TECHNOLOGY TRANSFER ASSISTANCE PROGRAM
MISSOURI DEPARTMENT OF TRANSPORTATION

Manual on

Identification, Analysis and Correction of High-Crash Locations

(the HAL Manual)

Third Edition – 1999

Prepared by Department of Civil and Environmental Engineering
University of Missouri-Columbia

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Prepared for: Technology Transfer Assistance Program
Missouri Department of Transportation

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The first two editions of this manual used the term “High-Accident Locations” and have often been referred to as the HAL manual. This edition adopts the term “High-Crash Locations” to reflect a change in terminology over the past few years.

The First Edition was published in 1975 by the Midwest Research Institute. The work was sponsored by the Missouri State Highway Commission in cooperation with the Missouri Division of Highway Safety and the Federal Highway Administration, U. S. Department of Transportation. The First Edition was written by Jerry Graham and John Glennon.

The Second Edition (1990) was sponsored through the Technology Transfer Assistance Program (TTAP) under a project with the Civil Engineering Department, University of Missouri-Rolla. The project director was Charles E. Dare, Professor of Civil Engineering at UMR.

This Third Edition was also sponsored by TTAP through a project with the Civil and Environmental Engineering Department, University of Missouri-Columbia. The project directors were Profs. Mark R. Virkler and Kristen L. Sanford Bernhardt. Graduate student Mahdi Shehab and undergraduate students Victoria Goessling, Jarrett Groccia, and Barbara Lappin assisted in the effort.

Appreciation is extended to Mr. Frank Abart, Director, Boone County Public Works Department; Mr. Steve Ake, Central Missouri State University, Missouri Safety Center; Mr. Wally Campbell, MoDOT District 5; Dr. Charles Dare, MoDOT Traffic Division; Mr. Jim Radmacher, MoDOT Research, Development and Technology Division; Mr. Mark Schroyer, Federal Highway Administration – Missouri Division; Mr. Randy Silvey, Missouri Division of Highway Safety; and Mr. Brian Umfleet, MoDOT District 6; all of whom contributed to the revision of this manual.

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CHAPTER 1

INTRODUCTION TO THE HIGH-CRASH LOCATION (HAL*) SYSTEM

Well-planned and maintained streets and highways are vital to all communities. Deficiencies in the street and highway system contribute to injuries, death, lower productivity, and serious economic loss. Although not all crashes are due to faulty characteristics of the roadway, a concentration of crashes at one location implies that there may be a failure in the system. A detailed study of the community's records of traffic crashes is a good start in making roadways safer and more efficient. This type of study can identify high-crash locations, indicating where changes are needed in the system. With further analysis, improvements can be made to reduce the number and severity of future crashes.

The Missouri Department of Transportation (MoDOT) works with local agencies and law enforcement to improve the safety of streets and highways. MoDOT can offer valuable assistance and expertise in addressing problems with a community's roadways. The Technology Transfer Assistance Program (TTAP), for example, offers advice on design and construction. TTAP is run by the MoDOT Research, Development and Technology Division. Local agencies may also request assistance by contacting the District Liaison Engineer at the nearest MoDOT District Office. Addresses and phone numbers for MoDOT offices are listed in Appendix K.

A community's police department and engineering or public works department must work together to improve the safety of its streets. The police department furnishes the traffic crash data required for analysis to the city engineer and can notify the engineer of particular traffic safety issues. The engineer then is responsible for implementing and maintaining the high-crash location (HAL) analysis system. If the community does not have a city engineer, responsibility for maintaining the HAL system could be given to the chief of police, to the police officer in charge of traffic safety, or to the city public works director. From this point forward, the term "city engineer" will refer to the person in charge of the HAL system.

This manual describes several procedures used to study high-crash locations. Figure 1-1 presents an overview of the HAL system. The city engineer should read through the entire manual to determine how the system works. On the first reading, the procedures in each chapter can be scanned quickly. After the basic processes are generally understood, the chapters can be reviewed to learn the details of each procedure. Although this manual covers all basic processes needed to analyze and correct high-crash locations, it does not contain information concerning improvement design. For assistance with design improvements, contact MoDOT or refer to the Manual on

* Previous editions of this manual used HAL as an acronym for High-Accident Locations. This edition retains the acronym to designate High-Crash Locations.

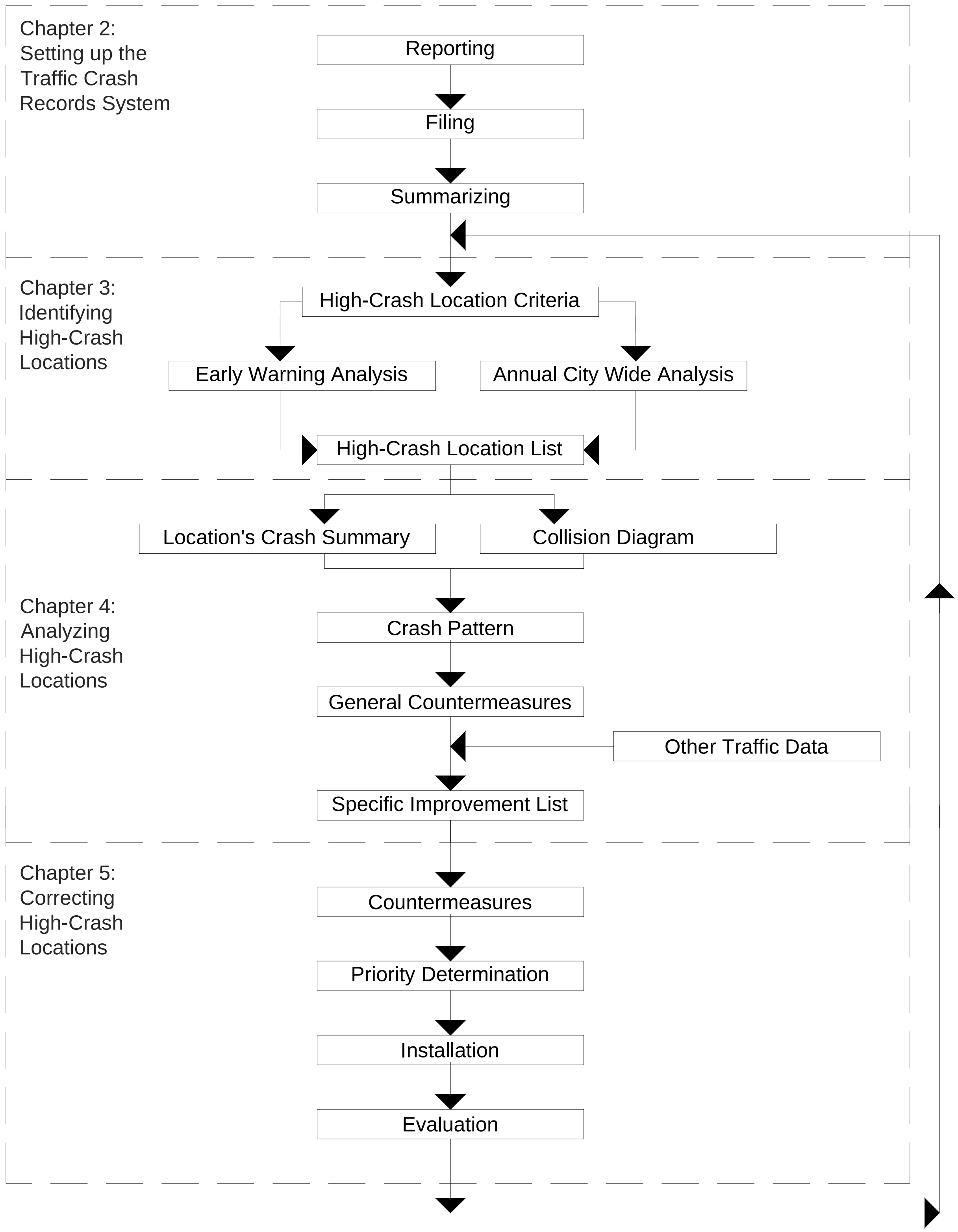

FIGURE 1-1: THE HIGH-CRASH LOCATION (HAL) ANALYSIS SYSTEM

Uniform Traffic Control Devices (MUTCD), the Traffic Control Devices Handbook (TCDH) or one of the other publications listed in the References section of this manual.

The manual contains worksheets to guide the user through the process of analyzing the high-crash locations in an area. The worksheets are intended for communities that do not have computer support. Spreadsheets, a computerized version of the worksheets, can offer more efficient analysis of high-crash locations for larger jurisdictions. MoDOT is considering means to make spreadsheet versions of the worksheets available to HAL users.

PURPOSE AND SCOPE OF THE HAL SYSTEM

The system described in this manual allows the user to identify, analyze, and correct high-crash locations. It was prepared for smaller communities in Missouri that do not necessarily have a traffic engineer, but do recognize the need to effectively deal with traffic crash problems at a local level. The HAL system is a continuing traffic safety program rather than a one-time “cure-all.” Instructions in each chapter guide city personnel through the establishment of procedures, implementation of the procedures, and the evaluation of the projects' results. Using this manual, city personnel should be able to implement a complete high-crash location analysis and improvement program.

BENEFITS AND COSTS OF THE HAL SYSTEM

The goal of reducing the number and severity of traffic crashes requires an investment of time and money on the part of the community. Although the cost of setting up the HAL system is negligible, the investment in time by the staff can become a concern since completing the analysis procedures often involves individuals such as the police chief and the city engineer. There are also, of course, many benefits to using the HAL system. The most significant benefit will be a reduction in the number and severity of traffic crashes. Table 1-1 presents cost estimates for different types of traffic crashes.

Crash Severity	Crash Cost ($)
Fatal Crash	3,390,000*
Injury Crash	44,100*
Property-Damage-Only	3,220
* A weighted average cost for combined fatal and injury crashes is recommended for application in economic analysis procedures - refer to Appendix H.	

TABLE 1-1: 1999 TRAFFIC CRASH COSTS

It is apparent from Table 1-1 that, in addition to lowering crash risks, substantial savings can be achieved by using an effective crash reduction program in a community. An example in Chapter 5 illustrates the benefits of installing safety improvements at a specific location.

Although police departments spend considerable time and money collecting and filing reports at crash scenes, the reports may not always be fully utilized. The HAL system puts those reports to the best possible use and provides easily accessible crash data. When crash data are well organized, the city's engineer (or an outside consultant) can concentrate on analyzing the causes of the crashes and developing the most effective countermeasures (improvements).

The HAL system described in this manual is a powerful traffic safety tool. The extent of benefits realized from a traffic safety improvement program will be determined by the strength of commitment by city officials and civic leaders.

ORGANIZATION OF THE MANUAL

This manual contains six chapters, with supporting information in the appendices.

Chapter 1: Introduction to the HAL System

The manual begins with a general overview of the HAL system, then explains the purpose of the worksheets and spreadsheets, and explains the benefits the system offers a community.

Chapter 2: Setting Up the Traffic Records System

This chapter describes the requirements for reporting, filing, and summarizing traffic crash data. It explains how to set up and maintain either a traditional filing system or a computerized version.

Chapter 3: Identifying High-Crash Locations

Chapter 3 discusses two methods for identifying locations with high numbers of traffic crashes. The Annual City-Wide Analysis is a year-long process of gathering and analyzing information. The worksheet shown in Figure 3-2 is filled out at the end of the year, listing the locations with the highest number of crashes. The Early-Warning Analysis is a way of identifying locations during the year which may need more immediate attention. Figure 3-3, an example of a file log of crashes for a particular location, is a part of the Early-Warning Analysis.

Chapter 4: Analyzing High-Crash Locations

Following identification of high-crash locations, as explained in Chapter 3, each location is analyzed to determine the probable causes of crashes and the appropriate countermeasures (or improvements). The principle aids used in this chapter are the Collision Diagram (Figure 4-1), the On-Site Observation Report (Figure 4-2), the Intersection Condition Diagram (Figure 4-3), the Location Analysis Worksheet (Figure 4-4), and the General Countermeasures Table (Table B-1).

This chapter gives step-by-step instructions for filling out the worksheets/spreadsheets needed to complete the analysis.

Chapter 5: Correcting High-Crash Locations

The locations analyzed in Chapter 4 are ranked using the best countermeasure, or set of countermeasures, for each location. The best set of countermeasures for a particular location is determined by the highest average annual benefit. The technique recommended for ranking improvements at different sites is the Benefit/Cost Ratio. This chapter also discusses the implementation and evaluation of improvements. The worksheets used are shown in Figure 5-1 and Figure 5-2.

Chapter 6: Evaluating the HAL Program

The entire HAL program can be evaluated using the worksheets shown in Figure 6-1 and Figure 6-2. The importance of the program to the community is also discussed.

Glossary

Terms which may be unfamiliar to the user of this manual are defined.

References

Publications and studies used or cited in the chapters are listed.

Appendix A: Non-Crash-Based Procedures

This appendix establishes a method for responding to citizens' complaints and suggestions and for making improvements before a location becomes a high-crash location. A procedure for conducting Safety Audits is also presented.

Appendix B: Probable Causes for Crash Patterns and General Countermeasures

Table B-1 lists crash patterns, their probable causes, and suggested improvements to sites.

Appendix C: Collection of Traffic Data

Appendix C explains the traffic studies necessary for completing location analysis. These include intersection volume studies with Average Daily Traffic estimates, spot speed studies (e.g., to help set speed limits), intersection sight distance studies, and traffic conflict studies.

Appendix D: General Guidelines for Several Traffic Safety Improvements

This appendix suggests guidelines for implementing many common traffic safety improvements.

Appendix E: Estimated Improvement Project Costs – 1999

Appendix E lists a sample of possible costs for various improvements. Appendix H discusses how to make adjustments in prices over time. Since prices for materials and labor vary from place to place, it may be advisable to consult with contractors and suppliers in a particular area for pricing.

Appendix F: Estimated Improvement Project Service Life

Various improvements are listed, with an estimate of how long the improvement will be of benefit to the location.

Appendix G: Estimated Crash Reduction Factors

Crash Reduction Factors are listed in table form according to the countermeasure category and crash reduction factor group. The factors are estimated based on safety project evaluations from across the United States.

Appendix H: Economic Analysis

This appendix discusses the costs involved in crashes and improvements and how these costs change over time.

Appendix I: HAL System Worksheets

Appendix I contains all worksheets illustrated in the figures in the HAL Manual. These figures may be photocopied as needed. MoDOT is considering means to make spreadsheet versions of the worksheets available to HAL users.

Appendix J: Crash Data Support Services and Programs

This appendix identifies traffic crash data support services currently available to Missouri communities.

Appendix K: Some Useful MoDOT Addresses

Appendix K provides information on how to contact the agencies/offices mentioned in the HAL Manual.

CHAPTER 2

SETTING UP THE TRAFFIC RECORDS SYSTEM

In setting up the HAL system, it is important that the crash data be as complete, accurate, and consistent as possible. For example, if more than one name is used to identify a street, crash records could be filed in more than one location, and some high-crash locations may not be identified. This chapter provides guidelines for reporting, filing, and summarizing crash data. Supplementary information on non-crash-based procedures appears in Appendix A.

REPORTING FORMS

For consistency in reporting, it is important to use the same form for all crash reports. An instruction manual entitled "Missouri Uniform Accident Report Preparation Manual" is available from the Missouri State Highway Patrol. The 3-page Uniform Accident Report Form is shown in Figure 2-1. The highway patrol provides this form in a carbon format to any agency assisting the patrol in data collection. The reporting agency (usually the police department) keeps the page labeled "ORIGINAL" and sends a copy labeled "STATE" back to the highway patrol.

Some Missouri law enforcement agencies use a six-page version of the same form, on 5½" x 8½" sheets, to record the crash information at the scene. That information is later (a) manually transferred to the 3-page form on 8½" x 11" sheets or (b) entered into the computer (leading to a printout of the 3-page form). If a computer printout is made, the highway patrol receives a printed copy rather than a carbon.

No matter what technology is used to record the information, the form provides all the information necessary to do a complete analysis of a community's streets if it is filled out completely and consistently.

CLASSIFICATION OF CRASHES

Although it is not always evident, crashes often result from the same set of circumstances. Classification of crash data will enable the city engineer to analyze crashes by their similarities and to discover some possible solutions. Traffic crashes can be grouped according to type, severity, or location. (More information on crash classification is provided in the "Manual on Classification of Motor Vehicle Traffic Accidents" published by the National Safety Council – see the list of references).

FIGURE 2-1: MISSOURI UNIFORM ACCIDENT REPORT - PAGE 1

FIGURE 2-1: MISSOURI UNIFORM ACCIDENT REPORT - PAGE 2

FIGURE 2-1: MISSOURI UNIFORM ACCIDENT REPORT - PAGE 3

Type

The type of crash is based on its characteristics. Some crashes involve both a vehicle and a person, an object, or another vehicle (collision), while other crashes only involve a single vehicle (non-collision). Collision crashes involve a collision between a motor vehicle in motion, in readiness for motion, or parked on a roadway (other than in a parking area) and one of the following:

- a pedestrian,
- another motor vehicle in motion,
- a motor vehicle on another roadway,
- a parked motor vehicle,
- a railway train,
- a cyclist,
- an animal,
- a fixed object, or
- other objects.

Non-collision crashes involve a motor vehicle in motion and an incident such as:

- overturning, or
- other non-collision.

Severity

The severity of crashes can be classified in several ways. However, the three most common categories are:

- Fatal: One or more persons are killed. The crash may also involve one or more injured persons and/or property damage.
- Injury: One or more persons are injured. There are no fatalities, but property damage is possible.
- Property Damage Only: Vehicle(s) and/or objects involved are damaged. However, there are no fatalities or injuries.

Location

A crash may also be classified by the intersection, block address, or grid coordinates at which it occurred. In this manual, a crash location will be classified according to "intersection" or "mid-block" categories.

REPORTING TRAFFIC CRASHES

The police department must monitor traffic crash reports for clarity and accuracy, not only for HAL manual purposes, but also for its own benefit. Problems with reports often stem from how the location is specified, how the crash diagram is drawn and described, or how the incident is described. Sometimes the issue is when to file reports on traffic crashes. When monitoring reports, check the following:

- Location
    - ✓ Is the crash location specified to within 50 feet?
    - ✓ If a road is a numbered highway and also has a street name, are the number and name both shown? (Example: MO 1 – Salem Ave.)
    - ✓ If a road has been renamed or goes by different names, is one name used consistently throughout all reports?
- Collision Diagram
    - ✓ Are directions of travel shown for all involved vehicles?
    - ✓ Are the necessary measurements shown in the diagram? Are they reported with enough accuracy to locate the point of impact in a follow-up study?
    - ✓ Is the location of the crash shown with reference to an intersection or other known landmark?
    - ✓ Is the north direction indicated?
- Officer's Statement
    - ✓ Is the writing legible?
    - ✓ Does the statement clearly explain what happened?
    - ✓ Does the statement fully identify the relationship of the crash to a nearby intersection? (Example: Instead of saying "Vehicle No. 1 was struck in the rear while stopped in traffic", the statement should say "Vehicle No. 1 was struck in the rear while stopped in traffic extending from the signal at 5th St.")
- Extent of the Crash
    - ✓ Does the severity or situation of the crash indicate a report should be filed? (Missouri statutes require that a report be filed for a vehicle crash resulting in injury or death of a person, or total property damage to an apparent extent of $500 or more to one person. Some city police departments file a report for any traffic crash their officers investigate. Other departments keep a separate file for crashes reported on private property. The important thing is to have a clear standard that is followed consistently.)

After checking a sample of reports, recommend any needed changes in the reporting practices. The officer in charge of crash investigations should review and implement these changes, eliminate any possible misunderstandings, set up consistent reporting standards, and make those standards clear to all investigating officers.

FILING THE TRAFFIC CRASH REPORT

Usually, the responsibility of filing reports for traffic crashes rests with the police department. However, in some medium to large communities, the engineering department does the filing. Wherever the responsibility resides, it is important that a plan exists for handling the reports so they are not lost or misfiled.

Reports of traffic crashes can be filed either manually or electronically. The first steps of the recommended filing procedure are essentially the same, whether or not a computer is used. They are as follows:

1. Log the report into a chronological list of reports received. The list should include information such as the names of the drivers involved, the location of the crash, the severity of the crash, and whether or not a summons was issued.
2. Check the report for completeness and accuracy. (See the previous section, “REPORTING TRAFFIC CRASHES”) Any contradictions, vagueness, or omissions must be clarified by reviewing the report with the investigating officer as soon as possible.
3. Plot the location of each crash on a spot map.
4. File the report labeled “ORIGINAL” in a crash location file or enter the information into a computerized record system.

Organizing Files Manually

If a small community experiences less than 200 traffic crashes per year, manually organizing and summarizing report data is usually sufficient. Setting up the location file with one year’s crash reports will normally take about three days (for communities with less than 1,000 traffic crashes per year). Once that is done, the filing should require less than one day per month by a clerk, secretary, or engineering-aide, with some assistance provided by the city engineer to classify the crashes as intersection-related or mid-block. The materials needed for setting up the file include a small file cabinet, left tab 1/3-cut guide cards, and center tab and right tab 1/3-cut file folders. The location file should initially hold a complete year of crash data. Later the file can be expanded to contain three years of data.

In a location file, reports are first identified as intersection or mid-block by the “intersection-related” method. This method does not classify crashes by the location, per se, but by the direct relationship of the crash to the location. For instance, if one vehicle rear-ends another vehicle at the end of a long line of traffic waiting at a signalized intersection, the crash is considered intersection-related and is filed with other reports of crashes occurring at this intersection. However, if a car pulls into traffic from a parking stall close to a corner and is sideswiped by a car coming from its rear, the crash is classified as a mid-block crash because it had nothing to do with the intersection.

If the crash is intersection-related, determine which street to use as the primary index by using the following ranking of route designations:

1. Interstate routes
2. U.S. routes
3. Missouri routes
4. County routes
5. Named municipal streets in alphabetical order
6. Numbered municipal streets in numerical order

If a numbered route and a municipal street intersect, file the reports by the highest category of route designation (e.g., the intersection of U.S. 69 and Ohio Street uses U.S. 69 as the primary index). If possible, include any alternate name on the index tab [e.g., U.S. 69 (VIVION ROAD)]. An example of filing a report for an intersection of two municipal streets is shown in Figure 2-2. A left-tab guide card is labeled with “MAIN STREET” (primary index) and a right-tab file folder is labeled with “Wilson Street” (secondary index). Note that the primary index is typed with all capital letters.

If the crash is not intersection-related, it is considered a mid-block crash. Use the street name or route number as the primary index and the block number as the secondary index. When the location file is first established, place each report in a center-tab file folder immediately behind the appropriate primary index card. When the number of reports in a file reaches 10, divide the street into sections according to crash concentrations. Write designations in pencil until the entire year’s reports are filed, then finalize the file label by typing block numbers on the tabs (Figure 2-3). (The number of blocks in a secondary index could be as short as one block or as long as the entire street.) These same sections are used for the following year’s file.

For both intersection-related and mid-block crashes, there are some general rules that should be observed to make retrieving the data easier:

- As the crash reports are filed, keep the most recent report at the front of each folder.

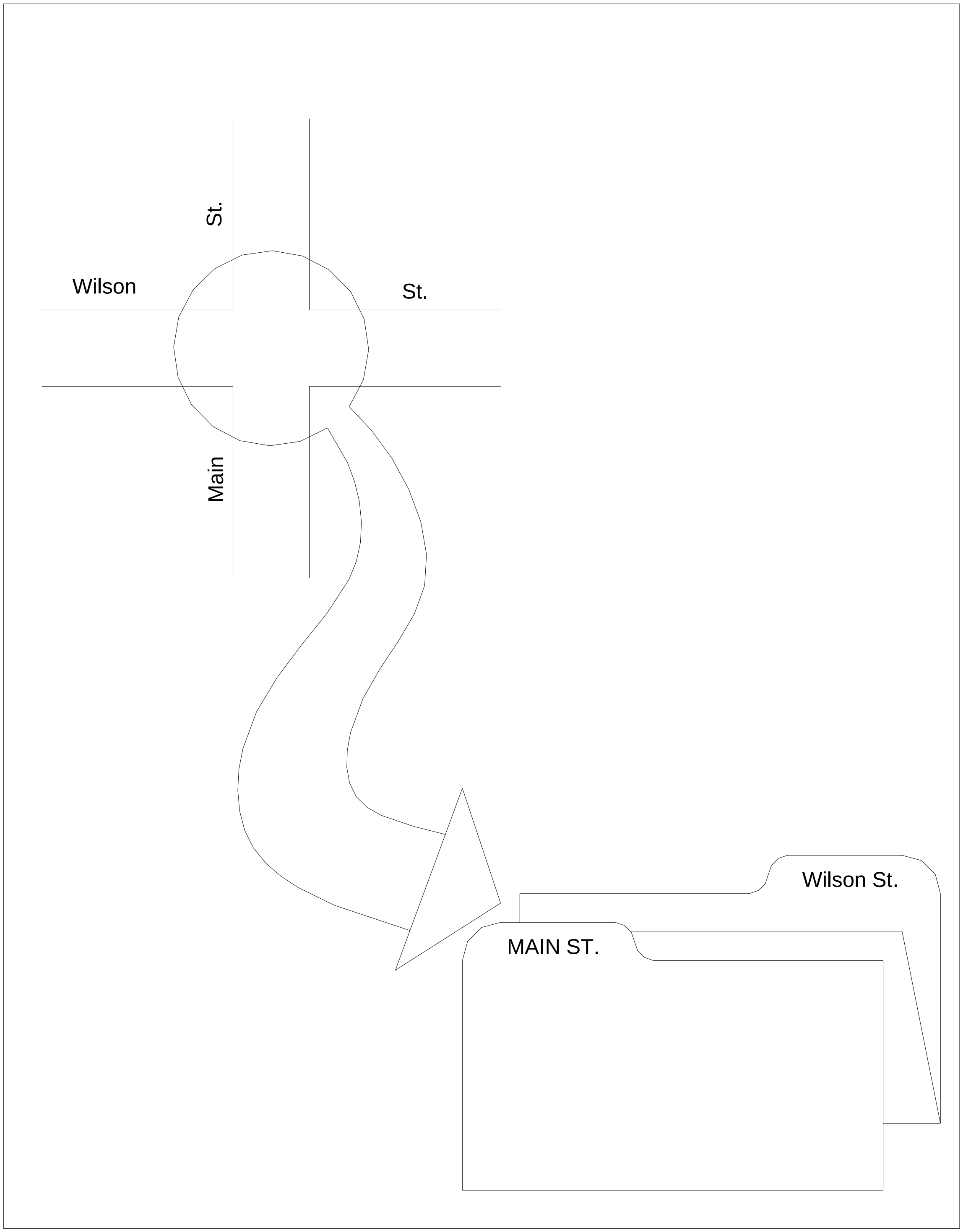

FIGURE 2-2: FILING AN INTERSECTION-RELATED CRASH REPORT

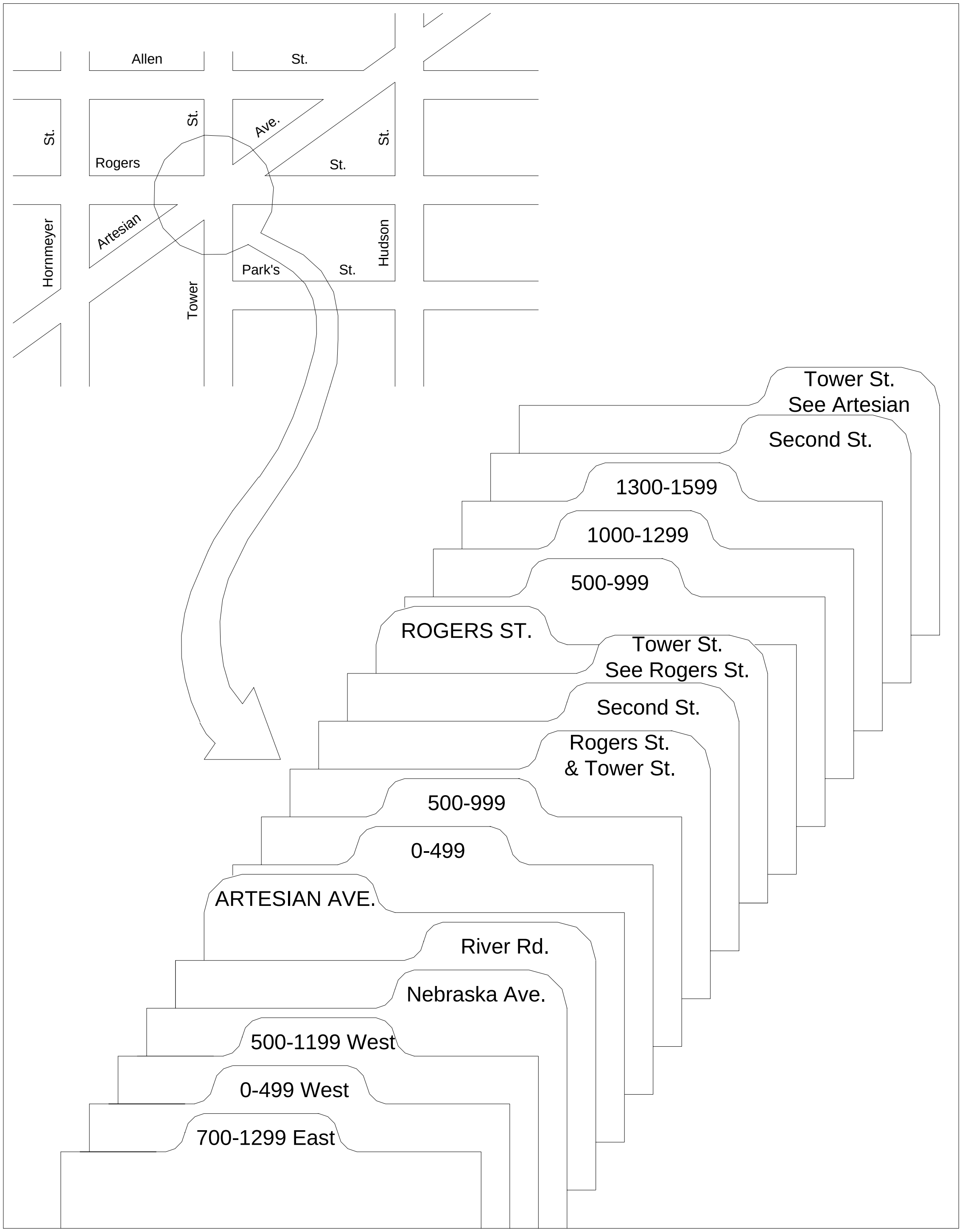

FIGURE 2-3: FILING REPORTS FROM AN INTERSECTION WITH THREE NAMES

- To save unnecessary work, type labels for primary and secondary indexes only as they are needed for filing purposes. Keep all reports of crashes at the same intersection in one file folder. Use a separate folder for each individual intersection.
- Filing errors can occur due to peculiarities in a city's road pattern. To avoid these situations, warning cards should be placed in the incorrect file folders, directing the user to the correct folder. Some examples of these situations include:
    - an intersection of three streets (Figure 2-3). In this case, all reports should have **"ARTESIAN AVE."** as the primary index and **"Rogers St. at Tower St."** as the secondary index. However, reports may be misfiled under "ARTESIAN AVE. / Rogers St.", "ARTESIAN AVE. / Tower St.", or "ROGERS ST. / Tower St."
    - an intersection where one or more of the streets have two names. The intersection of MO 1 (Antioch Road) and U.S. 69 (Vivion Road) should be filed with **"U.S. 69 (VIVION RD.)"** as the primary index and **"MO 1 (Antioch Rd.)"** as the secondary index. Errors in filing are "MO 1 / Vivion Rd.", "U.S. 69 / Antioch Rd.", and "ANTIOCH RD./ Vivion Rd."
    - two streets intersecting more than once (Figure 2-4). To avoid filing reports from both intersections same folder, one secondary folder should be labeled "Oak St. (North)" and the other should be labeled "Oak St. (South)."

