear-end percentage is in the after period is reasonably consistent with the low end of the range encountered thus far. Examination of the more detailed crash type distribution (not shown) indicates that many of the crashes classified as "other" in table 4-16 are one type of "driveway" crashes or another.

Overall, while these intersections are "different," it is noted that the same general trends as were noted for other more typical kinds of intersections are also noted here—a shift to rear-end crashes once the signal is installed.

4.6.2. Driveway Intersections: Crash Severity

The crash severity situation for driveways is also fairly similar to that noted for other types of intersections: there is an overall, although modest, shift to PDO crashes from the more serious personal injury classifications. The PDO percentage increases from 60 to 64%. It should, however, be noted that while this implies a safety benefit in a relative sense, there were absolute increases in the numbers of crashes in all categories except fatal crashes which decreased from 2 to 0. These results are summarized in table 4-17.

Table 4-17. Driveway intersections: before-and-after comparison of crash severity 45 m (150') from signal for 2 years

crash severity		**before**	**after**
PDO	count	73	121
	percentage	59.84%	64.02%
C-injury	count	30	46
	percentage	24.59%	24.34%
B-injury	count	12	13
	percentage	9.84%	6.88%
A-injury	count	5	9
	percentage	4.10%	4.76%
fatal	count	2	0
	percentage	1.64%	0.00%
total	count	122	189

4.6.3. Driveway Intersections: Summary and Synthesis of the Effects of Signalization

Based on the analysis of 12 driveway intersections included in this study, the following synthesis and summary of findings can be presented.

* The increase in driveway crashes is most dramatic, 55%, but may well be attributable to changes in development patterns and the opening of major new facilities (e.g., a shopping mall) rather than the signalization of the intersections *per se*.

* Rear-end crashes dominate the crash type distribution after the signalization and are generally consistent with other types of intersections.

* There is a general shift from personal injury to PDO crashes in a distributional sense although all categories (except fatal crashes) saw substantial increases in the absolute number of crashes.

4.7. Analysis of Crossover Intersections

Crossover intersections constitute another "different" type of intersection. These are intersections where the left-turn movements are handled by median (boulevard) crossovers which are beyond the core intersection. There is a variety of geometric and actual signalization possibilities which makes the aggregation of a selected few of these into one group problematic. Indeed, the signalization itself may well be accompanied by significant changes in the geometry that is present at any give site and the allowable turning movements. For these reasons, and the fact that separate studies have been done on crossovers, this type of intersection is also examined in the most general of terms. There were 21 crossover intersections considered here (and only 14 for the 2-year analysis period).

4.7.1. Crossover Intersections: Total Crashes and Crash Type Distribution

The total number of crashes and the before and after distributions by crash type are shown in table 4-18. The increase in crashes, in this instance, is in the general range that has been found for the traditional types of intersections. Moreover, the shifts among crash types is fairly consistent with the findings thus far: the rear-end category increases (in absolute and relative terms) while all other categories decrease except for head-on/left-turn crashes (of which there were very few) increased. An examination of the more detailed crash types showed that left turn-related crashes decreased substantially, which would be expected, although there only a few of them in the before period anyway.

Table 4-18. Crossover intersections: before-and-after comparison of crash type 45m (150') from signal for 2 years

crash type		before	after
rear-end	count	66	90
	percentage	44.59%	54.22%
right-angle	count	32	28
	percentage	21.62%	16.87%
head-on/left-turn	count	1	4
	percentage	0.68%	2.41%
other	count	49	44
	percentage	33.11%	26.51%
total	count	148	166

4.7.2. Crossover Intersections: Crash Severity

Changes in crash severity (table 4-19) were minor in this instance. While the predominant types of crashes were PDOs and C-injuries, there was very little shift between the before and after period although there were absolute increases in all but A-injury and fatal categories. Overall, however, it could be said that these intersections appeared to become at least somewhat safer as measured by severity.

4.7.3. Crossover Intersections: Summary and Synthesis of the Effects of Signalization

Based on the analysis of 21 crossover intersections included in this study, the following synthesis and summary of findings can be presented.

* There is an increase in the number of crashes which is generally consistent with other intersection types.

* There is a shift to rear-end crashes which is clear and consistent in both an absolute and relative sense.

Table 4-19. Crossover intersections: before-and-after comparison of crash severity 45 m (150') from signal for 2 years

crash severity		**before**	**after**
PDO	count	101	119
	percentage	68.24%	71.69%
C-injury	count	30	35
	percentage	20.27%	21.08%
B-injury	count	7	8
	percentage	4.73%	4.82%
A-injury	count	8	4
	percentage	5.41%	2.41%
fatal	count	2	0
	percentage	1.35%	0.00%
total	count	148	166

* The severity distributions changed only modestly as a result of signalization although the trend is toward less severe crashes.

5. Summary and Discussion

This study has been directed to the evaluation of the effects of signalizing previously unsignalized intersections. The basic question to be answered was: What happens (from an crash perspective) when an intersection is signalized. In order to answer this question, a set of intersections that had been recently signalized was provided by the Michigan Department of Transportation (MDOT). Descriptive data on these intersections as well as crash records were assembled from MDOT files and combined for the analysis. The analysis that has been presented was fairly straightforward and descriptive of general, broad trends for several classes of intersections: simple 4-way, simple 3-way, driveways, and crossovers. The primary focus was on the first two categories. Ramp-terminal intersections were excluded from this study because of the additional (and different) data manipulation required to identify the appropriate crashes. The analysis that was done was generally directed to considering the changes in the frequency of crashes, identification of intersection and/or signal characteristics that might also have an impact on the crash statistics, and changes in crash severity. Crash rates have generally **not** been addressed in any detail. The reason for this is the general lack of knowledge about the changing ADTs that the various intersections experienced (i.e., for most intersections, only one characteristic ADT was available, thus, crash rates "show" the same thing as frequency analysis).

5.1. Principal Results

The results that are reported below are based on consideration of a 2-year before and after window around the time of the signalization (less 30 days on either side of the assumed implementation date because of the inaccuracy inherent with that date). It should be noted that indications of increased (or decreased) numbers of crashes should be interpreted with some caution as there was substantial instability in the annual variations in statewide trends in all and intersection-only crashes. Lastly, the relative shifts in severity and crash type should be more reliable because these are largely unaffected by background variation.

5.1.1. Total Crashes

Notwithstanding variations in the background trends in intersection crashes over the entire analysis period, it appears that signalization results in an increase in crash frequency. For 4-way intersections, the increase was about 5%; for 3-ways, it was about 20%; for driveways, about 55%, and for crossover intersections, about 12%. The very large increase in crashes at driveways is most likely explained by the fact that signalized driveways occur in conjunction with large new land uses (e.g., shopping malls), thus, much of the increase is attributable to the substantial changes in travel patterns. These increases can also be expressed in terms of the mean number of crashes: for 4-ways, the increase was about one crash/intersection; for 3-ways, about 5 crashes; for driveways, about 7; and for crossovers, hardly any change. Interestingly, none of the changes in the mean number of crashes was statistically significant. This points to the fact that there was substantial variation in the numbers of crashes per intersection. The variation results from numerous factors (some which can be addressed and some not) and supports the notion that for any given intersection, an increase or decrease in the number of crashes would be difficult to predict, at least without more complex analysis.

5.1.2. Types of Crashes

For all intersection types, the shifts in crash type were as expected *a priori*—that is, angle crashes decreased while rear-end crashes increased. This shift was most always observed and generally fairly dramatic. However, this shift also varies considerably based upon different conditions.

5.1.3. Severity of Crashes

There was generally an increase in crash frequency for 4-way intersections. Offsetting this trend was a shift in crash severity from more to less severe crashes. PDO and C-injury crashes tend to increase in both absolute and relative terms while A-injury, B-injury, and fatal crashes decrease in both absolute and relative terms. On the other hand, the changes in severity observed for 3-way intersections were more modest—i.e., it is not possible to conclusively say whether severity really increased or decreased. For driveways, there was a general shift from personal injury to PDO crashes in a distributional sense although all categories (except fatal crashes) saw substantial increases in the absolute number of crashes. Finally, for crossovers, the severity distributions changed only modestly, although the shift was toward less severe crashes.

For specific crash types, the absolute and relative increases in rear-end crashes observed at 4-way intersections was accompanied by a shift toward minor personal-injury (C-injury) crashes. That is, C-injury crashes accounted for a higher percentage of the crashes after signalization. However, there were absolute increases in the numbers of crashes in all severity categories. At 3-way intersections, rear-end crashes became both more numerous and somewhat more severe.

On the other hand, the relative distribution of right-angle crashes by severity at 4-way intersections effectively remained the same although there were significant reductions in the absolute number of such crashes in all severity categories. Similar shifts were observed for 3-way intersections.

