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AAA ROAD IMPROVEMENT
DEMONSTRATION PROGRAM:
COMBINING THE PUBLIC AND PRIVATE SECTORS
TO IMPROVE TRAFFIC SAFETY AT
URBAN SIGNALIZED INTERSECTIONS IN MICHIGAN

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AAA ROAD IMPROVEMENT DEMONSTRATION PROGRAM: COMBINING THE PUBLIC AND PRIVATE SECTORS TO IMPROVE TRAFFIC SAFETY AT URBAN SIGNALIZED INTERSECTIONS IN MICHIGAN

By

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ABSTRACT

AAA ROAD IMPROVEMENT DEMONSTRATION PROGRAM: COMBINING THE PUBLIC AND PRIVATE SECTORS TO IMPROVE TRAFFIC SAFETY AT URBAN SIGNALIZED INTERSECTIONS IN MICHIGAN

By

Jeffrey S. Bagdade

The AAA Road Improvement Demonstration Program (AAA RIDP) is a public/private partnership designed to enhance traffic safety by reducing the frequency and severity of crashes at high-risk urban signalized intersections. Beginning in 1996 AAA Michigan partnered with state, county and city governments in Detroit and Grand Rapids to provide seed money for low cost safety improvements to the existing traffic signals and pavement markings with the goal of reducing traffic crashes at targeted high-crash intersections.

The safety improvements that were implemented included enhanced traffic signal visibility, the addition of left-turn lanes and phases, and longer all red intervals. An evaluation of the safety improvements showed statistically significant reductions in the number of vehicle crashes and personal injuries at 59 completed intersections in Detroit and Grand Rapids. These safety improvements are the result of cooperation and financial contributions by all of the public and private sector partners. The improvements have benefited society with safer roads and AAA Michigan with a positive impact to their loss reduction efforts. The AAA RIDP confirmed that since both the public and private sectors play important roles in preventing crashes and injuries that when they worked together, traffic safety could be improved.

ACKNOWLEDGEMENTS

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SECTION 1 – INTRODUCTION

Historically, it has been the responsibility of government agencies to build and maintain the nation's transportation infrastructure. This strategy has proven effective, as the American road network has become a model for the entire world. Every year in Michigan, more than 400,000 traffic collisions occur on this road network leading to 124,000 injuries and 1,300 deaths. "Many of these collisions occur at urban intersections that were designed for traffic flows and patterns from the 1940's and 1950's which have not been equipped to meet modern demands. This situation adversely impacts society with more injuries, property damage and higher insurance claims experience leading to higher costs and ultimately producing higher premiums for consumers." (1)

In response, AAA Michigan developed the AAA Road Improvement Demonstration Program (AAA RIDP). The AAA RIDP is a public/private partnership designed to enhance traffic safety by reducing the frequency and severity of crashes at high-risk urban signalized intersections. Based on the Insurance Corporation of British Columbia Road Improvement Program, the AAA RIDP allocated seed money and set up partnerships in Detroit and Grand Rapids, Michigan. These partnerships of public and private sector representatives planned and implemented low cost safety improvements to traffic signals, pavement markings and signs to reduce traffic crashes and injuries. The benefits of the AAA RIDP can extend to all motorists by reducing the number of intersection related collisions occurring in Michigan's urban areas. AAA Michigan could expect a positive economic impact to their loss prevention and loss reduction efforts resulting from the safety improvements. The primary objectives of the AAA RIDP are:

- To contribute knowledge, experience and seed money for defined demonstration projects intended to reduce the number and severity of collisions at high risk urban signalized locations.
- To achieve a minimum benefit-cost ratio of 2:1 on road improvements funded under this program.
- To encourage a proactive approach to traffic safety in future engineering projects, passing along knowledge and expertise gained to public agencies that may institutionalize the process. (1)

SECTION 2 – PROGRAM HISTORY

SECTION 2.1 – 1996

In early 1996, the City of Detroit's Mayor approached the automobile insurance industry with concerns about automobile insurance rates in the city. In response, a task force of automobile insurers formed the Detroit Urban Insurance Coalition to explore this issue.

One of the members of the coalition, AAA Michigan*, heard about a successful traffic safety program that was being implemented in Western Canada. The Insurance Corporation of British Columbia (ICBC) began a project called the Road Improvement Program as a way "to reduce the frequency and severity of motor vehicle crashes by identifying and investing in cost effective road improvement projects at high crash locations." (3)

SECTION 2.1.1 - CANADIAN MODEL

ICBC is a government owned third party automobile insurance provider that supplies insurance to more than 80% of the licensed drivers in the Canadian province of British Columbia. In recent history, most insurance providers had been involved in loss prevention programs such as lobbying automakers to enhance vehicle safety and public education campaigns to improve driver behavior. ICBC was involved in these types of safety initiatives through their "Road Sense" program. In 1989 they began conducting safety studies at high-

* AAA Michigan refers to the Auto Club Group of affiliated organizations that includes the Automobile Club of Michigan, the Auto Club Insurance Association, and several other Midwestern American Automobile Association (AAA) clubs.

crash intersections throughout the province. They hoped that, by identifying potential deficiencies in traffic signals, pavement markings and roadway geometry at these locations, they could then identify potential improvements. If the improvements were completed, the number of collisions occurring at the high-crash intersections would likely be reduced. The program could economically benefit ICBC with fewer claims due to the prevented collisions. This part of the Road Sense program became known as the ICBC Road Improvement Program.

"Until 1993, the program was limited to co-funding traffic safety studies at high crash locations. Since 1993, the program has provided funding for the implementation of cost-effective safety improvements that are identified in the studies." (3) They found that many of the proposed improvements identified in the earlier safety studies were not being implemented. It was not as if the road agencies did not want to implement the recommendations, they just did not have funding available. The ICBC safety projects had to compete for construction funds against already existing capacity and road paving projects. As a way to insure that the projects identified in the safety studies were constructed even if the local funds were inadequate, ICBC began giving the road agencies grants for constructing the improvements. Since the program began, ICBC has invested more than $15 Canadian in road improvement projects at over 500 intersections have been completed throughout British Columbia. According to Sayed and de Leur (4), the improvements at 26 of 31 evaluated intersections reported reductions in insurance claims. Similar programs have been organized and implemented in Alberta, Australia and Great Britain.

SECTION 2.1.2 - AAA MICHIGAN / CITY OF DETROIT PARTNERSHIP

AAA Michigan was the only member of the Detroit Urban Insurance Task Force that showed an initial interest in the ICBC program. AAA Michigan insures 22% of Michigan's drivers. Therefore implementing a similar Road Improvement Program in Michigan could prove very promising in the areas of loss prevention and loss reduction.

Based on the success of the ICBC Road Improvement Program abroad, AAA Michigan approached Detroit's Mayor in 1996 with the opportunity to begin a pilot road improvement demonstration program in Detroit as a way to address some of the city's traffic safety related concerns. During these discussions Mayor Archer agreed to allow AAA Michigan to help the city address safety problems at several high crash intersections. That discussion officially began the AAA Road Improvement Demonstration Program (AAA RIDP).

SECTION 2.1.3 - THE PROGRAM STRUCTURE

The AAA Michigan Traffic Engineer was delegated to coordinate this program both internally and externally. Internally, the traffic engineer would work directly with other AAA Michigan employees from Community Safety Services, Community Relations, Public Relations, Finance and Actuarial.

Externally, a steering committee was put together to include and coordinate the efforts including representatives from AAA Michigan and members of city government. Wayne County and Michigan Department of Transportation (MDOT) officials were also included in the steering committee because of their jurisdiction over some roads in Detroit. Representatives from the Southeast Michigan Council of Governments (SEMCOG) and the Michigan Office of Highway Safety Planning (OHSP) were also involved. The Community Safety Services Manager from AAA Michigan was selected to chair the committee. The steering committee's main task was to approve targeted high crash locations, discuss funding agreements and oversee the construction planning. To enhance efficiency, each of the representatives had budgeting authority in their respective agencies. (2)

Chairman: Community Safety Services Manager from AAA Michigan

AAA MICHIGAN Community Relations Manager Traffic Engineer	**MDOT** Engineer of Traffic and Safety Metro Office Representative
CITY OF DETROIT Public Works Director Traffic Engineering Division Director	**WAYNE COUNTY** Director of Engineering Engineer of Traffic Operations
OHSP Director	**SEMCOG** Director of Transportation

Figure 2-1 The Detroit Steering Committee Organizational Structure

The steering committee had engineering technical subcommittees for the city of Detroit, Wayne County and MDOT. These technical subcommittees were responsible for determining what type of safety improvements would be implemented at each targeted high-crash intersection. The AAA Michigan Traffic Engineer coordinated these subcommittees.

SECTION 2.2 – 1997

SECTION 2.2.1 - THE FIRST DETROIT INTERSECTION PROJECTS

It took less than a year for the first safety improvements to be constructed at three intersections in the city of Detroit. Detroit is Michigan's largest city with a population of 975,000 and approximately 48,000 traffic crashes per year. These three intersections each had histories of high numbers of vehicle crashes and personal injuries. They each met specific criteria outlined in Section 3.1 for identification as a target high-crash intersection. Safety improvements at these three high crash locations were selected and approved by the steering committee and the engineering technical subcommittee. AAA Michigan and the city shared the construction costs and the safety improvements were built between July and November 1997.

SECTION 2.2.2 - GRAND RAPIDS PARTNERSHIP

The safety problems experienced at urban intersections in Detroit were not unique. Based on the positive experience of the AAA RIDP in Detroit, a similar partnership was organized for Grand Rapids, Michigan. Grand Rapids is the second largest city in Michigan with a population of 258,000 and approximately 11,000 (1) traffic crashes per year. and has similar traffic crash problems to those existing in Detroit. It was determined that a AAA RIDP in Grand Rapids would be economically beneficial to AAA Michigan in the areas of loss prevention and loss reduction.

A similar steering committee was organized for the Grand Rapids program. Members included representatives from the city of Grand Rapids, MDOT and AAA Michigan. The steering committee began meeting to develop safety improvements for target high-crash intersections in Grand Rapids. By the middle of 1998, safety improvements were completed at four intersections.

Chairman: Community Safety Services Manager from AAA Michigan

AAA MICHIGAN Community Relations Manager Traffic Engineer	**MDOT** Engineer of Traffic and Safety Grand Region Representative
CITY OF GRAND RAPIDS Assistant City Manager Traffic Safety Engineer	**OHSP** Director

Figure 2.2 - The Grand Rapids Steering Committee Organizational Structure

SECTION 2.3 – 1998

SECTION 2.3.1 - MDOT AND WAYNE COUNTY PROJECTS

Both MDOT and Wayne County were active participants in the Detroit steering committee. During this time period, MDOT was attempting to complete a traffic signal modernization project for Woodward Avenue in Detroit. This project included the upgrading of traffic signals at 30 intersections. AAA Michigan participated in this project by providing a corridor safety study, construction funding and assistance in project coordination between MDOT and the city of Detroit.

While AAA Michigan was working on the Woodward project they were also planning a road improvement project with Wayne County at the high crash intersection of Evergreen at Schoolcraft in Detroit. Wayne County and AAA Michigan jointly funded the construction of safety improvements at this intersection. Construction was completed in late 1998.

SECTION 2.3.2 - AAA MICHIGAN/STATE FARM PARTNERSHIP

During the summer of 1998, AAA Michigan approached other insurance companies about the possibility of participating in the AAA RIDP. State Farm, the nations largest insurance company agreed to participate in one intersection project in Detroit; Davison at Linwood. Based on the positive experience gained, State Farm decided to leave the partnership to start their own national effort to improve intersection safety called the "Dangerous Intersections" program.

SECTION 2.4 – 1999 TO 2003

Between 1999 and 2001, 116 intersection projects were completed. By December 2003, safety improvements will be completed at an additional 134 intersections in Detroit and Grand Rapids. (Please see Figures D.1 and D.2

located in Appendix D for maps of which intersections have been completed and those slated for safety improvements).