Organizing Computerized Files

For medium to larger communities, it may be easier to enter crash data into a computer than to sort through paper files. Automated traffic crash data support services (including programs like MOTIS, described in Appendix J) can perform the necessary steps to create a crash location file. To set up the crash location files, follow the same general guidelines given for setting up a manual file system. The following steps, though, are specific to computerized filing:

1. For each street, create a directory (or folder) named for the street. (This corresponds to the left tab file folder in the manual system.)
2. In each directory, create separate spreadsheet files for each block of road and each intersection. (This step is similar to what is done with the middle sections of manual files, which contain most of the information.)
3. Each spreadsheet file will contain worksheets with all of the information needed for each block or intersection. The worksheets can be used to analyze either blocks or intersections.

CHAPTER 3

IDENTIFYING HIGH-CRASH LOCATIONS

Each community has a limited amount of time and money available to spend on roadway improvement. Thus, it becomes necessary to concentrate on the locations that will see the most significant improvement per dollar spent. This chapter describes the process for identifying these high-crash locations.

An orderly approach to studying crashes greatly improves the odds for bringing about a reduction in both number of crashes and their severity. The Annual City-Wide Analysis and Early Warning Analysis procedures described in this chapter are systematic step-by-step methods for identifying high-crash locations. Prior to discussing these procedures, the various ways of defining a high-crash location are described directly below.

HIGH-CRASH LOCATION CRITERIA

A high-crash location may be identified using one or more of the standard measures of crashes shown in Figure 3-1.

Number of Crashes
Crash Severity
Crash Rate
Number-Rate
Severity-Rate
Number-Quality-Control
Rate-Quality-Control

FIGURE 3-1: MEASURES OF CRASH EXPERIENCE

Measures of Crash Experience

Number of Crashes

The number of crashes is the basic measure of crash experience. According to this criterion, a location is usually considered to be in the high-crash category if ten or more crashes occur in a given year. This number may be adjusted, depending on changes in local crash experience. It is important to choose a number that is high enough to provide a reasonable number of locations to analyze, but low enough to include all locations in obvious need of improvement. The number of crashes, however, should not be the only criterion used to identify high-crash locations.

Crash Severity

The crash severity measure gives greater importance to fatal and injury crashes than to property-damage-only (PDO) crashes. For instance, the local policy may be to count each fatal or injury crash as six (6) PDO crashes. This would give a location with 1 fatal crash, 2 injury crashes, and 9 PDO crashes an equivalent-property-damage-only (EPDO) number of 27, as shown below:

Fatal:	1	x	6	=	6
Injury:	2	x	6	=	12
PDO:	9	x	1	=	9
EPDO Number:					27

Crash Rate

The crash rate is the number of crashes divided by the level of vehicular exposure at a given location. In other words, it accounts for the opportunity for crashes to happen. The crash rate is expressed in terms of the annual number of crashes per million vehicles entering the location (for an intersection) or the annual number of crashes per 100 million vehicle miles (for a mid-block section). A location is classified as a high-crash location if it has a crash rate higher than a predetermined level.

Number-Rate

The number-rate measure combines the number of crashes and the crash rate. This eliminates the weaknesses of the individual measures. The number of crashes taken alone as a criterion does not account for the exposure of vehicles to potential crashes. The crash rate measure does account for vehicle exposure, but it might also identify a low-volume location as a high-crash location by using an unreliably low number of crashes. A combination number-rate measure establishes both a minimum number of crashes and a minimum crash rate for identifying high-crash locations.

Severity-Rate

The severity-rate measure, often considered the most meaningful, combines the crash severity and the crash rate. This measure has the same advantages as the number-rate measure, but it also gives more importance to fatal and injury crashes than to PDO crashes. This measure, also called the EPDO rate, is calculated by dividing the EPDO number by the vehicle exposure at that location.

Number-Quality-Control & Rate-Quality-Control

The quality-control measures are used to compare a location's crash experience to a local or statewide average. Statistical tests make it possible to determine if a specific number of crashes or rate of crashes is significantly above the average value. These tests help rule out locations having somewhat high rates or numbers due to chance.

Using the High-Crash Location Criteria

The number of high-crash locations identified within a community depends on the values of the criteria that are applied. From a practical viewpoint, the high-crash criteria should be established so that a reasonable number of locations is selected for further study and potential improvement each year. Depending on community size and available resources, between five and 40 high-crash locations should be identified annually.

An initial analysis for each location should be performed using the number of crashes and crash rate measures. Those locations with the highest concentrations of crashes are then further evaluated by applying the EPDO number and EPDO rate measures. For most Missouri cities, both the number-rate and the severity-rate measures are recommended for use in the final selection of the high-crash locations to be considered for improvements.

ANNUAL CITY-WIDE ANALYSIS

The Annual City-Wide Analysis is a procedure that uses one, two, or three years of crash data to identify high-crash locations. All locations except state highways and private properties should be considered. The only locations that can be temporarily ignored are those already identified during the year as high-crash locations by the Early Warning System described in the next section. The worksheets used to complete the Annual City-Wide Analysis are described below:

Traffic Crash Summary Sheet (Figure 2-5)

This summary (Figure 2-5, described in Chapter 2) will reveal the most common types of intersection and mid-block crashes which have occurred in the jurisdiction over a period from one to three years.

High-Crash Location Identification Worksheet (Figure 3-2)

This worksheet identifies the high-crash locations (i.e. those with the highest EPDO numbers and EPDO rates) from the locations with the highest number of crashes. An explanation of the worksheet follows. Equations for the calculations are provided at the bottom of the worksheet.

1. Identify whether the worksheet is being used for intersections or mid-block sections. Do not mix entries. Use separate worksheets for each type of location.
2. Fill in the date and the initials of the person evaluating the locations.
3. Enter the locations of all intersections with three or more crashes in the past year and all mid-block sections with five or more crashes in the past year. It may be necessary to adjust the number of crashes used as a threshold, depending on the level of crash experience in the community from year to year.
4. For each location, enter the section length (for mid-block sections), year, number of fatal, injury, and PDO crashes, and the average daily traffic (ADT). If using the spreadsheet, skip to step 9.
5. Calculate the total number of crashes, EPDO number, exposure, crash rate, and EPDO rate.
6. If crash records are available for one or two years prior to the analysis year, repeat steps 3 & 4. Also indicate in the last two columns whether the given locations were identified as high-crash locations in those prior years.
7. Calculate the total fatal, injury, and PDO crashes, and the total of all crashes for each location.
8. 2 or 3 year averages: If crash records are available for one or two years prior to the analysis year, compute the average number of each type of crash and the

average ADT. Using these numbers, calculate the EPDO numbers, exposures, crash rates and EPDO rates as in step 4.

9. Identify the high-crash locations by reviewing all intersections and all mid-block sections on the analysis worksheets. Those locations having the highest EPDO number and EPDO rate should be chosen for further countermeasure evaluation. If more than one year of data is available, use the 2 or 3 year averages of the EPDO number and EPDO rate to qualify the location as high-crash. Indicate in the last two columns whether the given locations have been identified as high-crash locations or not. It also may be helpful to identify a location by either putting a tab on its file folder or flagging the computer file.

EARLY-WARNING ANALYSIS

The Early-Warning Analysis is a procedure that continuously monitors where crashes are occurring. This makes it easier to see which locations need immediate attention. The procedure identifies locations with an unusually high short-term number of crashes in either a three- or six-month period. These numbers are reviewed each time a report is filed.

The analysis is initiated after the location file has a complete year of crash reports and the high-crash locations have been identified. Then, as the second year's crash reports are added to the location file, the Early-Warning Analysis can begin.

If filing is done manually, the Early-Warning Analysis should be initiated as follows:

1. Each time a crash report is placed in a location file, add it to the Crash Location - File Log as shown in Figure 3-3. This log is a chronological listing of crashes at the location for the current calendar year. It should be securely attached to the front of the file folder. The log is a permanent record of crash experience at a location and assures reports are not missing from the folder.
2. When a report is added to a file log, check for high-crash locations by reviewing the most recent three- or six-month periods. Flag the location as a high-crash location by marking the file folder with a tab if any of the following criteria are met:

HIGH - CRASH LOCATION IDENTIFICATION WORKSHEET												[Form HCLIW]	
Intersection: *X*		Mid-Block Section:				Date:	*Jan. 12, 1999*			Evaluated by:		*JSJ*	
Location	Section Length (in miles) *mid-block only*	Year	Number of Crashes				EPDO Number*	ADT	Exposure	Crash Rate	EPDO Rate	High Crash Location	
			Fatal	Injury	PDO	Total						No	Yes
Pine		*1998*			*3*	*3*	*3*	*7,500*	*2,737,500*	*1.096*	*1.096*		
and		*1997*	*1*		*3*	*4*	*9*	*7,400*	*2,701,000*	*1.481*	*3.332*	*X*	
Second													
TOTALS			*1*	*0*	*6*	*7*							
2 OR 3 YR. AVG.			*0.50*	*0.00*	*3.00*	*3.50*	*6*	*7,450*	*2,719,250*	*1.287*	*2.206*	*X*	
Cedar		*1998*			*3*	*3*	*3*	*2,150*	*784,750*	*3.823*	*3.823*	*X*	
and													
Second													
TOTALS			*0*	*0*	*3*	*3*							
2 OR 3 YR. AVG.													
Elm		*1998*			*4*	*4*	*4*	*9,670*	*3,529,550*	*1.133*	*1.133*	*X*	
and													
Third													
TOTALS			*0*	*0*	*4*	*4*							
2 OR 3 YR. AVG.													
Adams		*1998*			*6*	*6*	*6*	*9,050*	*3,303,250*	*1.816*	*1.816*	*X*	
and													
Third													
TOTALS			*0*	*0*	*6*	*6*							
2 OR 3 YR. AVG.													
Lincoln		*1998*		*1*	*7*	*8*	*13*	*3,600*	*1,314,000*	*6.088*	*9.893*		
and		*1997*	*1*	*1*	*4*	*6*	*16*	*3,550*	*1,295,750*	*4.631*	*12.348*		*X*
Third		*1996*		*1*	*3*	*4*	*9*	*3,400*	*1,241,000*	*3.223*	*7.252*		*X*
TOTALS			*1*	*3*	*14*	*18*							
2 OR 3 YR. AVG.			*0.33*	*1.00*	*4.67*	*6.00*	*12.67*	*3,517*	*1,283,583*	*4.674*	*9.868*		*X*
Truman		*1998*		*3*	*6*	*9*	*24*	*7,500*	*2,737,500*	*3.288*	*8.767*		*X*
and													
Second													
TOTALS			*0*	*3*	*6*	*9*							
2 OR 3 YR. AVG.													

* EPDO Number = 6 x (Fatal + Injury) + PDO

INTERSECTIONS:

ADT = sum of one-way counts of all streets entering intersection

Exposure = ADT x 365

Crash Rate = (number of crashes x 1,000,000) / exposure

EPDO Rate = (EPDO number x 1,000,000) / exposure

MID-BLOCK SECTIONS

ADT = average two-way count of the street

Exposure = ADT x section length x 365

Crash Rate = (number of crashes x 100,000,000) / exposure

EPDO Rate = (EPDO number x 100,000,000) / exposure

FIGURE 3-2: HIGH-CRASH LOCATION IDENTIFICATION WORKSHEET

CRASH LOCATION - FILE LOG [Form CLFL]

LOCATION *300 - 800 Clinton Street* YEAR *1999*

DATE OF CRASH	LOCATION	SEVERITY
1/14/88	*426 Clinton*	*PDO*
2/7/88	*545 Clinton*	*1 injury*
5/19/88	*50 ft. north of 4th*	*PDO*
9/6/88	*370 Clinton*	*1 injury (ped.)*
12/3/88	*614 Clinton*	*PDO*
12/17/88	*735 Clinton*	*PDO*

FIGURE 3-3: CRASH LOCATION – FILE LOG

Three-Month Criteria:	*Intersection* - Three crashes, of which at least one is an injury or fatal crash; or five PDO crashes.
	Mid-Block - Five mid-block crashes in a three-block section.
Six-Month Criteria:	*Intersection* - Five crashes, of which at least one is an injury or fatal crash; or eight PDO crashes.
	Mid-Block - Eight mid-block crashes in a three-block section.

If filing is done by spreadsheet, keep a separate worksheet in each folder to help accomplish the same steps.

After high-crash locations are identified, use the same procedures as were used in the Annual City-Wide Analysis to correct the problems. Keep in mind, though, that a sudden increase in the number of crashes at a location could be due to chance, recent changes in driver habits or changes in the roadway environment.

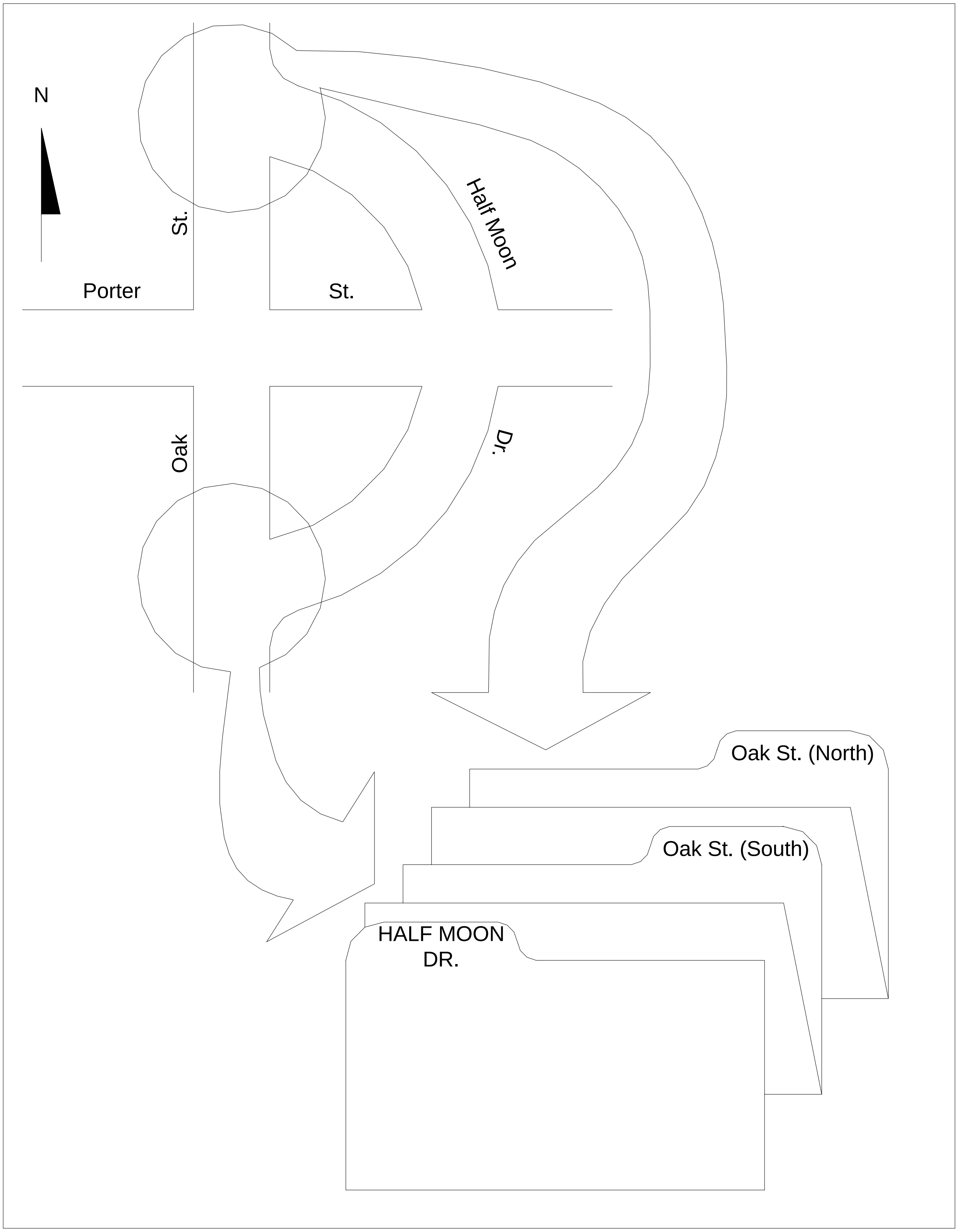

FIGURE 2-4: FILING REPORTS FROM IDENTICALLY NAMED INTERSECTIONS

SUMMARIZING TRAFFIC CRASH DATA

Summarizing traffic crash data is an important part of any traffic records system because it is the first step in identifying high-crash locations. In cities having a population of 10,000 or more, crash reports should be summarized monthly and annually. Smaller cities may need only quarterly and annual summaries.

Traffic crash data can be summarized according to crash type, location (intersection/mid-block), intersection control type, or crash severity. Figure 2-5 shows a summary of data into intersection-related and mid-block crashes. The crashes are categorized further by whether they occurred on a “major” or on a “minor” street. (Major streets are usually through streets with a volume greater than 2,000 vehicles per day.)

As each report is filed in the location file, reports of crashes are tallied on the summary sheet. A new summary sheet should be started at the beginning of each month. At the end of each year, the monthly totals are combined to create the annual summary.

Traffic Crash Spot Maps

A “spot map” provides an impressive visual summary of crash concentrations. As shown in Figure 2-6, pins are inserted into a city street map to mark the location of each traffic crash. While the spot map alone is not sufficient for selecting sites for improvement projects, it does indicate possible problem areas.

The spot map should cover crash experience for a time period of one calendar year. At the end of the year, the map is photographed and the pins removed. Toward the end of the year certain areas on the map (such as the central business district) may become too crowded with pins. If this occurs, a larger-scaled map of that area should be used as a supplement to the main map.

It is recommended that small- to medium-sized communities use spot maps to track crash locations. The spot map is an informative display that may also assist the police department to schedule selective law enforcement efforts. It is usually mounted near the location file so the person filing the reports can update the map. However, some cities find it more beneficial to mount a spot map at a highly visible location in a city building in order to educate citizens about traffic problems.

Supplies Needed for the Spot Map

The supplies needed for a spot map include:

- A street map or aerial photograph with a scale ranging between 1 inch = 400 feet and 1 inch = 800 feet (Maps that contain a variety of other information, such as zoning or land use maps, should not be used.), TRAFFIC CRASH SUMMARY: FROM *Jan. 1, 1998* TO *Dec. 31, 1998* [Form TCS]

INTERSECTION - RELATED CRASHES											
Major Street Intersection											
	Right Angle	Rear End	Side-Swipe Meeting	Side-Swipe Passing	Head On	Ped.	Fixed Object	Right Turn	Left Turn	Other	TOTAL
MAJOR - MAJOR											
2-Way Stop	14	6	0	1	1	0	4	3	5	1	35
4-Way Stop	10	14	2	1	0	1	4	0	7	0	39
Traffic Signal	12	27	2	4	4	2	5	5	9	0	70
MAJOR - MINOR											
Yield Sign	14	5	2	0	2	0	1	1	3	1	29
2-Way Stop	10	11	1	1	1	1	2	1	3	1	32
4-Way Stop	7	5	2	1	0	1	2	2	4	1	25
SUBTOTAL	67	68	9	8	8	5	18	12	31	4	230
Minor Street Intersection											
	Right Angle	Rear End	Side-Swipe Meeting	Side-Swipe Passing	Head On	Ped.	Fixed Object	Right Turn	Left Turn	Other	TOTAL
No Control	8	5	2	1	2	0	2	1	2	1	24
Yield Sign	4	2	0	0	0	0	1	0	1	1	9
2-Way Stop	9	5	4	1	1	0	3	4	0	0	27
4-Way Stop	8	10	2	0	1	0	2	5	3	1	32
SUBTOTAL	29	22	8	2	4	0	8	10	6	3	92
TOTAL INTERSECTION CRASHES	96	90	17	10	12	5	26	22	37	7	322

MID-BLOCK CRASHES										
	Vehicle Striking							Non-Collision		
	Vehicle on Street	Parked Car	Vehicle at Drive	Fixed Object	Ped.	Train	Other	Over-Turn	Other	TOTAL
Major Street	51	27	25	12	3	1	1	2	5	127
Minor Street	25	19	7	4	2	0	1	0	1	59
Alleys	0	3	0	2	0	0	0	0	0	5

FIGURE 2-5: TRAFFIC CRASH SUMMARY SHEET

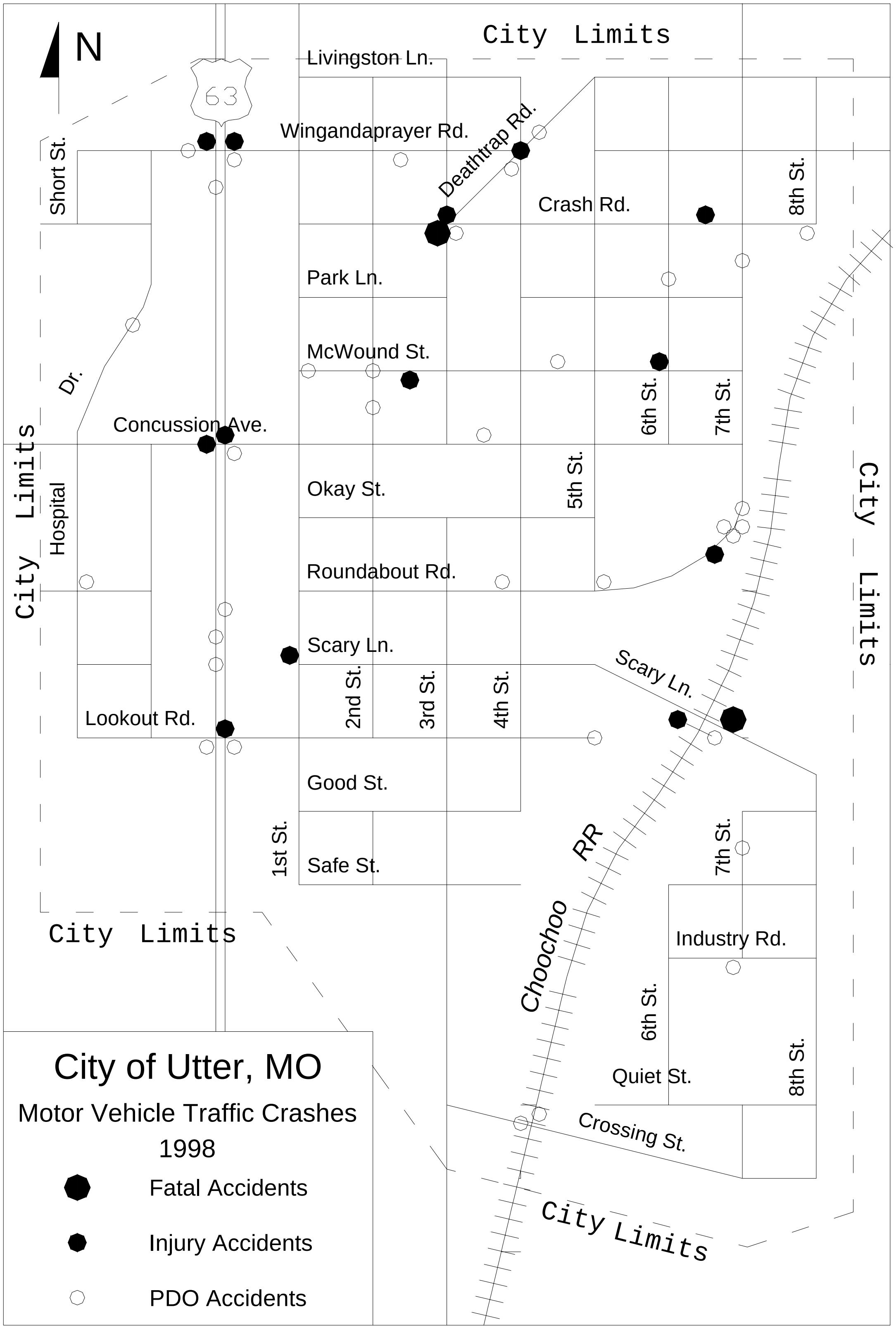

FIGURE 2-6: TRAFFIC CRASH SPOT MAP

- Soft, rigid, and non-warping backing material such as cork, cut to the same size as the map,
- Paste or adhesive to attach the map to the backing,
- Pins or “map-tacks” in at least three different colors (e.g., black, yellow, red),
- A legend identifying the area and time period covered by the map and indicating the meaning of each color of pin (e.g., a black pin indicates a fatal crash, a red pin an injury crash, and a yellow pin a property-damage-only crash.), and
- A small card, which can be attached to the map, listing cumulative crash totals for that year.

SUMMARY

Crash data should be as complete, accurate, and consistent as possible. Providing for accuracy and consistency in reporting, filing, and summarizing crash data is the first major step in a maintaining successful HAL system.