Finally, with regard to the most serious crashes at 4-way intersections, right-angle crashes accounted for all fatal crashes during both the before and after periods and decreased from six (6) to three (3) between the before and after periods for 4-way intersections. The results for 3-way intersections were not as clear-cut.

5.1.4. Type of Signalization

Differences in crash distributions are difficult to relate to the type of signal, fixed-time versus actuated, that is installed since there are differences between these two sets of sites during the before period. That is, sites where fixed-time signals are installed appear to have different crash statistics than those where actuated signals were installed. This was the case for both 3-and 4-way intersections although the same general trends were observed—e.g., shifts to rear-end crashes. There were some modest differences in shifts among severity categories although these would be hard to predict since the number of actuated sites was small.

5.1.5. Type of Area

The type of area where the signal installation took place was also investigated. While results seemed to differ by area type, it was also noted that the trends exhibited for 4-way intersections were not the same as for 3-ways. Thus, explanation of the reasons for these results is problematic.

For 4-way intersections, increases in crashes as a result of signalization appeared to be related to type of area (metro, mixed, rural) in which a signal was found. Intersections in rural areas increased the most (9%) followed by mixed areas (5%) and metro areas (4%). The changes in the mean number of crashes was not, however, statistically significant. Contrarily, rural 3-way intersections experienced fewer crashes while there were relatively significant increases noted for mixed and metro sites.

For 4-way intersections, rural sites tended to shift to more serious crashes while mixed areas had somewhat reduced severity and metro areas had some compensating shifts (fewer PDOs but also fewer A- and B-injury crashes). Fatal crashes occurred in rural areas (2 before) and mixed areas (4 before, 3 after). The results at 3-way intersections were similar with rural sites increasing in severity (although frequencies decreased), while mixed sites had largely compensating shifts among categories for, most likely, no real change in severity, and metro sites shifted toward less serious crashes.

5.1.6. Other Factors

At the level of analysis that was done, other factors that were investigated (e.g., time of day, day of week) did not appear to have an identifiable effect on the results. It should be noted, however, that some specific questions were beyond the scope of this project. For example, the effects of flashing operations were not assessed and could not be picked up through a simple time-of-day examination.

5.2. Discussion

Although (overall) there were consistent increases in crash frequencies for the various intersection types, the changes in the average number of crashes per intersection were statistically insignificant. The latter result was, in all likelihood, due to the variance in the before-to-after changes. Thus, while the changes were evident, they were not statistically large enough. In addition the changes in frequencies (or in average number per intersection) must also be considered in the context of the background trends in crashes. The magnitude and direction of changes in crash frequencies were also seen to vary according to several other factors—e.g., the rural 3-way intersections included in the study actually experienced crash reductions while 4-way intersections in similar locations experienced an increase. Overall then, on average, an increase in crash frequency might be expected as a result of signalization although the magnitude of the increase is virtually impossible to predict and decreases in the number of crashes are certainly possible.

The most reliable finding was that signalization will almost assuredly result in a shift from angle to rear-end crashes. This shift was evident for all types of intersections and, to the extent it could be examined, in all types of situations. There was some variance in the magnitude of the crash type shift. The general shift in crash type is consistent with findings elsewhere.

Overall, there appeared to be some evidence that crashes will be less severe as a result of signalization although, once again, the magnitude of the shift varies by intersection type and sometimes other factors. In some instances, the net increase in crashes serves to offset some of the shifting among severity categories (e.g., while there may be *relatively* fewer "B" crashes, the *absolute* number of "B" crashes may still be higher (as a result of the overall increase in crash frequency).

There was no attempt to develop predictive models based on intersection or signal characteristics or to analyze the intersections (and crashes) at any more sophisticated level. It is possible, for example, that there are more complex relationships among the several characteristics examined that could be identified to determine whether there are differences between newly signalized intersections that experience an increase in crash frequency (or severity) and those that do not. That is, for example, is there any identifiable difference between newly signalized intersections which experience crash increases and those where crashes decrease? Likewise, while there were no general differences related to the time of day of crashes, it may be that flashing operations have some other, as yet undetermined, impact(s). The availability of the combined intersection and crash files produced as part of this project do, however, make such additional investigation possible.

Appendix 3-1

Initial List of Intersections from MDOT

DATE = 05-22-95

MICHIGAN DEPARTMENT OF TRANSPORTATION
TRAFFIC & SAFETY DIVISION
TRAFFIC SIGNAL STATUS FILE --- HISTORY FIND OPTION REPORT