SECTION 3 – HOW THE PROGRAM WORKS

One of the first tasks of the steering committee was to develop a specific procedure for the partnership to follow when making safety improvements. The procedure developed involved six specific steps for the planning, implementation, construction and evaluation of the safety improvements.

First, an analysis of the historical traffic crash data for the community is conducted to determine what locations may be worthwhile candidates for AAA RIDP safety projects. Next the locations identified in step 1 are studied and countermeasures to mitigate the crashes are suggested. Then, a benefit to cost analysis is conducted to determine whether the sites meet the AAA Michigan criterion for them to invest for the improvements. If AAA Michigan meets the minimum investment criteria, the project partners develop a strategy to pay the improvements. The fifth step is to design and construct the improvements. Finally, a post-improvement evaluation study is performed to determine the safety and economic impact of the improvements.

Figure 3.1 – AAA RIDP Procedure

SECTION 3.1 - STEP 1: IDENTIFY TARGET INTERSECTIONS

In order to identify potential target intersections for improvement, traffic collision data from the Michigan State Police (MSP) crash database and the AAA Michigan claims database are collected for analysis. Using the MSP crash data, intersections are ranked by total crashes, collision rate, casualty ratio and frequency of various crash types. Total crashes account for all of the collisions occurring within 150-feet of the center of the intersection. Collision rate is the total crashes occurring at the intersection per million entering vehicles. This is calculated using the following formula:

ColRate=(TotCra*1,000,000)/(Approach ADT*365)

ColRate = Collision Rate (collisions per MEV)

TotCra = total crashes

Approach ADT = average daily traffic during the study period (sum of all of the approach volumes for an intersection)

The casualty ratio is the percentage of injury crashes to total crashes for a specific intersection. Intersections with a high casualty ratio tend to have higher annual claims costs to AAA Michigan. Therefore, these intersections will be ranked higher on the list of target intersections. Total crashes, collision rate and casualty ratio are compared to 95th percentile (critical) values listed in the SEMCOG Traffic Safety Manual (5). This manual compares the collision history of a specific intersection to others with similar characteristics. If the total crashes, collision rate or casualty ratio value for the location exceeds the critical value in one of these categories, it is classified as a high-crash location.

Intersections with high numbers of angle and left-turn head-on (LTHO) collisions are also ranked higher since these types of crashes tend to be more severe and can often be easily prevented using safety countermeasures.

The AAA Michigan claims database was origionally used to determine how many crashes have involved AAA Michigan insured vehicles. There is one shortcoming to using the claims database. It is extremely time consuming to query the data by location. For this reason, AAA Michigan discontinued relying on the claims database to determine actual locations. It is used to help choose communities where AAA Michigan can maximize their investment in road improvement projects.

SECTION 3.2 - STEP 2: CONDUCT A SAFETY STUDY

The second step of the AAA RIDP process is to conduct a traffic safety study at each of the identified target intersections. Each safety study focuses on determining the causes of the traffic crashes occurring at each of the intersections and whether they can be mitigated. AAA Michigan hires third-party traffic engineering consultants to study each intersection, document findings and suggest potential countermeasures. The safety study includes crash analysis, collision diagrams, traffic flow data and suggested countermeasures.

SECTION 3.2.1 - CRASH ANALYSIS AND COLLISION DIAGRAMS

The traffic crash data for each intersection undergoes a detailed analysis. Crash data is analyzed to determine what types of collisions are occurring, their degree of severity and their causal factors. The purpose of the crash analysis is to determine whether the crashes are occurring due to environmental factors or caused by driver error. In many situations, changing environmental factors such as roadway geometry or traffic signal visibility can prevent crashes. The safety study documents any consistencies in crash patterns caused by environmental factors. Collisions related to driver error such as drunk driving, drowsy driving and road rage are much more difficult to prevent. In order to prevent these types of crashes, drivers must be educated and convinced that these behaviors are hazardous. This process can take many years and is beyond the scope of the safety study.

Severity is the second type of crash data analyzed. Injury crashes are looked at in-depth. Injury and fatal crashes tend to be more costly both personally and to society than property damage only (PDO) crashes. The safety study does not include fatal crashes within the analysis. Fatal crashes usually do not offer specific collision trends at intersections.

All of the crash data are placed in a collision diagram, a visual illustration of the crash data. Each crash is shown on the diagram with a symbol corresponding to the type of collision. Collision diagrams are a simple way to identify crash patterns. The engineer can use the collision diagram to look for groupings of the same symbols. This helps to identify trends.

Based on their availability, UD-10 police crash reports are analyzed for intersections. These are the official reports filled out by the police officer at the scene of a crash. They provide a detailed written description of each collision and often include sketches. When analyzing these reports, it is often possible to determine whether environmental factors caused the collisions. For example, a review of UD-10 police crash reports was conducted for the intersection of Burton Street at Kalamazoo Avenue in the Burton Street Corridor Traffic Operations and Safety Review, Grand Rapids, Michigan. The review noted that "Grand Rapids Police Department comments indicated that parked cars and the presence of snow on the exit leg unexpectedly forced two lanes of southbound traffic into one lane south of the intersection, and contributed to sideswipe and secondary rear end collisions." (6) This type of information can be of considerable assistance in the process of determining whether environmental factors caused the collisions. It is clear that, based on the police officer's description the southbound rear ends and sideswipes were caused by the presence of parked cars and snow, not by driver error.

SECTION 3.2.2 - TRAFFIC FLOW DATA

Traffic flow data is gathered and analyzed for each intersection. This is accomplished by first collecting traffic volume data through the use of electronic counters or human observers. The traffic volume and geometric data is then analyzed using *Synchro 4.0* a software package designed for modeling and optimizing traffic signal timings. This type of software uses computerized models to identify locations where adjustments to the traffic signal timing or geometry can maximize capacity. The software will provide a level of service (LOS) calculation of how well the intersection is operating based on the provided traffic volume and geometric data. Defined in units of delay (seconds per vehicle), LOS takes into account driver discomfort, frustration, fuel consumption and lost travel time. (8) *Synchro 4.0* allows the engineer to use trial and error to adjust the traffic signal timing in order to reduce delays. In some cases, reductions in delay may help to improve safety. Other research such as spot speed studies and traffic conflict analysis may be necessary for certain intersections.

SECTION 3.2.3 - SUGGESTED COUNTERMEASURES

Once the analysis has been completed, countermeasures to potentially mitigate the crashes are suggested. Example suggested countermeasures include:

- Replace the existing eight-inch diameter traffic signals with larger twelve-inch lenses.
- Provide permitted/protected left-turn phasing for all approaches.
- Remove on-street parking near the intersection and add dedicated left-turn lanes.
- Re-time the traffic signals to include all-red intervals.

The suggested countermeasures are always stated in the safety study with supporting documentation.

SECTION 3.3 - STEP 3: CONDUCT A BENEFIT COST ANALYSIS

Once the safety study has been completed AAA Michigan conducts a benefit cost analysis to determine whether the suggested countermeasures warrant AAA Michigan investment. Using information extracted from the AAA Michigan insurance claims database a crash cost model was developed. The AAA Michigan Actuarial Department developed this model to determine the cost per property damage and injury crash to AAA Michigan. These crash costs are inserted into the benefit term (equation 3.3) of the benefit cost analysis. For a proposed intersection project to warrant investment by AAA Michigan, it must meet a minimum of a 2:1 benefit cost ratio (B/C) over two years using equation 3.3. AAA Michigan follows the mathematical process below to determine whether a proposed intersection project warrants investment:

$Benefit = (PDOy*AAAPDO) + (INJy*AAAINJ)$ <equation 3.1>

$Cost = (AAAinv*CapRec)$ <equation 3.2>

$Benefit/Cost = B/C \geq 2$ <equation 3.3>

- Benefit = Equivalent Uniform Annual Benefit;
- PDOy = Total number of property damage only crashes occurring at the intersection per year (based on police data);
- AAAPDO = Average cost to AAA Michigan for each property damage only crash;
- INJy = Total number of injury crashes occurring at the intersection per year;
- AAAINJ = Average cost to AAA Michigan for each injury crash;
- Cost = Equivalent Uniform Annual Cost
- AAAinv = Potential investment by AAA Michigan in dollars; and
- CapRec = Capital Recovery Factor.

First, the Benefit must be calculated. Next the Cost is determined using an estimated AAAinv and finally the B/C ratio is calculated. If the B/C is less than two, the estimated AAAinv must be changed until the B/C is greater than or equal to two. The maximum investment AAA Michigan can make occurs when the B/C = 2. If an intersection does not meet the minimum B/C ≥ 2, then AAA Michigan will not invest in improvements. This may occur when the total number of crashes is low and the cost of improvements is high. Intersections are then ranked based on AAA Michigan's minimum potential investment that meets the above criteria.

SECTION 3.4 - STEP 4: DEVELOP PROJECT FUNDING STRATEGY

If investment in the suggested countermeasures is warranted, AAA Michigan must work with the partners to develop a project funding strategy. There are two steps involved in developing a project funding strategy. The first is to determine which items AAA Michigan will pay and which items the partnering agencies will fund and the second is to propagate an official agreement or contract.

It is necessary to determine how much AAA Michigan will invest at each intersection based on the amount of funding available from the partnering agencies. AAA Michigan's investment must meet the minimum 2:1 benefit cost ratio criteria over two-years. That is the maximum amount AAA Michigan can invest. The rest must come from other sources.

Once it has been determined how much AAA Michigan will invest and how the remaining project costs will be funded, some type of official agreement must be signed between AAA Michigan and the partnering agency. The reason for an agreement is to indemnify AAA Michigan of all claims or lawsuits that may result from any of the improvements. All of the partnering agencies to date have agreed to this indemnification provision through a formal contract or a resolution passed by the agencies governmental authority.

SECTION 3.5 - STEP 5: DESIGN AND CONSTRUCT IMPROVEMENTS

Either the partnering agencies engineering staff or a private consultant design all of the safety improvements based on the countermeasures suggested in the safety study. Each of the safety improvements must be designed to meet standards outlined by partnering agencies involved and by AASHTO (American Association of State Highway and Transportation Officials). Once the designs have been completed, the safety improvements are then constructed either using the partnering agencies public works staff or a private contractor.

SECTION 3.6 - STEP 6: CONDUCT POST-IMPROVEMENT EVALUATION STUDY

After safety improvements have been implemented at an intersection, a post improvement evaluation study is conducted. The Highway Safety Improvement Program states "Evaluation involves obtaining and analyzing quantitative information on the benefits and costs of implemented highway safety improvements." (10) The purpose of conducting an evaluation of the AAA RIDP was to assess AAA Michigan's safety and economic benefits. That study was conducted using predicted collision reductions based on research. During this step, the economic analysis was revisited using actual post-improvement crash data. The post-improvement crash data was compared to the pre-improvement data analyzed in step 3. The final output of this comparison is always a benefit cost analysis detailing the cost savings to AAA Michigan due to reduced number of insurance claims occurring at an improved intersection. Many times the improved intersections will be compared to control intersections to assist in trend verification.

SECTION 4: EXAMPLE INTERSECTIONS

This section contains detailed descriptions of safety improvements completed at three high-crash intersections. The improvements implemented varied based on the existing geometry, traffic control, collision history and funding availability. The example intersections include:

- Seven Mile Road at Ryan Avenue in Detroit;
- Woodward Avenue at Milwaukee Street in Detroit; and
- Burton Street at Breton Avenue in Grand Rapids.

SECTION 4.1 - SEVEN MILE ROAD AT RYAN AVENUE IN DETROIT

Seven Mile at Ryan was the first intersection completed as part of the AAA RIDP. It is located on the east side of Detroit and falls under the city's jurisdiction. Seven Mile Road is classified as a primary arterial while Ryan Avenue is a minor arterial. The intersection has an average daily traffic of (ADT) of 30,000 vehicles per day.