CHAPTER 4

ANALYZING HIGH-CRASH LOCATIONS

The information in the previous one to three years of a community's crash reports provides clues as to what aspects of the driving environment could be contributing to crashes. However, because traffic crashes are statistically rare events, the true causes are not always evident. It is necessary to thoroughly study and investigate the situation to detect any crash patterns and to determine exactly what is causing these patterns.

Every location identified as a high-crash location, through either the Annual City-Wide Analysis or the Early-Warning Analysis, is examined again in the Location Analysis. It is especially important to consider all information that was reported by investigating officers on the crash report forms. To complete the Location Analysis Worksheet (Figure 4-4), it will be necessary to prepare a collision diagram, an on-site observation report and a condition diagram of the location, and to collect traffic data. It also may be advisable to conduct other studies, based on the situation. Instructions for conducting additional traffic studies are included in Appendix C. Table B-1 in Appendix B will be helpful in preparing a list of countermeasures.

This chapter describes the location analysis procedures that will help analyze high-crash locations and establish a list of crash countermeasures. Although the procedures are as complete as possible, they will not automatically produce a list of crash countermeasures. They serve primarily as tools to guide the engineer in assembling all the information needed to complete the analysis and to reduce the number of crashes. The following sections explain how to complete the diagrams and reports necessary in analyzing a high-crash location.

For most improvements, city personnel can develop the design and the cost estimate. However, if a project (e.g. traffic signal installation) requires the services of a registered professional engineer, or if a more detailed professional analysis is required to identify feasible countermeasures, contact the local MoDOT district office (see Appendix K) for assistance through the "Traffic Engineering Assistance Program" (TEAP). The service is available for any location not on a state-maintained street and is offered at no cost to the city.

COLLISION DIAGRAM

Just as a spot map shows where crashes are occurring city-wide, a collision diagram quickly shows where crashes are occurring at each high-crash location. A collision diagram, though, contains much more detail about each crash. With the diagram, it is easy to see any patterns in crash types that form during the analysis period. However, since this is a critical point in conducting a successful analysis, it is helpful to review all information pertaining to the location.

To prepare a collision diagram:

1. Obtain crash reports for all crashes at the location during the previous one to three years. If significant changes (signals, stop signs, construction, etc.) were made at the location in recent years, do not include reports for crashes that occurred before those changes.
2. Sketch a collision diagram similar to the one in Figure 4-1. The diagram must show the general path of all vehicles involved in each crash, as well as the approximate point of each impact. The diagram does not need to be to scale, but it should allow sufficient room to show these paths and the object(s) involved in each crash.
3. Be sure to include all the information shown in Figure 4-1, such as the type and location of all traffic-control devices. Use the suggested symbols on the form to show the type and severity of each crash. Write other basic characteristics of each crash on the crash symbols such as:
    - the date, day and time of the crash,
    - the light condition (day or night),
    - the pavement condition at the time of the crash (dry, wet, icy, etc.), and
    - the number of injuries or fatalities.
4. Note any special circumstances associated with a crash, especially any driver or investigating officers' comments concerning glare, non-functioning traffic control devices, poor pavement conditions or sight obstructions.
5. Show any non-involved (non-contact) vehicles or pedestrians on the diagram. An example is an incident where a vehicle is stopped in traffic behind a left-turn vehicle and, while waiting at the end of the line, it is struck in the rear by an approaching third vehicle. The vehicle making the left turn would be a non-involved vehicle since it was not involved in the actual collision. Its intended path should be shown with a dashed line because it was clearly related to the occurrence of the crash.
6. Identify any crash patterns that are present. Note the types of crashes occurring on each intersection approach or along the section of street.
7. Summarize the times when crashes occur and the weather and pavement conditions. These summaries will be entered in Part D of the Location Analysis Worksheet (Figure 4-4).

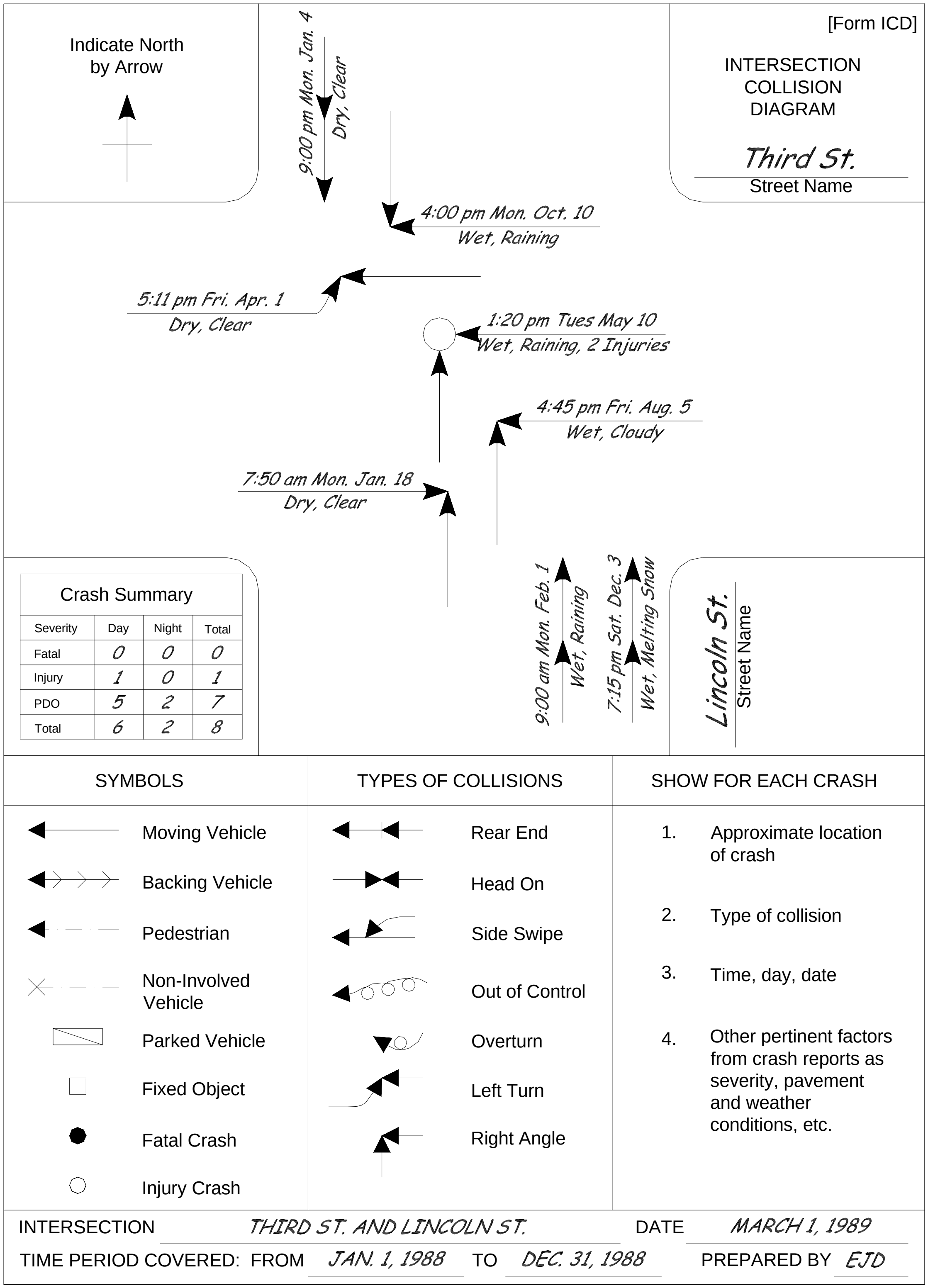

FIGURE 4-1: INTERSECTION COLLISION DIAGRAM

USING TABLE B-1 (GENERAL COUNTERMEASURES)

The analysis of a high-crash location should identify the predominant crash pattern at that location, such as a high number of rear-end collisions or an unusually high percentage of wet pavement crashes. Table B-1 (in Appendix B) shows feasible countermeasures for typical urban crash patterns. It is used to choose the types of improvements that are known to be helpful in reducing certain types of crashes.

To use Table B-1, first find the predominant crash pattern for the location. (If no predominant crash patterns are identified but a probable cause has been hypothesized, this probable cause is used to identify general countermeasures.) Then, carefully review the probable causes listed in the next column to see what could have contributed to the crash pattern. For each probable cause identified, pick out all the reasonable general countermeasures. As an example, consider an unsignalized intersection with a high percentage of rear-end collisions on two approaches controlled by stop signs. The probable causes could include pedestrian crossings, drivers not being aware of the intersection, a slippery surface or a large turning volume. With knowledge of the crash pattern and the information from the crash reports, it should be easy to identify several general countermeasures. If there is a secondary crash pattern, identify the probable causes and general countermeasures for it. All causes and countermeasures will be listed in Part E of the Location Analysis Worksheet (Figure 4-4).

ON-SITE OBSERVATION REPORT

The on-site inspection is an important step in the analysis. It should provide a useful perspective from which to choose the best countermeasures. The On-Site Observation Report shown in Figure 4-2 can be of great help in conducting an inspection.

Careful preparations should be made for the on-site visit. Review information concerning the site, including collision diagrams, crash summaries and traffic counts. Schedule the visit according to any predominant crash characteristics such as nighttime, peak volume or wet-pavement conditions. Be sure to fill in the first three lines of the report in advance of the field trip. Complete the observation report as follows:

1. Observation Points: Upon arriving at the site, drive through the location several times from different directions and pay close attention to how drivers might see the environment. Identify several good vantage points that provide a clear view of traffic from a safe position. Make sure the observation points are located so motorists will not notice that they are being observed (drivers will act differently if they suspect they are being watched).
2. Physical Checklist: Complete the “Physical Checklist” to become familiar with features of the location and to identify any potential hazards. Place a mark after the items on the list that might create problems or contribute to crashes.

3. Operational Checklist: Observe pedestrian and driver activity at the location and complete the "Operational Checklist". Note any sudden or erratic maneuvers, instances of driver or pedestrian confusion, and violations. Place a mark following the items on the "Operational Checklist" that might be associated with a confusing or hazardous characteristic of the site.
4. Comments: After observing traffic for about an hour, reconsider the items in the "Physical Checklist" to see if anything might have been overlooked during the original location assessment. Before leaving the site, list all marked items under the "Comments" section at the bottom of the second page. For each item listed, provide comments and descriptions that could be helpful in identifying any factors contributing to the crash experience. To produce a useful and valuable documentation of the on-site observations, make each commentary as complete as possible. Use extra pages, if necessary.
5. Photographs: It is a good idea to take photographs of the site to document location characteristics. If there is a need to know a dimension related to a feature in a photograph, place an object of known length next to the feature before taking the picture. Another method is to take a measurement and carefully note it on the rear of the report form along with the number of the photograph.
6. Interviews: It may also be advisable to interview people who live or work near the location. Record their remarks concerning hazardous conditions or dangerous operational characteristics. If causes other than those found in Table B-1 are identified, they will also be listed in Part E of the Location Analysis Worksheet shown in Figure 4-4.

CONDITION DIAGRAM

A condition diagram, or roadway inventory, is a drawing (to scale) of the existing roadway, control device locations and major features in the nearby environment. When prepared for a high-crash location, it helps relate crash patterns and probable causes to the physical features on and near the roadway.

A scale of 1 inch = 20 feet or 1 inch = 50 feet is typically used when drawing the condition diagram. The amount of information placed on the diagram is related to the type of improvements being considered. A location receiving only minor improvements, such as the installation of warning signs, would probably need only a few important measurements. A more detailed evaluation involving sight distance problems, possible alignment changes or left-turn channelization might require a complete drawing with lane widths, approach grades and distances to sight obstructions.

ON-SITE OBSERVATION REPORT

[Form OSOR-1]

LOCATION	*Third St. and Lincoln St.*			CONTROL DEVICES	*2-way stop*
OBSERVER	*EJD*	DAY	*Tues.*	DATE	*June 5, 1999*
		TIME	*4:30 pm*	WEATHER	*Occasional Rain*

PHYSICAL CHECKLIST:	CHECK ITEM IF PROBLEM EXISTS
1. Obstructions block view of traffic control devices at or near the location?	
2. Obstructions block view of opposing or conflicting traffic?	
3. The legal parking layout restricts sight distances?	*X*
4. Traffic signs are satisfactory as to number, size, message, placement, reflectivity, and visibility? (see MUTCD)	*X*
5. Traffic signals are satisfactory as to number, lense size, placement, visibility, and timing? (see MUTCD)	
6. Pavement markings are satisfactory as to location, size, message, color, and visibility? (see MUTCD)	*X*
7. Channelization devices, such as islands, are adequate for:	
A. Reducing traffic conflict areas?	
B. Defining traffic movement paths?	
C. Separating traffic flows?	
8. Curb radii are adequate for turning vehicles?	
9. Roadway horizontal curves too sharp?	
10. Approach grades at intersection too steep?	
11. Pavement has proper crown and superelevation?	*X*
12. Lane and street widths are adequate?	
13. The pavement surface condition is satisfactory? (Consider potholes, rutting wash board, edge drop-offs, raveling, bleeding surface, cracking, and poor drainage.)	*X*
14. The roadside is clear of hazardous objects?	
15. Driveways are properly placed and designed?	
16. Pedestrian crosswalks are properly placed and designed?	
17. Street lighting is satisfactory?	
18. Advertising signs or lights reduce driver visual capability?	

FIGURE 4-2: ON-SITE OBSERVATION REPORT – PAGE 1

ON-SITE OBSERVATION REPORT - PAGE 2 [Form OSOR-2]

OPERATIONAL CHECKLIST:	CHECK ITEM IF PROBLEM EXISTS
1. Drivers respond correctly to traffic control devices at and near the location?	
2. Repeated violations of traffic control devices or regulations?	
3. Vehicle speeds too high for existing conditions?	
4. Vehicles change speeds or stop unexpectedly?	
5. Vehicles change lanes unexpectedly?	
6. Certain traffic movements could create a hazard?	
A. Left-turning vehicles:	*X*
B. Straight-through vehicles:	*X*
C. Right-turning vehicles:	*X*
7. Parked vehicles or parking maneuvers create hazards?	*X*
8. Vehicles entering or departing from driveways create hazards?	
9. Traffic congestion and/or delays create hazards?	
10. Bicycles at the location cause confusion or conflicts?	
11. Pedestrians at the location cause confusion or conflicts?	

COMMENTS AND DESCRIPTION OF EACH PROBLEM IDENTIFIED ON CHECKLISTS:

(P = Physical with item number; O = Operational with item number)

P-3 Parking too close to corners; causes restricted view from Lincoln in all directions.
P-4 Signs for parking restrictions not in place.
P-6 Yellow curb markings faded.
P-11 No crown on Lincoln - causes ponding.
P-13 "Washboard" on Lincoln, slick patches & raveling on 3rd.
O-6 Any movement from Lincoln could be risky depending on location of parked vehicles.
O-7 Parking as close as 10 feet from corner.

(Contimue comments as necessary on additional pages.)

FIGURE 4-2: ON-SITE OBSERVATION REPORT – PAGE 2

A completed condition diagram for a high-crash location should contain the following items:

- date diagram was prepared,
- observer's name,
- street names,
- street functional classification (arterial, collector, local),
- traffic control devices (signs, signals, markings),
- north direction arrow,
- intersection angle,
- speed limits on all approaches,
- other traffic regulations,
- widths of all streets, lanes, medians and parking stalls,
- parking set-backs and regulations,
- sidewalk and crosswalk locations,
- location and height of objects obstructing view (fences, shrubs),
- location of fixed objects (buildings, utility poles, large trees, culvert headwalls, curb-side mail boxes, fire hydrants),
- position of street lights and light poles,
- driveway locations and widths,
- road surface materials and significant surface irregularities,
- grades on all the approaches,
- corner radii, and
- general classification of nearby land use and building use.

TRAFFIC DATA COLLECTION

A complete analysis of a high-crash location requires additional traffic data. Several studies, which are frequently needed, include traffic counts, spot speed studies, traffic conflicts studies and sight-distance evaluations. These studies are briefly described in the following sections, and more complete instructions with additional references are provided in Appendix C.

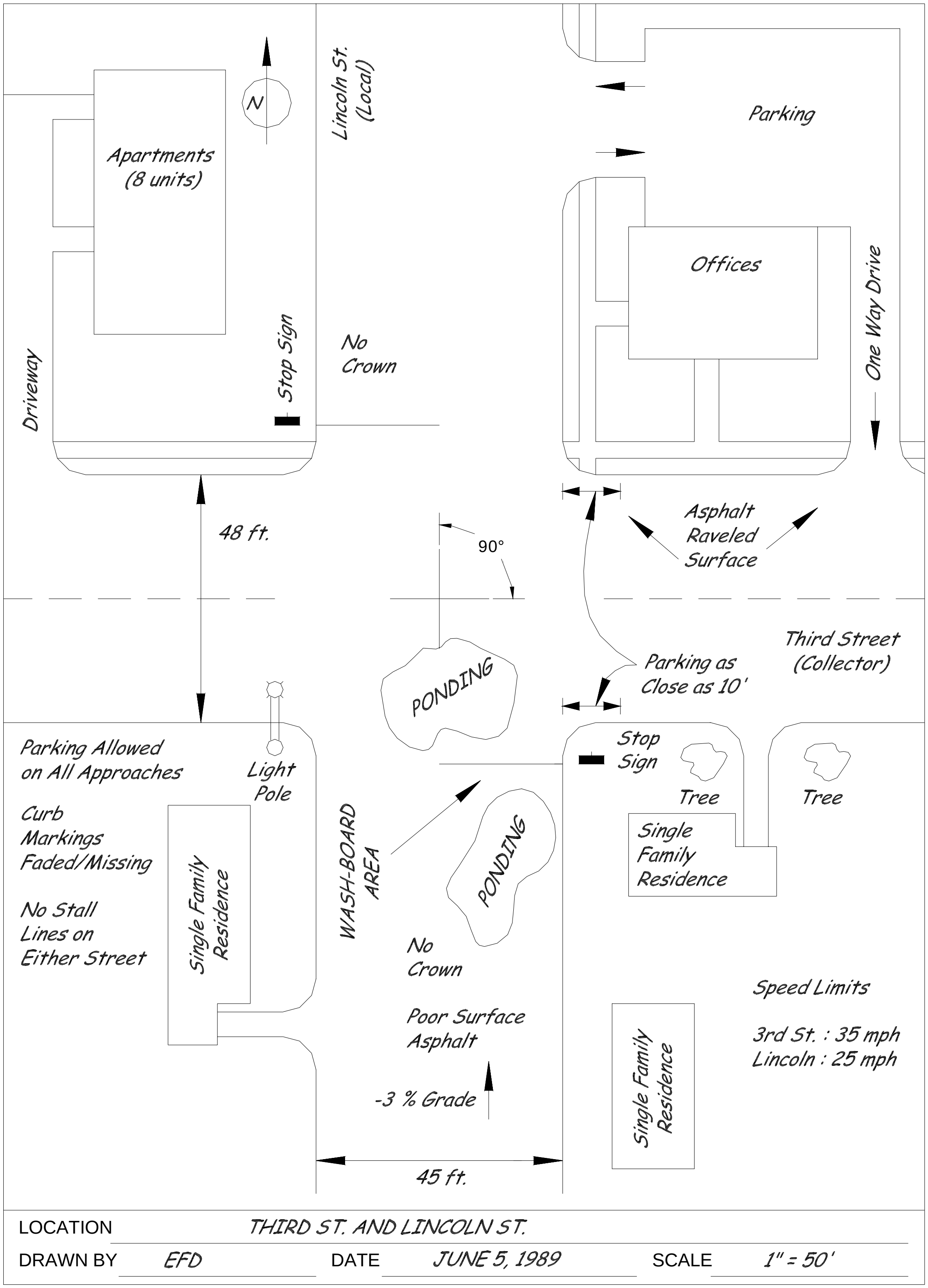

FIGURE 4-3: CONDITION DIAGRAM

Traffic Counts

Basic 24-hour traffic volume estimates are required to estimate the average daily traffic (ADT). Volume counts at an intersection should show the incoming directions, turns and departing directions for all vehicles. Counts taken at a mid-block section should specify the amount of traffic in each direction and in each lane. In urban areas, and especially near schools, pedestrian and bicycle counts may be very helpful for high-crash location analysis.

Spot Speed Studies

Speed studies should be conducted if vehicle speed is a possible causal factor in the crash experience. Because speed is related to stopping distance, it is necessary to know how fast vehicles are traveling. The spot speed study makes it possible to properly evaluate speed regulation in the vicinity and to check for adequate sight distances at critical locations, such as intersections and driveways.

Traffic Conflicts Studies

Traffic conflicts analysis is a method for observing situations in which one driver is forced to take evasive action, such as swerving or braking, to avoid a collision with another vehicle. The frequency of the different types of conflicts is assumed to indicate the potential for crashes at the site. It is generally agreed that a traffic conflicts analysis should not be used to replace crash data analysis. However, it can be used as a supplementary tool to help identify possible countermeasures.

Sight-Distance Evaluations

Sight-distance evaluations are important for determining the type of control device to use at an unsignalized intersection. These studies are primarily concerned with sight distances across intersection quadrants and along roads that must be crossed or entered. It is advisable to coordinate traffic control device selection with traffic characteristics and available sight distances.

LOCATION ANALYSIS WORKSHEET

The following steps describe how to complete the Location Analysis Worksheet (Figure 4-4).

1. Location Identification: Record the location name, date and existing traffic control devices at the top of the page.
2. Part A: If the location was identified in the annual city-wide analysis, copy the data from the High-Crash Location Identification Worksheet (Figure 3-2 in Chapter 3). If the location was identified during an early-warning analysis, use

the procedure demonstrated for the annual city-wide analysis in Chapter 3 to complete this section.

3. Part B or Part C: If the location is an intersection, complete Part B. If it is a mid-block section, complete Part C.
4. Part D: Complete this section with the information found in the Collision Diagram.
5. Part E, "Crash Patterns Identified": Using the information in Parts B or C, the collision and condition diagrams and the observation report, identify any one predominant crash pattern. Other patterns are classified as secondary.
6. Part E, "Probable Causes…": Using Table B-1 (in Appendix B), determine probable causes of crashes and their general countermeasures.
7. Part E, "Supporting Data Attached": Place a mark next to the data that will be included with the report.
8. Part E, "General Conclusions…": Using the supporting data, summarize the findings.
9. Part E, "Specific Countermeasures": Before entering the specific countermeasures, check that each one is feasible and satisfies established warrants. It is essential that warrants be considered to assure the selection of appropriate countermeasures. The "Manual on Uniform Traffic Control Devices" (MUTCD) contains warrants for installing signals and other traffic control devices. Guidelines for installing certain types of countermeasures are discussed in Appendix D. Even if the warrants for a particular countermeasure are satisfied, alternative improvements should be compared using the Countermeasure Analysis procedures described in Chapter 5. Finally, it may be necessary to review additional information about the site, such as right-of-way plans, to determine if a certain improvement would require property acquisition.
10. Part E, "Best Countermeasure, Benefit/Cost Ratio, etc.": Select the best countermeasure or combination of countermeasures from the specific countermeasures. Wait to enter the B/C ratio, costs, savings and priority until the Countermeasure Analysis Worksheets in Chapter 5 are completed.

LOCATION ANALYSIS WORKSHEET

[Form LAW-1]

LOCATION	*Third Street and Lincoln Street*	DATE	*June 6, 1999*
EXISTING TRAFFIC CONTROL	*two-way stop (on Lincoln)*		

PART A - CRASH NUMBER, RATE AND EPDO SUMMARY

Section Length (in miles) *mid-block only*	Year	Number of Crashes				EPDO Number	ADT	Exposure	Crash Rate	EPDO Rate
		Fatal	Injury	PDO	Total					
	1988		*1*	*7*	*8*	*13*	*3,600*	*1,314,000*	*6.088*	*9.893*
	1987	*1*	*1*	*4*	*6*	*16*	*3,550*	*1,295,750*	*4.631*	*12.348*
	1986		*1*	*3*	*4*	*9*	*3,400*	*1,241,000*	*3.223*	*7.252*
	TOTALS	*1*	*3*	*14*	*18*					
	2 OR 3 YR AVG	*0.33*	*1.00*	*4.67*	*6.00*	*12.667*	*3,517*	*1,283,583*	*4.674*	*9.868*

PART B - INTERSECTION-RELATED CRASHES

	Right Angle	Rear End	Side-Swipe		Head On	Ped.	Fixed Object	Right Turn	Left Turn	Other	TOTAL
			Meeting	Passing							
Number of Crashes	*8*	*6*				*1*		*1*	*2*		*18*
Percent of Total	*44.4%*	*33.3%*				*5.6%*		*5.6%*	*11.1%*		100%

PART C - MID-BLOCK CRASHES

	Vehicle Striking							Non-Collision		TOTAL
	Vehicle on Street	Parked Car	Vehicle at Drive	Fixed Object	Ped.	Train	Other	Over-Turn	Other	
Number of Crashes										
Percent of Total										100%

PART D - NUMBER OF CRASHES AND EXISTING CONDITIONS

Time of Day:	6:00 am - Noon	*5*		6:00 pm - Midnight	*5*				
	Noon - 6:00 pm	*7*		Midnight - 6:00 am	*1*				
Light Conditions:	Day	*13*	Night	*5*					
Surface Conditions:	Dry	*7*	Wet	*10*	Snow or Ice	*1*			
Weather:	Cloudy	*5*	Clear	*6*	Rain	*7*	Snow		Other
Other:									

FIGURE 4-4: LOCATION ANALYSIS WORKSHEET – PAGE 1

LOCATION ANALYSIS WORKSHEET - [Form LAW-2]

LOCATION *Third Street and Lincoln Street* DATE *June 6, 1999*

PART E - CRASH ANALYSIS SUMMARY

X COLLISION DIAGRAM ATTACHED

CRASH PATTERNS IDENTIFIED: Predominant *Right Angle*
Secondary *Rear End*

Probable Causes and Possible Countermeasures:

Restricted Site Distance: *1. Install 4-way*
2. Remove sight obstructions
3. Restrict parking near corners
4. Reduce speed limits
5. Install overhead beacon
Slippery Pavement Surface: *1. Deslick*
2. Improve drainage & crown

OPERATIONAL AND PHYSICAL DATA ANALYSIS

Supporting Data Attached:

X	On-Site Observation Report	*X*	Condition Diagram
X	Intersection Sight Distances		Spot Speed Study
X	Volume/Turning Movement Count		Traffic Conflict Study
	Other:		

General Conclusions from Supporting Data:

Sight distance in all directions from Lincoln is restricted by cars and vans parking too closely to corner.
Pavement has no crown on Lincoln.
Both Lincoln and Third have areas of "bleeding asphalt".
"Washboard" on Lincoln near stop line.

COUNTERMEASURE SELECTION

Specific Countermeasures:

1. Restrict parking.
2. Deslick pavement.
3. Combination of 1 and 2.

(Note: For each countermeasure, fill out a Countermeasure Analysis Worksheet)

Best Countermeasure	*3 - Combination*		
Benefit/Cost Ratio	*28.2*	Implementation Cost	*$13,300*
Average Annual Net Savings	*$62,527*	Priority Assigned	*1*

FIGURE 4-4: LOCATION ANALYSIS WORKSHEET – PAGE 2

CHAPTER 5

CORRECTING HIGH-CRASH LOCATIONS

Once several countermeasures having the potential to reduce the number and/or severity of crashes at each high-crash location have been identified, the next step consists of selecting the best countermeasure, or set of countermeasures, for each location and establishing priorities for making improvements.

BUDGET RESTRICTIONS AND ECONOMIC ANALYSIS

If funds were unlimited, all the countermeasures that promised a reduction in crashes at each location could be installed. However, because budgets are limited, it is necessary to obtain the greatest overall benefit from the available funds.

There are several techniques available for selecting the best countermeasures for a site and for assigning priority to each project. Some of the economic analysis procedures or techniques most commonly used include:

- Benefit/Cost (B/C) Ratio,
- Cost/Effectiveness Method,
- Net Benefit Method (Average Annual Net Savings),
- Incremental B/C Ratio, and
- Dynamic Programming.

The Benefit/Cost Ratio is recommended for prioritizing alternative high-crash location sites for independent projects. Independent projects are those that can be implemented without impacting one another (for example, those at different locations). The only limiting factor in implementing independent projects is the amount of money in the budget. The Benefit/Cost Ratio is a straightforward procedure illustrating the amount saved per dollar spent, making it valuable in communicating with government officials and others concerned with the financial viability of a project and the efficiency of the investment in safety.