WORK ORDER HISTORY DATA

Dave, Initial Listing. Please Return Tom

LT = '01' SIGNAL STATEWIDE WORK ORDERS ONLY TIME SPAN = 0186-1292

Not All Inclusive

D	CS	SPOT	LOCATION	LT	ST	LAST ACTION	DATE	REMARKS			FUND	IR DATE	CSJ	JOB NO	WO NO	AGENC
1	31051	003	US-41(SHELDON AVE)WB @ ISLE ROYAL ST	01	01	W O COMPLETE	100190	S/S W/TBC	12" PEDS	MAST ARMS	FUG	021290		31569A	03774	MDOT
1	31051	016	US-41(TOWNSEND) @ MACINNIS DR (UPLAND)	01	01	W O COMPLETE	092890	S/S W/TBC	12" PEDS	PED P/BUTN	FUG	081988		30506A	03672	MDOT
1	52042	034	US-41,M-28 BYPASS @ MCCLELLAN AVE	01	01	W O COMPLETE	110289	S/S W/TBC	12" HEADS	EB ADV WRN	M	112088		30312A	03653	MDOT
1	52044	013	US-41BR(WASHINGTON) @ MCCLELLAN AVE.	01	01	W O COMPLETE	020888	S/S CONTRL	12" PEDS	PRE-RR SIG	M	040287	NO	27493A	03226	MDOT
1	55011	003	US-41(10TH ST) @ 14TH AVE	01	01	W O COMPLETE	073191	S/S W/TBC	12" PEDS	SCHL X-ING	FUG	051590		32742A	03962	MDOT
2	17032	001	BS-75@ CASCADE CROSSINGS SHOPPING CENTER	01	01	W O COMPLETE	092492	S/S W/TBC	12" HEADS	12" PEDS	STG	032692		34425A	04169	MDOT
2	17032	017	BS-75 (ASHMUN) @ M-129/GLENNS MARKET DR	01	01	W O COMPLETE	050489	S/S W/TBC	WIDEN=DR		FUG	060188	NO	29233A	03478	MDOT
2	21021	005	US-2,US-41(LUDINGTON) @ 30TH ST	01	01	W O COMPLETE	092392	S/S: SEMI	12" HEADS	LOOPS	STG	112090		34018A	04130	MDOT
2	21025	001	US-2,US-41 AT M-35	01	01	W O COMPLETE	051089	FUT NB LTO	NLT= NORTH	ADV RESOLU	FUG	100682		29330A	03494	MDOT
2	21025	001	US-2, US-41 @ M-35 (4TH AVE.)	01	01	W O COMPLETE	051089	12" HEADS	OH ADV WAR	FLASHER	FUG	012188		29330A	03494	MDOT
2	75021	003	US-2 (RELOCATED) @ CEDAR ST	01	01	W O COMPLETE	110587	CLOSE OUT=	PER D.O.E.	1240= 8-84		022880	NO		02574	MDOT
3	10032	001	US-31 AT M-115 (N. JCT.)	01	01	W O COMPLETE	071087	S/S CONTRL	12" PEDS &	HEADS	FRG	082586		27034A	03089	MDOT
3	15011	001	US-31(BRIDGE) AT M-66(STATE)	01	01	W O COMPLETE	100590	S/S W/TBC	12" HEADS	SPLIT WIRE	FRG	111489		31447A	03796	MDOT
3	18031	011	US-27BR(MC EWEN) @ SCHOOLCREST AVE	01	01	W O COMPLETE	032488	S/S W/TBC	12" PEDS	ADV RESOLU	RSG	080886		27742A	03269	MDOT
3	28011	002	US-31 @ W SILVER LAKE RD (CO. RD. 633)	01	01	W O COMPLETE	111092	S/S W/TBC	RR PRE-SIG	WIDEN=CLLT	STG	091688	NO	33511A	04078	MDOT
~~3~~	~~28012~~	~~006~~	~~US-31,M-37 @ MANUFACTURERS MARKET PLACE~~	01	01	W O COMPLETE	092690	S/S W/TBC	SEMI-ACTUA	SB RT LN	FRG	121589	NO	31331A	03758	MDOT
3	28012	014	US-31/M-37 @ MEIJER DRIVE "B"	01	01	W O COMPLETE	050389	S/S W/TBC	12" HEADS		FUG	040887		29381A	03517	MDOT
3	28013	023	US-31,M-72(MUNSON) AT HOLIDAY RD	01	01	W O COMPLETE	050989	S/S W/TBC	12" HEADS		FUG	031488		29304A	03491	MDOT
3	45071	003	M-22 @ CHERRY BEND ROAD	01	01	W O COMPLETE	070391	S/S CONTRL	12" HEADS	WIDN= X-RD	FRG	081188	NO	31369A	03780	MDOT
3	51011	007	US-31 @ MERKEY RD	01	01	W O COMPLETE	060292	S/S: 4 PHS	12" HEADS	LOOPS=X-RD	STG	102590		33512A	04053	MDOT
3	51012	001	US-31 @ M-55	01	01	W O COMPLETE	060690	S/S CONTRL	12" HEADS		FRG	091889		30712A	03714	MDOT
~~3~~	~~53032~~	~~005~~	~~US-10,31 @ US-31 RELOCATED (SB ON RAMP)~~	01	01	W O COMPLETE	072090	SEMI-ACTUA	W/S LT PHA	12" HEADS	FRG	012689	NO	30258A	03632	MDOT
3	83021	003	M-55,115 @ M-55 NW JCT.	01	01	W O COMPLETE	102386	12" HEADS	& PEDS		MNT	062984	NO		02952	MDOT
3	83032	009	US-131 @ BOON ROAD (CO. RD. 34)	01	01	W O COMPLETE	050290	S/S W/TBC	12" HEADS	4-W C/SIGN	FUG	063089		30512A	03645	MDOT
4	16021	001	M-68(WILSON)@OLD US-27(STRAITS HWY)S.JCT	01	01	W O COMPLETE	082389	S/S CONTRL	12" PEDS	WIDEN=CLLT	FRG	070886	NO	28283A	03338	MDOT
4	16021	002	M-68 @ M-68(OLD 27) N. JCT.	01	01	W O COMPLETE	061786	G.I.= 4-85	GET PLANS	NEED= 6-86	FRG	070183	NO	25616A	02896	MDOT
4	16032	015	M-27 (MAIN) @ B&C SHOPPING CENTER DR	01	01	W O COMPLETE	040391	S/S W/TBC	12" PEDS	12" HEADS	FRG	111589	NO	31608A	03838	MDOT
4	16071	001	M-108(NICOLET) @ US-23	01	01	W O COMPLETE	061686	FULL ACTUA	12" HEADS	ADV WARN F	RSG	080585		25393A	02886	MDOT
~~4~~	~~16071~~	~~001~~	~~M-108(NICOLET) @ US-23~~	01	01	W O COMPLETE	061686	ADD RT LNS	ADD LOOPS		RSG	031786	NO	25393A	A2886	MDOT
4	20021	001	M-72, M-93 @ M-93 W. JCT.	01	01	W O COMPLETE	051190	S/S CONTRL	SEMI-ACTUA	12" HEADS	M	093087		30255A	03629	MDOT
4	24011	024	US-31 AT REED AVE.	01	01	W O COMPLETE	052490	S/S SEMI	PED ACTUAT	1C = REED	M	061588	NO	30091A	03596	MDOT
4	24051	002	US-31,M-68 @ M-119	01	01	W O COMPLETE	092288	S/S CONTRL	EB LAG LTO	SB RTGA	RSG	041585		27674A	03263	MDOT
4	35012	001	M-65 @ ESMOND RD.	01	01	W O COMPLETE	093087	SEMI-ACTUA	PED P/BUTN	XING M-65	FRG	072985		27037A	03090	MDOT
~~4~~	~~35012~~	~~001~~	~~M-65 @ ESMOND RD~~	01	01	W O COMPLETE	093087	REPL POLE	SE QUAD W/	HD STEEL	FRG	061087		27037A	A3090	MDOT
4	65021	001	BL-75 @ M-55 E JCT	01	01	W O COMPLETE	080586	$$ FOR T.S	1240= 4-86	NEED= 6-86	RSR	111379	NO	20541A	02911	MDOT
4	65052	001	M-33 @ M-55	01	01	W O COMPLETE	070387	FULL ACTUA	REST"N"RED	CONST REQD	MNT	061284	NO		02905	MDOT
4	69011	005	BL-75 (OTSEGO) @ GRANDVIEW BLVD.	01	01	W O COMPLETE	091588	S/S W/TBC	12" HEADS	X-RD=LT LN	FRG	081887	NO	28137A	03304	MDOT
4	69014	102	I-75 NB OFF RAMP @ M-32(MAIN)	01	01	W O COMPLETE	072387	SEMI-ACTUA	S/S W/TBC	12" HEADS	FRG	051386		27039A	03028	MDOT
4	72022	002	M-55 @ M-18 @ MAIN (W. JCT.)	01	01	W O COMPLETE	101687	S/S CONTRL	F/PREEMPT	NB RTGA	FRG	101885	NO	27270A	03158	MDOT
4	72031	002	M-55 @ LOXLEY/MT PLEASANT	01	01	W O COMPLETE	052087	SEMI-ACTUA	12" HEADS	WIDEN X-RD	FRG	112684	NO	25666A	02916	MDOT
5	19031	003	US-27 @ ROUND LAKE RD.	01	01	W O COMPLETE	060988	SEMI ACTUA	12" HEADS	ADV WARN F	FRG	032785	NO	27094A	03108	MDOT
~~5~~	~~19031~~	~~003~~	~~US-27 @ ROUND LAKE RD~~	01	01	W O COMPLETE	060988	RELOC POLE	NE QUAD	ISLAND REV	FRG	041188	NO	27094A	A3108	MDOT
5	19031	014	US-27 AT TOWNSEND ROAD	01	01	W O COMPLETE	112090	FULL ACTUA	PED P/BUTN	12" HEADS	M	062189	NO	31528A	03761	MDOT
5	19062	001	M-21 @ MAIN ST.	01	01	W O COMPLETE	042289	S/S: SEMI	ADV WARN	ADV RESOLU	FRG	091085		29084A	03415	MDOT
5	29031	010	US-27BR(SUPERIOR) AT WOODWORTH ST	01	01	W O COMPLETE	071190	S/S W/TBC	C/SIGN	ADV RESOLU	M	070588		30322A	03625	MDOT
5	34032	010	M-66(STATE) @ TUTTLE RD	01	01	W O COMPLETE	080489	S/S W/TBC	12" HEADS	ADV WRN FL	M	042588	NO	29880A	03558	MDOT
~~5~~	~~34032~~	~~010~~	~~M-66(STATE) @ TUTTLE RD~~	01	01	W O COMPLETE	080489	ADD PEDS	ADV RESOLU		M	071789		29880A	A3558	MDOT
5	34042	004	BS-96(GRAND RIVER @ DIVINE HIGHWAY	01	01	W O COMPLETE	080787	S/S W/TBC	NO PEDS	ADV RESOLU	RSG	101086		27040A	03038	MDOT
5	37021	010	M-20(HIGH/REMUS) @ BRADLEY	01	01	W O COMPLETE	100287	S/S W/TBC	WIDEN:X-RD	NOT REQ'D	FUG	082786	NO	27096A	03107	MDOT
5	41013	012	M-44(NORTHLAND) @ 7 MILE/ROGUE RIVER	01	01	W O COMPLETE	121487	S/S CONTRL	12" HEADS	ADV RESOLU	FUG	082285		27097A	03114	GR RAPI
5	41024	004	I-96 WB ON RAMP @ 28TH ST	01	01	W O COMPLETE	011289	S/S W/TBC	EB THRU GR	ARROWS		052788	NO	24283A	03440	MDOT
5	41026	003	I-96 WB OFF RAMP AT WALKER AVE	01	01	W O COMPLETE	112888	S/S: SEMI	12" HEADS	ADV RESOLU	M	050288		28624A	03389	GR RAPI
5	41027	106	I-196 WB OFF RAMP @ COLLEGE AVE	01	01	W O COMPLETE	121190	S/S W/TBC	12" PEDS	NB LTGA	IRG	120186		29910A	03557	GR RAPI
5	41031	003	M-37(CHERRY VALLEY AVE) AT MAIN ST	01	01	W O COMPLETE	061792	EPAC: SEMI	12" HEADS	ADV WRN FL	STG	120191		33739A	04110	GR RAPI

MICHIGAN DEPARTMENT OF TRANSPORTATION
TRAFFIC & SAFETY DIVISION
TRAFFIC SIGNAL STATUS FILE --- HISTORY FIND OPTION REPORT   WORK ORDER HISTORY DATA