In late 1996, AAA Michigan identified this intersection as a target location for potential improvements. Collision data from 1993 to 1995 indicated that the intersection was averaging 71 total crashes per year. The crash rate was also very high, 6.10 collisions per million entering vehicles (col/MEV). As the collision rate of 6.10 col/MEV is greater than the critical rate of 1.88 col/MEV, the intersection was identified as high-crash and designated as a target intersection for improvement. Table 4.1 compares the critical crash frequency and rate to the actual crash frequency and rate.

Table 4.1 – Critical Value Comparison for Seven Mile at Ryan

	Actual	Critical
Total Crashes	71	14
Crash Rate	6.10	1.88

Intersection photos and collision diagrams can be found in Appendix A. A condition diagram of the intersection geometry can be found in figure 4.1. A condition diagram is a pictorial representation of the intersection including traffic control devices, pavement markings and the geometric layout.

Figure 4.1 – Condition Diagram for Seven Mile at Ryan (Before Improvements)

Once the intersection was identified as a high crash location, the traffic safety study was conducted. The safety study revealed the following issues:

- Left-turn head-on collisions;
- Angle collisions; and
- Rear-end and sideswipe collisions.

SECTION 4.1.1 - LEFT-TURN HEAD-ON COLLISIONS

Crash data indicated that the intersection experienced an average of 19 Left-turn head-on (LTHO) collisions each year. High numbers of LTHO collisions usually indicate that vehicles may be having difficulty making left-turns. Two safety countermeasures, dedicated left-turn lanes and permitted/protected phasing are commonly used to assist with left-turns and were not present at this intersection. There are two benefits of adding dedicated left-turn lanes to an intersection. First, making left-turns on roadways with no dedicated left-turn lanes can limit sight distance. This occurs when an opposing vehicles waits to make a left-turn, it can block the oncoming traffic. Adding a dedicated left-turn lane typically improves sight distance. Second, the absence of dedicated left-turn lanes can result in a vehicle blocking a through travel lane while waiting to make a left-turn. This can cause crashes by forcing vehicles to choose inadequate gaps when through traffic queues begin to form behind the left-turning driver. Research conducted by G.D. Hamilton Associates for ICBC (10) examined nine intersections in Vancouver, British Columbia where dedicated left-turn lanes were added. They concluded "the average proportion of LTHO collisions decreased from 32 to 22." Furthermore, "the average collision rates were reduced from 1.6 to 1.3 col/MEV." According to this research, adding dedicated left-turn lanes can significantly reduce the risk of a collision.

Since the intersection averaged more than five LTHO collisions for the combination of the eastbound and westbound approaches per year, permitted/protected left-turn phasing for those approaches was also suggested as a safety countermeasure. Three LTHO collisions per year for the eastbound/westbound or northbound/southbound approach combinations have been used throughout the AAA RIDP as the critical value for determining where to add left-turn phasing. Research outlined in by J.E. Fisher (11) supports this critical value. Finally, in order to add left-turn lanes and phasing, the new lane configuration and signal timing had to satisfy an acceptable approach level of service (LOS) C or higher. Intersections operating at LOS D or lower typically operate at or near capacity with significant congestion and vehicle delays. Intersections operating at LOS E or F, have already reached capacity. If the LOS can be enhanced to C, the delays are typically shorter. Dedicated left-turn lanes typically are not implemented if they will cause increased congestion since this may lead to more crashes.

SECTION 4.1.2 – ANGLE COLLISIONS

The intersection of Seven Mile and Ryan also had a very high number of angle collisions, eight per year. There were two environmental factors causing these angle collisions, signal visibility and inadequate all-red intervals. The traffic signals had eight-inch diameter traffic signal lenses. Research by Creasey and Agent (12) has shown that upgrading traffic signals from eight-inch diameter lenses to twelve-inch diameter lenses can reduce angle collisions by as much as 10%.

Traffic signal visibility could also be improved by adding low-level traffic signals. Low-level traffic signals are supplementary signals that are not placed overhead on the span-wire or mast-arms, but rather on the far side of the intersection, lower to the ground closer to the driver's eye height. Low-level traffic signals are installed also as a way to increase conspicuity by placing additional signal heads within the driver's cone of vision.

The intersection also lacked all-red intervals, a standard endorsed by the Institute of Transportation Engineers (ITE). All-red intervals are part of the traffic signal timing where all directions briefly have a red indication (typically 1.0 to 2.5 seconds) to clear the intersection. The all-red interval can prevent collisions occurring when vehicles enter the intersection during the last few moments of the yellow indication. Before the improvements were implemented, Ryan Avenue had an all-red of 0.1 seconds and Seven Mile Road had no all-red interval. The safety study suggested that all red intervals of two-seconds be implemented to meet the ITE standard (13). The equation used for timing all-red intervals can be found in Appendix F.

SECTION 4.1.3 – REAR END AND SIDESWIPE COLLISIONS

When no dedicated left-turn lanes are present, the inside lane becomes a de-facto left-turn lane. This occurs because vehicles must stop in the primary travel lane while waiting for a gap to make a left-turn. This leads to an increased potential to strike the stopped vehicle in the rear or, by having to switch lanes at the last moment sideswiping the stopped vehicle.

SECTION 4.1.4 – IMPLEMENTED SAFETY IMPROVEMENTS

Five safety improvements were implemented at the intersection of Seven Mile Road at Ryan Avenue. First, left-turn lanes were added to all four-approaches as a way to reduce the number of LTHO collisions at the intersection. The addition of the left-turn lanes required changing the lane configuration and removing on-street parking within 200 feet of the intersection. The intersection's level of service improved from C to B with the new lane configuration. Permitted/protected left-turn phasing was added for the eastbound and westbound approaches of Seven Mile Road to further assist in reducing the risk for LTHO collisions.

To reduce the number of angle collisions, the traffic signal heads were upgraded from eight-inch diameter lenses to twelve-inch diameter lenses. Low-level traffic signals were added to the Ryan Avenue approaches to further increase the traffic signal visibility by increasing the total number of signal heads. The all red intervals were increased to 2.0 seconds for through movements and 1.5 seconds for the left-turn phase. These new all red intervals conformed to the

ITE standards. Please see figure 4.2 for a condition diagram of the improvements.

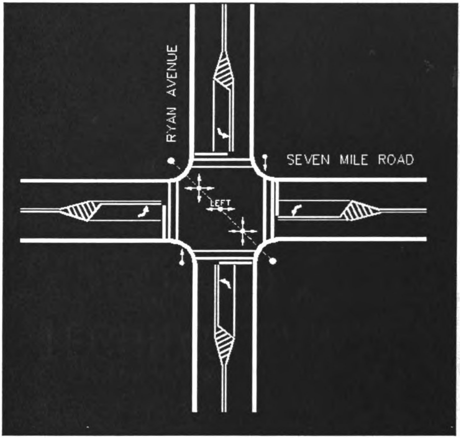


Figure 4.1 – Condition Diagram for Seven Mile at Ryan (After Improvements)

SECTION 4.1.5 – PROJECT FUNDING

Three partners were involved in funding this $35,000 safety project. AAA Michigan contributed $20,000 for project construction. The City of Detroit paid for the remaining $15,000 for the design and construction. The safety study was completed by Wayne State University using grant money allocated by the Michigan Office of Highway Safety Planning (OHSP).

SECTION 4.1.6 – POST IMPROVEMENT EVALUATION STUDY

The safety improvements to Seven Mile Road at Ryan Avenue were completed in July 1997. Before and after data were analyzed using UD-10 police crash reports collected from the Detroit Police Department. The before (January 1995 to December 1996) and after (July 1997 to October 2001) periods were used in determining the annual average of total crashes, total injuries and each specific collision type. Total crashes have been reduced by 53% and total injuries have been reduced 70%. The addition of left-turn lanes and permitted/protected phasing has reduced the number of LTHO crashes by 87% per year. The left-turn lanes also helped reduce the number of rear end and sideswipe crashes. While the reduction in the number of sideswipe collisions was significant, (77%), the 36% reduction of rear end collisions was not statistically significant. The larger signal lenses and longer all red intervals have helped reduce the angle collisions by 76% per year. Each of the statistically significant reductions met a 95% level of confidence using the Poisson test. These large reductions translate into significant reductions in claims for AAA Michigan and exceeded the goal of a 2:1 benefit cost ratio over two years. The intersection delays and congestion was reduced as LOS improved from D to B. (Please see Table 4.2 for a detailed description of the before and after collision data. Statistically significant reductions are denoted in bold.)

Table 4.2 – Before and After Collision Data for Seven Mile at Ryan

	Before	After	% Change
Rear End	14	9	36%
Angle (Intersection)	**20**	**5**	**75%**
Sideswipe	**13**	**3**	**77%**
Left-Turn Head-On	**22**	**8**	**64%**
Other	**39**	**9**	**77%**
Total Crashes	**71**	**34**	**52%**
Total Injuries	**19**	**5**	**74%**

"Before" period represents an annual average of 24-months from 1/95 to 12/96

"After" period represents an annual average of 53-months from 7/97 to 10/01

SECTION 4.2 - WOODWARD AVENUE AT MILWAUKEE STREET IN DETROIT

During discussions in early 1998 with the Michigan Department of Transportation (MDOT), AAA Michigan agreed to participate in a project to make safety improvements to 30 traffic signals along Woodward Avenue in Detroit. Woodward Avenue (M-1) is a state trunkline route with an ADT of 23,000 vehicles per day with eight travel lanes and a continuous center left-turn lane. Milwaukee Street intersects Woodward in Detroit's New Center Area central business district. Milwaukee Street is a minor arterial with an ADT of 7,000 vehicles per day.

According to a crash analysis of the Woodward at Milwaukee intersection before the improvements were made, it experienced 22 crashes per year with a 0.43 casualty ratio and a crash rate of 1.83 col/MEV. Because the casualty ratio and the collision rate exceeded critical values, this intersection was classified as a high crash location and a target for additional safety analysis. Please see Table 4.3 for the critical value comparisons.

Table 4.3 – Critical Value Comparison for Woodward at Milwaukee

	Actual	Critical
Casualty Ratio	0.43	0.42
Crash Rate	1.83	1.65

Before the safety improvements were made, the Woodward Avenue approaches had two overhead traffic signals with eight-inch lenses. The Milwaukee Street approaches had one overhead signal, also with eight-inch lenses. There were two far-side low-level signals for each approach and no pedestrian signal heads. No all red intervals were present in the traffic signal timing. Due to the low volumes of left-turning traffic from Milwaukee Street, it did not have dedicated left-turn lanes. (Please see figure 4.3 for a condition diagram of the existing geometry and traffic signal layout.) Once the intersection was identified as a high crash location, the traffic safety study was conducted. The safety study revealed the following issues related to angle collisions.

SECTION 4.2.1 – ANGLE COLLISIONS

Before the improvements, angle collisions accounted for 43% of the intersection's crashes. This exceeds the critical angle collision percentage of

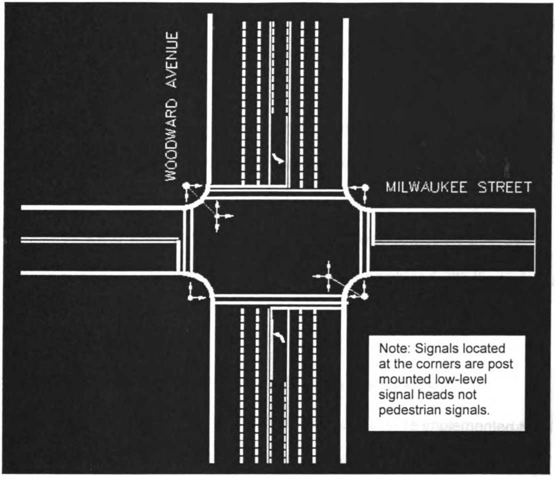


Figure 4.4 – Condition Diagram for Woodward at Milwaukee (Before Improvements)

24% for this type of intersection according to the SEMCOG Traffic Safety Manual. This was the only collision type with any identifiable trends. A more in depth look at the UD-10 crash data identified three hazardous actions associated with these angle collisions. Disobey traffic control, unable to stop and failure to yield hazardous actions accounted for more than 50% of the angle collisions. The Woodward Avenue Traffic Safety and Operations Review noted, “these hazardous actions indicate that vehicles are entering the intersection during the yellow interval, and are related to driver inattention to the traffic signals and lack of signal conspicuity. The lack of an all red interval in the existing signal timings may further increase collision risk." (6) The lack of signal conspicuity was related to three factors:

1. Smaller eight-inch lenses on the traffic signals;
2. Signal heads placed outside of many of the driver's cone of vision; and
3. Relatively few number of overhead signal heads.