The Average Annual Net Savings method should be used when ranking mutually exclusive projects. Mutually exclusive projects are found in situations where more than one option exists for improving a location, but only one of those options can be implemented. For example, a location that could be improved by either adding a median barrier or by adding a continuous two-way left-turn lane. Only one option can be chosen.

The Average Annual Net Savings method is more appropriate than the Benefit/Cost ratio for considering mutually exclusive projects. For example, suppose a city has two mutually exclusive safety investments that can be made. Option A involves an annual cost to the city of $10,000, and the citizens would receive a reduction in crashes worth $20,000 per year (for a Benefit/Cost Ratio of 20,000/10,000 or 2.0). Option B involves a cost to the city of $500/year and the citizens would receive a reduction in crashes worth $3,000/year (for a Benefit/Cost Ratio of 3,000/500 or 6.0). While Option B has a much higher Benefit/Cost Ratio, the net benefit of Option A is $10,000 ($20,000 - $10,000) while the net benefit of Option B is only $2,500. Since only one of the two options can be selected, the greatest benefit to the city will come from Option A.

COUNTERMEASURE ANALYSIS

"Benefit" vs. "Cost" and the Preferred Countermeasure

The "average annual benefit" refers to the average annual savings by motorists due to the reduction in the number of crashes achieved by a countermeasure or combination of countermeasures at a particular location. The "average annual cost" is the expense incurred by the public agency in implementing the improvement. The "average annual net savings" equals the "average annual benefit" minus the "average annual cost."

To improve a particular site, one or more sets of improvements (i.e., one or more countermeasures or combinations of countermeasures) are identified as described in Chapter 4. The best set of improvements for that site will be the set with the highest average annual net savings. Once the best set of improvements for each site has been identified, the different sites can be ranked by Benefit/Cost Ratio.

The B/C Ratio is "average annual benefit" divided by "average annual cost". To be a candidate for acceptance, the B/C ratio must be greater than 1.0. If the ratio is equal to 1.0, it is a borderline project. Any project having a B/C ratio of less than 1.0 is undesirable. The most desirable sites for improvement within a region are the sites with the highest B/C ratios. Therefore, improvements at different locations can be ranked in priority from highest to lowest B/C ratio. This will yield the greatest benefit from the funds available for improvements.

Note that the form used to evaluate alternatives ranks the best alternative improvements at a given site by "Average Annual Net Savings" and ranks improvements at different locations by "Benefit/Cost Ratio".

Steps in the Selection Process Using the Benefit/Cost Ratio

Follow the following steps to complete the Countermeasure Analysis Worksheet (Figure 5-1):

1. Top section: Fill in the location of the site being analyzed and the date. Then, starting with the lowest implementation cost countermeasure listed on the Location Analysis Worksheet (see Figure 4-4), record the countermeasure number and description.
2. Service Life: Estimate the service life of the improvement(s) using either local experience or Appendix F. Record it on the worksheet. (Note: Improvement projects having different service lives must be analyzed on separate pages. Lines 1 - 9 must be repeated for each service life.)
3. ADT Adjustment: Enter the ADT for the current year at the specific location. Then, estimate the ADT growth factor and calculate the ADT for the year associated with the improvement service life. Contact the MoDOT TTAP office (see Appendix K) for assistance in estimating ADT growth factors.
4. Estimated Annual Crash Reduction: Complete this portion of the worksheet by listing each type of crash that will be reduced, the estimated percent crash reduction (divided by 100) and the average annual number of PDO and fatal or injury crashes of each type. (See Table G-1 for estimated crash reduction factors.) Multiply the number of PDO and fatal of injury crashes by the crash reduction factor. Then, add the estimated annual reductions for both the PDO crashes and the fatal or injury crashes.

   If a combination of countermeasures is being considered at a given location, the total percent reduction in crashes cannot be calculated simply by adding the percent reduction of each countermeasure. The total percent crash reduction can be estimated, however, by the following equation:

$$P_T = P_1 + \left[\frac{100 - P_1}{100}\right] P_2 + \left[\frac{100 - P_1}{100}\right]\left[\frac{100 - P_2}{100}\right] P_3 + \ . \ . \ .$$

P_T = total percent reduction in crashes
P_1 = largest percent reduction in crashes due to any one of the countermeasures
P_2 = second largest percent reduction in crashes due to any one of the countermeasures
P_3 = third largest percent reduction in crashes due to any one of the countermeasures

To illustrate, if it is estimated that one type of countermeasure will reduce all crashes by 30% and another countermeasure will reduce them by 25%, the total percent reduction that could be expected would be 30% of all crashes plus a 25% reduction of crashes that are uncorrected by the first countermeasure. In other words,

$$30(100\%) + 25(100\%\text{-}30\%) = 47.5\%$$

or

$$30(1.00) + 25(.70) = 47.5\%$$

5. Average Annual Benefits (lines 1 & 4): Enter the estimated total reduction of PDO crashes on line 1 and the estimated total reduction of fatal or injury crashes on line 4.
6. Average Annual Benefits (lines 2 & 5): Unless local estimates of traffic crash costs are available or your analysis is for a location other than a city street, enter $3,220 on line 2 and $69,000 on line 5.
7. Average Annual Benefits (lines 3, 6 & 7): Make the appropriate calculations on lines 3, 6 & 7.
8. Average Annual Benefits (lines 8 - 13): If the ADT is expected to increase during the service life of the improvement, complete lines 8 – 13.
9. Average Annual Benefits (line 14): Enter any estimated secondary annual benefits, such as reduced delay.
10. Average Annual Benefits (line 14): Add line 14 to either line 7, if ADT is constant, or line 13, if ADT is increasing.
11. Average Annual Cost: The initial costs of the improvement, the terminal (salvage) value of the improvement and any additional annual costs should be considered in determining the Average Annual Costs. If a combination of several improvements with different service lives is being evaluated for a location, lines 1 through 9 on page 2 of the worksheet must be repeated for each of the different lives. For instance, if the improvements being considered have either a life of 5 years or a life of 2 years, they must be analyzed on two separate pages. All initial costs and terminal values must be adjusted to reflect changes in the value of money over time. Appendix H provides factors for typical interest rates and several example applications.
12. Average Annual Net Savings: Subtract the Average Annual Cost from the Average Annual Benefit to find the Average Annual Net Savings. If the average annual cost has been analyzed on more than one page due to project

improvements having multiple service lives, combine the results onto one worksheet in order to complete this step. This method will be used to find the best alternative for a particular location, since the countermeasures are mutually exclusive.

13. Benefit/Cost Ratio: Using the Average Annual Cost and Savings for the project, determine the Benefit/Cost Ratio. Any improvement with a Benefit/Cost Ratio greater than 1.0 or any improvement with positive Average Annual Net Savings will be a benefit to the city. Improvements that do not meet these criteria are not economically justified at the time of the analysis. The Benefit/Cost Ratio will be used to rank improvements at different locations, since the countermeasures are independent of each other.

When the most effective countermeasure, or set of countermeasures, has been identified, enter the countermeasure description, Average Annual Net Savings, Benefit/Cost Ratio and Implementation Cost (initial cost) on the Location Analysis Worksheet (Figure 4-4).

The third page of Figure 5-1 (Countermeasure Analysis Worksheet) shows several of the supporting computations used in this example.

PRIORITIZATION OF IMPROVEMENTS

A prioritized list of independent projects should be based on the Benefit/Cost Ratio. Projects are ranked according to their B/C ratios with the project having the highest B/C ratio ranked highest. Priority for implementation is given first to that project with the highest B/C ratio. The process is repeated with each subsequent project until the remaining funds are insufficient to implement the improvements at the locations. The remaining funds should be assigned to lower-cost improvements, based again on the highest B/C ratios. (Depending on the improvement projects selected, it may be possible to obtain special funding. Contact the local MoDOT district office for more information.) When priorities have been assigned, enter the results on the Location Analysis Worksheet (Figure 4-4, page 2) for each location selected.

Numerical examples are provided in Appendix H to illustrate the use of both the Benefit/Cost Ratio Method and the Average Annual Net Savings Method.

If long delays occur from the time a high-crash problem is first identified to the time of the actual project implementation, the countermeasures should be analyzed with more current crash information to see if priorities have been affected. A countermeasure analysis and priority ranking should be reviewed and updated at least once each year.

COUNTERMEASURE ANALYSIS

[Form CAW-1]

LOCATION: *Third Street and Lincoln* DATE: *July 6, 1999*

COUNTERMEASURE NUMBER: *3* ESTIMATED COUNTERMEASURE SERVICE LIFE: *7* YEARS

COUNTERMEASURE DESCRIPTION: *Deslicking of pavement & parking removal at*

ADT ADJUSTMENT

Current Year	*1989*	ADT	*3,600*	ADT Increase *3*	% Annually
Estimated Year	*1996*	ADT	*4,428*		

ESTIMATED ANNUAL CRASH REDUCTION

Crash Type	Estimated % Reduction (div. by 100)	x	Annual Number of Crashes of This Type Before Improvement				=	Estimated Annual Reduction for Crashes of This Type			
Right Angle	*0.69*	x	PDO	*3*			=	PDO	*2.07*		
		x			F & I	*1*	=			F & I	*0.69*
Rear End	*0.40*	x	PDO	*3*			=	PDO	*1.20*		
		x			F & I	*0*	=			F & I	*0.00*
		x	PDO				=	PDO			
		x			F & I		=			F & I	
		x	PDO				=	PDO			
		x			F & I		=			F & I	
			Total Estimated Crash Reduction:					PDO	*3.27*	F & I	*0.69*

AVERAGE ANNUAL BENEFITS

1. Enter the estimated reduction of PDO crashes.	*3.27*	
2. Enter the average cost of a PDO crash.	*$3,220*	
3. Multiply Line 1 by Line 2 (average annual benefit of reducing PDO crashes).		*$10,529*
4. Enter the estimated reduction of fatal and injury crashes.	*0.69*	
5. Enter the average cost of fatal or injury crashes.	*$69,000*	
6. Multiply Line 4 by Line 5 (average annual benefit of reducing fatal and injury crashes)		*$47,610*
7. Add Line 6 to Line 3 (average annual benefit from reducing crashes)		*$58,139*

COMPLETE LINES 8 THROUGH 13 IF ADT WILL INCREASE DURING THE SERVICE LIFE OF IMPROVEMENT.
IF ADT DOES NOT INCREASE DURING THE SERVICE LIFE OF IMPROVEMENT, GO TO LINE 14.

8. Enter the expected ADT at the end of the service life.	*4,428*	
9. Enter the current year's ADT.	*3,600*	
10. Add Line 9 to Line 8.	*8,028*	
11. Divide Line 10 by 2 (average ADT during service life).	*4,014*	
12. Divide Line 11 by Line 9 (ADT growth factor).	*1.115*	
13. Multiply Line 7 by Line 12 (average annual benefits from reducing crashes with ADT increasing).		*$64,825*
14. Enter secondary annual benefits from improvement (if known).		*$0*
15. If ADT is constant, add Line 14 to Line 7. If ADT is increasing, add Line 14 to Line 13.	Average Annual Benefits	*$64,825*

FIGURE 5-1: COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 1

COUNTERMEASURE ANALYSIS WORKSHEET

[Form CAW-2]

LOCATION	*Third Street and Lincoln Street*	DATE	*July 6, 1999*
COUNTERMEASURE NUMBER	*3*	ESTIMATED COUNTERMEASURE SERVICE LIFE	*7* YEARS
COUNTERMEASURE DESCRIPTION	*Deslicking of pavement & parking removal at corners*		

AVERAGE ANNUALIZED COST

1. Enter the initial cost of the improvement.	*$13,300*
2. Enter the Capital Recovery Factor for the service life of improvement from Interest Factors Table in Appendix H *.	*0.17282*
3. Multiply Line 1 by Line 2.	*$2,299*
4. Enter the residual (salvage) value of the improvement.	*$0*
5. Enter the Sinking Fund Factor for the service life of the improvement from Interest Factors Table in Appendix H *.	*0.12282*
6. Multiply Line 4 by Line 5.	*$0*
7. Subtract Line 6 from Line 3.	*$2,299*
8. Enter any other annual costs associated with the improvement.	*$0*
9. Add Line 7 and Line 8 to obtain Average Annualized Costs.	*$2,299*

AVERAGE ANNUAL NET SAVINGS

1. Enter the Average Annual Benefits (from Line 15, page 1).	*$64,825*
2. Enter the Average Annualized Costs (from Line 9, above).	*$2,299*
3. Subtract Line 2 from Line 1 to obtain Average Annual Net Savings.	*$62,527*

BENEFIT/COST RATIO

1. Enter the Average Annual Benefits (from Line 15, page 1).	*$64,825*
2. Enter the Average Annualized Costs (from Line 9, above).	*$2,299*
3. Divide Line 1 by Line 2 to obtain the Benefit/Cost Ratio.	*28.2*

* The example countermeasure analysis assumes a 5% interest rate. An agency might use a different interest rate, which would require applying factors from an interest table. Appendix H contains interest factor tables for rates of 3%, 4%, and 5%.

FIGURE 5-1: COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 2

COUNTERMEASURE ANALYSIS WORKSHEET - SUPPORTING CALCULATIONS [Form CAW-3]

LOCATION	*Third Street and Lincoln*	DATE	*July 6, 1999*
COUNTERMEASURE NUMBER	*3*	ESTIMATED COUNTERMEASURE SERVICE LIFE	*7* YEARS
COUNTERMEASURE DESCRIPTION	*Deslicking of pavement & parking removal at corners*		

Crash - Reduction Estimates (Based on App G.)

Right-Angle Collisions reduced by combined effect of deslicking pvmt. and parking removal

(Note: 3 right-angle collisions were on wet pvmt.)

Deslicking of Pvmt. - 1 block in all directions

Use 55% Crash - Reduction for wet pvmt crashes

Improve Sight Distance

Use 30% Crash - Reduction Factor

Combined Effect:

$PT = 55 + ((100-55)/100)\, 30 = 55 + 13.5 = 68.5$

use 0.69

Rear-End Collisions reduced by deslicking pvmt.

Use 40% Crash - Reduction Factor

Initial Cost for Improvements

deslicking and crown - 4 streets	
8,600 sq. yds. @ $1.36	= 11,700
work zone control, restripe	= 800
	12,500
install 8 NO PARKING signs	
and paint curbs	800
	13,300

FIGURE 5-1: COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 3

IMPLEMENTATION OF IMPROVEMENTS

After prioritizing improvements, each project must be designed, scheduled and implemented. In order to improve future countermeasure evaluations, keep good records of all costs involved in making improvements. If improvements are done under contract, make an effort to keep the cost of each countermeasure separated so specific costs can be determined.

Design

Although the HAL Manual does not cover design of improvements, several sources on this subject are included in the reference list. Keep in mind, though, that design and placement of traffic control devices must conform to the MUTCD.

Project Scheduling

A project schedule is a plan outlining when each project will be started and completed. Scheduling projects has many advantages; for example:

- materials can be ordered and delivered in a timely manner,
- the workforce can be used more effectively, and
- the public can be alerted to road and lane closures so people may select alternate routes.

Implementation/Installation

Proper work-zone traffic control is critical during project installation and all related construction activities. The safety of workers and motorists depends on the use of proper traffic control and advance warnings. The MUTCD is the reference for all work-zone traffic control devices and procedures.

Evaluation of Countermeasures

Following the implementation/installation of countermeasures, continue to analyze the crash data to determine the effectiveness of improvements at each location. This is essential in improving the selection of countermeasures in the future.

The most common method of evaluating countermeasure effectiveness is the Before-After Analysis. The analysis compares crash experience at a location for a specified time before and after an improvement is installed. To properly evaluate a countermeasure, start a documentation file on each improved location using the completed Location Analysis Worksheets. Then, complete the Countermeasure Evaluation Worksheet (Figure 5-2). The third page of Figure 5-2 illustrates several of the calculations used in the example. Use the following steps as a guide to complete the worksheet:

1. Observation of Operations: Perform field observations of operations at the location immediately after it has been improved. Note any serious problems that have developed unexpectedly. If any problems are observed, record the problems and the changes that were made in the documentation file.
2. "Previous Habits" and Unexpected Crashes: Record the project completion date on the Crash Location - File Log. The Early-Warning Analysis should be started three months after the improvements are completed. If the site is again flagged as a high-crash location, immediately reinstate the Location Analysis and conduct appropriate field studies to determine the crash cause(s). It might be necessary to develop alterations to the initial improvements based on the new analysis. It is important to realize, however, that a few crashes may occur at an improved site due to "previous habits" of motorists who frequently use the location. For instance, drivers using a previously unsigned intersection may not notice a stop sign that has been installed. Therefore, if some unexplained crashes occur shortly after the improvement, it might be desirable to eliminate them from the Before-After Analysis. Depending on local policy, an engineer may allow a three-month "driver familiarization" period to elapse between the before and after periods. If a familiarization period is allowed, it should be noted on the Crash Location - File Log and the Countermeasure Evaluation Worksheet.
3. When to Begin the Before-After Analysis: Begin the Before-After Analysis of the location when the following conditions have been met:
    - Crash data are available for comparable time periods of at least one year before and one year after an improvement. The "before" data should not include any time period from which crash data were used to justify the improvement.
    - ADT data are available for both periods. This allows the numbers of crashes to be adjusted for exposure.
    - The characteristics of the traffic flow are basically unchanged during the two periods.
    - The appropriate "driver familiarization" period has elapsed.
4. Conducting the Before-After Analysis: To conduct the Before-After Analysis, fill out the Countermeasure Evaluation Worksheet (Figure 5-2) as follows:
    - Complete the first page of the Countermeasure Evaluation Worksheet using data collected after the improvements were made to the site. (Parts A, B, C, D)
    - Indicate whether a collision diagram will be attached to the report and identify the crash patterns. (Part E, section 1)

- If the ADTs after the improvements are different from the ADTs before the improvements, calculate the ADT ratio by dividing the average "after" ADT by the average "before" ADT. (Part E, section 1)
- Adjust the numbers of crashes in the "after period" by dividing them by the ADT ratio. (Part E, section 2)
- Calculate the percent crash reduction for all crash types and severity levels using the following equation (Part E, section 3):

$$P = \frac{(N_B - N_A)(100)}{N_B}$$

where: P = percent crash reduction
N_B = number of crashes in the before period
N_A = number of crashes in the after period

If the numbers of crashes for the "after" period have been adjusted for ADT changes, use the adjusted numbers when calculating percent reductions. Crash rates do not have to be adjusted since ADT has already been used to determine the rates.

In addition to evaluating the implemented countermeasures, the engineer should evaluate the HAL system as a whole. The next chapter guides the user through the evaluation procedure.

COUNTERMEASURE EVALUATION WORKSHEET [Form CEW-1]

LOCATION *Third Street and Lincoln Street* DATE *Jan. 18, 1999*

COUNTERMEASURE DESCRIPTION *Pavement Overlay and Parking Removed at Corner*

DATE COUNTERMEASURE INSTALLATION COMPLETED *Nov. 20, 1997*

PART A - NUMBER OF CRASHES, RATE AND EPDO SUMMARY

Section Length (in miles) *mid-block only*	Year	Number of Crashes				EPDO Number	ADT	Exposure	Crash Rate	EPDO Rate
		Fatal	Injury	PDO	Total					
	1998			*4*	*4*	*4*	*3,900*	*1,423,500*	*2.810*	*2.810*
	TOTALS	*0*	*0*	*4*	*4*					
	2 OR 3 YR. AVG.									

PART B - INTERSECTION-RELATED CRASHES

	Right Angle	Rear End	Side-Swipe		Head On	Ped.	Fixed Object	Right Turn	Left Turn	Other	TOTAL
			Meeting	Passing							
Number of Crashes	*2*	*1*							*1*		*4*
Percent of Total	*50.0%*	*25.0%*							*25.0%*		100%

PART C - MID-BLOCK CRASHES

	Vehicle Striking							Non-Collision		TOTAL
	Vehicle on Street	Parked Car	Vehicle at Drive	Fixed Object	Ped.	Train	Other	Over-Turn	Other	
Number of Crashes										
Percent of Total										100%

PART D - NUMBER OF CRASHES AND EXISTING CONDITIONS

Time of Day:	6:00 am - Noon		*1*		6:00 pm - Midnight		*1*		
	Noon - 6:00 pm		*1*		Midnight - 6:00 am				
Light Conditions:	Day	*3*	Night	*1*					
Surface Conditions:	Dry	*2*	Wet	*1*	Snow or Ice				
Weather:	Cloudy		Clear	*2*	Rain	*1*	Snow	*1*	Other
Other:									

FIGURE 5-2: COUNTERMEASURE EVALUATION WORKSHEET - PAGE 1

COUNTERMEASURE EVALUATION WORKSHEET - PAGE 2 [Form CEW-2]

LOCATION	*Third Street and Lincoln Street*
DATE	*Jan. 18, 1999*
COUNTERMEASURE DESCRIPTION	*Deslicked Pavement and Parking Removed from Corner*
DATE COUNTERMEASURE INSTALLATION COMPLETED	*Nov. 20, 1997*

PART E - AFTER IMPROVEMENT CRASH REDUCTION SUMMARY

COLLISION DIAGRAM ATTACHED

CRASH PATTERNS IDENTIFIED: Predominant: *None*

Secondary:

ADT RATIO: After ADT / Before ADT = *3900* / *3517* = *1.109*

NUMBER OF CRASHES AFTER IMPROVEMENT (ADJUSTED WITH THE ADT RATIO)

By Crash Type:				By Crash Severity:	
Left turn	*0.90*	Skidding		Fatal	
Head on		Wet pavement	*0.90*	Injury	
Rear end	*0.90*	Night	*0.90*	PDO	*3.61*
Right angle	*1.80*	RR crossing			
Side swipe		Pedestrian			
Fixed object		________			
Overturn		________			
All Crashes:	*3.61*				

CRASH PERCENT REDUCTION: % Reduction = ((Before - After) / Before) x 100

By Crash Type:				By Crash Severity:	
Left turn	*54.9* %	Skidding	%	Fatal	*100.0* %
Head on	%	Wet pavement	*91.0* %	Injury	*100.0* %
Rear end	*85.0* %	Night	*82.0* %	PDO	*22.7* %
Right angle	*77.5* %	RR crossing	%		
Side swipe	%	Pedestrian	*100.0* %		
Fixed object	%	________	%		
Overturn	%	________	%		
All Crashes:	*80.0* %				

FIGURE 5-2: COUNTERMEASURE EVALUATION WORKSHEET - PAGE 2

[Form CEW-3]

COUNTERMEASURE EVALUATION WORKSHEET - SUPPORTING COMPUTATIONS

LOCATION *Third Street and Lincoln Street* DATE *Jan. 18, 1999*

COUNTERMEASURE DESCRIPTION *Pavement Overlay and Parking Restricted*

PART E:

ADJUSTED "AFTER" NUMBER OF CRASHES:

Left Turn : 1/0.370 = 2.70

Rear End : 1/0.370 = 2.70

Right Angle : 2/0.370 = 5.41

Wet Pvmt : 1/0.370 = 2.70

Night : 1/0.370 = 2.70

PDO & All Crashes : 4/0.370 = 10.82

PERCENT REDUCTION :

Left Turn : (1-2.70)/1 = -1.705 = -170.5%

Head On : (1-0)/1 = 1 = 100%

Rear End : (6-2.71)/6 = 0.548 =54.8%

Right Angle : (5-5.41)/5 = -0.082 = -8.2%

Side Swipe : (3-0)/3 = 1 = 100%

Fixed Object : (1-0)/1 = 1 =100%

Wet Pvmt. : (10-2.71)/10 = 0.729 = 72.9%

Pedestrian : (2-0)/2 = 1 = 100%

Fatal : (2-0)/2 = 1 = 100%

Injury : (4-0)/4 = 1 = 100%

PDO : (14-10.82)/14 = .227 = 22.7%

All Crashes : (20-10.82)/20 = 0.459 = 45.9%

FIGURE 5-2: COUNTERMEASURE EVALUATION WORKSHEET - PAGE 3

CHAPTER 6

EVALUATION OF THE HAL SYSTEM

As stated in Chapter 1, identification, analysis and correction of high-crash locations requires a commitment of time and money from a community. This chapter presents guidelines for evaluating the benefits of crash countermeasures versus the cost of those countermeasures. The problem of regression-to-the-mean, which leads to overestimates of HAL benefits, is also described.

PROCEDURE

The HAL system should be evaluated according to the following procedure:

1. For each year that countermeasures are evaluated using the Before-After Analysis, complete a HAL System Evaluation Worksheet as shown in Figure 6-1. Enter the number of locations being evaluated and the year of the evaluation at the top of the worksheet.
2. Total the average annual number of “before” and “after” crashes from all the Countermeasure Evaluation Worksheets. (Lines 1, 2, 4, 5) Use the crash data for the “after” period that are properly adjusted for ADT changes. (For instance, with a 5% increase in ADT, 1 fatal or injury crash becomes 0.95 and 12 PDO crashes become 11.42.)
3. Benefits (Lines, 3, 6, 7): Following the instructions on lines 3, 6 and 7, determine the total crash reduction. Refer to Figure 6-2 to determine if there was a significant crash reduction achieved at the improved locations. In the example, for a total of 33 crashes in the “before” period, the required percent change in the after count is 40% of 33 or 13.2 crashes. Since the total reduction in crashes of 20.63 is much greater than 13.2, the crash reduction is due not to chance, but to the countermeasures.
4. Benefits (Lines 8-12): Using the crash costs either from Appendix H or from local data, fill in lines 8, 9, 10 and 11. The total financial benefit from reducing the number of crashes is estimated by adding lines 9 and 11.
5. Improvement Costs: Determine the total cost of making the improvements by adding the annual cost of the improvements, the annual cost of labor and materials (from both the engineering department and the police department) and any other indirect costs that were involved in implementing the improvements.

HAL SYSTEM EVALUATION WORKSHEET

[Form - HALSEW]

EVALUATION FOR *7* IMPROVED LOCATIONS YEAR *1999* EVALUATED BY *AMJ*

BENEFITS DUE TO CRASH REDUCTION

1. Enter the average annual number of fatal or injury crashes before improvement.	*4.83*
2. Enter the average annual number of fatal or injury crashes after improvement.	*0.95*
3. Subtract Line 2 from Line 1. (reduction in fatal or injury crashes)	*3.88*
4. Enter the average annual number of PDO crashes before improvement.	*26.67*
5. Enter the average annual number of PDO crashes after improvement.	*11.42*
6. Subtract Line 5 from Line 4. (reduction in PDO crashes)	*15.25*
7. Add Line 6 to Line 3. (total crash reduction)	*19.13*

WAS CRASH REDUCTION SIGNIFICANT ACCORDING TO FIG. 6-2? Yes *X* No

8. Enter the unit cost of fatal or injury crashes.	*$69,000*
9. Multiply Line 3 by Line 8. (the benefit of reducing fatal and injury crashes)	*$267,950*
10. Enter the unit cost of PDO crashes.	*$3,220*
11. Multiply Line 6 by Line 10. (the benefit of reducing PDO crashes)	*$49,094*
12. Add Line 9 to Line 11. (total benefit due to crash reduction)	*$317,044*

IMPROVEMENT COSTS

1. Enter the total annual cost of improvements.	*$13,600*
2. Enter the annual cost to engineering department.	*$4,300*
3. Enter the annual cost to police department.	*$1,250*
4. Enter other cost.	*$400*
5. Add Lines 1, 2, 3, and 4. (total cost of making improvements)	*$19,550*

BENEFIT/COST RATIO

1. Enter the total benefit. (Line 12 under "Benefits Due to...")	*$317,044*
2. Enter the total cost. (Line 5 under "Improvement Costs")	*$19,550*
3. Divide Line 1 by Line 2 to obtain the Benefit/Cost Ratio.	*16.22*

FIGURE 6-1: HAL SYSTEM EVALUATION WORKSHEET

FIGURE 6-2: THE STATISTICAL SIGNIFICANCE OF THE PERCENT CHANGE IN THE NUMBER OF CRASHES

6. Benefit/Cost Ratio: Divide the total estimated annual benefits by the total annual costs for the improvements being evaluated. The resulting ratio will indicate how much benefit was received per dollar spent.

The benefit/cost ratio determined by the procedure on the previous page shows how the HAL System is benefiting the community for only the locations covered in the specified analysis year. Traffic safety projects completed many years ago will probably not be recognized in the HAL System Evaluation Worksheet. Thus, a benefit/cost ratio computed according to this procedure may substantially underestimate the benefits being realized by the city and its motorists.