DATE = 05-22-95

LT = '01' SIGNAL   STATEWIDE   WORK ORDERS ONLY   TIME SPAN = 0186-1292

D	-CS	SPOT-	LOCATION	LT	ST	LAST ACTION	-DATE-	REMARKS			FUND	IR DATE	CSJ	JOB NO	WO NO	AGENC
6	56023	033	US-10BR,M-20(LYONS) EB @ BAYLISS ST	01	01	W O COMPLETE	050191	S/S CONTRL	PEDS	HARWIRE	FUG	120489		32153A	03910	MIDLAND
6	56044	004	US-10 EB RAMPS @ US-10BR(EASTMAN)	01	01	W O COMPLETE	100291	S/S W/TBC	12" HEADS	SB LTGA	FUG	012390	NO	33074A	04018	MIDLAND
6	56044	104	US-10 WB RAMPS @ US-10BR(EASTMAN)	01	01	W O COMPLETE	100391	S/S W/TBC	12" HEADS	WB RTGA	FUG	012390	NO	33073A	04017	MIDLAND
6	73031	001	M-52(SAGINAW) @ M-52(BELL)	01	01	W O COMPLETE	040188	S/S,12"PED	CITY= PARK	REMVL 2-87	FRG	110376	NO	27864A	03273	MDOT
6	73061	003	M-46(GRATIOT) @ M-52(GRAHAM)	01	01	W O COMPLETE	053090	S/S CONTRL	EB/WB LAG	LTO W/RTGA	FRG	051983	NO	27209A	03141	MDOT
~~6~~	~~73061~~	~~003~~	~~M-46(GRATIOT) @ M-52(GRAHAM)~~	01	01	W O COMPLETE	053090	ADD PRESEN	LOOPS		FRG	081987		27209A	A3141	MDOT
6	73062	017	M-46(GRATIOT)@ GOLFVIEW/COUNTRY CLUB DRS	01	01	W O COMPLETE	111192	NEMA 4 PHS	12" HEADS	12" PEDS	STG	040191	NO	34551A	04181	MDOT
6	73101	002	I-675 NB OFF RAMP TO TITTABAWASSEE RD	01	01	W O COMPLETE	030889	S/S CONTRL	12" HEADS	ADV RESOLU	IRG	020687		28813A	03411	MDOT
6	73111	003	I-75,US-23 NB OFF RAMP@ M-81(WASHINGTON)	01	01	W O COMPLETE	101289	RETN TEMP	S&G; RELOC	CONTROLLER	M	081588		28869A	03429	MDOT
~~6~~	~~73111~~	~~003~~	~~I-75,US-23(NB OFF RAMP)@M-81(WASHINGTON)~~	01	01	W O COMPLETE	101289	REPLC POLE	RELOCATE	CONTROLLER	M	120888		28869A	A3429	MDOT
6	73111	009	I-75 SB OFF RAMP @ DIXIE HIGHWAY	01	01	W O COMPLETE	060188	S/S W/TBC	12" HEADS		IRG	062185		27926A	03317	MDOT
6	73131	003	M-46(HOLLAND) @ M-83(GERA RD.)	01	01	W O COMPLETE	062989	S/S: SEMI	12" HEADS	NO PEDS	FRG	053084	NO	29085A	03437	MDOT
6	73131	011	M-83(MAIN ST.) @ BAVARIAN MALL DR	01	01	W O COMPLETE	053190	S/S CONTRL	CONSTRUCT	5 LANES	FRG	011885	NO	30600A	03704	MDOT
6	73171	001	I-75,US-10,23 NB OFF RAMP @ M-54,83	01	01	W O COMPLETE	061992	S/S SEMI	12" HEADS	IN=1-15-88	FRG	052285	NO	27382A	03184	MDOT
6	74062	005	M-19/M-46(SANILAC) @ MAPLE VALLEY/DAWSON	01	01	W O COMPLETE	011990	S/S W/TBC	PEDS: X-RD	REALIGNMT	FRG	031088	NO	30118A	03601	MDOT
6	79051	003	M-46(SANILAC) AT M-24(MERTZ)	01	01	W O COMPLETE	062389	S/S CONTRL	FULL ACTUA	REST-N-RED	M	050686		29001A	03446	MDOT
6	79052	001	M-81(CARO RD) AT CLEAVER-ELLINGTON RDS	01	01	W O COMPLETE	101089	S/S W/TBC	12" HEADS	RELOC X-RD	FRG	072087	NO	29526A	03534	MDOT
6	79061	003	M-81(STATE) AT HOOPER-VANGEISEN-COLLING	01	01	W O COMPLETE	111386	S/S CONTRL	W/ PEDS	NEED= 9-86	MNT	070783			02960	MDOT
7	03023	013	M-89 @ CROSS OAKS MALL DR	01	01	W O COMPLETE	073087	S/S CONTRL	12" HEADS	PEDS	FRG	082385		27045A	03005	MDOT
7	03032	011	US-31(BYPASS) @ CENTRAL AVE	01	01	W O COMPLETE	061688	S/S W/TBC	PED P/BUTN	OH ADV WRN	FUG	050786	NO	27112A	03106	MDOT
7	08034	003	M-37,M-43(STATE) AT INDUSTRIAL PARK RD	01	01	W O COMPLETE	061292	S/S:SEMI	W/ LOOPS	WIDN= X-RD	STG	082090	NO	33605A	04089	MDOT
7	11012	001	BL-94(LAKE SHORE) @ I-94 SWB OFF RAMP	01	01	W O COMPLETE	012788	S/S CONTRL	NB ADV WAR	1240=12-87	IRG	050486		27401A	03182	MDOT
7	11012	014	BL-94(LAKE SHORE) AT MAIDEN LANE	01	01	W O COMPLETE	012390	SEMI-ACTUA	12 HEADS	NB RTLN	M	042288	NO	29323A	03487	MDOT
7	11021	007	US-12 @ RED BUD TRAIL	01	01	W O COMPLETE	072486	S/S CONTRL	12" HEADS	NEED= 7-86	FRG	011085		25601A	02895	MDOT
7	11031	018	US-31(SCOTTDALE)@US-33RELOC/MINER	01	01	W O COMPLETE	041786	S/S CONTRL	ADV WARN :	NB US-31	FUG	022779	NO	25123A	02828	MDOT
7	11052	007	M-63(NILES) AT LINCOLN AVE	01	01	W O COMPLETE	040391	S/S W/TBC	SB ADV WAR	WIDEN=X-RD	FRG	030189	NO	31566A	03779	MDOT