The remaining angle collisions were caused be hazardous actions such as speeding and other unknown factors. These factors combined with the lack of all red intervals were the cause of the high number of angle collisions.

SECTION 4.2.2 – IMPLEMENTED SAFETY IMPROVEMENTS

In November 1999, five safety countermeasures were implemented at this intersection. First, the existing traffic signals with eight-inch diameter lenses were replaced with larger and more visible twelve-inch diameter lenses. Next, the overhead signals were moved closer to the centerline of the road. This would improve their placement in relation to the driver's cone of vision. Additional overhead signal heads were placed on the Milwaukee approaches and the clearance intervals were adjusted to include all-red intervals. Finally, pedestrian signals were added to the intersection. Although no pedestrian crashes occurred at the intersection during the crash analysis period, up to 150 pedestrians crossed during the afternoon peak period. Pedestrian signals were installed as a way to reduce the risk for future pedestrian crashes. (Please see Figure 4.4 for a condition diagram of the safety improvements.)

SECTION 4.2.3 – PROJECT FUNDING

Similar to the Seven Mile at Ryan intersection, three partners were involved in funding these safety improvements. AAA Michigan had already commissioned a safety study of the entire Woodward corridor. Included was a section related to this intersection. Constructions of these improvements were part of a $2 million effort to make safety improvements to 30 intersections along

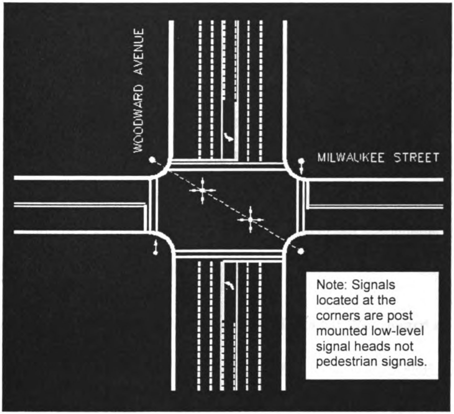


Figure 4.4 – Condition Diagram for Woodward at Milwaukee (After Improvements)

Woodward Avenue. MDOT contributed $1.8 million of Congestion Mitigation Air Quality (CMAQ) funds, the city of Detroit contributed $150,000 and AAA Michigan provided a grant for the remaining $50,000.

SECTION 4.2.4 – POST IMPROVEMENT EVALUATION STUDY

Since the Woodward Avenue at Milwaukee Street improvements were implemented in November 1999, total crashes have decreased by 71%. Similarly, total injury crashes have decreased by 71%. Before and after data was analyzed using UD-10 police crash reports collected from the Detroit Police Department. The before (November 1996 to October 1998) and after (November 1999 to December 2001) periods data represent an annual average of total crashes, total injuries and each specific collision type. The improvements to the traffic signals have almost eliminated angle crashes from occurring as they have decreased by 92%. All of these reductions are statistically significant with a 95% level of confidence interval using the Poisson test. This intersection also satisfies AAA Michigan's 2:1 benefit cost ratio over two years. (Please see Table 4.4 for a description of the intersections average annual crash reductions. Statistically significant reductions are listed in bold.)

Table 4.4 – Before and After Collision Data for Woodward at Milwaukee

	Before	After	% Change
Rear End	1	2	-100%
Angle (Intersection)	**12**	**1**	**92%**
Sideswipe	4	2	50%
Left-Turn Head-On	**6**	**0**	**100%**
Other	6	3	50%
Total Crashes	**24**	**7**	**71%**
Total Injuries	**7**	**2**	**71%**

"Before" period represents an annual average of 24-months from 11/96 to 10/98
"After" period represents an annual average of 26-months from 11/99 to 12/01

SECTION 4.3 - BURTON STREET AT BRETON AVENUE IN GRAND RAPIDS

In 1998, AAA Michigan identified the Burton Street corridor in Grand Rapids, Michigan as a potential candidate for safety improvements. Since the intersection of Burton and Breton had the highest collision frequency on the corridor, it was identified for detailed analysis. Both streets are primary arterials, which fall under the jurisdiction of the city of Grand Rapids. The combined ADT of the intersection is 65,000 vehicles per day. The land use surrounding the intersection is predominantly commercial and includes the busy Breton Village Shopping Mall on the northeast corner.

Before the improvements, the intersection had both permitted/protected left-turn phasing and dedicated left-turn lanes. The traffic signals consisted of smaller eight-inch diameter lenses mounted in a diagonal span configuration. (Please see Figure 4.5 for a condition diagram of the geometry and traffic signal layout before any safety improvements were implemented.)

During 1997 and 1998, the intersection averaged 61 collisions per year. The collision rate of 2.57 col/MEV exceeded the critical rate of 1.70. The intersection also had high numbers of LTHO, angle and driveway related crashes. Please see Table 4.5 for a comparison of actual and critical crash frequency and rate for this intersection. Once the intersection was identified as a high crash location, the traffic safety study was conducted. The safety study revealed the following issues related to LTHO and driveway related collisions.

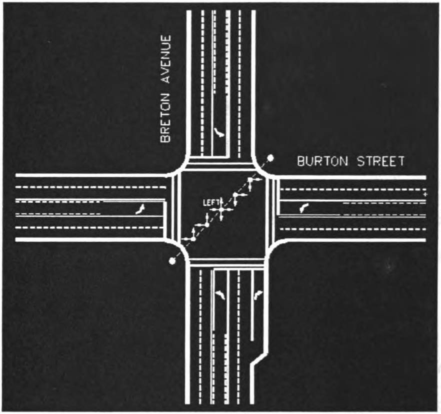


Figure 4.5 – Condition Diagram for Burton at Breton (Before Improvements)

Table 4.5– Critical Value Comparison for Burton at Breton

	Actual	Critical
Total Crashes	61	47
Crash Rate	2.57	1.70

4.3.1 – LEFT TURN HEAD ON COLLISIONS

The analysis of the crash data identified high numbers of LTHO collisions. Even with the presence of dedicated left-turn lanes and permitted/protected left-turn phasing, this intersection experienced ten LTHO collisions per year. Limited signal head visibility or unacceptable levels of service for the left-turn movements may have been causative factors in these LTHO collisions.

Before the improvements were implemented, the intersection had traffic signals with eight-inch diameter lenses mounted on a diagonal span, similar to the two previously discussed intersections. This intersection had the same issues related to the visibility of traffic signals with eight-inch diameter lenses discussed earlier in section 4. There were also two issues related to traffic signal visibility that were unique to this intersection. First, the placement of the permitted/protected left-turn phase signal was difficult to see. Since the intersection had lagging left-turn phases, vehicles tended to pull out into the center of the intersection during the leading permitted phase while waiting for a gap to make a left-turn. This is a normal maneuver at this intersection. When this occurs, the left-turn phase signal is no longer within the driver's cone of vision. The second issue is the unacceptable levels of service for the left-turning movements. "Poor levels of service experienced by the left-turn movements, especially for the north, south and west approaches, may contribute to driver frustration and encourage drivers to accept inadequate gaps." (5) These issues appear to be the primary causes of the LTHO collisions.

4.3.2 – DRIVEWAY RELATED COLLISIONS

The intersection of Burton Street at Breton Avenue is the center of a bustling commercial district with developments present on all four corners. Each of the commercial developments have high volumes of traffic entering and exiting from their driveways. The large number of driveways combined with the width of Burton Street and Breton Avenue and the high traffic volumes lead to an average of 16 driveway related collisions per year. Rear end and angle crash types accounted for a majority of the driveway related collisions. The rear end collisions occurred when a vehicle on Burton or Breton had to unexpectedly slow down or stop for another vehicle entering or exiting a driveway. The angle collisions occurred primarily when vehicles attempted to make left-turns while exiting a driveway and crossing three or four lanes of oncoming traffic.

SECTION 4.3.3 – IMPLEMENTED SAFETY IMPROVEMENTS

Safety improvements were implemented at this intersection in April 2000. The only AAA RIDP suggested improvements constructed to date have been upgrades to the traffic signals. The existing traffic signals have been replaced with larger twelve-inch diameter lenses. The overhead traffic signals were reconfigured from a diagonal span to a box span. The box span allows a vehicle, waiting to make a left-turn during the permitted phase, to have adequate visibility of the traffic signal. A box span configuration places the traffic signals on the far side of the intersection with a signal head over each lane "greatly improving the signal visibility for vehicles which have entered the intersection, especially for left-turn movements." (5) Black back plates on overhead traffic signals and far left low-level left-turn phase signals were added to further increase the conspicuity of the intersections traffic signals.

There were no improvements to the intersection's access management. A narrow concrete median was proposed for both Burton Street and Breton Avenue as a way to physically restrict vehicles from making left-turns in and out of the driveways. The narrow median was not implemented due to a lack of available funding resources.

SECTION 4.2.4 – PROJECT FUNDING

Safety improvements at Burton Street and Breton Avenue were constructed as part of a wider $600,000 project that included 18 other intersections along the Burton Street and Eastern Avenue corridors. AAA Michigan provided funding for the Burton Street Corridor Safety and Operations Review, project design and a grant for a portion of the construction. The City of Grand Rapids and MDOT shared the remaining construction costs using a combination of Transportation Economic Development and local funding.

SECTION 4.3.5 – POST IMPLEMENTATION EVALUATION STUDY

Since the safety improvements were implemented at the intersection of Burton Street at Breton Avenue, total collisions have been reduced by 26%. Before and after data was analyzed using UD-10 police crash reports collected from the Grand Rapids Police Department. The before (January 1998 to December 1999) and after (April 2000 to December 2001) periods represent an annual average of total crashes, total injuries and each specific collision type. As

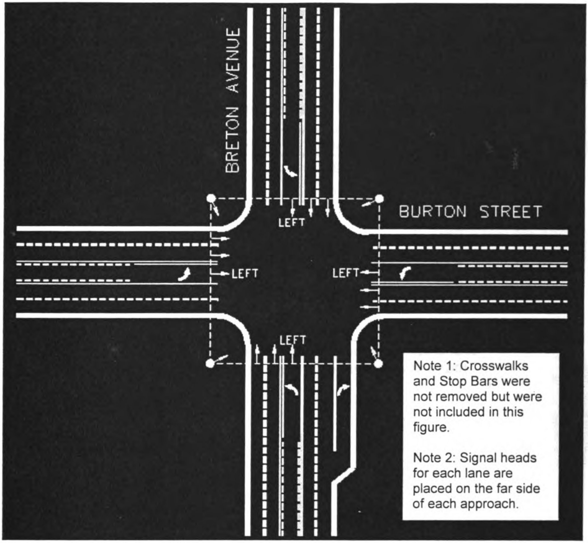


Figure 4.6 - Condition Diagram for Burton at Breton (After Improvements)

a result of the safety improvements targeted on left-turning issues, LTHO crashes declined by 80%. These reductions were statistically significant with a 95% level of confidence using the Poisson test. There was no significant reduction in driveway related crashes since no improvements were made to the access management plan. (Please see Table 4.6 for a detailed description of the before and after collision data. Statistically significant reductions are denoted in bold.)