The HAL System evaluation provides documentation of the effectiveness of crash reduction projects and should be a means of enlisting more support for traffic safety efforts. The HAL evaluation should be prepared annually and submitted as a report for administrative review. Staff requirements, funds expended and the benefits realized should be presented in this annual report. The improvement projects should be described, and the results of improvements tabulated for easy review. Also, locations which experienced a higher than average crash rate, but were not improved, should be documented as being on a "waiting list."

Needs for future HAL System activities should be estimated so they may become a part of the city budgeting and planning procedures. Following administrative review, the HAL System evaluation should be released to the news media so the public may become better informed about the potential benefits that are attainable by traffic safety improvements.

THE REGRESSION-TO-THE-MEAN PROBLEM

When a list of the most hazardous sites in a community is compiled based on the crash rates over a period of time (e.g., one- year, three years, etc.), a statistical phenomenon known as "regression-to-the-mean" (r-t-m) can occur. The crash rate for any location is due both to hazards that are present and some element of randomness. R-t-m results in overly optimistic predictions of the benefits to be gained from improvements.

For example, assume that the six most hazardous sites in a city have similar characteristics and, over a long time period (many years), each site would be expected to average 10 crashes per year. However, in any given year there will be some variation in the number of crashes at the six sites. Perhaps during one particular year the six sites experience 15, 11, 10, 8, 7 and 5 crashes, respectively. The total number of crashes during that year is 56, a number that is fairly close to the expected number of 60 crashes.

(10 crashes per year per intersection) x (6 intersections) = 60 crashes

However, the city only has enough money to address the three “worst sites.” The worst sites that year had 15, 11 and 10 crashes. These three sites had a total of 36 crashes, rather than the “expected” number of 30. When Crash Reduction Factors are applied to the number of crashes at the top three sites, the expected crash reduction will be based on the crash record from that year (36 total crashes) rather than the true expected value of 30 total crashes. In this case, the number of crashes prevented by the improvements will be overestimated by 20%.

Overestimation = 100% x [(36-30)/30] = 20%

If no improvements are made at those top three sites, over a long period of time they will each average about ten crashes per year. Placed in broad terms, even though no improvements are made, the “worst” sites in a jurisdiction in any given year will “regress” toward the mean number of crashes in later years, even though no improvements are made. (Note, however, that the sites that are truly the most hazardous in a region will have high crash rates during most years and will therefore be identified by HAL analysis.)

We cannot know the true expected crash rate because we can only examine the crash rate over a limited period of time. Therefore, the r-t-m problem is not easily avoided. The BEATS software, cited in the References section, is one technique developed for the Federal Highway Administration to aid in crash analysis. The software requires a great deal of effort and data to use, but it can be effective in handling the r-t-m problem.

R-t-m will often mean that some safety benefits are overestimated. While the r-t-m problem is real, it should not discourage users of the HAL manual. The locations that have the highest numbers of crashes or highest crash rates during any significant time period will be identified by the HAL system. These sites are likely to be among the most hazardous in the jurisdiction, and, therefore, any improvements that appear beneficial from a HAL analysis should yield significant benefits to the public.

GLOSSARY

Accident – see “Crash”

Annual City-Wide Analysis – A procedure to identify high-crash locations using one to three years of crash data.

Average Daily Traffic (ADT) – The average 24-hour volume or the total volume during a stated period divided by the number of days in that period.

Benefit/Cost (B/C) Ratio - The annual economic value of the reduction in fatalities, injuries, and property damage divided by the annual cost of the accident reducing countermeasures.

Collision Diagram – A schematic diagram showing the direction of vehicle travel prior to a crash, the type and severity of crash, and any vehicles or pedestrians whose presence might have contributed to the crash. Collision diagrams are not drawn to scale, but represent the approximate crash location. Collision diagrams are prepared for intersections or locations between intersections.

Condition Diagram – A scaled drawing of the important physical condition of a highway location or section and the surrounding features. It is used in conjunction with the collision diagram as an aid to interpreting crash patterns and to relate the crash patterns to the roadway and operational factors.

Correctable Crashes – Crashes which could be reduced by a feasible safety-related countermeasure at the study site.

Countermeasure (Improvement) – A physical or operational measure designed to reduce the severity and number of traffic crashes.

Countermeasure Analysis – A procedure used to determine the best countermeasure from a group of alternatives using economic considerations.

Crash (Accident) – An unplanned event that results in a fatality, personal injury, and/or property damage.

Crash Rate – The number of crashes that occur during a specified period of time, divided by a measure of the extent of vehicular exposure over the same period. For intersections, crash rate is expressed as crashes per million entering vehicles, while for mid-block sections, the rate is expressed as crashes per 100 million vehicle miles traveled on the section.

Crash Reduction Factors – Estimates of the percent crash reduction likely to be obtained due to a countermeasure; derived from previously observed and documented crash reductions on one or more highway safety improvement projects.

Crash Severity – A measure of the seriousness of a crash or all crashes at a highway location. Crash severity usually is expressed in terms of number of fatalities, injuries, or property damage crashes.

Crash Type – Classification of the specific crash occurrence related to the movements of the involved vehicle(s). Examples of crash types include right-angle, rear-end, head-on, and fixed object.

Design Speed – A speed which is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favorable that the design features of the highway govern.

Deslicking – Any procedure involving the application of a pavement surface coating, surface treatment, or an added layer of paving material, with a primary objective being to improve the skid resistance of the pavement.

Economic Analysis – Determination of the worth of a project by comparing the benefits derived and the costs incurred.

Early-Warning Analysis – A procedure to identify high-crash locations using 3 or 6 months of crash data.

Eighty-Fifth (85^{th}) Percentile Speed – The speed at which 85 percent of vehicles travel at or below. The 85th percentile speed is commonly used with the 10-mph pace for assigning speed limits.

Equivalent-Property-Damage-Only (EPDO) Number – A weighted crash number giving fatal and injury crashes more importance than property-damage-only crashes.

Exposure – A measure of the frequency at which vehicles are exposed to collisions; for intersections the unit is one million entering vehicles, while for mid-block sections the unit is 100 million vehicle miles traveled.

Fatal Crash – A crash event involving at least one fatality.

HAL System – The set of procedures provided in this manual for the identification, analysis and correction of <u>h</u>igh-cr<u>a</u>sh <u>l</u>ocations.

Injury Crash – A crash event involving at least one injury but no fatalities. An injury crash may also involve property damage.

Intersection-Related Crash (Intersection Crash) – A crash that occurs as a result of the operation of an intersection.

Location Analysis – A procedure involving analysis and study of a high-crash location in order to determine appropriate countermeasures to reduce the crash experience at that location.

Mid-Block Crash – A crash that is not related to any operations or events occurring at an intersection.

Non-Correctable Crashes – Crashes which are not usually amenable to correction by a countermeasure.

Pace (10-mph Pace) – The 10-mph range of traffic speeds containing the largest number of observations during a spot speed study.

Property-Damage-Only Crash (PDO) – A crash involving damage to one or more vehicles or other property, but no injuries or fatalities.

Salvage (Terminal) Value – Estimated residual worth or value of a project, program, or project components at the end of the expected service life.

Service Life – The number of years during which the components of a project or the entire project can be expected to satisfactorily perform an intended function.

Spot Speed Study – The measurement of a sample of vehicular speeds at a specific location. Spot speed studies are conducted to determine the speed distribution of all vehicles passing a particular location under the conditions prevailing at the time of the study.

Stopping Sight Distance – The minimum distance required for a driver, after seeing an object, to stop the vehicle without hitting the object.

Technology Transfer Assistance Program (TTAP) – A program that provides service and assistance to local transportation agencies. It is administered by the Missouri Department of Transportation (MoDOT) with the support of the Federal Highway Administration.

Traffic Conflict – A traffic event involving two or more road users, in which one user performs some unusual or unexpected action that places another user in jeopardy of a collision unless an evasive maneuver is undertaken. The action could be a change in direction or speed.

Traffic Control Device – A sign, signal, marking, or other device placed on or adjacent to a street or highway, by authority of a public body or official having jurisdiction, to regulate, warn, or guide traffic.

Traffic Records System – The personnel, equipment, facilities, information, and procedures necessary to correlate crash data with vehicle, driver, and/or highway data. This allows the causes of traffic crashes and the means of preventing crashes to be identified.

Warrants – Minimum specified values of traffic crashes, traffic volumes or other location characteristics that serve as a guide to indicate when a countermeasure or improvement should be installed at a location.

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APPENDIX A

NON-CRASH-BASED PROCEEDURES

In addition to the crash files, procedures, and summaries that have been described in this manual, locations needing improvement can also be identified through other means. Information other than the numbers, types, and locations of crashes can often help to identify hazardous locations before a large number of crashes occur. Other sources of information include citizen complaints and suggestions concerning road safety and repair, employee reports of hazardous locations or ideas for improving traffic safety, and road safety audits. The city should have a system in place to receive and act on this information in a timely and organized manner.

NON-CRASH SOURCES OF INFORMATION FOR IMPROVEMENTS

Citizen Complaints

Responses to complaints from citizens should be acted upon according to the importance of the situation to public health and well being. A complaint regarding a hazardous situation could necessitate an immediate response, such as replacing a missing STOP sign. A telephone call reporting a large pothole, on the other hand, may be justification to alter the street maintenance schedule.

Employee Reports

All city employees and officials, not just police officers, should be encouraged to submit ideas for improving traffic safety. Files on public and employee input should include:

- The time and date when the information was received,
- The nature of the reported hazard,
- The name of the person who was assigned the responsibility to investigate the problem,
- The actions taken to remedy the situation, and
- The time and date when the corrective action was completed.

Road Safety Audits

The road safety audit is a relatively new technique aimed at identifying potential road hazards on existing and future roads. In a report published by the Institute of Transportation Engineers (ITE), a road safety audit is defined as, “a formal examination of an existing or future road or traffic project, or any project that interacts with road users, in which an independent, qualified examiner looks at the project’s crash potential and safety performance.” Two of the key aspects of a road safety audit are that it is a formal, unbiased evaluation of the roadway (primarily identifying safety problems) and that it employs qualified and experienced auditors.

A road safety audit has two main objectives. The first objective is to identify areas on roads where potential crashes may occur. The second objective is to reduce or eliminate safety problems by taking proper remedial measures. Benefits realized by safety audits include:

- Reduction in the frequency and severity of traffic crashes,
- Elimination of post-construction work,
- Increase in the economic benefits of a project by reducing the lifecycle costs of a project, and
- Promotion of safe design practices during planning, design, construction, and maintenance stages of projects.

Application of Road Safety Audits

Road safety audits can be conducted at different stages of the project, including:

- Feasibility Stage: Road safety audits can affect the scope of the project, selection of routes, design standards, the road network currently in service, and many of the other activities taking place at this stage.
- Preliminary Design Stage: Aspects of the project that can be affected by safety audits during this stage include horizontal and vertical alignment, lane width, shoulder width, intersection layouts, and super-elevation.
- Detailed Design Stage: During this stage, many aspects of the detailed design are considered, such as line markings, signs, delineation, lighting, and details of intersection layouts.
- Pre-opening Stage: The auditor or audit team should drive, ride, and walk through the facility at different times and under different weather and climate conditions to locate areas where the user is at risk.
- In-service Stage: During this stage, a systematic examination of the existing roads is performed to evaluate their safety. This type of audit can be used to monitor a newly opened facility or to evaluate the safety of an existing road or network of existing roads.

Conducting Road Safety Audits

The road safety audit is a valuable tool for preventing crashes. It can be performed with a limited amount of crash and traffic data, which makes it especially feasible and cost-effective for small cities. Sample worksheets for safety audits are provided in Figures A-1 and A-2. The audit is made up of the following steps:

1. Select an auditor or audit team: The auditor or audit team should be experienced in the field of traffic safety and management, crash investigation, road design, and human factor analysis. The selection should be such that the auditor or audit team will conduct the audit in an independent and objective manner. Independence of the auditor or audit team can be ensured by hiring qualified consultants in the city or by utilizing an auditor from another city.
2. Conduct the road safety audit: A program should be developed that ensures the auditing of the entire network of roads and streets. Then, an audit checklist should be formulated covering all the important safety problems. This checklist is used as a supplement to support the experience and knowledge of the auditor or audit team. During the audit, safety must be considered from the viewpoint of all road users, and all possible movements of traffic must be examined. The audit should also address different climate conditions, conditions at different times of the day, and different traffic conditions. Finally, the audit should address the possibility of enhancing safety by providing a more consistent street environment.
3. Produce a road safety report: The final report describes the results, and hence the safety needs for the street network. Priorities and general auditor recommendations may be included in the report.
4. Hold a follow-up evaluation: The auditor or audit team, persons with jurisdiction over the network, and those funding the project should discuss the results and findings of the audit in a follow-up meeting. During the meeting, some safety needs are given priorities over others. Any action regarding the audit itself should be documented, as well as resulting programs, schedules, and safety actions to be taken.

SETTING UP A SYSTEM FOR RECEIVING INFORMATION

The city should have a well-organized system for receiving information from individuals, prioritizing city responses, assigning work to be done, and documenting job completion. This allows the city not only to respond to citizen complaints more effectively, but also to expand the ability of the city to detect traffic safety problems throughout the entire jurisdiction. The system can be set up as follows:

1. Establish a specific contact point in the city offices to receive all complaints and suggestions concerning local traffic safety. Each contact must be logged into a permanent record giving the name, address, and phone number of the individual making the report, the time the report was received, and a description of the problem reported.

SAFETY AUDIT CHECKLISTS FOR EXISTING STREETS

Auditor(s): ____ Date: ________________

Location (Reference Map included):____

TRAFFIC SIGNS

Traffic signs must: 1) Fulfill a need, 2) Command attention, 3) Convey a clear, simple message, 4) Command respect of road users, and 5) Give adequate time for proper response. When correcting problems, priority is recommended for regulatory signs (i.e. Stop, Yield, Speed Limit, Do Not Enter, and Road Closed) and for major warning signs (i.e. Stop Ahead, Yield Ahead, Turn, Curve, and Railroad Crossings).

Check

☐ Are signs visible, **both day and night**, at a distance that provides response time for motorists?

☐ Is sign visibility affected by:
- Vegetation, Dirt, Other Materials?
- Sharp Curves?
- Steep Hills?
- Other Signs?
- Poor Lighting?
- Reflectivity at Night?

☐ Have damaged, vandalized, or missing signs been repaired or replaced?

☐ Does the sign have a clear and simple message?

☐ Are signing practices consistent at similar locations?

☐ Are signs correctly positioned with respect to:
- Lateral Clearance? (2 feet recommended)
- Height? (7 feet to bottom of the sign recommended)

☐ Are sign supports breakaway or yielding?
- If not, are the sign supports located to minimize exposure to traffic?

Site-specific factors may require engineering judgment. The Manual on Uniform Traffic Control Devices (MUTCD) is the basis for all traffic control device standards. The MUTCD and applicable state and local standards should be referenced as needed. The necessary advance warning distance depends on several factors such as vehicle speed, site conditions, and required motorist action; consult the MUTCD for further guidance.

FIGURE A-1 AUDIT CHECKLIST FOR TRAFFIC SIGNS ON EXISTING STREETS (FROM HAIAR AND WILSON 1999)

SAFETY AUDIT CHECKLISTS FOR EXISTING STREETS

Auditor(s): ____ Date: __________________

Location (Reference Map included):____

INTERSECTIONS

Site-specific factors often require engineering judgment. The Manual on Uniform Traffic Control Devices (MUTCD) and applicable state and local standards should be referenced as needed for guidance as to the appropriate traffic control and sight distance for an intersection. The signing checklist provides a more detailed examination of signing issues.

Check

☐ Is the visibility of the intersection or any approaches limited by:
- Parked or Queued Traffic?
- Signs, Utility Poles, Fences?
- Embankments?
- Buildings?
- Vegetation?
- Other Sight Obstructions?

☐ Has an effort been made to improve the sight distance of the intersection before installing traffic control measures?
- An engineering study is usually necessary for the placement of traffic control.
- Use of stop signs is not recommended for speed control.

☐ Are hidden or unexpected intersections located on:
- Hills or curves?
- At the end of high-speed streets?
- Streets that do not intersect at 90°?

If so, additional warning for the motorist may be necessary.

☐ Are pedestrians (children, bicyclists, etc.) and motorists readily visible at the intersection?

FIGURE A-2: AUDIT CHECKLISTS FOR STREET INTERSECTIONS (FROM HAIAR AND WILSON 1999)

2. Enact a procedure to prioritize complaints in the event there are multiple complaints received at about the same time. The following four-level priority system is suggested:

   Priority A: URGENT. Should respond as soon as possible (day, night, weekends, or holidays), suspending lower priority work if necessary. This condition represents an immediate hazard to the public, such as roadside fixture knockdown onto street, traffic signal bulb out, or stop sign missing.

   Priority B: MODERATE RISK. Should respond as soon as possible, but within normal working hours and only after Priority A repairs are finished. This situation results in some danger to the motoring public and most drivers would normally not expect it to exist. Examples include roadside fixture knockdown onto shoulder, warning sign missing, or sight distance restricted due to vegetation.

   Priority C: LOW RISK. Only slight danger to motoring public if some degree of caution is not exercised. Repair should be accomplished with more urgency than routine maintenance. Examples are: lighting fixture malfunction, lack of pavement stripe, or loose gravel on a paved surface.

   Priority D: ROUTINE MAINTENANCE. Repair not urgent, situation is a reasonably common occurrence, with little or no hazard to the motoring public. Repair would be considered as routine maintenance, but maintenance schedule could be altered to give earlier attention to reported condition. Examples are spalled pavement areas or small potholes.

3. Any corrective action should be recorded on a form designed to describe the complaint, its location, the priority of action to be taken, the name of the person assigned to investigate and handle the problem, the time the repair work was initiated, the nature of the work that was completed, and the time when the work was completed.
4. After the work has been completed, the person who filed the complaint or provided the suggestion should be contacted to inform him or her of the actions taken. Then, a permanent record should be kept, by location, to supplement the high-crash location countermeasure selection process.

It is also advisable for the city engineer to record other data that will prove useful for traffic studies, city planning, and activity reports. Examples of supplementary information that should be kept include:

- Dates and descriptions of major street and intersection improvements,
- Dates of completion and descriptions of any new, major facility that causes changes in traffic volumes or traffic patterns, and
- Files on public input and city employee reports.

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APPENDIX B

PROBABLE CAUSES FOR CRASH PATTERNS AND GENERAL COUNTERMEASURES

The primary purpose of the crash pattern-cause-countermeasure table (Table B-1) is to assist the user in establishing a list of general countermeasures (or possible improvements) for a high-crash location. It is assumed that particular crash patterns have associated probable causes. Crash patterns are identified from crash summaries and collision diagrams. Probable causes relating to crash patterns are inferred from crash reports, on-site reviews, and other traffic studies conducted at the site.

Table B-1 is a basic guide to the general types of countermeasures that have been found to be effective in crash reduction. There may be other improvements not in the table that could be appropriate for a particular high-crash location. Those improvements may be identified by professional judgment or by consulting with other engineers.

The crash pattern-cause-countermeasure table is organized according to the following crash patterns:

- Right-angle collisions at un-signalized intersections
- Right-angle collisions at signalized intersections
- Rear-end collisions at un-signalized intersections
- Rear-end collisions at signalized intersections
- Pedestrian crashes at intersections
- Pedestrian crashes at locations between intersections
- Fixed object collisions
- Fixed object collisions and/or vehicles running off road
- Collisions with parked vehicles or vehicles being parked
- Collisions at driveways
- Wet pavement crashes
- Crashes at night
- Collisions at railroad grade crossings
- Sideswipe or head-on collisions between vehicles traveling in opposite directions
- Lane change, sideswipe, or turning collisions between vehicles traveling in the same direction
- Left-turn collisions at intersections

- Right-turn collisions at intersections
- Pedestrian crashes at intersections

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CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Right-angle collisions at un-signalized intersections	restricted sight distance	1-remove sight obstructions 2-restrict parking near corners 3-install warning signs * 4-install yield signs * 5-install stop signs * 6-install overhead flashing beacon * 7-channelize intersection 8-install/improve street lights at intersection 9-install traffic signals * 10-set appropriate speed limit ** 11-improve intersection approach angle
	high approach speed	1-set appropriate speed limit ** 2-install rumble strips 3-install overhead flashing beacon *
	large total traffic volume at location	1-install stop signs * 2-restrict parking near corners 3-add traffic lanes 4-re-route through-traffic 5-install signals *
	inadequate roadway lighting	install/improve street lights at intersection
	inadequate advance intersection warning signs	install/improve warning signs *
	inadequate traffic control devices	1-upgrade traffic control devices 2-increase enforcement
Right-angle collisions at signalized intersections	restricted sight distance	1-remove sight obstructions 2-restrict parking near corners 3-install/improve warning signs * 4-set appropriate speed limit ** 5-provide adequate channelization 6-provide pavement markings to supplement signs

TABLE B-1: GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Right-angle collisions at signalized intersections (cont'd)	poor visibility of traffic signals	1-remove sight obstructions 2-set appropriate speed limit ** 3-install or improve warning sign(s) * 4-install 12-inch signal lenses * 5-install signal visors or back plates 6-install overhead signals * 7-add signal heads * 8-re-locate signals
	inadequate traffic signal timing or type of signal	1-adjust yellow change interval 2-add all-red clearance interval 3-adjust phase times and cycle time 4-install multi-dial controller 5-install traffic actuated signal 6-adjust minimum green or extension time 7-interconnect traffic signals and improve timing 8-install signal speed signs *
	excessive speed	1-set appropriate speed limit ** 2-adjust yellow change interval 3-install rumble strips
	inadequate roadway lighting	install/improve street lights at intersection
	inadequate advance intersection warning signs	install/improve warning sign(s) *
	large total intersection volume	1-add lane 2-adjust signal timing
Rear-end collisions at un-signalized intersections	pedestrians crossing roadway	1-improve crosswalk markings and/or signs * 2-install/improve street lights at intersection 3-relocate crosswalk
	excessive speed	set appropriate speed limit **

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Rear-end collisions at un-signalized intersections (cont'd)	large volume of vehicles turning	1-increase curb radii 2-install turning lanes 3-prohibit turns
	slippery surface	1-overlay pavement (friction course) 2-chip and seal or slurry seal approaches 3-groove pavement surface 4-provide adequate drainage and/or improve crown 5-set appropriate speed limit ** 6-use "SLIPPERY WHEN WET" sign *
	driver not aware of intersection	1-install/improve warning signs * 2-install overhead flashing beacon * 3-improve intersection approach angle
	inadequate roadway lighting	install/improve street lights at intersection
	lack of adequate gaps	1-install traffic signal * 2-install stop sign *
Rear-end collisions at signalized intersections	poor visibility of traffic signals	1-install/improve warning sign * 2-install 12-inch signal lenses * 3-install signal visors or back plates 4-install overhead signals * 5-add signal heads * 6-re-locate signals 7-remove sight obstructions 8-set appropriate speed limit **
	inadequate traffic signal timing	1-adjust yellow change interval 2-add all-red clearance interval 3-adjust phase times and cycle time 4-install multi-dial controller 5-install traffic actuated signal 6-adjust minimum green or extension time 7-interconnect traffic signals and improve timing

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Rear end collisions at signalized intersections (cont'd)	slippery surface	1-overlay pavement (friction course) 2-chip and seal or slurry seal approaches 3-groove pavement surface 4-provide adequate drainage and/or improve crown 5-set appropriate speed limit ** 6-use "SLIPPERY WHEN WET" sign *
	pedestrians crossing roadway	1-improve crosswalk markings/signs * 2-provide pedestrians with "WALK" phases 3-install/improve street lights at intersection
	unwarranted signals	remove signal *
	large volume of vehicles turning	1-prohibit turn 2-install turn lane 3-increase curb radii 4-add left-turn signal phase
	inadequate roadway lighting	install/improve street lights at intersection
Pedestrian crashes at intersections	inadequate protection for pedestrians	1-add pedestrian refuge island 2-install pedestrian barrier 3-install pedestrian signals * 4-install pedestrian bridge or tunnel
	inadequate traffic signals	1-add pedestrian "WALK" phase * 2-improve timing of pedestrian phase
	excessive speed	1-install/improve warning sign * 2-set appropriate speed limit ** 3-increase enforcement 4-install pedestrian barrier
	inadequate signal timing	re-time signal

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Pedestrian crashes at intersections (cont'd)	school crossing area	1-remove parking from crosswalk location 2-remove sight obstructions 3-add school zone markings * 4-install school crossing signs * 5-install school speed limit signs * 6-install school crossing signals * 7-use school crossing guards 8-revise school route plan map * 9-install pedestrian bridge or tunnel
	sight distance inadequate	1-remove sight obstructions 2-install/improve pedestrian crosswalk 3-install/improve pedestrian crossing signs * 4-reroute pedestrian path/mid-block crossing 5-restrict parking near corner/crosswalk
	inadequate/improper pavement markings	1-install thermoplastic markings 2-provide signs to supplement markings 3-improve/install pavement markings
Pedestrian crashes at locations between intersections	driver has inadequate warning of frequent mid-block crossings	1-install/improve warning signs * 2-set appropriate speed limit ** 3-install pedestrian barrier 4-prohibit parking
	pedestrians walking on road or jay-walking	1-install sidewalks 2-install "CROSS ONLY AT CROSSWALK" sign * 3-install pedestrian barrier
	distance too long to nearest crosswalk	1-install additional crosswalks and signs * 2-install pedestrian actuated signals *
	excessive speed	1-install/improve warning sign * 2-set appropriate speed limit ** 3-increase enforcement 4-install pedestrian barrier

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Pedestrian crashes at locations between intersections (cont'd)	inadequate roadway lighting	improve roadway lighting
	lack of adequate gaps	1-provide traffic signal * 2-install/improve pedestrian crosswalk traffic control devices * 3-provide pedestrian signal *
	inadequate/ improper pavement markings	1-install thermoplastic markings 2-provide signs to supplement markings 3-improve/install pavement markings
Fixed object collisions	objects located too close to the roadway	1-remove/re-locate large objects 2-install object marker * 3-modify poles/posts with breakaway features 4-eliminate poles by burying utility lines 5-install barrier curbs or guardrail 6-install crash cushioning device
	excessive speed	set appropriate speed limit**
	slippery surface	1-provide adequate drainage 2-provide "SLIPPERY WHEN WET" signs * 3-widen lane 4-improve skid resistance
	inadequate roadway lighting	install/improve roadway lighting
	inadequate/improper pavement markings	install/improve pavement markings
	inadequate roadway design for conditions	1-install/improve warning signs * 2-provide proper superelevation

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Fixed object collisions (cont'd)	inadequate traffic control devices and guardrails	paint/install reflectors on obstructions
Fixed objects/run-off the road crashes	slippery surface	1-overlay pavement (friction course) 2-chip and seal or slurry seal roadway 3-groove pavement surface 4-provide adequate drainage and/or improve crown 5-set appropriate speed limit on approaches ** 6-use "SLIPPERY WHEN WET" sign *
	roadway design is no longer adequate for traffic conditions	1-widen lanes and/or shoulders 2-relocate or remove islands 3-flatten side slope 4-provide proper superelevation on curve 5-construct more gradual horizontal curve 6-install post-mounted delineators on horizontal curve 7-install chevron alignment sign on horizontal curve
	poor delineation	1-install/improve warning signs * 2-install/improve pavement markings 3-install roadside delineators or chevron alignment signs *
	driver has inadequate warning of roadway alignment change	1-install curve warning sign * 2-install advisory speed plate or curve warning sign(s) * 3-install large arrow warning sign *
	excessive speed	set appropriate speed limit **
	inadequate roadway lighting	install/improve roadway lighting
	poor visibility of traffic control devices	increase sign size

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Fixed objects/run-off the road crashes (cont'd)	inadequate shoulder	upgrade roadway shoulder
	inadequate channelization	provide adequate channelization
	inadequate pavement maintenance	repair road surface
Collisions with parked vehicles or vehicles being parked	high rate of parking turnover	1-change from angle to parallel parking 2-provide short-term off-street parking 3-prohibit parking 4-restrict parking during rush hours 5-reroute through traffic 6-create one-way streets
	roadway design is not adequate for traffic conditions	1-widen lanes 2-change from angle to parallel parking 3-prohibit parking 4-restrict parking during rush hours 5-reroute through traffic 6-set appropriate speed limit on traveled way **
	inadequate parking clearance at driveway	restrict parking near corner/ crosswalk/driveway
	excessive speed	set appropriate speed limit **
	inadequate or improper pavement markings	mark parking stall limits
	angle parking	convert angle to parallel parking
	illegal parking	1-increase enforcement 2-prohibit parking 3-create off-street parking