7	11052	020	US-31 AT GARLAND RD	01	01	W O COMPLETE	041290	S/S W/TBC	12" PEDS	ADV WRN=NO	RSG	051387		29927A	03685	MDOT
7	13012	002	M-37(WASHINGTON) @ HAMBLIN AVE	01	01	W O COMPLETE	011487	"PRIORITY"	S/S,SB LTO	12" PEDS	MNT	061385			02936	MDOT
~~7~~	~~13012~~	~~002~~	~~M-37(WASHINGTON) @ HAMBLIN AVE~~	01	01	W O COMPLETE	011487	REMOVE SB	LT PHASE		MNT	103186			A2936	MDOT
7	13032	017	M-66(CAPITAL) AT ROOSEVELT AVE	01	01	W O COMPLETE	050790	S/S W/TBC	12" PEDS	WIDEN=X-RD	FUG	051788	NO	30710A	03713	BATTLE
7	13042	003	BL-94(MICHIGAN) @ WEST DR.	01	01	W O COMPLETE	030486	S/S CONTRL	12" HEADS	WB LT PROH	MUG	072384		25133A	02833	MDOT
7	13061	032	BL-94(MICHIGAN) AT WATTLES RD	01	01	W O COMPLETE	021792	NEMA 4 PH	SEMI-ACTUA	IN= 112791	FRG	062590	NO	33212A	04055	MDOT
7	39013	002	US-131 @ SHAVER RD.	01	01	W O COMPLETE	062086	SEMI:ACTUA	12" HEADS	REM FLSHR	FRG	100783		23325A	02507	MDOT
7	39024	004	I-94 EB OFF RAMP AT OAKLAND DR.	01	01	W O COMPLETE	092289	S/S W/TBC	12" HEADS		IRG	041988		29696A	03544	MDOT
7	39024	004	I-94 EB & WB OFF RAMPS AT OAKLAND DR	01	01	W O COMPLETE	051491	NTS=WB	PHASING=EB	"EPAC"	M	033090		31576A	03819	MDOT
7	39042	017	M-96(MICHIGAN) AT 35TH ST(SHAFTER RD)	01	01	W O COMPLETE	043092	S/S W/TBC	12" HEADS	RR PREEMPT	STG	062689	NO	33646A	04097	MDOT
7	39081	017	M-43(W. MAIN) @ TURWILL LANE	01	01	W O COMPLETE	091286	S/S CONTRL	W/ TBC	12" PEDS	MNT	062885			02961	MDOT
7	78051	007	M-66(CENETERVILLE) @ WENZEL/MCDONALDS DR	01	01	W O COMPLETE	090487	S/S W/TBC	PED P/BUTN	SCHL X'ING	FUG	102985		27269A	03160	MDOT
7	78061	002	M-86(MAIN) AT CLARK ST (COVERED BRIDGE)	01	01	W O COMPLETE	092792	S/S W/TBC	12" PEDS	ADV RESOLU	M	050692		34427A	04155	MDOT
8	23012	010	BL-69(LANSING RD) @ ISLAND HWY	01	01	W O COMPLETE	021288	S/S CONTRL	PEDS: CITY	WIDN X-RD	M	052985	NO	27650A	03254	MDOT
8	23041	010	M-43(SAGINAW) @ JENNE ST.	01	01	W O COMPLETE	082587	S/S W/TBC	WB RTGA	EB ADV FLS	FUG	062185		27048A	03041	MDOT
8	23092	003	M-99(MICHIGAN RD) @ HOLT RD	01	01	W O COMPLETE	100886	S/S CONTRL	SEMI-ACTUA	ADV WARN	FUG	031385		25289A	02869	MDOT
8	33011	013	M-99(LOGAN) @ I-96 WB OFF RAMP	01	01	W O COMPLETE	100490	S/S W/TBC	12" HEADS		FUG	011189		30684A	03692	LANSING
8	33011	030	M-99(EATON RAPIDS RD) @ BISHOP RD	01	01	W O COMPLETE	082587	S/S W/TBC	ADV WARN	WIDEN X-RD	FUG	081486	NO	27095A	03109	MDOT
8	33021	009	M-36(CEDAR) AT M-36(ASH)	01	01	W O COMPLETE	071890	S/S W/TBC	12" PEDS	WB RTGA	M	121989		30886A	03732	MDOT
~~8~~	~~33021~~	~~009~~	~~M-36(CEDAR) @ M-36(ASH)~~	01	01	W O COMPLETE	071890	ADD CPCO	COST FOR	SPAN,POLE	M	070990		30886A	A3732	MDOT
8	33032	037	BL-96(CEDAR) @ NORTHRUP ST.	01	01	W O COMPLETE	062788	S/S CONTRL	W/ PEDS	WIDEN X-RD	M	022785	NO	27264A	03161	LANSING
8	33042	018	M-43 (GRAND RIVER) AT FAIRVIEW AVE	01	01	W O COMPLETE	082986	PEDS=N,E,S	ADD INTERC		FUG	022081	NO	22954A	02432	LANSING
8	~~33082~~	~~009~~	~~M-43(GRAND RIVER) AT BOGUE~~	01	01	W O COMPLETE	030486	WB LAG LTO	PEDS=S LEG		MUG	063083	NO	23616A	02527	MDOT
~~8~~	~~33082~~	~~009~~	~~M-43(GRAND RIVER) @ BOGUE~~	01	01	W O COMPLETE	030486	REVISE	DISPLAY	NEED ROW	MUG	072385	NO	23616A	A2527	MDOT
8	33082	009	M-43(GRAND RIVER) @ BOGUE	01	01	W O COMPLETE	030486	NO ROW REQ	USE 3-WAY		MUG	010386	NO	23616A	R2527	MDOT
8	33082	027	M-43(GRAND RIVER) @ PARK LAKE RD.	01	01	W O COMPLETE	082986	WIDEN X-RD	EB LAG LTO	NEED:OCT 1	MUG	021084	NO	25324A	02875	MDOT
~~8~~	~~33082~~	~~027~~	~~M-43(GRAND RIVER) @ PARK LAKE RD~~	01	01	W O COMPLETE	082986	ADD ADV	WARN FLSHR	MEDIAN	MUG	041786	NO	25324A	A2875	MDOT
8	33082	031	M-43 GRAND RIVER @ DOBIE RD.	01	01	W O COMPLETE	082587	S/S W/TBC	12" HEADS	ADV WARN	M	092686		27181A	03133	MDOT