Table 4.6 – Before and After Collision Data for Burton at Breton

	Before	After	% Change
Rear End	18	19	-6%
Angle (Intersection)	2	0	100%
Left-Turn Head-On	**10**	**2**	**80%**
Sideswipe	8	10	-25%
Other	**9**	**1**	**89%**
Driveway Related	16	13	19%
Total Crashes	**61**	**45**	**26%**
Total Injuries	9	6	33%

"Before" period represents an annual average of 24-months from 1/98 to 12/99
"After" period represents an annual average of 21-months from 4/00 to 12/01

SECTION 5 – PROGRAM FUNDING SOURCES

Funding for the AAA RIDP has come from various sources. Between 1997 and 1999, AAA Michigan allocated $2 million for safety studies, design and construction of safety improvements at high crash intersections in Detroit and Grand Rapids. This allocation leveraged more than $20 Million of federal, state, county and city funds. (Figure 5.1 outlines the funding sources by agency used to pay for the safety improvements.)

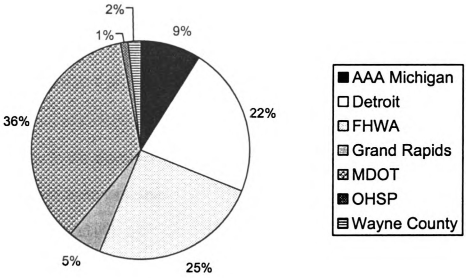


Figure 5.1 – Funding Sources by Agency

SECTION 5.1 – AAA MICHIGAN SOURCES

The majority of the AAA Michigan contribution went to fund design of the safety improvements. It was easier and quicker for AAA Michigan to contract out the designs to third-party engineering consultants than it was for any of the partners. This helped to decrease the time required to design and implement the safety improvements.

AAA Michigan also lobbied state government to have Transportation Economic Development Funds (TEDF) dedicated for specific use for AAA RIDP safety improvements. This effort resulted in more than a quarter of the government funds leveraged for the safety improvements.

SECTION 5.2 – FEDERAL SOURCES

The Federal Highway Administration (FHWA) provided 25% of the funding for the safety improvements. All of this funding was allocated through Detroit, Grand Rapids, MDOT and Wayne County. Each of those agencies receives a specific amount of FHWA funding each year. They can also apply for funding in addition to the initial allocation. The types of federal (FHWA) funding used for the safety improvements were:

- TEDF;
- Congestion Mitigation Air Quality (CMAQ);
- Federal Aid Traffic Signal Modernization Program; and
- Safety.

To use any of these federal funds, the receiving agency must match 20% of the federal allocation.

SECTION 5.3 – STATE AND COUNTY SOURCES

TEDF accounted for the majority of the funding provided by the MDOT for the AAA RIDP. In 1998 and 1999, MDOT allocated a total of $4 million of state funding for use on safety improvements constructed as part of the AAA RIDP. This funding required a 50% match by Detroit, Grand Rapids or Wayne County. MDOT also used some of their federal CMAQ allocation to pay for the safety improvements. All of this funding came from MDOT general operating budget which is made up state gas tax revenue. Wayne County provided matching funds to came from their general operating budget, which is made up of county tax and public bond revenue. During early meetings of the AAA RIDP steering committee both MDOT and Wayne County committed to using portions of their federal allocations and providing the matching funds for implementation of the safety projects.

SECTION 5.4 – CITY OF DETROIT SOURCES

The city of Detroit has allocated 22% of the funding used for construction of AAA RIDP safety improvements. Similar to MDOT and Wayne County, Detroit used portions of their annual federal allocation to pay for the majority of their share. The city's federal allocation includes Category C TEDF and Federal Aid Traffic Signal Modernization funds. CMAQ and Safety funds were also awarded for a few additional intersections. The remaining funds which were used for MDOT and federal matching, came from the Detroit's Department of Public

Works operating budget which is a combination of city tax and public bond revenue.

SECTION 5.5 – CITY OF GRAND RAPIDS SOURCES

Funding of safety improvements in Grand Rapids is a bit different to what occurred in Detroit. The Grand Rapids annual federal allocation is smaller than Detroit's. Therefore Grand Rapids had to apply for safety and CMAQ funds for some projects. AAA Michigan successfully lobbied for TEDF funds to help pay for safety improvements. Their matching funds came from their city-operating budget. In order to reduce construction costs, the City of Grand Rapids Streets and Lighting Department constructed all of the safety improvements.

SECTION 5.6 – OHSP GRANTS

Beginning in 1997, The Michigan Office of Highway Safety Planning, (OHSP), a division of the Michigan Department of State Police, provided government grants for safety research. OHSP provided Wayne State University with grants to conduct safety and post-improvement evaluation research of the AAA RIDP. These grants allowed Wayne State University to conduct safety studies at more than 75 target high-crash intersections, primarily in Detroit as well as some post-improvement evaluation research.

SECTION 6 – POST IMPLEMENTATION EVALUATION OF THE SAFETY IMPROVEMENTS

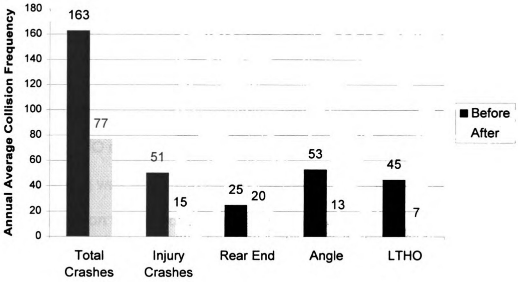
Post implementation evaluation studies have been conducted to analyze the safety and economic impacts of the improvements. Of the 120 completed intersections where safety improvements have been applied, 59 have sufficient data for evaluation. The three intersections discussed in section 4 of this report are included within the 59 completed intersections. These 59 completed intersections have been divided into three evaluation categories:

- Detroit intersections completed in 1997;
- Woodward Corridor in Detroit; and
- Grand Rapids completed intersections.

SECTION 6.1 – DETROIT INTERSECTIONS COMPLETED IN 1997

In 1997 safety improvements were completed at three high crash intersections in the city of Detroit. The intersection of Seven Mile at Ryan is included within this category. At these three intersections, total crashes were reduced by 53% and total injuries were reduced by 70%. These reductions are based on two years of pre-improvement "before" and more than four years of post-improvement "after" collision data. These reductions were statistically significant with a 95% level of confidence using the Poisson test. According to research conducted in 1999 by T. Datta, Schattler and S. Datta two years after implementation on the effects of these improvements, "the before and after comparison of right-angle, injury and total crashes at all three treatment sites show that the crash frequencies were significantly lower after treatment. This indicates the positive effectiveness of properly designed and installed clearance intervals, exclusive left-turn lanes at all approaches, left-turn phases where warranted and larger signal lenses." (11) A list of the specific safety improvements can be found in Table E.1 in Appendix E. Figure 6.1 illustrates the before and after crash data for the Detroit intersections completed in 1997. The crash data was compiled from UD-10 police crash report forms collected from the Detroit Police Department. The before period represents the annual average of collisions from January 1995 to December 1996. The after period represents the annual average of collisions from July 1997 to October 2001.

Figure 6.1– Before and After Crash Data for Detroit Sites Completed in 1997

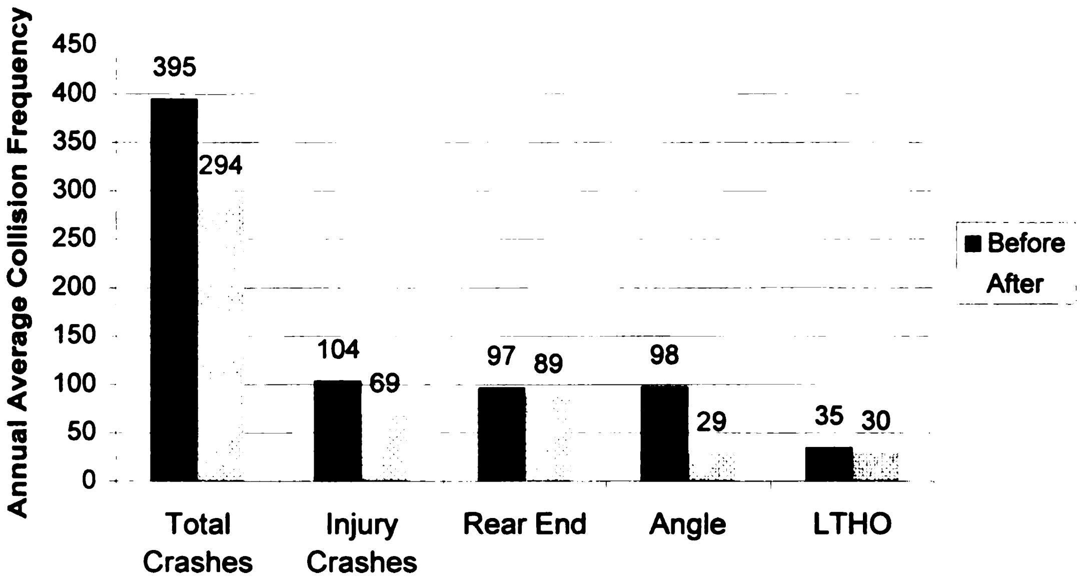


SECTION 6.2 – WOODWARD CORRIDOR IN DETROIT

In 1999, safety improvements to 30 intersections (including Woodward at Milwaukee) were completed. The primary improvement was enhancing the visibility of the traffic signals. A list of all of the safety improvements can be found in Table E.2 located in Appendix E. The crash data were compiled from UD-10 police crash report forms collected from the Detroit Police Department and the Highland Park Department of Public Safety. The before period represents the annual average of collisions from January 1997 to December 1998. The after period represents the annual average of collisions from November 1999 to December 2001. A comparison of the before collision data to the after collision data shows a 26% reduction in total crashes and a 34% reduction in total injuries. Angle crashes, a target for improvement, were reduced by 71%. Both of these reductions are statistically significant with a 95% level of confidence using the Poisson test. Rear end and LTHO crashes did not decrease significantly. This was most likely due to the fact that the improvements were targeted toward mitigating angle collisions. Additionally, most of the LTHO collisions were clustered at a few isolated intersections where left-turn phasing was warranted but not installed.

The reason these reductions are smaller than what was found for the Detroit intersections completed in 1997 was that the crash problems in the before period were less severe and therefore, the potential for reduction was smaller. Figure 6.2 illustrates the collision reductions for the 30 intersections included in the Woodward Corridor.

Figure 6.2 - Before and After Crash Data for the Woodward Corridor



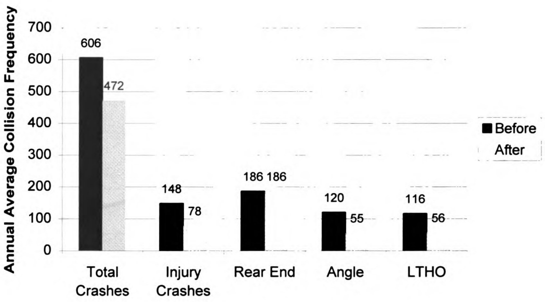
SECTION 6.3 – GRAND RAPIDS COMPLETED INTERSECTIONS

Between 1998 and 2000, safety improvements were completed at 26 intersections in Grand Rapids including Burton Street at Breton Avenue. The safety improvements varied by intersection but primarily included enhancements to traffic signal visibility, additional dedicated left-turn lanes and permitted/protected left-turn phasing. A list of the actual improvements made at each intersection and implementation dates can be found in Table E.3 in Appendix E.

Collision data for these analyses were collected from the Grand Rapids Police Department. The before period represents an annual average of the two-years before implementation of the safety improvements. The after period represents an annual average of a minimum of one-year of after data. Before and after periods vary by site as each had a different implementation date.

Since the improvements have been made, total crashes have been reduced by 22% and total injuries have decreased by 47%. Angle collisions have been reduced by 54% and LTHO collisions have decreased by 52%. All of these reductions are statistically significant with a 95% level of confidence using the Poisson test. Rear end collisions remained unaffected. Figure 6.3 illustrates the collision reductions at the 26 completed Grand Rapids intersections.