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Collisions at driveways	improperly located driveway	1-regulate minimum spacing of driveways 2-regulate minimum corner clearances 3-move driveway to side street 4-install curb to define driveway location 5-combine adjacent driveways
	inadequate sight distance	1-remove sight obstructions 2-restrict parking near driveway 3-install/improve lighting at driveways 4-set appropriate speed limit ** 5-improve vertical curve
	left-turn vehicles	1-install median barrier 2-install continuous two-way left-turn lane 3-install protected left-turn bays
	right-turn vehicles	1-install right-turn lanes 2-restrict parking near driveways 3-increase roadway width 4-widen through-lanes 5-increase driveway curb radii
	excessive speed	set appropriate speed limit **
	large volume of through traffic	1-move driveway to side street 2-construct a local service road 3-re-route through traffic
	large volume of driveway traffic	1-install signal at driveway 2-provide acceleration and/or deceleration lanes 3-widen and/or channelize driveway 4-construct additional driveway 5-change to one-way driveway
	inadequate roadway lighting	improve roadway lighting

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Crashes on wet pavement	water ponding on roadway	1-provide adequate drainage and/or improve crown 2-remove turf or other drainage impediments from shoulder
	slippery surface	1-overlay pavement (friction course) 2-chip and seal or slurry seal roadway 3-groove pavement surface 4-set appropriate speed limit ** 5-use "SLIPPERY WHEN WET" sign * 6-provide adequate drainage 7-improve skid resistance
	inadequate/improper pavement markings	install raised/reflectorized pavement markers
Crashes at night	poor visibility	1-install/improve street lighting 2-install/improve reflectorized signs 3-install/improve reflectorized pavement markings 4-remove distracting commercial lighting or other sources of glare
	poor visibility of traffic control devices	1-install/improve warning signs * 2-improve roadway lighting 3-install/improve delineation
	inadequate signing	1-upgrade traffic control devices * 2-provide illuminated signs 3-install chevron alignment sign on horizontal curve
	inadequate delineation	1-install/improve warning signs * 2-provide raised markings 3-install/improve delineation 4-install post-mounted delineators on horizontal curve

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Crashes at night (cont'd)	inadequate channelization	1-install/improve warning signs * 2-provide raised markings 3-install/improve delineation 4-install/improve pavement markings
Collisions at railroad grade crossing	inadequate sight distance	1-remove sight obstructions 2-improve/install advance warning signs * 3-provide stop sign * 4-improve/install pavement markings * 5-reduce grade 6-install train actuated signals * 7-install overhead flashing beacon * 8-install automatic crossing gates 9-improve intersection approach angle 10-install bridge or tunnel
	poor visibility	1-install/improve lighting at crossing 2-install larger, reflectorized signs
	slippery surface	1-improve drainage 2-install skid-resistant surface
	excessive vehicle or train speed	1-set appropriate speed limit ** 2-reduce train speed near crossing
	inadequate/improper pavement markings	1-add markings to supplement signs 2-install limit lines 3-install/improve pavement markings
	improper traffic signal preemption timing	re-time signal
	improper signal or gate warning time	re-time automatic flashers or flashers with gates

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Collisions at railroad grade crossing (cont'd)	rough crossing surface	improve crossing surface
	sharp crossing angle	rebuild crossing with proper angle
Sideswipe or head-on collisions between vehicles traveling in opposite directions	roadway design is no longer adequate for traffic conditions	1-install/improve center line markings * 2-channelize intersection 3-widen lanes and/or shoulders 4-remove constriction such as parked vehicles 5-install median barrier 6-create one-way streets
	excessive speed	set appropriate speed limit **
	inadequate/ improper pavement markings	install/improve pavement markings
	inadequate shoulder	upgrade roadway shoulder
	inadequate channelization	1-provide adequate channelization 2-provide turn lane 3-install acceleration/deceleration lane 4-install median barrier
	inadequate signing	1- install illuminated street name signs 2-install advance guide sign *
	inadequate pavement maintenance	repair road surface
Lane change, sideswipe or turning collisions between vehicles traveling in the same direction	inadequate traffic control devices	1-install/improve pavement lane lines 2-install advance route identification signs or street name signs

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Lane change, sideswipe or turning collisions between vehicles traveling in the same direction (cont'd)	roadway design is no longer adequate for traffic conditions	1-widen lanes and/or shoulders 2-remove constriction such as parked vehicles 3-channelize intersection 4-provide turning bay for high-volume driveway 5-install continuous two-way left turn lane 6-set appropriate speed limit **
	excessive speed	set appropriate speed limit **
	inadequate/improper pavement markings	install/improve pavement markings
	inadequate shoulder	upgrade roadway shoulder
	inadequate channelization	1-provide adequate channelization 2-provide turn lane 3-install acceleration/deceleration lane
	inadequate pavement maintenance	repair road surface
	inadequate signing	1-install illuminated street name signs 2-install advance guide sign *
Left turn collisions at intersections	restricted sight distance	1-provide left-turn signal phase 2-provide adequate channelization 3-remove sight obstructions 4-provide turn lane 5-install/improve warning sign * 6-set appropriate speed limit **
	absence of left-turn phase	add left-turn signal phase

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

CRASH PATTERN	PROBABLE CAUSE	COUNTERMEASURE
Left turn collisions at intersections (cont'd)	large volume of left-turn traffic	1-create one-way street 2-install left-turn lane 3-add left-turn signal phase 4-prohibit left-turn 5-re-route left-turn traffic 6-provide adequate channelization 7-install stop sign * 8-adjust signal phase sequence 9-provide turning guidelines for multiple left-turn lanes 10-install new traffic signal * 11-re-time signal
	yellow phase too short	1-adjust yellow change interval 2-add all-red interval
	excessive speed	set appropriate speed limit **
Right-turn collisions at intersections	inadequate turning path	increase curb radii
	restricted sight distance	1-remove sight obstructions 2-add "NO TURN ON RED" signs if signalized * 3-set appropriate speed limit on approaches **
Pedestrian crashes at driveways	sidewalk too close to the roadway	move sidewalk laterally away from street

* Refer to Manual on Uniform Traffic Control Devices for proper application and warrants.
** Spot speed study should be conducted to justify speed limit.

TABLE B-1 (CONT.): GENERAL COUNTERMEASURES FOR CRASH PATTERNS AND THEIR PROBABLE CAUSES

APPENDIX C

COLLECTION OF TRAFFIC DATA

This appendix explains how to conduct several types of studies used to collect traffic data.

INTERSECTION VOLUME STUDIES AND ENTERING ADT ESTIMATES

One of the most important reasons for conducting an intersection traffic count is to collect the information needed to estimate the entering Average Daily Traffic (ADT). To conduct an intersection traffic count, record the vehicle paths of entry and departure at the location. Occasionally, it is necessary to classify vehicles by type and to count pedestrians and cyclists.

Due to staff and cost constraints, the manual counting period duration is limited, and the counts are samples of actual traffic volumes. The sampling period for manual counting may range from 1 to 12 hours. Mechanical or automated equipment can provide longer sample periods, from a few hours to a full year.

Manual Traffic Counts

The following sections explain the recommended procedures for obtaining accurate manual traffic counts.

What to Count

Use the following guidelines for counting and classifying:

- Unless otherwise directed, only count vehicles entering the intersection. When required, tally pedestrians and cyclists.
- Record each vehicle according to the direction from which it approaches the intersection and whether it turns right or left, or goes straight. Count pedestrians each time a crosswalk is used.
- Count U-turns as left turns.
- Classify vehicles as:
  - Passenger vehicles: cars, vans, smaller trucks (e.g. pick-ups), and motorcycles,
  - Trucks: larger trucks (six or more tires) and semi-trailer or combination trucks, and
  - Buses: commercial and school buses.

Guidelines for detailed vehicle classification studies are available from the MoDOT Technology Transfer Assistance Program (TTAP) office. The TTAP office can also provide information on the community traffic counting program and community traffic maps.

Tally Sheet

Manually record vehicle volume and turning movement counts at intersections using the Traffic Count Field Sheet shown in Figure C-1. The tally sheets have 12 rectangles for recording vehicle movements and 4 squares for recording pedestrian crossing activity. Before beginning the counts, enter the street name, date, time, and other related information on the tally sheet. It is best to prepare all sheets that will be needed prior to the first counting period. A single field sheet could be used for whatever time period is desired; however it is recommended that a new sheet be started every 15 minutes during the study.

To record pedestrians and vehicles, use a tally system consisting of four vertical marks with every fifth mark placed diagonally across the four marks (i.e. ~~||||~~). Symbols such as a "T" for a truck, "B" for a bus, and "SB" for a school bus should be utilized to classify vehicles.

Note any unusual events that affect the traffic flow during the counting period, and their duration. If an incident occurs that substantially disrupts traffic flow (in a way that would eliminate the usefulness of the study), stop the count and conduct the study at another time.

Suggested Equipment

The observer(s) conducting the traffic count should have the following equipment on site:

- A watch with a second hand or a digital watch,
- Several pencils with erasers,
- A pencil sharpener,
- A clip board, and
- An accumulating register (optional).

Procedures

Most intersection counts require two observers. However, one observer can usually count a low-volume intersection. When two people are counting traffic at a four-leg intersection, they should be positioned in diagonally opposite quadrants (e.g. the northwest and southwest corners). Each observer should tally vehicles entering on two approaches. The observer must be inconspicuous, so his or her presence does not affect traffic operations.

INTERSECTION TRAFFIC COUNT FIELD SHEET [Form ITCFS]

N/S Street: *Third St.* Day: *Tues.* Date *3/1/99*

E/W Street: *Lincoln* Time Start: *4:30 p.m.* End: *4:45 p.m.*

Observer: *JJG* Weather: *fair*

P or (~~||||~~): Passenger cars, pickups, vans

T: Trucks with six or more tires North Arrow:

B: Buses SB: School Buses

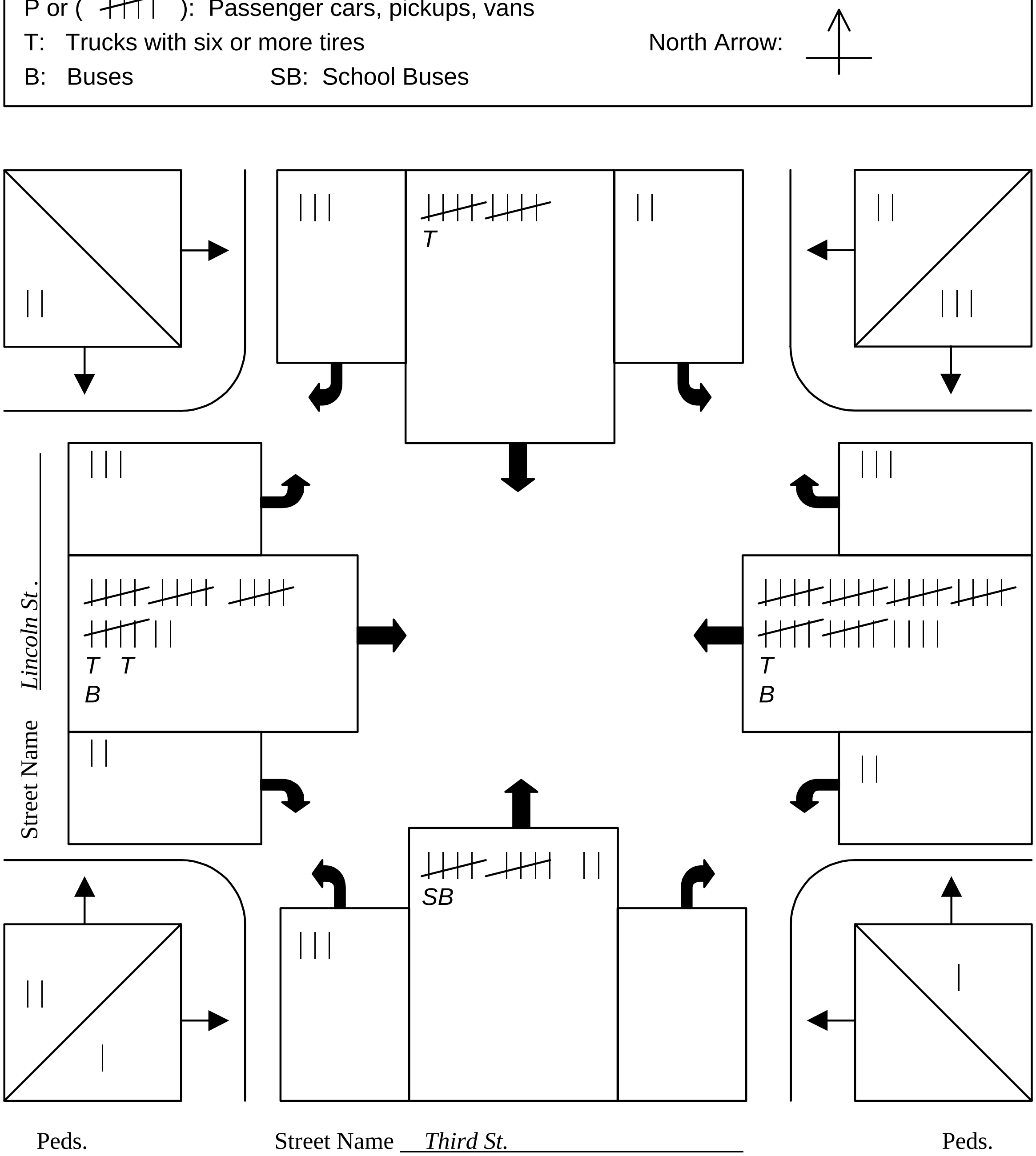


FIGURE C-1: INTERSECTION TRAFFIC COUNT FIELD SHEET

Hand-operated accumulating registers can be used to ease the tallying process. These registers are available in configurations representing intersection turning movements. Running totals are recorded at appropriate sampling intervals.

When scheduling traffic counting periods, care should be taken to avoid unusually busy or idle times. Data should not be gathered on a weekend, a Friday, the day of a special event, or a holiday.

Count Summaries

Traffic counts from the field study should be summarized as illustrated in Figure C-2, the Turning Movement Count Summary. The traffic counts in this figure are for the HAL Manual example location, the intersection of Lincoln and Third Street.

In this example, the counts were taken during a Tuesday evening peak hour. To arrive at the estimated intersection entering ADT, an adjustment factor of 10 was applied to the one-hour counts on each incoming approach. Then, as shown at the bottom of Figure C-2, the ADT estimates from each incoming approach were summed to form the "Intersection ADT Estimate."

Automated Traffic Counts

Automated traffic counts enable an agency to gather large amounts of volume data at a reasonable cost. For a long study, automated traffic counts are less expensive than manual counts because labor costs are lower. The main drawback to the automated system is the possibility that the equipment could fail due to malfunctions or vandalism.

Equipment

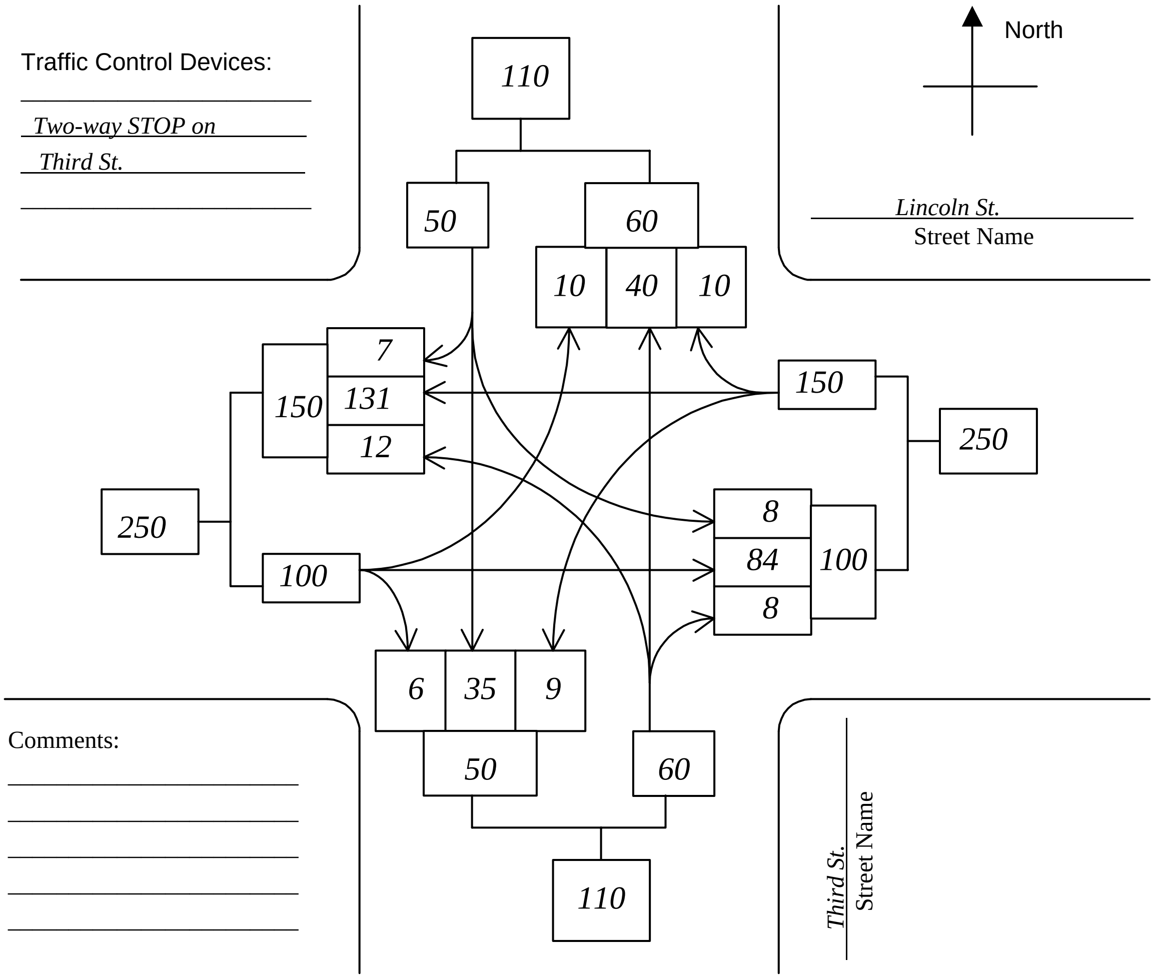
The many different types of automated counters can be divided into three categories:

- Portable Counters – Portable counters are usually used for short periods of time (24 hours). The most common sensors in these counters include pneumatic road tubes, piezoelectric strips, tape switches, or temporary induction loop detectors. Count readers range from simple accumulating counters to micro-computer-driven classification counters.
- Permanent Counters – Permanent counters are used for long-term projects that can last for a year or more. These counters use the same type of recording components as the portable counters, but the sensors are more permanent. The most common type of sensor is an induction loop, which is installed in the pavement.
- Videotapes – Videotapes give the observer an exact account of the number of vehicles during the study. They also provide the observer with information that can

VEHICLE TURNING COUNT SUMMARY AND ADT ESTIMATE [Form TCSAE]

Location *Third St. & Lincoln St.* Observer *JJG*

Day *Tues.* Date *3/1/99* Time *4:30 - 5:30 p.m.* Weather *fair*



Inbound Approach Street Name and Direction	Inbound Count	Adjustment Factor *	Average Daily Traffic Estimate
Eastbound on Lincoln	*100*	*10*	*1,000*
Westbound on Lincoln	*150*	*10*	*1,500*
Northbound on Third	*60*	*10*	*600*
Southbound on Third	*50*	*10*	*500*

Intersection ADT Estimate (total entering vehicles per day): *3,600*

* Use factor of 10 with peak 1-hour counts; use 1.3 with 12-hour counts

FIGURE C-2: VEHICLE TURNING COUNT SUMMARY AND ADT ESTIMATE be reused in other studies. After the tapes are recorded, someone must watch the tape and manually count the vehicles. Agencies typically use videotapes only if very high accuracy is needed. An alternative to manual counting from the tapes is video imaging, which counts automatically. The cost of video systems is falling, and the system is 80 to 95% accurate during the day or night, making it a more feasible option in the future.

Selecting the Count Location

Use the following guidelines to ensure the location selected for the traffic count is appropriate:

- Deploy sensors at right angles to traffic flow.
- For directional counts, place sensors at least 1 foot away from the centerline of the roadway.
- Fasten the sensor securely to the pavement with nails, clamps, tape, and/or adhesives made especially for this purpose.
- At intersections or near driveways, place sensors where double counting of turning vehicles can be avoided.
- Locate the count reader near a signpost or tree and secure it with a lock and chain, or place it in a locked signal cabinet to prevent vandalism.
- Keep the cable or tube that connects the sensor to the recorder as short as possible.
- Record sensor placement by noting the physical location on a condition diagram sketch.
- Use a test vehicle to ensure that bi-directional counts are recording the proper direction.
- Set the count interval to ensure that totals will occur on the hour or day to make the data more compatible with other counts.
- Note the time that counter operation begins.
- Check the installation periodically to ensure that it is in place and functioning properly. In cold weather, check sensors whenever it snows to ensure that snowplows do not remove the sensors from the roadway.
- Do not place sensors across parking lanes, where a parked vehicle could activate the sensor continuously. Parking lanes may not always be marked.
- Avoid placing sensors on pavement expansion joints, sharp pavement edges, or curves.

Once the counts are complete, use the form in Figure C-2 to summarize the data.

CONDUCTING SPOT SPEED STUDIES AND SETTING SPEED LIMITS

A spot speed study measures the individual speeds of a sample of vehicles passing a specific point on a roadway. The individual vehicle speeds are used to estimate the speed distribution of the entire traffic stream at that location. Speeds are determined using an observer with a stopwatch, radar, or automated traffic detectors.

Spot speed studies are used to help determine the appropriate speed limit and to evaluate sight distance problems at intersections and other critical locations.

Selection of Study Location and Time

To conduct a spot speed study, choose a mid-block location away from the influence of stop signs, signals, major driveways, and sharp curves. The site must have an observation point near the roadway, where a vehicle with radar equipment can be concealed or made inconspicuous to approaching drivers.

Perform spot speed studies in good weather and under normal traffic conditions. Usually, speed studies are conducted during off-peak hours. A recommended method is to sample for one or two hours, three times during a day. Under most circumstances, the three studies should be conducted from 9:00 AM to 11:30 AM; 1:30 PM to 4:00 PM; and 7:00 PM to 10:00PM.

Study Procedure

Measure at least 100 vehicle speeds, preferably more, during a spot speed study. Low-volume roads might require more than one day of observation to obtain the required minimum sample size.

Select vehicles to be measured at random, or according to a predetermined pattern, so the data are not biased. Determine the vehicle selection pattern before beginning the field study. For instance, the observer could measure every fourth or fifth vehicle whenever possible.

If vehicle selection is not random or according to a pre-determined pattern, then record only the speeds of free-flowing vehicles. Free-flowing vehicles are those whose speeds are not influenced by preceding vehicles. Select trucks for speed observation in proportion to their presence in traffic. Observers should avoid the temptation to measure only the fastest vehicles. Observations are usually recorded by tallying the number of vehicle speeds that occur within a certain speed interval, such as a two- or five-mph interval.

Data Analysis

Traffic speed data may be summarized for analysis purposes, as shown in Table C-1. The example speed data in this table contain 120 observations. The observations are grouped into two-mph intervals, and the intervals range from 20 mph to 41.9 mph.

A Speed Interval in mph	B Number Observed	C Cumulative Number Observed	D Percent Observed	E Cumulative Percent of Observations	F 10-mph Pace
20 to 21.9	3	3	2.5	2.5	
22 to 23.9	3	6	2.5	5	
24 to 25.9	6	12	5	10	
26 to 27.9	12	24	10	20	12
28 to 29.9	18	42	15	35	18
30 to 31.9	27	69	22.5	57.5	27
32 to 33.9	24	93	20	77.5	24
34 to 35.9*	13	106	10.8	88.3*	13
36 to 37.9	8	114	6.7	95	
38 to 39.9	4	118	3.3	98.3	
40 to 41.9	2	120	1.7	100	

* The 85th percentile is in the interval from 34 to 35.9.

TABLE C-1: SPOT SPEED STUDY DATA ANALYSIS

The number of vehicle speeds observed in each interval is recorded in the column B. The cumulative number observed (column C) is calculated by adding the number observed in each speed interval to the previous number observed. The percent observed in each two-mph speed interval (column D) is calculated by dividing each number in column B by last number in column C. The cumulative percent of observations (column E) is calculated by adding the percent observed in each speed interval to the previous percent observed. The percent corresponding to the last speed interval should be 100%. Column C is also used for finding the 85th percentile speed, discussed in a following paragraph.

Two of the most frequently used traffic speed characteristics to be computed from spot speed studies are the "85th Percentile Speed" and the "10-mph pace."

85th Percentile Speed

The 85th percentile speed is the speed below which 85% of the observed vehicles travel. It is the most important factor in speed zoning practice for communities. Traffic engineers generally assume that the majority of drivers will be reasonable and will travel at a speed that is safe and proper for the exisiting conditions. However, this practice does recognize that a few drivers will be operating at a speed somewhat greater than the speed considered appropriate by a large number of drivers.

For the data in Table C-1, the 85th percentile is contained within the interval from 34.0 to 35.9 mph. This can be verified by noting that 77.5% of the observations were accumulated when the speed reached 33.9 mph, and that 88.3% were accumulated after 35.9 mph. This provides a good indication that a 35-mph speed limit would be appropriate.

10-mph Pace

The 10-mph pace is the 10-mph range of speeds that includes the greatest number of observations. The top limit of the 10-mph pace indicates the highest speed many drivers prefer, and it may be used to confirm the value selected according to the 85th percentile analysis.

Column F in Table C-1 identifies the 10-mph pace. For this speed study, the 10-mph pace is between 26.0 and 35.9 mph, since that 10-mph range contains the largest number of vehicles (12+18+27+24+13 = 94 vehicles).

Since the upper limit of the 10-mph pace is 35.9 mph, then the choice of 35 mph for the speed limit is supported.

Several other factors to consider when setting speed limits include:

- Crash experience,
- Presence of restricted sight distances,
- Design speed,
- Roadway surface characteristics,
- Extent of turning movements,
- Parking conditions, and
- Number of pedestrians.

It is important not to establish a speed limit that is too high or too low. Speed limits that appear highly unreasonable to motorists may lead to driver frustration and disregard for all traffic control devices. Speed limits must be posted in increments of 5 mph, using speeds such as 30, 35, 40 mph, and not at unusual limits like 33 mph.

INTERSECTION SIGHT DISTANCE STUDIES

Sight distance studies at intersections help to identify hazardous locations.

Sight Distance for Intersections With Yield or No Control

Sight distance studies for intersections with yield or no control are essentially triangle analyses. A driver approaching an intersection where direction priority is not assigned (no control) should have an unobstructed view of the entire intersection and sufficient length along the crossroad to avoid a collision. Therefore, an unobstructed line of sight must be provided to allow a driver to detect a vehicle approaching on a conflicting path.

The required sight distances for safe operation when approaching an intersection are shown in Figure C-3. The distances represented as “a” and “b” in this figure should provide sufficient time for drivers to adjust their speeds and, if necessary, stop their vehicles prior to entering the intersection.