MICHIGAN DEPARTMENT OF TRANSPORTATION
TRAFFIC & SAFETY DIVISION
DATE = 05-22-95 TRAFFIC SIGNAL STATUS FILE --- HISTORY FIND OPTION REPORT WORK ORDER HISTORY DATA

LT = '01' SIGNAL STATEWIDE WORK ORDERS ONLY TIME SPAN = 0186-1292

D	-CS	SPOT-	LOCATION	LT	ST	LAST ACTION	-DATE-	REMARKS	FUND	IR DATE	CSJ	JOB NO	WO NO	AGENC
9	50111	006	I-94 NB OFF RAMP @ N. RIVER RD	01	01	W O COMPLETE	073186	S/S W/TBC 12" HEADS 1240= 8-85	IRG	070584		24769A	02773	MCRC
9	50111	009	I-94 OFF RAMPS AT LITTLE MACK	01	01	W O COMPLETE	011791	S/S W/TBC LTO & RTGA BOTH RAMPS	IRG	081586		30245A	03646	MCRC
9	50112	001	I-94 NB OFF RAMP @ M-29(23 MILE RD)	01	01	W O COMPLETE	061688	S/S CONTRL 12" HEADS HARDWIRE	FUG	020386		27687A	03264	MCRC
9	63021	016	OLD BL-96(GRAND RIVER) @ GROVE ST	01	01	W O COMPLETE	022288	S/S: MBT PED P/BUTN	M	091785		27251A	03148	OCRC
9	63022	004	I-96 WB OFF RAMP @ PONTIAC TRAIL(MILFORD	01	01	W O COMPLETE	071289	S/S W/TBC 12" HEADS 3 PHASE	IRG	051685		28812A	03459	OCRC
9	63022	014	I-96 WB OFF RAMP @ WIXOM ROAD	01	01	W O COMPLETE	010390	S/S W/TBC 12" HEADS HARDWIRE	IRG	042088		29889A	03572	OCRC
~~9~~	~~63022~~	~~022~~	~~I-96 EB OFF RAMP @ WIXOM ROAD~~	01	01	W O COMPLETE	010390	S/S W/TBC 12" HEADS HARDWIRE	IRG	042088		29890A	03573	OCRC
9	63022	110	M-102(GR RIVER)EB@ X-O 525' W MIDDLEBELT	01	01	W O COMPLETE	121988	S/S CONTRL HARDWIRE 12" HEADS	M	011287		28330A	03327	OCRC
9	63022	210	M-102(GD RIVER)NWB @ X-OVR SE MIDDLEBELT	01	01	W O COMPLETE	121490	S/S W/TBC 12" HEADS HARDWIRE	M	011889		30182A	03606	OCRC
9	63031	024	US-24(TELEGRAPH)SB @ X-OV .6 MI N 8 MILE	01	01	W O COMPLETE	120487	S/S W/TBC 12" HEADS	M	071886		27212A	03142	OCRC
9	63031	026	US-24(TELEGRAPH) @ HICKORY GROVE RD	01	01	W O COMPLETE	112487	CANC FLSHR LAYOUT S&G DTSE=11-86	FUG	103184		27100A	03099	OCRC
9	63042	020	OLD M-59(AUBURN) @ BARCLAY/PRIMROSE DR	01	01	W O COMPLETE	091492	S/S "EPAC" 12" HEADS 12" PEDS	STG	012291		33625A	04095	OCRC
9	63043	006	M-59 WB OFF RAMP @ ADAMS ROAD (N. JCT)	01	01	W O COMPLETE	020687	12" HEADS WB PASS/FL ADV RESOLU	M	100885	NO	26241A	03013	OCRC
9	63043	007	M-59 EBD OFF RAMP @ CROOKS RD.	01	01	W O COMPLETE	090387	12" HEADS CNTY SYSTM INTERCONNC	FUG	102984		27101A	03100	OCRC
9	63043	008	M-59 WB OFF RAMP @ M-150(ROCHESTER RD)	01	01	W O COMPLETE	051587	SB RT LN ADD TBC "PRIMARY"	M	022884	NO	26520A	03052	OCRC
9	63052	029	US-10(TELE) @ OAKLAND PTE/SUMMIT PL DR	01	01	W O COMPLETE	011188	S/S W/TBC ADD E LEG	M	062686	NO	27318A	03176	OCRC
9	63052	030	US-10(TELEGRAPH)@ SUMMIT PLACE MALL-N DR	01	01	W O COMPLETE	060688	S/S W/TBC DTSE NOTIF	M	062686	NO	27578A	03246	OCRC
9	63071	008	M-15(ORTONVILLE)@ GRANGE HALL RD/MILL ST	01	01	W O COMPLETE	090992	S/S W/TBC 12" PEDS TEMP=12690	FUG	120889	NO	32255A	03915	OCRC
9	63071	013	M-15(ORTONVILLE) @ SOUTH ST	01	01	W O COMPLETE	091692	S/S: EPAC 12" HEADS SB LT PROH	STG	020692		34173A	04140	OCRC
9	63112	017	M-24(LAPEER) @ SCRIPPS RD	01	01	W O COMPLETE	090788	S/S:SEMI PED P/BUTN WDN X-RD	M	012985	NO	27585A	03244	OCRC
9	63132	012	M-150(ROCHESTER) @ BARCLAY CIRCLE	01	01	W O COMPLETE	021788	S/S W/TBC 12" PEDS	M	070285		27492A	03222	OCRC
9	63172	002	I-75 NB OFF RAMP @ BALDWIN RD	01	01	W O COMPLETE	082691	S/S W/TBC 12" HEADS 1240= 1-91	IRG	010390		31628A	03797	OCRC
9	63172	008	I-75 NB OFF RAMP @ SASHABAW ROAD	01	01	W O COMPLETE	091989	S/S W/TBC 12" HEADS CALL BOX	IRG	120186	NO	28667A	03401	OCRC
9	63172	009	I-75 NB OFF RAMP @ JOSLYN ROAD	01	01	W O COMPLETE	091990	S/S W/TBC FULL ACTUA 12" HEADS	IRG	020889		29891A	03567	OCRC
9	63174	004	I-75 NB OFF RAMP @ ADAMS RD	01	01	W O COMPLETE	082988	S/S W/TBC 12" HEADS SB ADV WRN	IRG	070786		27440A	03245	OCRC
9	63174	208	I-75 SB OFF RAMP@ WB BIG BEAVER(16 MILE)	01	01	W O COMPLETE	020692	BY CO PROJ CO HES $$		012489	NO			OCRC
9	77052	017	M-29(BUSHA) @ MICHIGAN AVE	01	01	W O COMPLETE	012491	S/S W/TBC 12" HEADS CK SPOT 11	FRG	101888		31785A	03868	MDOT
9	77091	016	M-136 (PINE GROVE) AT KRAFFT ROAD	01	01	W O COMPLETE	051992	S/S CONTRL 12" HEADS CLLT = ALL	EDF	091587	NO	31096A	04001	MDOT
9	77111	003	I-94 EBD OFF RAMP @ WATER STREET	01	01	W O COMPLETE	060288	S/S CONTRL SEB LAG LT 12" HEADS	IRG	071885		27930A	03270	MDOT
9	82022	018	I-94 EB OFF RAMP @ PELHAM RD	01	01	W O COMPLETE	010887	PROJECT $$ 1240=12-86		121580	NO	18880A	03025	WCPS
~~9~~	~~82022~~	~~118~~	~~I-94 WB OFF RAMP @ PELHAM RD~~	01	01	W O COMPLETE	010887	PROJECT $$ 1240=12-86		121580	NO	18880A	03026	WCPS
9	82052	014	US-24(TELEGRAPH) SB OFF RAMP @ ECORSE RD	01	01	W O COMPLETE	050788	S/S W/TBC 12" HEADS	FUG	080185		27996A	03288	WCPS
9	82052	103	US-24(TELEGRAPH)SB @ X-OVER N OF GODDARD	01	01	W O COMPLETE	091788	S/S CONTRL HARDWIRE	FUG	073081	NO	28026A	03295	WCPS
9	82052	113	US-24(TELEGRAPH)NB@X-OV 675' S NORTHLINE	01	01	W O COMPLETE	092488	S/S CONTRL HARDWIRE EXTEND LN	FUG	022885	NO	28254A	03323	WCPS
9	82053	104	US-24(TELEGRAPH)SB@ X-OV 700'N OF WARREN	01	01	W O COMPLETE	092086		FUG	052383	NO	23112A	02461	WCRC
9	82053	106	US-24(TELEGRAPH)SB@ X-OV 690'N - CHICAGO	01	01	W O COMPLETE	053186		FUG	052383	NO	23118A	02466	WCRC
9	82053	204	US-24(TELEGRAPH)NB@ X-OV 650'S OF WARREN	01	01	W O COMPLETE	092086		FUG	052383	NO	23114A	02463	WCRC
9	82081	043	M-153(FORD) WB @ ARTESIAN	01	01	W O COMPLETE	032888	S/S CONTRL & LOW LEVL ADV RESOLU	FUG	050185		27062A	03021	WCPS
9	~~82081~~	~~062~~	~~M-153 (FORD) AT HEIGHTS SHOPPING CENTER~~	01	01	W O COMPLETE	062787	S/S W/MBT PED P/BUTN NEED 4-87	M	101686	NO	26997A	03083	WCPS
9	82081	062	M-153(FORD) @ HEIGHTS SHOPPING CENTER	01	01	W O COMPLETE	062787	ADD DE CO COSTS	M	050587		26997A	A3083	WCPS
9	82081	064	M-153(FORD) AT CENTRAL CITY PARKWAY	01	01	W O COMPLETE	091590	S/S W/TBC F/PREEMPT 12" HEADS	M	061689		31449A	03782	WCPS
9	82081	065	M-153(FORD) @ MORTON-TAYLOR RD	01	01	W O COMPLETE	081791	S/S W/TBC 12" PEDS WIDEN=X-RD	FUG	072089	NO	32843A	03974	WCPS
9	82101	011	OLD M-14(ANN ARBOR RD) @ BECK RD	01	01	W O COMPLETE	072192	S/S W/TBC 12" HEADS ADV WRN FL	STG	100891		34019A	04134	WCPS
9	82101	074	OLD M-14(PLYMOUTH) @ TECH CENTER DR.	01	01	W O COMPLETE	121689	S/S W/TBC 12" PEDS REVISE DR	M	081387	NO	30430A	03665	WCPS
9	82143	205	M-102(8 MILE) WB @ X-OV 650' E DEQUINDRE	01	01	W O COMPLETE	092389	S/S CONTRL 12" HEADS HARDWIRE	M	110888		29915A	03563	WCPS
9	82143	217	M-102(8 MILE) EB @ X-OVR NEAR BEL-AIR DR	01	01	W O COMPLETE	092387	RELOC S&G S/S W/TBC 12" HEADS	M	060585	NO	26980A	03073	WCPS
9	82144	023	M-102(VERNIER) WB @ 8 MILE RD	01	01	W O COMPLETE	050292	S/S W/TBC 12" HEADS WIDN=2 LNS	M	080985	NO	32717A	03961	WCPS
9	82211	113	M-85(FORT) NB @ X-OV 485' S EUREKA RD	01	01	W O COMPLETE	110489	S/S CONTRL HARDWIRE 12" HEADS	M	032288		30073A	03586	WCPS