Figure 6.3 - Before and After Crash Data for Grand Rapids



SECTION 6.4 – CITYWIDE CRASH TRENDS

The before and after crash data for the improved intersections has been compared to citywide total collision and injury trends for both Detroit and Grand Rapids. Figure 6.4 illustrates the total collision and injury trends for 1994 and

Figure 6.4 – Citywide Crash Trends for Detroit

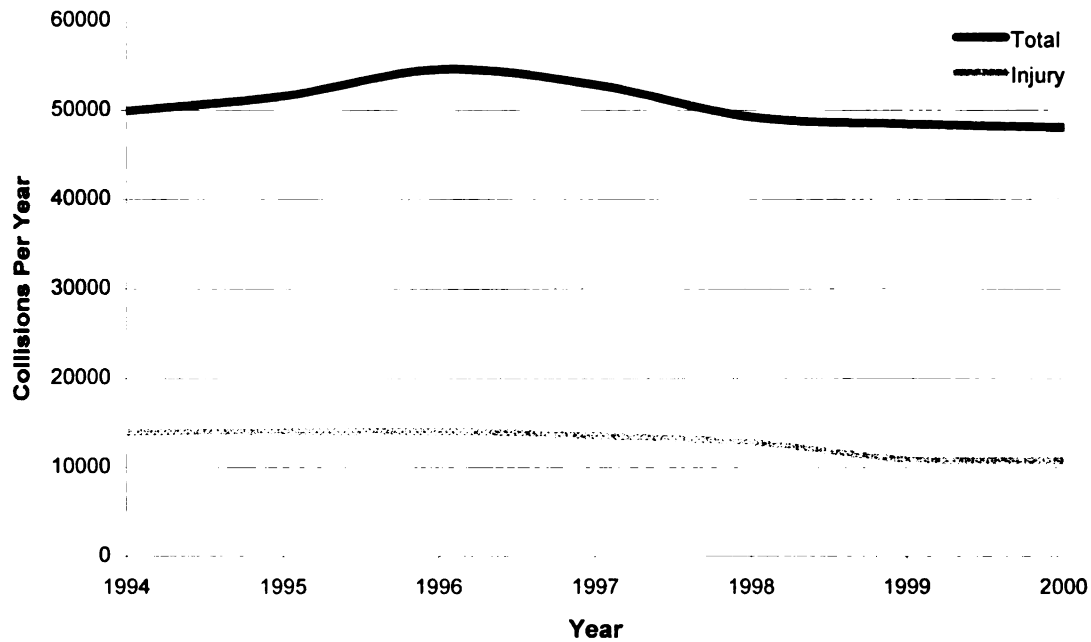
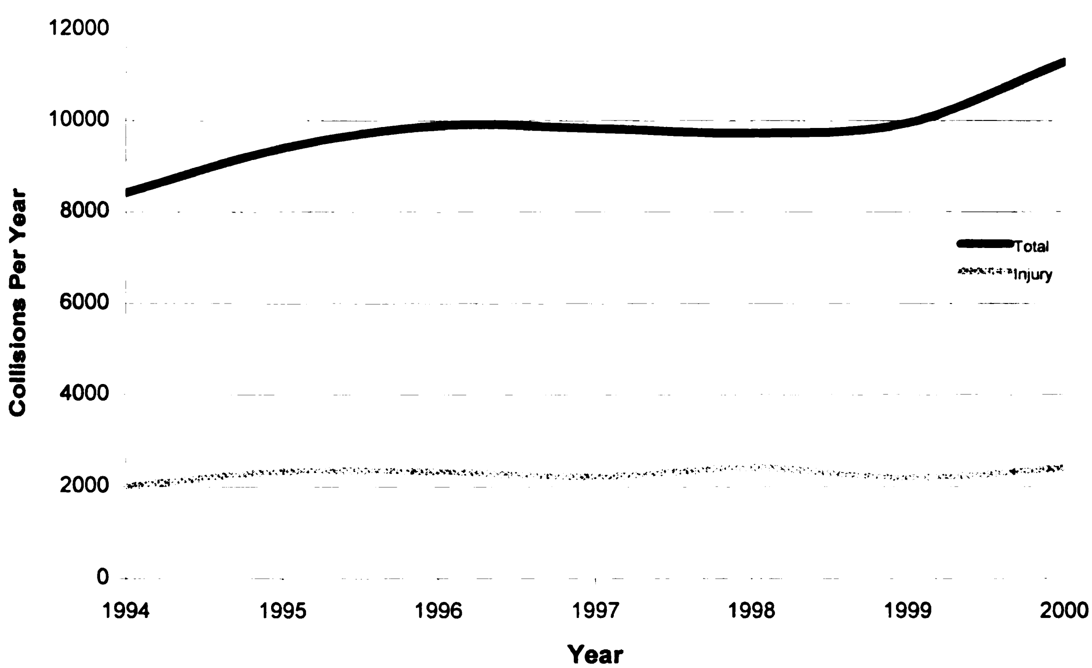


Figure 6.4 – Citywide Crash Trends for Grand Rapids



2000. During that time period, total collisions decreased at a rate of 1.5% per year while injuries decreased at 3% per year. The annual decrease is less than the decreases experienced sue to the improvements. In Grand Rapids, total collisions increased by 3.5% per year and injuries increased 2% per year. In Grand Rapids, the annual increases may indicate that the improvements may have had a larger effect.

SECTION 6.5 - ECONOMIC ANALYSIS

The safety improvements in Detroit and Grand Rapids have benefited society with safer roads and AAA Michigan with a positive impact to their loss reduction effort. Societal costs such as medical expenses, wage losses and vehicle damage have been significantly reduced as a result of the improvements. Each of those societal costs occurs as a result of traffic crashes.

The impact to AAA Michigan of the safety improvements has been positive. Improvements satisfied the minimum 2:1 benefit cost ratio criterion as described in Section 3.3. Costs associated with paying claims at the completed intersections are significantly smaller for AAA Michigan.

SECTION 7 – CONCLUSION

The AAA Road Improvement Demonstration Program (AAA RIDP) has satisfied its primary objective of reducing the frequency and severity of traffic crashes at high-risk urban signalized intersections. Traffic crashes and injuries have been significantly reduced at the completed intersections in both Detroit and Grand Rapids. Crash decreases varied among the three categories based on each intersection's potential for reduction. The AAA RIDP met its economic objective as the safety improvements have satisfied the minimum 2:1 benefit cost ratio.

These safety improvements are the result of cooperation and financial contributions by all of the public and private sector partners. The AAA RIDP has confirmed that when public and private sectors work together to provide safety improvements to high-risk urban signalized intersections that vehicle crashes and personal injuries could be prevented. Traffic safety in Detroit and Grand Rapids will continue to improve as safety improvements are applied on larger scales. These agencies are now routinely conducting safety studies and implementing safety countermeasures such as traffic signal visibility enhancements, left-turn lanes, left-turn phases and all-red intervals on their individual road projects.

This proactive approach to traffic safety has demonstrated the potential to greatly improve the safety and reduce the risk of collisions for all motorists in Detroit and Grand Rapids. The safety improvements have benefited society with safer roads and AAA Michigan with a positive impact to their loss reduction efforts. The AAA RIDP has confirmed that when public and private sectors work together to provide safety improvements to high-risk urban signalized intersections that vehicle crashes and personal injuries could be prevented.

APPENDIX A

SEVEN MILE AT RYAN ROAD

Figure A.1 – Seven Mile At Ryan Before Improvements

Figure A.2 – Seven Mile At Ryan After Improvements

Table A.1 - Before and After Collision Data for Seven Mile at Ryan Listed by Month

	Before												
Crash Type	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	12-Month Total
Rear-End	1	2	0	0	0	0	0	1	2	1	1	3	11
Angle (Intersection)	2	0	0	1	2	4	1	1	2	0	2	1	16
Left-Turn Head-On	3	6	0	0	1	4	2	3	1	2	1	1	24
Sideswipe-Same	1	0	0	1	2	0	4	4	1	0	0	0	13
Other	0	2	1	0	0	1	0	0	0	1	1	0	6
Total	7	10	1	2	5	9	7	9	6	4	5	5	70
Injury	3	4	0	1	1	3	2	3*	1	2	1	2	20

	Before												
Crash Type	Jan-96	Feb-96	Mar-96	Apr-96	May-96	Jun-96	Jul-96	Aug-96	Sep-96	Oct-96	Nov-96	Dec-96	12-Month Total
Rear-End	2	0	3	1	1	1	1	0	3	2	0	2	16
Angle (Intersection)	3	2	1	2	1	5	2	4	2	0	1	1	24
Left-Turn Head-On	1	0	0	1	2	5	1	3	3	1	1	2	20
Sideswipe-Same	1	0	1	1	0	1	0	1	4	2	1	0	12
Other	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	7	2	5	5	4	12	4	8	12	5	3	5	72
Injury	1	2	0	0	0	2	3	1	4	0	0	2	17

	Implementation					After							
Crash Type	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97	Aug-97	Sep-97	Oct-97	Nov-97	Dec-97	7-Month Total
Rear-End						0	0	0	2	1	2	0	5
Angle (Intersection)						2	0	1	1	1	0	0	5
Left-Turn Head-On						1	0	1	0	1	0	0	3
Sideswipe-Same						0	1	0	1	1	1	0	4
Other						1	0	0	1	2	0	1	5
Total						4	1	2	5	6	3	1	22
Injury						1	0	1	0	1	0	0	3

	After												
Crash Type	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	12-Month Total
Rear-End	0	0	1	0	2	0	0	1	1	1	1	0	7
Angle (Intersection)	0	0	0	0	1	0	0	0	0	0	1	0	2
Left-Turn Head-On	0	1	0	0	0	0	0	0	2	2	0	1	6
Sideswipe-Same	0	0	0	1	1	1	0	5	1	2	0	0	11
Other	1	0	1	2	0	1	0	2	0	0	0	0	7
Total	1	1	2	3	4	2	0	8	4	5	2	1	33
Injury	0	1	0	1	0	0	0	2	0	0	0	1	5

	After												
Crash Type	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99	12-Month Total
Rear-End	0	1	2	0	1	0	2	1	0	2	1	1	11
Angle (Intersection)	0	0	2	0	0	0	0	1	1	1	4	0	9
Left-Turn Head-On	0	0	0	0	0	0	0	0	0	1	0	0	1
Sideswipe-Same	3	0	1	0	3	1	0	1	0	2	0	0	11
Other	0	1	0	0	1	0	0	0	0	2	0	0	4
Total	3	2	5	0	5	1	2	3	1	8	5	1	36
Injury	0	1	2	0	2	0	0	0	0	1	0	0	6

	After												
Crash Type	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	12-Month Total
Rear-End	1	2	1	1	1	1	1	2	0	1	1	0	12
Angle (Intersection)	1	0	1	0	1	1	0	0	0	0	0	0	4
Left-Turn Head-On	0	0	1	0	0	0	0	0	1	0	0	0	2
Sideswipe-Same	0	0	0	1	0	0	0	0	0	0	2	0	3
Other	1	2	0	1	0	1	2	1	2	1	2	1	14
Total	3	4	3	3	2	3	3	3	3	2	5	1	35
Injury	2	0	1	1	0	0	0	1	0	2	1	0	8

	After												
Crash Type	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	12-Month Total
Rear-End	1	1	0	1	0	0	0	0	2	0	1	1	7
Angle (Intersection)	0	0	0	1	0	0	0	0	1	0	0	0	2
Left-Turn Head-On	0	0	0	0	0	0	0	0	0	0	0	0	0
Sideswipe-Same	1	0	1	0	0	1	0	0	3	0	0	0	6
Other	4	0	2	0	1	1	0	0	0	2	0	1	11
Total	6	1	3	2	1	2	0	0	6	2	1	2	26
Injury	0	0	0	0	0	0	0	0	0	1	0	0	1

APPENDIX B

WOODWARD AVENUE AT MILWAUKEE STREET

Figure B.1 – Woodward At Milwaukee Before Improvements

Figure B.2 – Woodward At Milwaukee After Improvements

Table B.1 - Before and After Collision Data for Woodward at Milwaukee Listed by Month