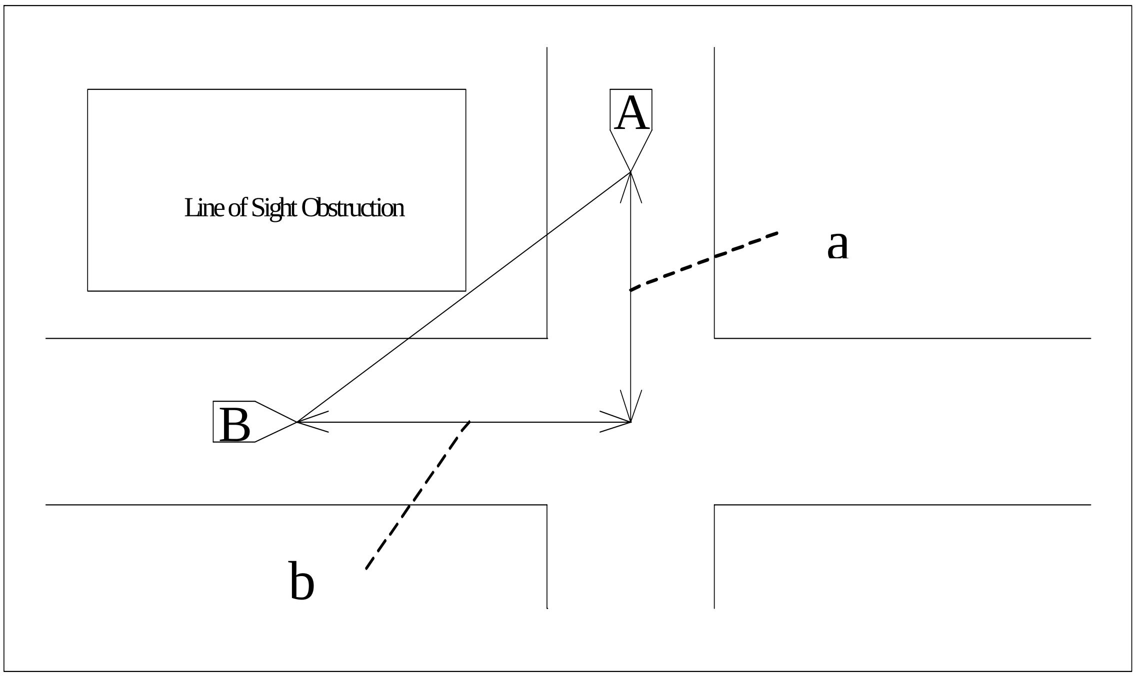


FIGURE C-3: INTERSECTION SIGHT TRIANGLE FOR SAFE APPROACH SPEED

Table C-2 lists the safe stopping distances for vehicles approaching the intersection at different speeds. For example, if the speed of Vehicle A was 20 mph, and the speed of Vehicle B was 45 mph, then the line of sight drawn in Figure C-3 must be unrestricted when Vehicle A is 125 feet from the intersection and Vehicle B is 400 feet from the intersection.

Posted Speed, 85th Percentile Speed, or Design Speed, in mph	Stopping Sight Distance, in feet
20	125
25	150
30	200
35	250
40	325
45	400
50	475
55	550
60	650
65	725
70	850

TABLE C-2: RECOMMENDED STOPPING SIGHT DISTANCE
(ADAPTED FROM AASHTO 1990)

The recommended procedures for determining safe approach speeds at intersections with no control are:

1. Determine the minimum required stopping sight distance from Table C-2 for all intersection roadways, using the largest of the 85th percentile speed, the speed limit, or the design speed on the approach.
2. Provide an observer with a sighting rod that is 3.5 feet high (representing driver eye height) and an assistant with a target rod 4.25 feet high (representing the top of a car). The observer and assistant should position themselves on different approaches at the appropriate stopping distance from the intersection.
3. Hold both rods vertically on the road at their respective stopping distances. The observer looking over the top edge of the sighting rod should determine whether the top of the target rod is visible. If the target rod is visible, the visibility triangle is satisfactory for the pair of approaches.
4. If the top of the target rod is not visible, then the assistant with the target rod should walk toward the intersection until the top of the rod becomes visible to the observer. This position should be marked and the distance to the intersection measured. The safe speed for the approach can be determined by referring to the stopping distances listed in Table C-2.
5. Repeat the intersection sight triangle study for all approach legs, considering traffic approaching from both the right and left.

6. Conduct sight distance measurements during, or at least with consideration given to, possible short-term adverse conditions. For example, trees, shrubs, and parked cars can all affect sight lines.
7. If the available stopping sight distance is not equal to or greater than that required for safe vehicle operation, the obstruction within the triangle should be removed or lowered. If this is not possible, other options include reducing the speed on one or both of the roadways to be compatible with the safe approach speed, or installing a STOP sign.

Sight Distances on Controlled Approaches

Instructions for locating intersection traffic control devices such as STOP signs or YIELD signs are provided in the Manual on Uniform Traffic Control Devices (MUTCD). If the visibility of a STOP sign or YIELD sign at a location is restricted, a warning sign must be installed in advance of the regulatory sign.

STOP signs and YIELD signs should be visible to approaching drivers for the safe stopping sight distances in Table C-2. These distances may be checked in the field using a sighting rod 3.5 feet high. The sighting rod should be placed at the appropriate safe stopping distance on the approach as required by the approach speed. If the intersection sign is not visible from the sighting rod, a warning sign must be installed.

Since warning sings are primarily for the benefit of the driver who is unacquainted with the road, care must be given to the placement of such signs. Table C-3 contains minimum advance sign placement distances for conditions where a driver will likely be required to stop.

Posted Speed or 85th Percentile Speed, in mph	Warning Sign Location in Advance of Regulatory Sign, in feet
20	100*
25	100*
30	100
35	150
40	225
45	300
50	375
55	450

* At low speeds, sign location may depend on physical conditions at the site or view obstruction.

TABLE C-3: GUIDE FOR ADVANCE WARNING SIGN PLACEMENT
(ADAPTED FROM AASHTO 1990)

Leaving Two-Way Stop Intersections

Safe sight distances must be provided for a driver to turn onto or cross a highway from each STOP controlled approach where major road traffic does not stop. Sight distances to the left and right must allow a stopped car to perform an entry or crossing maneuver without risking a collision with a vehicle that may appear just after the driver decides to proceed.

Assume that a car waiting at a STOP sign will be positioned so the vehicle front bumper is 10 feet from the near edge of the pavement on the crossroad. To determine if the line of sight from a stopped car is adequate, measure sight distances from a driver's eye height (3.5 feet above the pavement) to the top of the object representing an on-coming car (4.25 feet above the pavement). Table C-4 lists the sight distances required for a passenger car to turn safely onto or cross a two-lane highway.

If a safe distance does not exist along an approach, then take corrective measures to improve the sight distance, provide warnings to approaching drivers, or reduce speeds on the major roadway.

Speed on Major Road (mph)	Sight Distance (in Feet) Along Major Road for Maneuver Indicated			
	Cross the Major Road	Right Turn to Enter Roadway in Front of Vehicle Approaching From the Left*	Left Turn to Enter Roadway in Front of Vehicle Approaching	
			From the Left*	From the Right*
25	240	295	260	295
30	285	375	310	375
35	335	470	360	470
40	385	575	410	575
45	430	710	460	710
50	480	845	510	845
55	525	990	560	990

* Distances shown for turning maneuvers assume an approaching vehicle will reduce its speed from the design speed to 85% of design speed.

TABLE C-4: SIGHT DISTANCES REQUIRED FOR A PASSENGER CAR STOPPED AT AN INTERSECTION TO CROSS OR TURN ONTO A MAJOR ROAD (ADAPTED FROM AASHTO 1990)

TRAFFIC CONFLICT STUDIES

A traffic conflict is an event involving two or more road users. A conflict occurs when the action of one user, such as a change in direction or speed, causes the other to make a sudden, evasive maneuver, such as swerving or braking, to avoid a collision.

A secondary traffic conflict occurs when the second vehicle makes an evasive maneuver, placing another road user (third vehicle) in danger of a collision. Generally, the road users are motorists, but pedestrians and cyclists may also be affected.

There are several categories of intersection traffic conflicts, and they are classified according to the vehicle maneuvers involved. In each traffic conflict category, the road users must have been on a collision course.

If traffic conflicts are not addressed in a timely manner, the result is frequently a crash. A "near-miss" situation occurring without braking or evasive maneuvers is also considered a traffic conflict.

Traffic Conflict Types

A general knowledge of traffic conflict types is necessary before an observer conducts an on-site conflict study. Figures C-4 through C-16 show examples of the types of traffic conflicts most likely to be observed. Note that the conflicts are named from the perspective of the observer, represented by an "X" in the figures.

- An opposing left-turn conflict occurs when an on-coming vehicle makes a left-turn, placing another vehicle going in the opposite direction in danger of a head-on or broadside collision (Figure C-4).

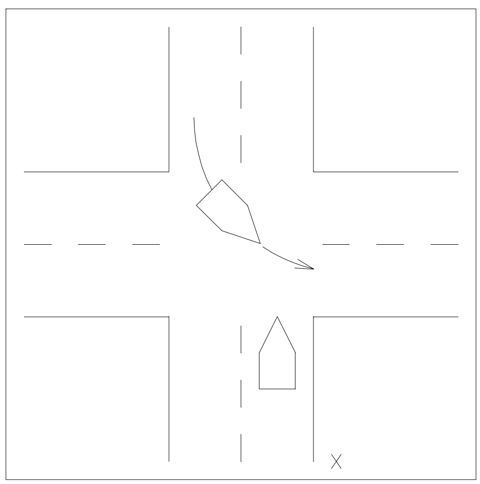


FIGURE C-4: OPPOSING LEFT-TURN CONFLICT

- A conflict occurs when a vehicle on the left-hand cross street makes a left-turn, placing a second vehicle on the main street in danger of a broadside or rear-end collision (Figure C-5).

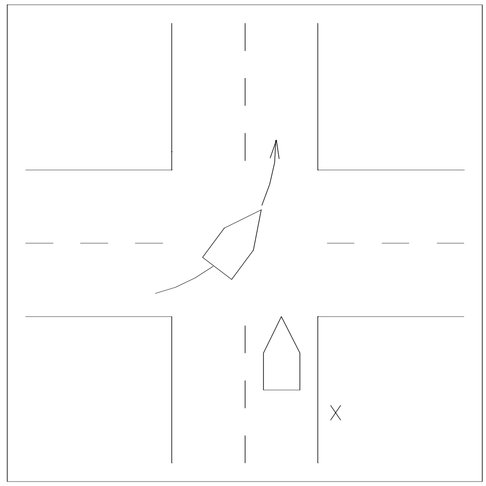


FIGURE C-5: LEFT-TURN CROSS-TRAFFIC FROM LEFT CONFLICT

- A conflict occurs when a vehicle on the left-hand cross street crosses in front of a second vehicle on the main street, placing it in danger of a broadside collision (Figure C-6).

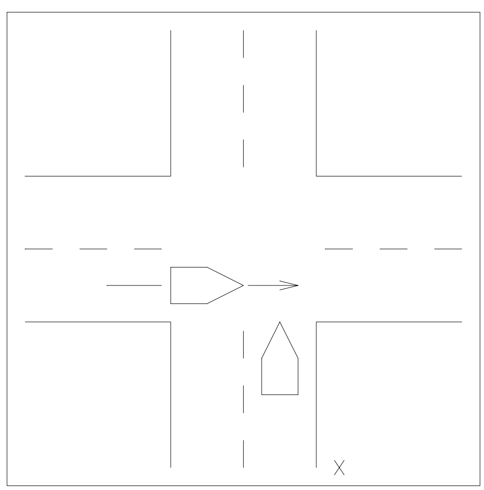


FIGURE C-6: THROUGH-TRAFFIC CROSS-TRAFFIC FROM LEFT CONFLICT

- A conflict occurs when a vehicle on the left-hand cross street turns right across the center of the main street roadway into an opposing lane, placing the vehicle in that lane in danger of collision (Figure C-7). Note that the first driver must cross the centerline for a conflict to exist.

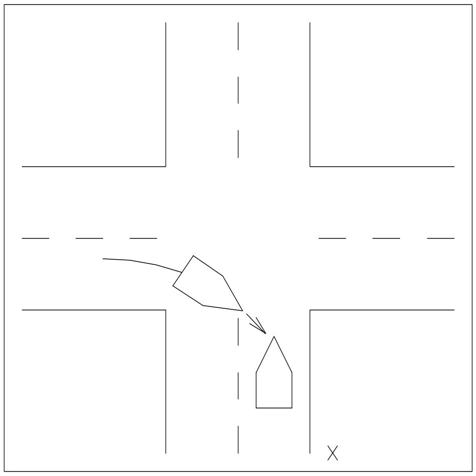


FIGURE C-7: RIGHT-TURN CROSS-TRAFFIC FROM LEFT CONFLICT

- A conflict between a vehicle turning left and traffic in the same direction occurs when the first vehicle slows to make a left-turn, thus placing a second, following vehicle in danger of a rear-end collision (Figure C-8).

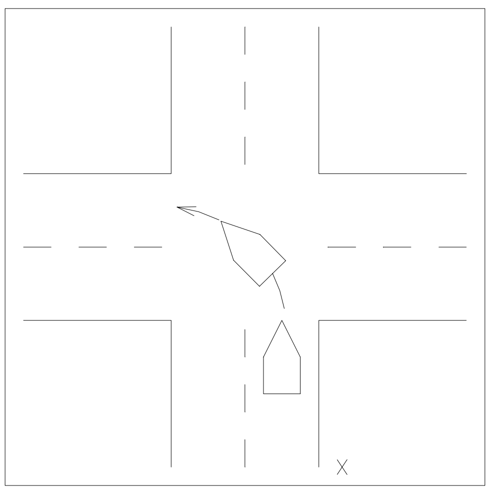


FIGURE C-8: LEFT-TURN SAME DIRECTION CONFLICT

- A conflict between a slow vehicle and traffic in the same direction occurs when the first vehicle slows while approaching or passing through an intersection, placing a second, following vehicle in danger of a rear-end collision (Figure C-9).

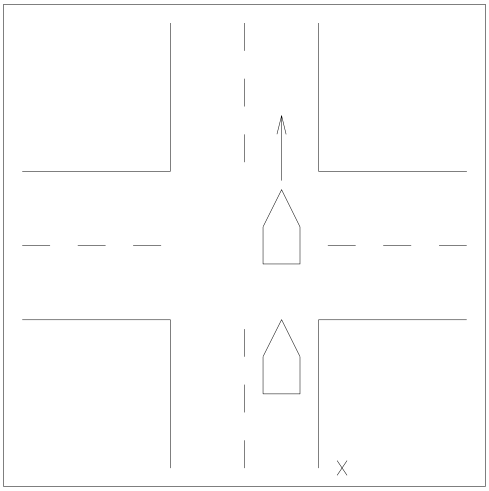


FIGURE C-9: SLOW-VEHICLE SAME DIRECTION CONFLICT

- A conflict between vehicles in the same lane occurs when the first vehicle changes from one lane to another, thus placing a second, following vehicle in the new lane in danger of a rear-end collision (Figure C-10).

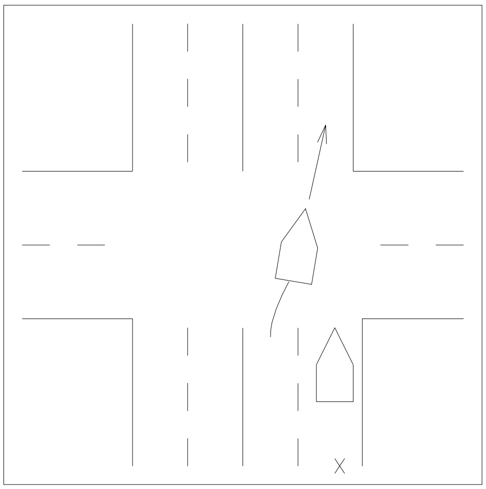


FIGURE C-10: LANE-CHANGE SAME-DIRECTION CONFLICT

- A conflict between traffic turning right and traffic in the same direction occurs when the first vehicle slows to make a right turn, thus placing the second, following vehicle in danger of a rear-end collision (Figure C-11).

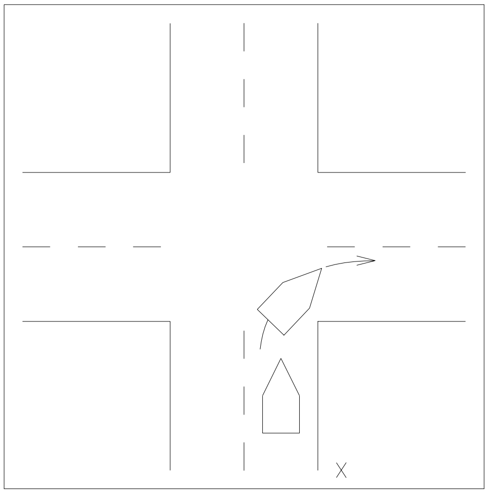


FIGURE C-11: RIGHT-TURN SAME DIRECTION CONFLICT

- A conflict occurs when a vehicle on the right-hand cross street makes a left-turn, placing a second vehicle in danger of having a broadside collision with the turning vehicle (Figure C-12).

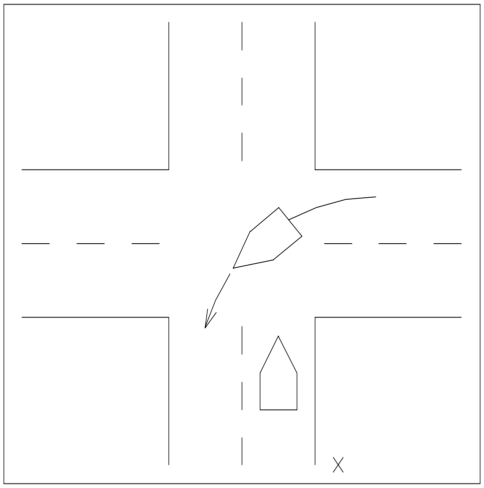


FIGURE C-12: LEFT-TURN CROSS-TRAFFIC FROM RIGHT CONFLICT

- A conflict occurs when a left-turning vehicle on the right-hand cross street crosses in front of a second vehicle on the main street, placing it in danger of a broadside collision (Figure C-13).

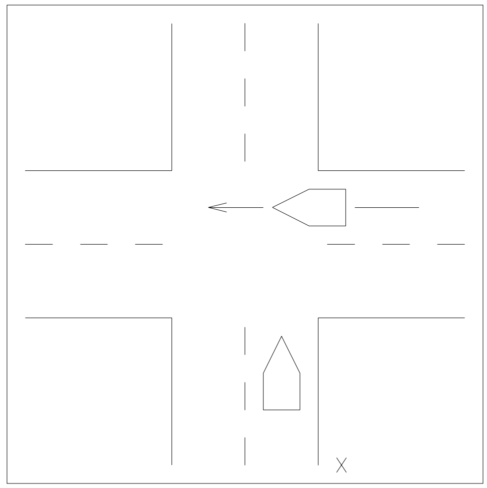


FIGURE C-13: THROUGH CROSS-TRAFFIC FROM RIGHT CONFLICT

- A conflict occurs when a vehicle on the right-hand cross street makes a right-turn, thus placing a second vehicle, on the main street, in danger of making a broadside or rear-end collision (Figure C-14).

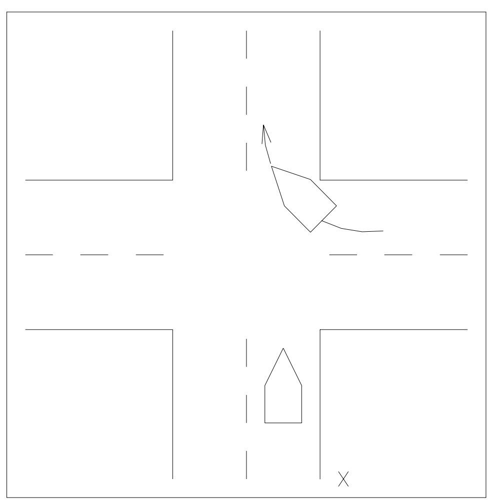


FIGURE C-14: RIGHT-TURN CROSS-TRAFFIC FROM RIGHT CONFLICT

- An example of a secondary conflict is a situation similar to RIGHT-TURN CROSS-TRAFFIC FROM RIGHT, except a third vehicle is involved. The third vehicle is in danger of colliding with the rear-end of the vehicle it is following (Figure C-15).

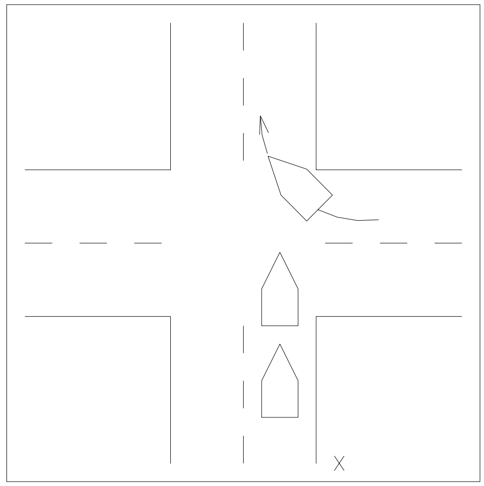


FIGURE C-15: SECONDARY TRAFFIC CONFLICT EXAMPLE – RIGHT-TURN CROSS-TRAFFIC FROM RIGHT

- A pedestrian conflict occurs when a pedestrian crosses in front of a vehicle, creating a potential collision. The pedestrian could be in the near-side or far-side crosswalk. Pedestrian movements involving right-turn and left-turn vehicles are not considered conflicts if the pedestrians have the right-of-way, as in a "WALK" phase (Figure C-16).

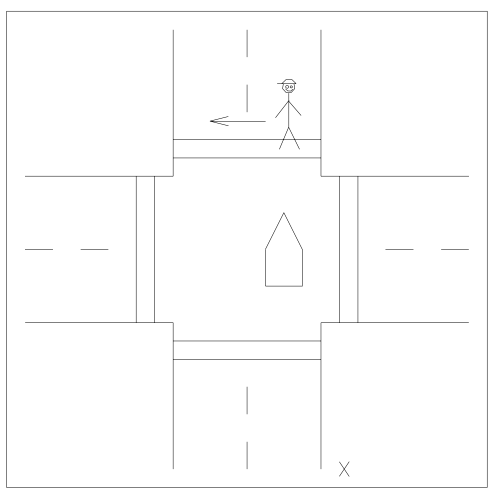


FIGURE C-16: PEDESTRIAN CONFLICT

The Traffic Conflict Summary Sheet

The traffic conflict summary sheet in Figure C-17 may be used for recording and summarizing conflict counts. Each conflict classification has two columns for recording observations. Record conflicts with pedestrians, cyclists, or vehicles from access points near the intersection in the last column.

Fill out all heading information prior to beginning the conflict study. The diagram in the upper right corner displays the approach leg number. For example, traffic approaching the site from the North is on leg 1; traffic from the East is on leg 3; etc. Use a separate form for each leg observed at the intersection.

Coordinating the Traffic Conflict Study

A traffic conflict study includes counting conflicts and collecting other data needed to make a complete study of the location. These auxiliary data may include intersection condition diagrams, on-site observation reports, traffic volume counts, and sight distance studies. Conflict studies should be performed during dry conditions, unless the study is specifically designed for wet conditions.

Traffic Conflict Study Team

The number of observers needed to conduct a conflict survey depends on the number of conflicts and amount of data needed. Usually, the team consists of two observers in a vehicle – one to collect conflict data and one to collect traffic volume data.

Observer Locations

Upon arriving at the site, the study team members should familiarize themselves with the location, noting the traffic movements to be observed. At three- and four-leg signalized locations, observations are usually taken on all approaches. At an unsignalized intersection, observations are made only on approaches where vehicles have the right-of-way.

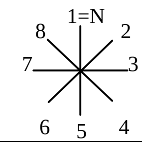
Since braking and weaving actions identify conflicts, it is necessary to place the observer sufficiently far back on the approach to observe these maneuvers. A distance of 100 to 300 feet back from the intersection facing the direction of traffic movement is suggested.

If either observer is to sit in a vehicle, it should be parked off the road wherever possible. If on-street parking is permitted, check for an adequate spot to conduct the study that will not disturb traffic movements or interfere with any sight distances. If parking is not available, the observers will have to conduct the study outside of the vehicle, being as inconspicuous as possible. In all instances, the observer must not use a vehicle that could be recognized as a police or other official car.

Location ____ Date_______________

Observer ____ Day _______________ Leg Number: _______

[C = Conflict SC = Secondary Conflict] Time of Study: From: _________ To: ____________



Time	OPPOSING		FROM LEFT						SAME DIRECTION								FROM RIGHT						OTHER	
Start ____ End	Left Turn		Left Turn		Thru		Right Turn		Left Turn		Slow Vehicle		Lane Change		Right Turn		Left Turn		Thru		Right Turn			
	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC
____																								
____																								
____																								
____																								
SUM																								
SUM C+SC																								

COMMENTS:

FIGURE C-17: INTERSECTION TRAFFIC CONFLICT SUMMARY (ADAPTED FROM PARKER AND ZEEGER 1989)

Once the observation positions are determined, all forms should be prepared and double-checked before data collection begins. If more than one observer is performing the study, their watches must be synchronized.

Study Schedule

At least one 10-hour period should be allocated for each pair of approaches studied. The days generally chosen are Tuesday, Wednesday, or Thursday. Each study should be a 10-hour counting day extending from 7:30 AM to 12 noon and from 12:45 PM to 6:15 PM. Variations in these times might be necessary to include peak morning and evening traffic volumes.

Two approach legs are typically observed during the 10-hour survey. Observations should alternate from one approach to the other approach in 30-minute periods. Within each 30-minute period, allocate the initial 20 minutes for data gathering and the remaining time for summarizing the data. This time can also be used to write helpful notations on the forms and to change observation positions.

Data Analysis

A conflict study is used primarily as a diagnostic tool. The primary objective is to identify predominant conflict types and compare these with crash patterns for the location. The traffic conflict data can then be used to address safety and operational problems, to recommend corrective measures, or to show the effectiveness of improvements already implemented.

REFERENCES FOR CONDUCTING SPOT SPEED STUDIES AND SETTING SPEED LIMITS

"Introduction to Traffic Practices – A Guidebook for Local Agencies," 2nd Edition, Technology Transfer Assistance Program, Missouri Highway and Transportation Department, 1994.

"Manual of Traffic Engineering Studies," 4th Edition, Institute of Transportation Engineers, 1976.

"Manual of Transportation Engineering Studies," Institute of Transportation Engineers, 1994.

"Traffic Control Devices Handbook," Federal Highway Administration, 1983.

REFERENCES FOR INTERSECTION SIGHT DISTANCE STUDIES

"Local Highway Safety Studies-User Guide," Federal Highway Administration, July 1986.

"Manual on Uniform Traffic Control Devices for Streets and Highways," Federal Highway Administration, 1988.

"A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials, 1990 (U.S. units) or 1994 (S.I./metric units).

"Traffic Control Devices Handbook," Federal Highway Administration, 1983.

REFERENCES FOR TRAFFIC CONFLICT STUDIES

Glauz, W. and D. Migletz, "Application of Traffic Conflict Analysis at Intersections," Transportation Research Board, NCHRP Report 219, 1980.

Parker, M. and C. Zeeger, "Traffic Conflict Techniques for Safety and Operations – Engineers Guide," Federal Highway Administration, Report No. FHWA-IP-88-026, January 1989.

Parker, M. and C. Zeeger," Traffic Conflict Techniques for Safety and Operations – Engineers Guide," Federal Highway Administration, Report No. FHWA-IP-88-027, January 1989.

APPENDIX D

GENERAL GUIDELINES FOR SEVERAL TRAFFIC SAFETY IMPROVEMENTS

Once a location has been identified as needing improvement, it is necessary to select a countermeasure that will achieve the desired results. In this appendix, the following areas will be discussed:

- CONSISTENCY in implementing countermeasures,
- DEFINITIONS of warrants, guidelines and crash reduction factors. (They can help determine which countermeasure should be used.), and
- GENERAL GUIDELINES for common traffic safety improvements. (The guidelines *are not intended* to be a substitute for a thorough evaluation of any possible improvements at high-crash locations.)

CONSISTENCY

Be cautious when making a change in the driving environment. Sometimes, all that is needed to alleviate a traffic problem is a localized, or “spot”, improvement. Spot improvements will often improve a hazardous location by removing a non-standard roadway element or traffic control device.

All countermeasures should be applied consistently according to the Manual on Uniform Traffic Control Devices (MUTCD) standards so that motorists will have no difficulty in navigating the roadways. The MUTCD must remain the standard by which traffic control devices are selected, installed, and operated. The use of non-standard control devices or improvements is not an acceptable practice.

DEFINITIONS

Warrants

Warrants are specific criteria found in the MUTCD. Generally speaking, warrants must be followed when deciding which traffic control devices or safety improvements to use. They are based on factors such as crash experience and traffic volume, among others. A commonly used warrant in the MUTCD is for the installation of devices such as traffic signals.

Warrants are very important since they represent thresholds generally accepted by practicing professionals for the use of specific improvements. However, the MUTCD is careful to point out that warrants need to be applied with engineering judgment. Warrants are standards for traffic control device installation, but they do not constitute a legal requirement for installation.