MICHIGAN DEPARTMENT OF TRANSPORTATION
TRAFFIC & SAFETY DIVISION

DATE = 05-23-95 TRAFFIC SIGNAL STATUS FILE --- HISTORY FIND OPTION REPORT WORK ORDER HISTORY DATA

LT = '01' SIGNAL STATEWIDE CONTR SIG JOB, ST = 01 AGENCY = JOB NO =
TIME SPAN = 0186-1292

D	-CS	SPOT-	LOCATION	LT	ST	LAST ACTION	-DATE-	REMARKS			FUND	IR DATE	CSJ	JOB NO	AGENCY
5	37011	001	US-27BR(MISSION) AT BLUEGRASS/CAMPUS DR	01	01	CONTRACT CPT	052191	S/S:SEMI	ACTU=LT PH	12" PEDS	FUG	091289	YES	31155A	MDOT
5	37021	009	M-20(HIGH) AT WATSON ST	01	01	CONTRACT CPT	042292	S/S W/TBC	12" HEADS	12" PEDS	FRG	030890	YES	32032A	MDOT
5	41031	010	M-37(BROADMOOR) AT BARDEN DR (STEELSTOW)	01	01	CONTRACT CPT	122691	S/S W/TBC	12" HEADS		EDA	091390	YES	31264A	GR RAPIDS
5	41033	113	M-37(ALPINE) AT GREEN RIDGE/K-MART DRIVE	01	01	CONTRACT CPT	080889	S/S: FULL	ACTUA:EPAC	12" PEDS		050587	YES	CITY	GR RAPIDS
5	41051	008	M-44(E BELTLINE) @ 4 MILE RD	01	01	CONTRACT CPT	112091	S/S W/TBC	NEMA 8 PHS	NEGOTIATE	FUG	082490	YES	25746A	GR RAPIDS
5	41051	015	M-44(EAST BELTLINE) @ 5 MILE ROAD	01	01	CONTRACT CPT	121388	S/S W/TBC	12" HEADS		FUG	021087	YES	27964A	GR RAPIDS
5	41051	106	M-44(E BELTLINE)NB @ X-OV 650' S LEONARD	01	01	CONTRACT CPT	121990	BLVD CONST	S/S W/TBC	12" HEADS	FUR	031389	YES	25745A	GR RAPIDS
5	41051	111	I-96 WB OFF RAMP @ M-44 (E BELTLINE)	01	01	CONTRACT CPT	121990				FUR	121289	YES	25745A	GR RAPIDS
5	41051	112	M-44(E BELTLINE)NB@ X-OV 200' S BRADFORD	01	01	CONTRACT CPT	121990	BLVD CONST	S/S W/TBC	LOOPS	FUR	031389	YES	25745A	GR RAPIDS
5	41051	208	M-44(E BELTLINE)SB @ X-OV 630' N LEONARD	01	01	CONTRACT CPT	121990	BLVD CONST	S/S W/TBC	12" HEADS	FUR	031389	YES	25745A	GR RAPIDS
5	41051	211	M-44(E BELTLINE)SB @ X-OV 430'N OF I-96	01	01	CONTRACT CPT	121990	TEMP S&G	STAGE CONS	RETN=FINAL	FUR	121289	YES	25745A	GR RAPIDS
5	41051	212	M-44(E BELTLINE)SB@ X-OV 600' N BRADFORD	01	01	CONTRACT CPT	121990	BLVD CONST	S/S W/TBC	LOOPS	FUR	031389	YES	25745A	GR RAPIDS
5	41062	013	M-11(28TH ST) @ JENKINS AVE	01	01	CONTRACT CPT	112387	S/S SEMI	PED P/BUTN	CABLE TV	M	071387	YES		MDOT
5	41063	020	M-11(28TH ST) AT ENGLEWOOD/GRAND CENTRAL	01	01	CONTRACT CPT	050990	FULL-ACTUA	12" PEDS	PED P/BUTN	FUG	031088	YES	29985A	GR RAPIDS
5	70041	007	M-45 @ 42ND (GRAND VALLEY STATE UNIV DR)	01	01	CONTRACT CPT	100690	S/S ACTUA	LAG LT PHS	PED P/BUTN	FRG	080389	YES	31155A	MDOT
6	44012	012	M-24 (LAPEER RD) @ DALEY RD	01	01	CONTRACT CPT	082592	S/S W/TBC	12" HEADS	ADV WRN FL	FRG	082589	YES	32033A	MDOT
6	73033	013	M-84(BAY) @ SAGINAW VALLEY UNIVERSITY DR	01	01	CONTRACT CPT	061991	S/S:SEMI	CALL LOOPS	POLICE BOX	FRG	032390	YES	31156A	MDOT
6	76062	014	M-21 @ OWOSSO MALL/BONANZA	01	01	CONTRACT CPT	120787	S/S CONTRL	12" HEADS	C/SIGN	FUG	021886	YES	25737A	MDOT
7	03023	011	M-89 AT 12TH ST	01	01	CONTRACT CPT	071390	S/S W/TBC	PED P/BUTN	NEGOTIATE	FRG	042988	YES	29988A	MDOT
7	03072	002	M-40(LINCOLN) AT M-40(48TH/146TH)	01	01	CONTRACT CPT	111992	S/S W/TBC	N/S LT PHS	POLICE BOX	EDA	051591	YES	29534A	MDOT
7	11016	101	I-94 NEB OFF RAMP @ PIPESTONE RD	01	01	CONTRACT CPT	120189	RELOC RAMP	NEW S&G	S/S W/TBC	IRG	010286	YES	28840A	MDOT
7	11057	002	PROPOSED US-31 AT RELOCATED US-31	01	01	CONTRACT CPT	102292	S/S W/TBC	12" HEADS	WB ADV C/S	FR	013190	YES	29512A	MDOT
7	12021	011	US-12(CHICAGO) AT WESTERN/BUTTERS AVE	01	01	CONTRACT CPT	031692	S/S W/TBC	12" HEADS	12" PEDS	FUG	052289	YES	32036A	MDOT
7	13043	009	BL-94,M-99(MICHIGAN) AT INGHAM	01	01	CONTRACT CPT	070789	S/S W/TBC	12" PEDS	ADV RESOLU	FUG	121686	YES	27968A	MDOT
7	13061	047	M-89(MICHIGAN) AT STRINGHAM	01	01	CONTRACT CPT	073191	S/S W/TBC			FUG	053188	YES	31158A	BATTLE CK
7	39013	001	US-131 SB OFF RAMP AT CENTRE	01	01	CONTRACT CPT	111187	S/S W/TBC	ADD=DISTWD	CONTRACT	FUG	101486	YES	27384A	MDOT
7	39081	014	M-43(W. MAIN) AT LODGE LANE/10TH	01	01	CONTRACT CPT	112388	S/S W/TBC	12" HEADS		FUG	012787	YES	27968A	MDOT
7	39082	017	M-43(GULL) @ "G" AVE	01	01	CONTRACT CPT	111387	S/S: SEMI	12" HEADS	M-43: CLLT	FUG	042386	YES	25739A	MDOT
7	78012	004	US-131,M-60 AT BROADWAY	01	01	CONTRACT CPT	052990	S/S W/TBC	12" HEADS	NB ADV WAR	FUG	101287	YES	29988A	MDOT
7	78012	008	US-131(WASHINGTON) AT US-131(BROAD)	01	01	CONTRACT CPT	041591	RETN TEMP	S&G AS	PERMANENT	M	042288	YES	29347A	MDOT
8	33032	132	BL-96(CEDAR)@MASON ST/IMMAC HEART SCHOOL	01	01	CONTRACT CPT	062790	PED ACTUAT	STAGE CONS	RETN FINAL	MUR	103087	YES	30499A	LANSING
8	47014	010	US-23 NB OFF RAMP @ M-59	01	01	CONTRACT CPT	021392	S/S W/TBC			FRG	101789	YES	32038A	MDOT
8	47014	110	US-23 SB OFF RAMP @ M-59	01	01	CONTRACT CPT	021492	S/S W/TBC			FRG	101789	YES	32038A	MDOT
8	81011	007	M-52 AT CHELSEA COMMUNITY HOSPITAL DR	01	01	CONTRACT CPT	030392	S/S W/TBC	12" HEADS	12" PEDS	FRG	052990	YES	32038A	MDOT
8	81031	011	US-12(MICHIGAN) @ AUSTIN RD (RELOCATED)	01	01	CONTRACT CPT	102392	S/S W/TBC	12" HEADS	STG $=6-92	NHG	050190	YES	34015A	MDOT
8	81074	105	US-23 NB OFF RAMP @ GEDDES RD	01	01	CONTRACT CPT	012892	S/S W/TBC	12" HEADS	2-W C/SIGN	FRG	100489	YES	32038A	MDOT
9	50011	112	M-53(VAN DYKE) NB @ X-OVER 610' S 15 MI	01	01	CONTRACT CPT	082289	S/S CONTRL	12" HEADS	HARDWIRE	MU	051586	YES	25657A	MCRC
9	50011	116	M-53(VAN DYKE) NB @ X-OVER 620' S 16 MI	01	01	CONTRACT CPT	101789	S/S CONTRL	12" HEADS	HARDWIRE	MU	051586	YES	25657A	MCRC
9	50011	124	M-53(VAN DYKE)SB @ X-OV 400' N 16 1/2 MI	01	01	CONTRACT CPT	031590	S/S W/TBC	12" HEADS		MU	051586	YES	25657A	MCRC
9	50011	125	M-53(VAN DYKE)SB @ X-OV 210' N PLUMBROOK	01	01	CONTRACT CPT	031590	S/S W/TBC	F/PREEMPT	12" HEADS	MU	030487	YES	25564A	MCRC
9	50011	135	M-53(VAN DYKE) NB @ X-OVER 700' S 17 MI	01	01	CONTRACT CPT	031590	S/S CONTRL	12" HEADS	HARDWIRE	MU	051586	YES	25657A	MCRC
9	50011	155	M-53(VAN DYKE)NB @ X-OV 150' S BROUGHAM	01	01	CONTRACT CPT	092889	S/S CONTRL			MU	051586	YES	25657A	MCRC
9	50011	212	M-53(VAN DYKE) SB @ X-OVER 620' N 15 MI	01	01	CONTRACT CPT	081689	S/S CONTRL	12" HEADS	HARDWIRE	MU	051586	YES	25657A	MCRC
9	50011	216	M-53(VAN DYKE) SB @ X-OVER 570' N 16 MI	01	01	CONTRACT CPT	110889				MU	051586	YES	25657A	MCRC
9	50011	225	M-53(VAN DYKE)NB @ X-OV 200' S PLUMBROOK	01	01	CONTRACT CPT	031590	S/S W/TBC	F/PREEMPT	12" HEADS	MU	081287	YES	25564A	MCRC
9	50011	233	M-53(VAN DYKE) SB @ X-OV 630' N 18 MILE	01	01	CONTRACT CPT	031590	S/S CONTRL	12" HEADS	HARDWIRE	MU	060987	YES	25564A	MCRC
9	50011	235	M-53(VAN DYKE) SB @ X-OVER 650' N 17 MI	01	01	CONTRACT CPT	031590	S/S CONTRL	12" HEADS	HARDWIRE	MU	030487	YES	25564A	MCRC
9	50011	255	M-53(VAN DYKE)SB @ X-OV 330' S BROUGHAM	01	01	CONTRACT CPT	092889	S/S W/TBC	12" HEADS		MU	041387	YES	25657A	MCRC
9	50011	316	16 MI RD(EB)@ X-OV 390' W M-53(VAN DYKE)	01	01	CONTRACT CPT	102389	S/S CONTRL	12" HEADS	HARDWIRE	MU	041387	YES	25657A	MCRC
9	50011	416	16 MI RD(WB)@ X-OV 570' E M-53(VAN DYKE)	01	01	CONTRACT CPT	012990	S/S CONTRL	12" HEADS	HARDWIRE	MU	041387	YES	25657A	MCRC
9	63031	029	US-24(TELEGRAPH)SB @ DENSO DR(S FRANKLIN	01	01	CONTRACT CPT	100389	S/S:HARDWR	12" HEADS	NEGOTIATE	FUG	071488	YES	27970A	OCRC
9	63031	030	US-24(TELEGRAPH)NB @ X-OV 980' N 8 MI RD	01	01	CONTRACT CPT	062590	S/S W/TBC	12" HEADS		FUG	042588	YES	29991A	OCRC
9	63031	031	US-24(TELEGRAPH)NB@ RALEIGH OFFICECENTRE	01	01	CONTRACT CPT	062590	S/S W/TBC	12" HEADS	HARDWARE	FUG	020789	YES	29991A	OCRC