Crash Type	Before Period												
	Nov-96	Dec-96	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97	Aug-97	Sep-97	Oct-97	12-Month Total
Rear End	0	0	0	0	1	1	0	0	0	0	0	0	2
Angle (Intersection)	2	0	1	0	0	1	0	0	1	0	1	0	6
Sideswipe	1	0	0	0	1	0	0	1	1	0	1	1	6
Left-Turn Head-On	1	0	0	0	0	0	0	0	0	0	0	0	1
Other	0	1	0	1	0	1	0	1	0	2	0	0	6
Total	4	1	1	1	2	3	0	2	2	2	2	1	21
Injury	2	0	1	0	1	0	0	0	0	0	1	0	5

Crash Type	Before Period												
	Nov-97	Dec-97	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	12-Month Total
Rear End	0	0	0	0	0	0	0	0	0	0	0	0	0
Angle (Intersection)	1	0	2	1	1	2	6	2	3	0	0	0	18
Sideswipe	0	0	0	0	0	0	1	1	0	0	0	0	2
Left-Turn Head-On	0	0	0	0	0	0	0	1	0	0	0	0	1
Other	1	0	2	0	1	0	1	0	1	0	0	0	6
Total	2	0	4	1	2	2	8	4	4	0	0	0	27
Injury	0	0	2	0	1	1	2	1	2	0	0	0	9

Crash Type	After Period												
	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	12-Month Total
Rear End	0	0	1	0	0	0	0	1	0	1	1	0	4
Angle (Intersection)	0	0	1	0	0	0	0	0	0	0	0	0	1
Sideswipe	0	0	0	0	0	0	0	1	0	0	0	0	1
Left-Turn Head-On	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0	0	1	0	0	1
Total	0	0	2	0	0	0	0	2	0	2	1	0	7
Injury	0	0	1	0	0	0	0	1	0	0	1	0	3

Crash Type	After Period												
	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	12-Month Total
Rear End	1	0	0	0	0	0	0	0	0	0	0	0	1
Angle (Intersection)	0	0	0	0	0	0	0	0	0	0	0	0	0
Sideswipe	0	1	0	0	0	0	0	0	0	0	2	0	3
Left-Turn Head-On	0	0	0	0	0	0	0	0	0	0	0	0	0
Other	0	0	1	0	0	1	2	0	0	0	0	0	4
Total	1	1	1	0	0	1	2	0	0	0	2	0	8
Injury	1	0	0	0	0	0	0	0	0	0	0	0	1

Crash Type	After Period												
	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	2-Month Total
Rear End	0	0											0
Angle (Intersection)	0	0											0
Sideswipe	0	0											0
Left-Turn Head-On	0	0											0
Other	1	0											1
Total	1	0											1
Injury	0	0											0

APPENDIX C

BURTON STREET AT BRETON AVENUE

Figure C.1 – Burton at Breton Before Improvements

Figure C.2 – Burton at Breton After Improvements

Table C.1 - Before and After Collision Data for Burton at Breton listed by Month

Crash Type	Before Period												12-Month
	Jan-98	Feb-98	Mar-98	Apr-98	May-98	Jun-98	Jul-98	Aug-98	Sep-98	Oct-98	Nov-98	Dec-98	Total
Rear End	1	1	3	0	1	0	4	2	1	4	3	1	**21**
Angle (Intersection)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Left-Turn Head-On	2	0	0	1	1	0	2	0	1	1	2	2	**12**
Sideswipe	1	1	0	0	0	1	1	3	0	0	2	1	**10**
Other	0	0	0	3	0	2	0	0	0	1	0	1	**7**
Driveway Related	3	3	1	2	2	0	1	1	1	1	2	0	**17**
Total	8	5	4	6	4	3	8	6	3	7	9	5	**68**
Injury	0	1	0	2	0	1	1	1	1	2	1	0	**10**

Crash Type	Before Period												12-Month
	Jan-99	Feb-99	Mar-99	Apr-99	May-99	Jun-99	Jul-99	Aug-99	Sep-99	Oct-99	Nov-99	Dec-99	Total
Rear End	0	2	3	0	1	2	0	1	3	0	0	2	**14**
Angle (Intersection)	0	0	0	0	0	0	2	0	0	0	0	0	**2**
Left-Turn Head-On	2	0	1	2	1	0	1	0	0	0	0	0	**7**
Sideswipe	2	0	1	0	0	0	1	1	1	0	0	0	**6**
Other	0	0	0	1	4	0	0	1	2	2	1	0	**11**
Driveway Related	3	3	1	0	0	1	0	1	2	2	1	0	**14**
Total	7	5	6	3	6	3	4	4	8	4	2	2	**54**
Injury	1	1	2	0	0	0	1	0	1	2	0	0	**8**

Crash Type	Implementation			After Period									12-Month
	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Total
Rear End				0	3	3	1	4	2	1	4	2	**20**
Angle (Intersection)				0	0	0	0	0	0	0	0	0	**0**
Left-Turn Head-On				0	0	0	0	0	0	0	1	0	**1**
Sideswipe				0	0	0	0	2	0	1	1	3	**7**
Other				0	0	1	0	0	0	0	0	0	**1**
Driveway Related				0	0	1	1	0	2	1	3	1	**9**
Total				0	3	5	2	6	4	3	9	6	**38**
Injury				0	0	2	1	1	0	0	0	0	**4**

Crash Type	After Period												12-Month
	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01	Total
Rear End	3	0	2	1	0	0	1	1	2	0	1	3	**14**
Angle (Intersection)	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Left-Turn Head-On	0	0	0	1	0	0	1	1	0	0	0	0	**3**
Sideswipe	0	0	0	1	1	1	0	0	4	1	0	2	**10**
Other	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Driveway Related	3	1	1	1	2	0	1	0	1	2	2	0	**14**
Total	6	1	3	4	3	1	3	2	7	3	3	5	**41**
Injury	2	0	0	0	1	0	0	0	1	0	0	2	**6**

APPENDIX D

LOCATIONS OF ALL AAA RIDP INTERSECTIONS

Figure D.1 – Intersections where safety improvements have been planned and implemented in Detroit

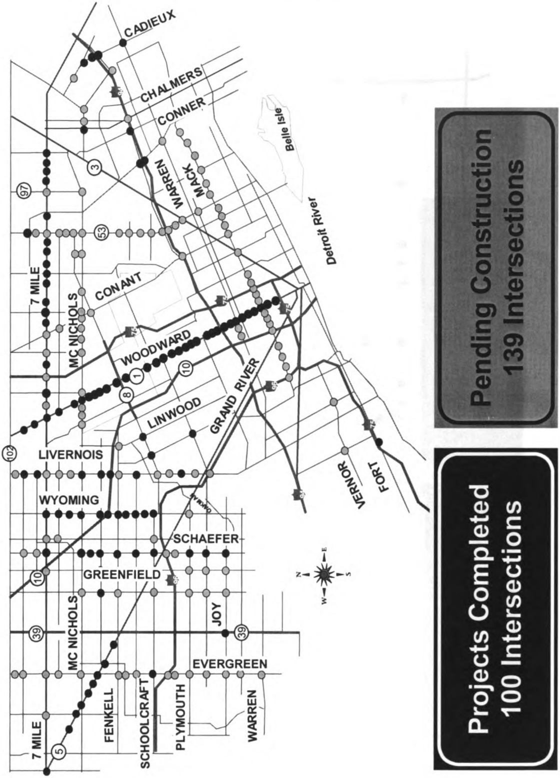
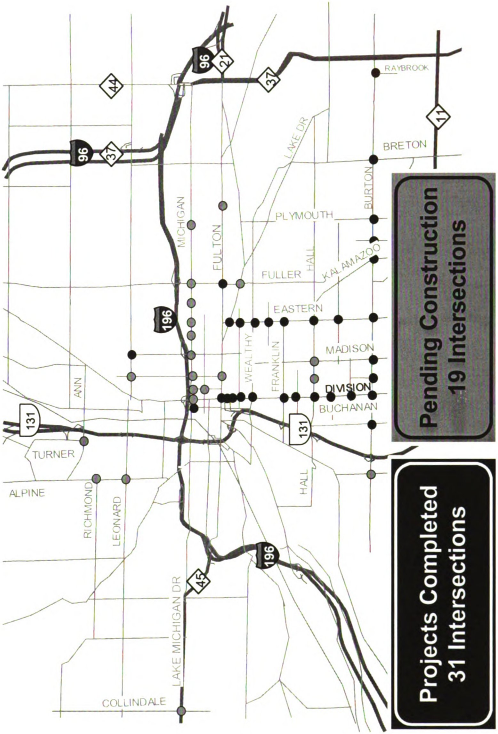


Figure D.2 – Intersections where safety improvements have been planned and implemented in Grand Rapids



APPENDIX E

BEFORE AND AFTER CRASH DATA

Table E.1 - Collision Data and Implemented Safety Countermeasures for the Detroit Intersections Completed in 1997

Intersection	Year Completed	12"	LTL	LTP	LL	AR	P	AO	ISP	Avg Annual Total Crashes Before	Avg Annual Total Crashes After	% Reduction	Avg Annual Total Injuries Before	Avg Annual Total Injuries After	% Change
1. Seven Mile at Ryan	1997	X	X	X	X	X				71.0	34.0	52%	18.5	5	73%
2. Seven Mile at John R	1997	X	X	X	X	X				56.0	29.0	48%	19.0	6	68%
3. Hubbell at Puritan	1997	X	X		X	X				36.0	14.0	61%	13.0	4	69%
									Total	163.0	77.0	53%	50.5	15.0	70%

Safety Countermeasures

12" - Upgraded traffic signals from 8" to 12" diameter lenses
LTL - Added exclusive left-turn lanes
LTP - Added permitted/protected left-turn phasing
LL - Added low level traffic signals
AR - Added an all red interval to the signal timing
P - Added pedestrian signals
AO - Added additional overhead traffic signals
ISP - Improved the traffic signal placement

Table E.2 - Collision Data and Implemented Safety Countermeasures for the Woodward Corridor

Intersection	Year Completed	12"	LTL	LTP	LL	AR	P	AO	ISP	Avg Annual Total Crashes Before	Avg Annual Total Crashes After	% Reduction	Avg Annual Total Injuries Before	Avg Annual Total Injuries After	% Change
1. Woodward at Alexandrine	1999	X				X	X	X	X	15	10	33%	2.5	1.4	44%
2. Woodward at Antionette/Medbury	1999	X				X	X	X	X	4	1	75%	1.0	0.5	50%
3. Woodward at Baltimore	1999	X				X	X	X	X	12	8	33%	4.0	1.8	55%
4. Woodward at Bethune	1999	X				X	X	X	X	7	8	-14%	2.0	2.3	-15%
5. Woodward at Buena Vista	1999	X			X	X	X	X	X	5	9	-70%	0.0	2.5	-
6. Woodward at Calvert/Trowbridge	1999	X				X	X	X	X	8	4	50%	1.0	0.0	100%
7. Woodward at Canfield	1999	X				X	X		X	15	9	40%	3.5	1.8	49%
8. Woodward at Charlotte	1999	X				X	X		X	6	3	50%	1.5	0.9	40%
9. Woodward at Chicago/Arden Park	1999	X				X	X	X	X	13	5	62%	*4.5*	*0.0*	*100%*
10. Woodward at Clairmont/Owen	1999	X				X	X		X	16	7	56%	6.0	1.0	83%
11. Woodward at Cortland	1999	X				X	X		X	1	2	-50%	0.0	0.0	-
12. Woodward at Euclid	1999	X				X	X	X	X	15	7	53%	*4.5*	*1.4*	*69%*
13. Woodward at Fansworth/Putnam	1999	X				X	X		X	14	12	14%	2.5	1.8	28%
14. Woodward at Forest	1999	X				X	X		X	30	21	30%	5.5	4.6	16%
15. Woodward at Gerald	1999	X				X			X	3	6	-100%	0.8	1.0	-25%
16. Woodward at Glendale/McLean	1999	X				X		X	X	16	23	-44%	4.7	6.0	-28%
17. Woodward at Hazelwood/Holbrook	1999	X				X	X	X	X	11	9	18%	2.5	2.8	-12%
18. Woodward at Kirby	1999	X				X			X	14	6	57%	*4.5*	*0.9*	*80%*
19. Woodward at Mack/MLK	1999	X				X			X	19	30	-58%	4.0	6.5	-63%
20. Woodward at Manchester	1999	X				X			X	39	18	54%	*13.9*	*6.0*	*57%*
21. Woodward at Milwaukee	1999	X				X	X	X	X	24	8	67%	*7.0*	*1.8*	*74%*
22. Woodward at Palmer	1999	X			X	X	X	X	X	14	10	29%	2.5	1.8	28%
23. Woodward at Parsons	1999	X				X			X	5	5	0%	0.5	1.8	-260%
24. Woodward at Pilgrim/Ferris	1999	X				X	X		X	11	10	9%	2.7	3.0	-11%
25. Woodward at Sears/Ford	1999	X				X	X		X	22	12	45%	7.3	4.0	45%
26. Woodward at Seward/Marston	1999	X				X	X	X	X	9	6	33%	3.0	1.4	53%
27. Woodward at Sibley/Adelaide	1999	X				X		X	X	1	2	-43%	0.0	0.9	-
28. Woodward at Stimson/Eliot	1999	X				X			X	2	2	0%	0.0	0.5	-
29. Woodward at Tuxedo/Tennyson	1999	X				X	X	X	X	2	3	-50%	1.3	0.0	100%
									Total	*354*	*256*	*28%*	*93*	*58*	*37%*

Safety Countermeasures

12" - Upgraded traffic signals from 8" to 12" diameter lenses
LTL - Added exclusive left-turn lanes
LTP - Added permitted/protected left-turn phasing
LL - Added low level traffic signals
AR - Added an all red interval to the signal timing
P - Added pedestrian signals
AO - Added additional overhead traffic signals
ISP - Improved the traffic signal placement

Table E.3 - Collision Data and Implemented Safety Countermeasures for the Completed Grand Rapids Intersections

	Intersection	Year Completed	12"	LTL	LTP	LL	AR	Avg Annual Total Crashes Before	Avg Annual Total Crashes After	% Reduction	Avg Annual Total Injuries Before	Avg Annual Total Injuries After	% Change
1.	Leonard at College	1998	X	X			X	*26*	*7*	*73%*	4	2	50%
2.	Michigan at Ottawa	1998		X			X	*23*	*46*	*-100%*	2	5	-150%
3.	Division at Franklin	1998	X		X		X	34	32	6%	11	7	36%
4.	Division at Hall	1998	X	X	X	X	X	43	27	37%	15	5	67%
5.	Division at Burton	1999	X	X	X		X	63	49	22%	14	7	50%
6.	Eastern at Hall	2000	X	X		X	X	21	13	38%	7	3	57%
7.	Eastern at Oakdale	2000	X	X		X	X	10	16	-60%	2	4	-100%
8.	Burton at Buchanan	2000	X		X	X	X	27	24	11%	6	6	0%
9.	Burton at Jefferson	2000	X			X	X	10	17	-70%	3	4	-33%
10.	Burton at Madison	2000	X	X	X	X	X	27	17	37%	12	3	75%
11.	Burton at Plymouth	2000	X	X	X	X	X	16	13	19%	5	2	60%
12.	Division at Cottage Grove	1999	X	X			X	16	12	25%	3	1	67%
13.	Burton at Breton	2000	X			X	X	*61*	*45*	26%	9	6	33%
14.	Burton at Kalamazoo	2000	X		X	X	X	33	26	21%	10	3	70%
15.	Burton at Raybrook	2000	X			X	X	*21*	*13*	*38%*	4	4	0%
16.	Burton at Sylvan	2000	X			X	X	9	9	0%	3	2	33%
17.	Division at Weston	1999	X				X	*16*	*8*	*50%*	2	1	50%
18.	Division at Oakes	1999	X				X	9	5	44%	3	0	100%
19.	Division at Wealthy	1999	X		X		X	41	28	32%	10	5	50%
20.	Division at Cherry	2000	X				X	11	14	-27%	2	3	-50%
21.	Division at Delaware	2000	X	X			X	8	3	63%	3	0	100%
22.	Eastern at Cherry	2001	X	X		X	X	*13*	*2*	*85%*	2	0	100%
23.	Eastern at Franklin	2001	X	X	X	X	X	28	17	39%	7	3	57%
24.	Eastern at Lake	2001	X	X	X	X	X	14	5	64%	2	1	50%
25.	Eastern at Sherman	2001	X	X		X	X	14	10	29%	2	3	-50%
26.	Eastern at Wealthy	2001	X	X	X	X	X	12	15	-25%	4	0	100%
							Total	606	473	22%	147	80	46%

Safety Countermeasures

12" - Upgraded traffic signals from 8" to 12" diameter lenses
LTL - Added exclusive left-turn lanes
LTP - Added permitted/protected left-turn phasing
LL - Added low level traffic signals
AR - Added an all red interval to the signal timing
P - Added pedestrian signals
AO - Added additional overhead traffic signals
ISP - Improved the traffic signal placement

APPENDIX F

ALL RED INTERVAL EQUATION

Clearance Interval = Yellow + All Red

Yellow = $t + v / (2a \pm 64.4g)$

> t = Driver perception reaction time, typically 1.0 second
>
> v = Approach speed, usually taken as the 85^{th} percentile speed.
>
> a = deceleration rate for stopping taken as 10 ft/s^2.
>
> g = percent of grade divided by 100.

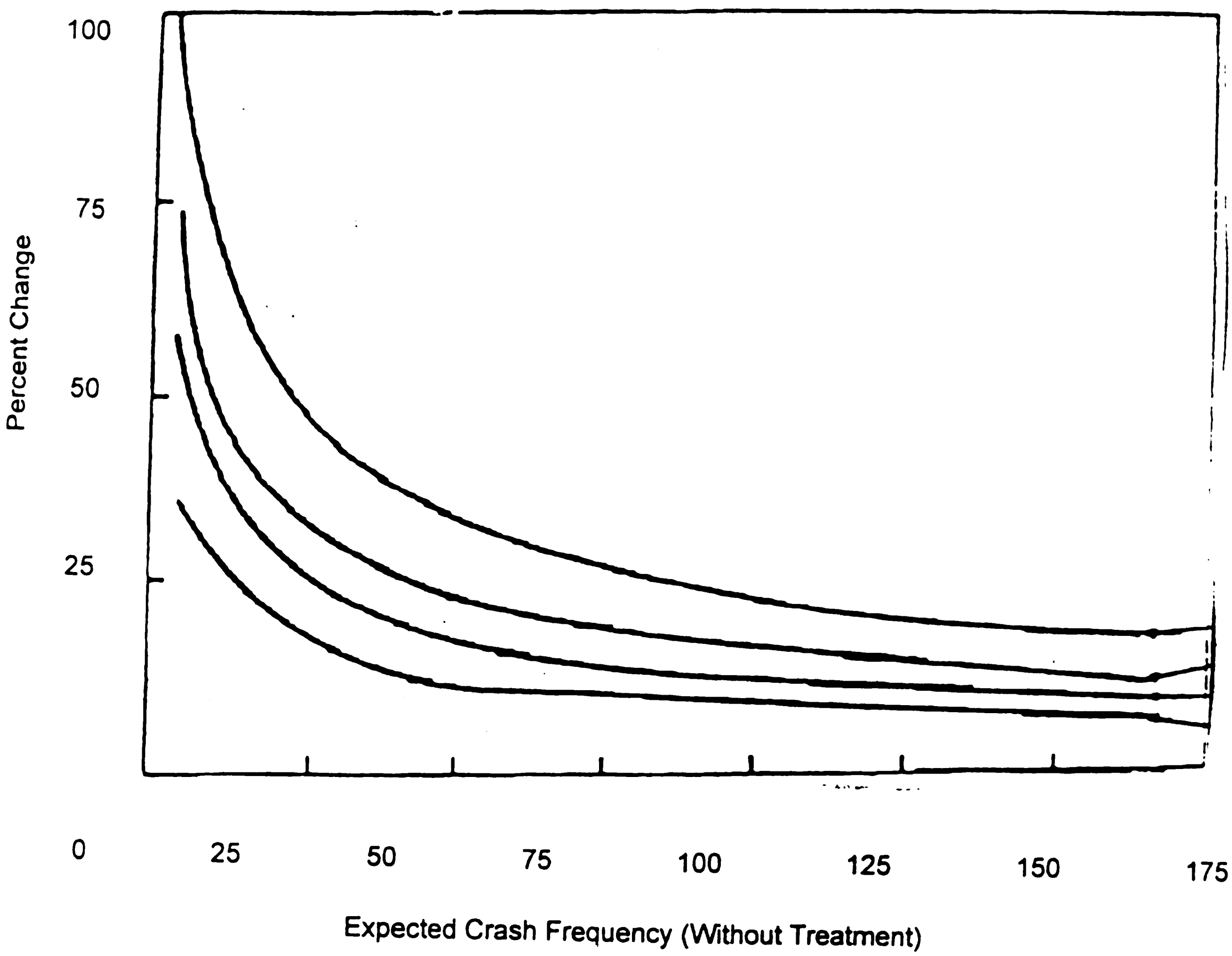
All Red = $(W + L) / v$

> W = Width of the intersection measured from the upstream stop bar to the downstream crosswalk.
>
> L = Length of a typical vehicle usually taken as 20 ft.

APPENDIX G

POISSON TEST

Figure G 1 – Poisson Distribution Curves (9)



BIBLIOGRAPHY

BIBLIOGRAPHY

1. Michigan Department of State Police, Office of Highway Safety Planning (2000) 2000 Traffic Crash Facts, Lansing, MI.

2. Feber, D.; Feldmeir, J.; and Crocker, K., (1999). The AAA Road Improvement Demonstration Program: An analysis of the effectiveness of using safety enhancements to help reduce societal and insurance costs, 79th Annual Meeting of the Transportation Research Board, January 9 to 13, 2000, Washington, D.C. (Paper No. 00-1432)

3. Johnson, M.; and Nepomuceno, J., (1996) Road Improvement Program – Road Safety Engineering Five Year Implementation Plan, 1997 to 2001, Insurance Corporation of British Columbia.

4. Sayed, T.; and de Leur, P., (2001). Program Evaluation Report: Road Improvement Program, Insurance Corporation of British Columbia.

5. Southeast Michigan Council of Governments (1997). SEMCOG Traffic Safety Manual Second Edition.

6. G.D. Hamilton Associates (1999). Burton Street Traffic Operations and Safety Review, Grand Rapids, Michigan.

7. Husch, D., J. Albeck (1999) Synchro 4.0 Users Guide, Trafficware, Albany, CA.

8. Transportation Research Board, National Research Council (1997) Highway Capacity Manual, Special Report 209.

9. FHWA (1981) Highway Safety Improvement Program (HSIP) User's Manual. FHWA-TS-81-218. National Highway Institute, Federal Highway Administration.

10. G.D. Hamilton Associates (1994). Economic Evaluation of Left-Turn Lanes as a Safety Improvement Strategy for the Insurance Corporation of British Columbia, Vancouver, British Columbia, Canada.

11. Fisher, J.E., (1998) Towards Uniform Left-Turn Guidelines, Table 1. Los Angeles, CA.

12. Creasey, T. and K. R. Agent (1985) Development of Accident Reduction Factors, Kentucky Highway Research Program, Research Report UKTRP-85-6. Lexington: University of Kentucky, March.

13. Wayne State University, Department of Civil and Environmental Engineering (1997) Traffic Crash Analysis and Safety Recommendations for the intersection of Seven Mile Road and Ryan Road, Detroit, MI.

14. G. D. Hamilton Associates (1998). Woodward Avenue Traffic Operations and Safety Review, Detroit and Highland Park, Michigan.

15. Datta, T.K., K. Schattler, S. Datta (1999) Red Light Violations and Crashes at Urban Intersections, Transportation Research Record 1734. (Paper No. 00-0480)