MICHIGAN DEPARTMENT OF TRANSPORTATION
TRAFFIC & SAFETY DIVISION

DATE = 05-23-95 TRAFFIC SIGNAL STATUS FILE --- HISTORY FIND OPTION REPORT WORK ORDER HISTORY DATA

LT = '01' SIGNAL STATEWIDE CONTR SIG JOB, ST = 01 AGENCY = JOB NO =
TIME SPAN = 0186-1292

D	-CS	SPOT-	LOCATION	LT	ST	LAST ACTION		-DATE-	REMARKS	FUND	IR DATE	CSJ	JOB NO	AGENCY
9	63102	408	I-696 EB SERV DR@ FINAL X-OV W EVERGREEN	01	01	CONTRACT	CPT	121289	NEW S&G STAGE CONS SES-5A	I	060286	YES	21958A	OCRC
9	63102	713	GREENFIELD RD (SB) @ X-OVER N OF 10 MILE	01	01	CONTRACT	CPT	030591	S/S CONTRL HARDWIRE	MU	062089	YES	21388A	OCRC
9	63102	723	GREENFIELD RD (NB) @ X-OVER S OF 10 MILE	01	01	CONTRACT	CPT	030591	S/S CONTRL HARDWIRE	MU	062089	YES	21388A	OCRC
9	63112	007	BL-75 (PERRY) @ OPDYKE ROAD	01	01	CONTRACT	CPT	120190	S/S W/TBC 12" HEADS ADV RESOLU	FUG	030188	YES	31161A	OCRC
9	63112	028	M-24(LAPEER) @ HARMON RD (PISTON ARENA)	01	01	CONTRACT	CPT	021489	S/S W/TBC	M	042286	YES	27883A	OCRC
9	63112	029	M-24(LAPEER) @ AUBURN HILLS ARENA (S DR)	01	01	CONTRACT	CPT	021489	S/S W/TBC	M	110786	YES	27883A	OCRC
9	63112	124	M-24(LAPEER) SB @ X-OV 410' N INDIANWOOD	01	01	CONTRACT	CPT	011790		FUR	030487	YES	11320A	OCRC
9	63172	005	I-75 NB OFF RAMP @ UNIVERSITY DR	01	01	CONTRACT	CPT	012789	S/S W/TBC 12" HEADS NEGOTIATE		010987	YES	25414A	OCRC
9	63172	006	I-75 NB OFF RAMP @ M-15(ORTONVILLE RD)	01	01	CONTRACT	CPT	050590	S/S CONTRL FULL ACTUA NEGOTIATE	FUG	090789	YES	29991A	OCRC
9	63172	007	I-75,M-24(CONNECTOR) @ M-24(LAPEER) NB	01	01	CONTRACT	CPT	021489	S/S W/TBC PISTONS ARENA	M	121586	YES	27883A	OCRC
9	77023	013	BL-69 (OAK) EB AT 16TH STREET	01	01	CONTRACT	CPT	031789	S/S W/TBC 12" PEDS	FUG	040187	YES	27970A	MDOT
9	77023	019	BL-69 (GRISWOLD) WB AT 16TH STREET	01	01	CONTRACT	CPT	032989	S/S W/TBC 12" PEDS	FUG	040187	YES	27970A	MDOT
9	77111	103	I-94 SWB OFF RAMP @ WATER ST	01	01	CONTRACT	CPT	010692	BLUEWTR BR RETN=FINAL IN= 1-6-92	I	122288	YES	20425A	MDOT
9	77132	003	M-25(LYMBURNER) @ KEEWAHDIN AVE	01	01	CONTRACT	CPT	101090	S/S W/TBC 12" HEADS	FUR	081890	YES	29219A	MDOT
9	77132	004	M-25(LYMBURNER) @ BIRCHWOOD MALL DRIVE	01	01	CONTRACT	CPT	092790	S/S W/TBC 12" HEADS CLLT		092589	YES	29219A	MDOT
9	82053	049	US-24(TELEGRAPH)SB @ X-OV 300' S EATON	01	01	CONTRACT	CPT	071592	S/S W/TBC 12" HEADS	FRG	102188	YES	32042A	WCPS
9	82053	149	US-24(TELEGAPH)NB @ X-OV 150' S EATON	01	01	CONTRACT	CPT	071592	S/S W/TBC 12" HEADS	FRG	102188	YES	32042A	WCPS
9	82061	054	US-12(MICHIGAN)EB@ X-OV 1915' E JOHN HIX	01	01	CONTRACT	CPT	102188	S/S CONTRL S&G @ NEW X-OVER		042986	YES	03091A	WCPS
9	82061	113	US-12(MICHIGAN)EB @ X-OV 625' W NEWBURGH	01	01	CONTRACT	CPT	102188	S/S CONTRL HARDWIRE NEW X-OVER		042986	YES	03091A	WCPS
9	82061	213	US-12(MICHIGAN)EB @ X-OV 450' E NEWBURGH	01	01	CONTRACT	CPT	112288	S/S CONTRL HARDWIRE NEW X-OVER		042986	YES	03091A	WCPS
9	~~82071~~	~~071~~	~~M-3(FORT) @ FIFTH ST~~	01	01	CONTRACT	CPT	112486	EXTN LODGE SERVICE DR BY CITY		103184	YES		PLD
9	82112	003	US-10(LODGE FRWY) WB SERV DR @ LIVERNOIS	01	01	CONTRACT	CPT	102186	FUR $$$ REFER TO CEA#399		031584	YES	24850A	WCPS
9	82112	103	US-10(LODGE) EB SERVICE DR @ LIVERNOIS /	01	01	CONTRACT	CPT	102186	TEMP LT PH SB:EB REFR TO CEA#399		031584	YES	24850A	WCPS
9	82112	203	US-10(LODGE)EB SEV DR @ X-OV W LIVERNOIS	01	01	CONTRACT	CPT	102186	INTR RECON REFER TO CEA#399		031584	YES	24850A	WCPS
9	82131	069	M-1(WOODWARD)NWBD@ X-OV 125'S STRATHCONA	01	01	CONTRACT	CPT	111590	S/S W/TBC 12" HEADS	MUR	030989	YES	26749A	PLD
9	82131	070	M-1(WOODWARD) NWBD @ W GRIXDALE & X-OVER	01	01	CONTRACT	CPT	111590	S/S W/TBC 12" HEADS 12" PEDS	MUR	030989	YES	26749A	PLD
9	82131	071	M-1(WOODWARD) NWBD @ W NEVADA & X-OVER	01	01	CONTRACT	CPT	111590	S/S W/TBC 12" HEADS 12"¢ PEDS	MUR	030989	YES	26749A	PLD
9	82131	170	M-1(WOODWARD)SEBD @ X-OV 125' S GRIXDALE	01	01	CONTRACT	CPT	111590	S/S W/TBC 12" HEADS 12" PEDS	MUR	030989	YES	26749A	PLD
9	82131	171	M-1(WOODWARD)SEBD @ X-OV 125' S NEVADA	01	01	CONTRACT	CPT	111590	S/S W/TBC 12" HEADS 12" PEDS	MUR	030989	YES	26749A	PLD
9	82141	016	M-102(8 MILE) EB @ X-OVER W OF BILTMORE	01	01	CONTRACT	CPT	051986	S/S CONTRL HARDWIRE DECL LN RQ		050384	YES	24435A	WCPS
9	82191	208	I-75(NEW NB OFF RAMP) @ WEST RD (S07)	01	01	CONTRACT	CPT	010588	NEW S&G		083085	YES	06747A	WCPS