Guidelines

Guidelines usually pertain to situations where selecting countermeasures requires substantial engineering judgment. Guidelines are based on instances where specific improvements have proven beneficial to motorists and cost-effective to the community.

Several guidelines in this appendix contain suggested thresholds for improvements based on crash experience. However, remember that the crash experience at a site is due to many factors, and any improvement being considered is only one of many that could be implemented.

An economic analysis should be performed to determine the feasibility of a potential improvement.

Crash Reduction Factors

The guidelines for access control in this appendix, as well as in Appendix G of this manual, contain crash reduction factors. Crash reduction factors are used to estimate the change in crash experience to be expected from installing a specific improvement.

Most crash reduction factors listed in the HAL Manual are based on studies of improvements at high-crash locations. Therefore, it is unlikely that there will be any significant reduction in the crash experience at a location if the given location does not have an unusually high crash experience.

GENERAL GUIDELINES

Access Control Improvements

There are several points to consider when addressing roadway access control.

Development and the Increased Risk of Crashes

As the traffic volume on a street or highway increases, the neighboring land becomes more attractive to businesses. Every business needs access to the roadway, but often the driveways are poorly spaced and inadequately designed for the needs of the growing community. This inevitably leads to traffic delays, disruption in the flow of traffic and crashes, especially rear-end collisions and left-turn crashes. These problems only increase in severity as more businesses are added and the volume of traffic grows.

Solutions

The solutions to this problem come in different forms. One possibility is to by-pass the congested area by building another road. Often this is ruled out because it tends to be expensive and complicated. The preferred solution is to control access, or to control where vehicles can enter and exit a roadway. This involves improvements both to the roadway and to driveways. Some examples of ways to control access include:

- Roadway Improvements
    - Left-turn channelization
    - Two-way left-turn lane
    - Median barriers
- Driveway Improvements
    - Widening driveways
    - Conversion to one-way driveways
    - Combining driveways
    - Improving traffic control at driveways

Considering Locations for Improvement

Tables D-1 and D-2 contain minimum crash rates and numbers which, if exceeded, would justify a detailed review of crash data and possible route or spot improvements. If the existing roadway and driveway volumes are high, or if the crash experience is high at a particular driveway, the MUTCD warrants for traffic signal installation should also be reviewed. But, while traffic volumes and crash levels indicate the need for access improvements, they should not be the only criteria. Each roadway, or specific location, must be evaluated with regard to:

- Highway function,
- Traffic speeds,
- Placement of driveways relative to each other,
- Available sight distances, and
- Crash levels.

Crash Reduction

Table D-3 shows the crash reduction expected from several types of access control improvements. It describes the countermeasure, its general effects, and the crash reduction that may be anticipated. Table D-3 clearly shows that the crash reduction factors for access improvements vary widely, depending on the traffic volumes and driveway density involved.

A detailed discussion of these improvements, as well as several other types of improvements, is available in the references cited at the end of this appendix.

Driveway Volume (ADT)	Annual Number of Crashes		
	Highway Volume (ADT)		
	Less than 5000	5000 to 15000	More than 15000
Less than 500	3.8	7.4	11
500 to1500	11.3	22.1	32.9
More than 1500	18.8	36.8	54.8

TABLE D-1: ACCESS CONTROL: CRASH THRESHOLDS FOR ROUTE IMPROVEMENTS

Density of Roadside Development (Driveways per Mile)	Annual Number of Crashes per Mile		
	Highway Volume (ADT)		
	Less than 5000	5000 to 15000	More than 15000
Less than 30	0.26	0.45	0.62
30 to 60	0.63	1.10	1.50
More than 60	0.97	1.70	2.30

TABLE D-2: ACCESS CONTROL: CRASH THRESHOLDS FOR DRIVEWAY IMPROVEMENTS

Countermeasure	Effects	Crash Reduction			
Install Raised Median Divider and Left-Turn Deceleration Lanes	Protects vehicles turning left and allows left-turns from roadway to be made only at intersections and high-volume driveways. May increase travel distance.	Annual Crash Reduction per Mile			
		Number of Commercial Driveways per Mile	Highway Volume (ADT): Less than 5000	Highway Volume (ADT): 5000 to 15,000	Highway Volume (ADT): More than 15,000
		Less than 30	2.2	4.1	6.3
		30 to 60	5.8	11.2	17.2
		More than 60	10.7	20.7	31.2
Install Continuous Two-Way Left-Turn Lane in Median	The two-way left-turn lane protects turning vehicles from through vehicles, thus reducing rear-end crashes. This countermeasure is very effective on roadways that have closely spaced drives with a somewhat uniform density of left turns.	Annual Crash Reduction per Mile			
		Number of Commercial Driveways per Mile	Highway Volume (ADT): Less than 5000	Highway Volume (ADT): 5000 to 15,000	Highway Volume (ADT): More than 15,000
		Less than 30	4.4	8.8	13.3
		30 to 60	7.1	13.9	20.9
		More than 60	9.7	20.9	28.6
Add Acceleration Lane or Add Deceleration Lane at Driveway Location	An acceleration lane will allow right turn vehicles leaving the drive to merge with through traffic at a more compatible speed. A deceleration lane will reduce rear-end collisions since right-turn vehicles may reduce speed after leaving the through lane.	Annual Crash Reduction per Driveway			
		Driveway Volume (ADT)	Highway Volume (ADT): Less than 5000	Highway Volume (ADT): 5000 to 15,000	Highway Volume (ADT): More than 15,000
		Less than 500	0.02	0.03	0.05
		500 to 1500	0.05	0.08	0.11
		More than 1500	0.07	0.13	0.17
Improve Sight Distance at Driveway Exits by Removing Parking from Traveled Way, Either Totally or Partially	Adequate sight distance at exits makes it easier for drivers to see oncoming traffic and, therefore, to enter the roadway safely. Physical sight obstructions such as shrubbery should also be removed.	Annual Crash Reduction per Mile of Parking Removed			
		Number of Commercial Driveways per Mile	Highway Volume (ADT): Less than 5000	Highway Volume (ADT): 5000 to 15,000	Highway Volume (ADT): More than 15,000
		Less than 30	1.9	3.8	5.7
		30 to 60	3.0	6.0	9.0
		More than 60	4.2	8.2	12.3
Install Two One-Way Driveways in Lieu of Two Standard Two-Way Driveways	This driveway design will eliminate several traffic conflict points, thereby reducing total crashes. Driveways must be marked and signed properly to avoid wrong-way use.	Annual Crash Reduction per Driveway			
		Driveway Volume (ADT)	Highway Volume (ADT): Less than 5000	Highway Volume (ADT): 5000 to 15,000	Highway Volume (ADT): More than 15,000
		Less than 500	0.28	0.50	0.68
		500 to 1500	0.70	1.22	1.66
		More than 1500	1.08	1.88	2.56
Install Isolated Median with Deceleration Lane or Close Median Opening on Traveled Way to Prevent All Left-Turn Movements In and Out of the Drive	The isolated median with a deceleration lane removes left-turn vehicles from the through lanes, thereby protecting them from rear-end collisions. The closing of a median opening is a restrictive measure that should be used only if the driveway's left-turn demand is low (less than 100 vehicles per day).	Annual Crash Reduction per Driveway			
		Driveway Volume (ADT)	Highway Volume (ADT): Less than 5000	Highway Volume (ADT): 5000 to 15,000	Highway Volume (ADT): More than 15,000
		Less than 500	0.13	0.23	0.31
		500 to 1500	0.32	0.55	0.75
		More than 1500	0.49	0.85	1.15

TABLE D-3: CRASH REDUCTION ESTIMATES FOR ACCESS CONTROL AND CHANNELIZATION COUNTERMEASURES

Flashing Beacons

A flashing beacon is a traffic control device used to supplement other devices at potentially hazardous sites. Flashing beacons consist of one or more sections of a standard traffic signal head with a flashing circular yellow or circular red light in each section. The MUTCD describes the following types of flashing beacons:

- Hazard Identification Beacon,
- Speed Limit Sign Beacon,
- Stop Sign Beacon, and
- Intersection Control Beacon.

Hazard Identification Beacon

Description:

- A hazard identification beacon flashes yellow. It should be used only to supplement an appropriate warning or regulatory sign or marker.

Guidelines:

- Use where obstructions are in or immediately adjacent to the roadway.
- Use as a supplement to advance warning signs.
- Use at mid-block crosswalks.
- Use at intersections where warning is required.
- Use to supplement certain regulatory signs.

Speed Limit Sign Beacon

Description:

- A speed limit sign beacon flashes yellow and is used with either a fixed or variable speed limit sign.

Guidelines:

- Use with a speed limit sign to emphasize that the speed limit shown on the sign is in effect.

Stop Sign Beacon

Description:

- A stop sign beacon flashes red and is mounted above the stop sign.

Guidelines:

- Use in locations where surrounding developments and/or commercial lights divert motorists' attention away from the stop sign.
- Use in locations where a stop sign is not immediately visible to the approaching driver due to vertical or horizontal roadway alignment.

Intersection Control Beacon

Examples of Intersection Control Beacons:

- 4-way stop – Beacon flashes red to all approaches.
- 2-way stop – Beacon flashes red to the minor approaches and yellow to the major approaches.

Guidelines:

- Intersection control beacons are intended for use at intersections where volumes or physical conditions do not yet justify conventional traffic signals, but where high crash rates indicate a special hazard exists. Specifically,
    - Four or more left-turn plus right angle crashes occur in one year. (“Evaluation” 1967)
    - Six or more left-turn plus right angle crashes occur in two years. (“Evaluation” 1967)

Note that the MUTCD does not state warrants for use of an intersection control beacon.

Recommendations for Installation:

- An intersection control beacon should be suspended over the center of an intersection so it is visible from all approaches.
- 2-way stop – Entering volume of the minor road divided by the entering volume of the major road equals 0.50 or less.
- 4-way stop – Entering volume of the minor road divided by the entering volume of the major road is greater than 0.50.
- Installation of a flashing beacon at an offset, multi-leg or "Y" intersection should be avoided since these designs frequently do not provide an adequate line of sight from the driver to the center-mounted flashing beacon. (Hammer and Tye 1987)
- The driver stopped on the red-controlled approach of a red-yellow beacon may not be aware that drivers on the yellow-controlled approaches do not have to stop. To alleviate this confusion, a supplementary sign may have to be mounted on the minor approach stating that the crossroad traffic does not stop. (Hammer and Tye 1987)

- An intersection control beacon should be installed only after a proper traffic engineering study has been performed. This service may be requested through your nearest MoDOT District Office as a part of the Traffic Engineering Assistance Program.

Left-Turn Channelization

Channelization on streets and highways guides drivers through a location. For either an intersection or a driveway entrance, channelization involves the application of pavement markings or the construction of raised curbs and traffic islands. The two applications for left-turn channelization most commonly used in smaller communities are:

- Providing left-turn lanes on intersection approaches, and
- Constructing a continuous two-way left-turn lane in the middle of a street with numerous driveways.

Each location being considered for a channelization project should be carefully studied before beginning installation to be certain that all traffic islands or markings will safely accommodate vehicles. This is especially important where it is necessary to provide adequate paths for turns by large vehicles. A channelization design can be field-tested before permanent installation by temporarily placing sandbags on the roadway to represent curbs or pavement markings.

Left-Turn Lanes

Guidelines for installing a left-turn lane:

- Left-turn lane construction should be considered for intersections having a substantial number of left-turn-involved crashes. The exact number of left-turn-related collisions justifying a left-turn lane varies depending on several factors. One of those factors is the occurrence of injury or fatal crashes.
- The criteria listed in Table D-4 are appropriate for considering left-turn lane installation.

Examples of left-turn-involved crashes include:

- Rear-end collisions with vehicles waiting to turn left,
- Same direction sideswipe collisions, and
- Left-turn angle collisions.

Advantages of a left-turn lane include:

- The left-turn lane removes a vehicle from the through lane as it waits for an opportunity to turn. This separation significantly reduces the danger of rear-end and sideswipe collisions.

- Since opposing, left-turning drivers will be in a direct line with each other, it is easier for them to see opposing through-traffic.

Type of Control on Intersection Approach	Number of Left-Turn Related Collisions
Unsignalized Approach	2 collisions in each of 2 years, or 3 collisions in 1 year
Signalized Approach (no left-turn phase)	4 collisions in each of 2 years, or 5 collisions in 1 year

TABLE D-4: MINIMUM CRASH EXPERIENCE FOR LEFT-TURN LANE CONSIDERATION

Continuous Two-Way Left-Turn Lanes (CTWLTL)

Major two-lane and four-lane urban streets attract a large amount of commercial development along the roadside. With that development comes an increase in mid-block crashes. The seriousness of this crash problem usually depends on the number of driveways present, the volume and composition of traffic, and the volume of traffic using the driveways. An effective countermeasure for reducing these mid-block crashes is to modify the roadway by adding a single lane in the middle known as a continuous two-way left-turn lane (CTWLTL). Thus, a two-lane road becomes a three-lane road, and a four-lane road becomes a five-lane road.

Guidelines for Installing a CTWLTL:

- If a two-lane undivided or four-lane undivided roadway has a crash rate higher than those listed in Table D-5, the CTWLTL installation should be considered.
- Exact guidelines for when to consider such a major street modification as a CTWLTL are not currently available. (However, an example of estimated crash rates along commercially developed streets is shown in Table D-5.)

Instructions for Using a CTWLTL:

- A CTWLTL extends for at least several blocks, and it must have signs and markings (see MUTCD) permitting median lane use for left-turns only.

Advantages of a CTWLTL:

- Improves safety for vehicles turning left to enter and exit driveways;
- Separates vehicles traveling in opposite directions, thus reducing the chance for head-on collisions and opposite direction sideswipe collisions;
- Results in fewer delays at driveways;

- Reduces the number of serious mid-block crashes on the through lanes of the street;
- Reduces the number of rear-end collisions and sideswipes due to vehicles waiting to turn left into a drive; and
- Decreases the chance impatient drivers will force their way across oncoming traffic.

Roadway Category	Number of Driveways per Mile	Average Daily Traffic		
		7000 to 10,000	10,000 to 15,000	15,000 to 20,000
Two-Lane Undivided	Under 30	5.2	8.7	12.2
	30 to 60	6.3	10.4	14.6
	Over 60	7.3	12.2	17.1
Four-lane Undivided	Under 30	6.5	10.8	15.1
	30 to 60	7.5	12.5	17.6
	over 60	8.6	14.3	20

* Assumes 5 to 10% trucks, and under 5 intersections/mile

TABLE D-5: TYPICAL ANNUAL CRASH RATES PER MILE FOR NON-INTERSECTION CRASHES IN URBAN COMMERCIAL AREAS *

Safety Lighting

The primary purpose of roadway lighting, or illumination, is to increase the visibility of the pavement and its surroundings, thereby giving the driver a chance to avoid potentially hazardous situations. Many studies have stated that the installation of roadway lighting increases safety.

Several suggested warrants for intersection lighting were evaluated in an extensive study of minor safety improvements (Tamburri et al. 1968). According to this study, “It is recommended that safety lighting be considered at locations which experience 4 night crashes in one year or 6 or more night crashes in two years.”

This study also found that the intersection crashes most susceptible to correction by lighting were single-vehicle crashes (primarily those where a driver proceeded straight at a three-leg intersection on the dead-end leg) and crossing (right-angle) collisions at a four-leg intersection.

A general assumption, which could be applied when evaluating almost any safety lighting project, is that the rate for nighttime crashes should be about equal to the rate for daytime crashes. The ideal situation would be a ratio of 1.0:1; that is, the crash rate at night is the same as the crash rate during daylight conditions.

Using the decision criteria developed by Walton and Rowan (1974), a ratio of nighttime crashes to daytime crashes of 1.5:1 is somewhat high, but not unusual. However, a ratio of 2.0:1 or greater indicates that nighttime visibility is inadequate and lighting should be considered for the location.

One-Way Streets

It has been consistently shown that proper planning and implementation of a conversion from two-way streets to one-way streets will reduce total crashes by as much as 10% to 50% on the affected streets. The crash types that generally see the greatest reduction are:

- sideswipe crashes with vehicles travelling in opposite directions,
- head-on collisions,
- parking crashes,
- right-angle collisions,
- rear-end collisions,
- turning collisions,
- pedestrian crashes, and
- fatal or injury crashes.

Generally, two-way streets should be changed to one-way operation when the following conditions are satisfied:

- There is the possibility of noticeably improving safety along an entire corridor. (Conversion to one-way streets is not likely to be advantageous if only one or two intersections along a particular street are in the high crash category.)
- It is clear that a specific traffic problem will be alleviated and overall efficiency of the street system will be improved.
- One-way operation is more desirable and cost-effective than the alternative solutions.
- A parallel street of suitable width, preferably not more than a block away, exists or can be constructed.
- The parallel and adjacent streets are continuous in that they carry traffic through and beyond the congested areas.
- A sufficient number of intersecting streets of satisfactory design to permit circulation of traffic exist.
- Safe transition to two-way operation can be provided at the end points of the one-way sections.
- Proper public transit services can continue to be provided on the one-way pair of streets.
- The proposed one-way streets are compatible with the community master plan and adjacent land uses.

- Thorough study shows the advantages of the one-way street system far outweigh the total disadvantages.

Conversion to one-way operation usually involves many intersections and a variety of mid-block situations such as parking, loading zones, alleys, driveways, and pedestrian crossings. Business owners along a proposed one-way pair of streets are sometimes reluctant to support such an extensive modification in traffic flow as the one-way conversion. However, the traffic safety improvements and reduced congestion can usually be accomplished without adverse financial impact on adjacent businesses.

Advantages of One-Way Streets

- Capacity is increased by reducing conflicts and by running traffic control devices more efficiently.
- Travel speed is increased as a result of fewer conflicts and delays caused by turning vehicles. An increase in the number of lanes in one direction also permits easier passing of slower or double-parked vehicles.
- One-way operation permits good progressive timing of signals.
- The number and severity of crashes is reduced by eliminating head-on crashes and reducing several types of intersection conflicts.
- Full use can be made of an odd number of traffic lanes when traffic flows in only one direction. When a street is used in two directions, fewer lanes may be possible due to width requirements.
- On-street parking that would have otherwise been removed might be retained due to better use of the street width.

Disadvantages of One-Way Streets

- Travel distances to certain destinations may be increased by having to drive around the block.
- One-way streets may be confusing to strangers.
- Emergency vehicles may be blocked at intersections by vehicles waiting in all lanes on an approach.
- Additional signs and markings must be installed and must be carefully maintained (see MUTCD).

A possible change to one-way streets should be thoroughly evaluated with the assistance of traffic engineering professionals. It is possible for Missouri communities that do not have a traffic engineer on staff to arrange for these services through the MoDOT Traffic Engineering Assistance Program.

Roadside Safety Features

When a moving vehicle unintentionally leaves the roadway, overturning or collision with a fixed object is likely to occur unless a safe roadside has been provided. Two characteristics of the roadside generally determine whether a vehicle will recover safely after leaving the roadway: the roadside geometry and the presence of non-yielding large objects.

Roadside Geometry

Roadway embankments are classified as recoverable, non-recoverable, or critical.

- Recoverable slopes: 4:1 (horizontal to vertical) or flatter
  A motorist who encroaches on a recoverable slope can usually regain control of the vehicle if no hazardous objects are encountered.
- Non-recoverable slopes: range from 4:1 to as steep as 3:1
  Motorists on side slopes this steep usually are not able to stop the vehicle until it travels to the bottom of the embankment.
- Critical slopes: greater than 3:1
  A vehicle is most likely to overturn on a critical slope.

If a critical embankment exists along an urban street, a barrier such as a guardrail should intercept errant vehicles before reaching the side slope. The height of the embankment is related to the necessity for the barrier as shown in Figure D-1.

Roadside Obstacles (Fixed Objects)

Roadside obstacles may be non-traversable hazards or fixed objects. Ideally, a reasonable recovery area, or “clear zone,” containing no hazards should be provided along the roadway. Alternatives for dealing with existing roadside hazards are usually considered in this order:

1. Remove the obstacle or redesign it so it can be safely traversed.
2. Re-locate the obstacle so it is less likely to be struck.
3. Reduce impact severity by using a breakaway device for signs and light poles.
4. Re-direct a vehicle by installing a barrier or crash cushion.
5. Delineate the obstacle if above alternatives are not appropriate.

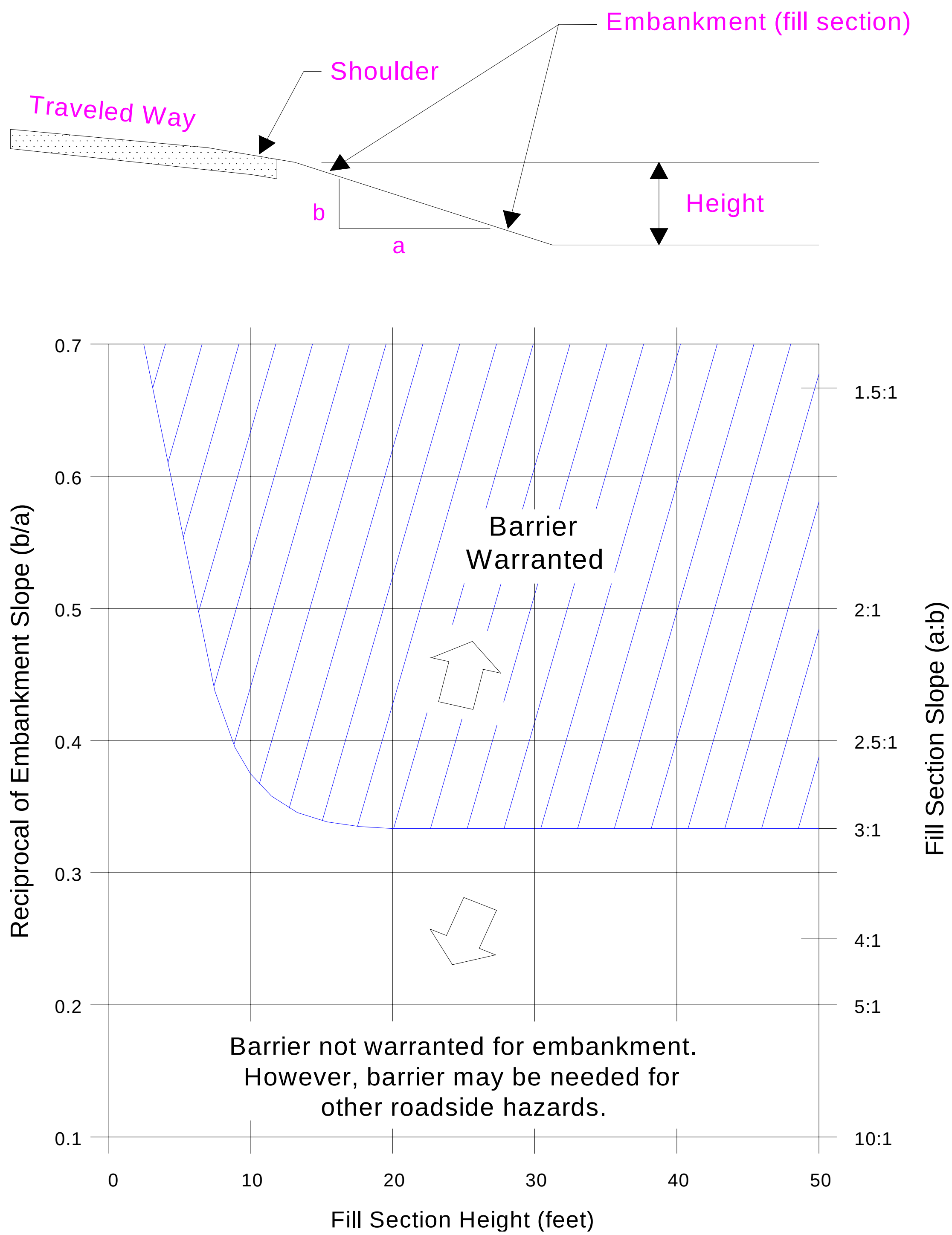


FIGURE D-1: COMPARATIVE RISK WARRANTS FOR EMBANKMENTS (ADAPTED FROM AASHTO ROADSIDE DESIGN GUIDE 1996)

Alternative 1 & Alternative 2:

Removing or redesigning an object is highly preferred, but it is not always practical in urban areas.

Signs, signals, and light poles must be located near the road in most cities. This practice often makes it difficult to increase safety at the side of the road.

Alternative 3:

Breakaway devices are easily provided, and they are extremely effective in reducing vehicle occupant injuries. It may be possible to bury a utility line and thereby eliminate an entire series of poles.

Alternative 4:

Installing a barrier requires consideration of applicable warrants (e.g. guardrail).

A barrier should be installed only if it is apparent that the results from a vehicle striking the barrier will be less severe than the crash resulting from hitting the unshielded object. Although no specific number of crashes may be related to the need for installing a barrier, general guidelines do exist for their use, as shown in Table D-6. When a barrier is installed, the following things should be considered:

Design: Specific roadside barrier designs depend on the function the barrier must perform, as well as the speed and size of the involved vehicle.

Location: The barrier should be placed as far from the traveled way as conditions permit.

Size: The length of barrier must be determined based on the length of the hazard and the vehicle approach path.

Lateral Offset: The lateral offset of the barrier from the fixed object must be sufficient to allow for barrier deflection.

Alternative 5:

Delineating the obstacle alerts the motorist to presence of hazardous objects.

Hazardous objects can be delineated using markers recommended in the MUTCD (Section 3C). Types of roadside hazards especially prevalent in urban areas include trees, mailboxes, and drainage features.

Hazard	Barrier Warrant
Bridge Piers, Abutments, and Railing Ends	Shielding generally required
Boulders	A judgment decision based on nature of hazard and chance of impact
Culverts, Pipe, Headwalls	A judgment decision based on size, shape, and location of hazard
Cut Slopes (smooth)	Shielding generally not required
Cut Slopes (rough)	A judgment decision based on likelihood of impact
Ditches (parallel)	*See* AASHTO Roadside Design Guide
Ditches (transverse)	Shielding generally required if chance of head-on impact is high
Embankment	A judgment decision based on embankment height and slope
Retaining Walls	A judgment decision based on wall smoothness and angle of impact
Sign/Luminaire Supports	Shielding generally required for non-breakaway supports
Trees	A judgment decision based on circumstances at the site (as size and number of trees)
Utility Poles	Shielding may be warranted on a case-by-case basis
Permanent Bodies of water	A judgment decision based on location, water depth and likelihood of encroachment

TABLE D-6: GUIDELINES FOR ROADSIDE BARRIERS
(AASHTO ROADSIDE DESIGN GUIDE 1996)

Trees

A tree with a trunk diameter greater than 6 inches is considered a fixed object. The recommended distance of trees from a roadway depends on the design speed of the road, as shown in Table D-7.

Design Speed	Minimum Setback from Edge of Road
50 mph or more	30 feet
Less than 45 mph	7 – 18 feet

TABLE D-7: RECOMMENDED SPACING OF TREES FROM ROADWAY

If these distances are impractical for a community, the removal of trees should be prioritized according to the danger they present. For instance, trees located along curves are a greater hazard than trees along straight sections.

Mailboxes

Roadside mailbox installations result in an object being placed very close to the traveled path, with the mailbox typically at the height of a vehicle's windshield.

- Mailbox supports should be a nominal 4-inch by 4-inch wood post, or metal post with strength no greater than a 2-inch diameter standard strength steel pipe, embedded no more than 24 inches.
- Mailbox-to-post attachments should prevent mailboxes from separating from their supports when hit by an errant vehicle.

Drainage Features

Culverts, inlets, headwalls, and ditches are serious traffic hazards if they are not properly designed and located. The following guidelines pertain to drainage structures:

- Eliminate non-essential drainage structures.
- Design or modify drainage structures so they are traversable or present a minimal hazard to an errant vehicle.
- If a major drainage feature cannot be re-designed or re-located, it should be shielded by a suitable traffic barrier.
- Roadside hardware, such as posts, should not be in or near a ditch bottom.

- Drop inlets on the roadway should be installed flush with the pavement surface and designed for safe passage of bicycle tires.
- Drop inlets located off the traveled way should be installed flush with the ditch bottom or slope on which they are located.

TRAFFIC CONTROL AT LOW-VOLUME INTERSECTIONS

A community should adopt a signing policy for low-volume intersections that can be applied with a high degree of consistency throughout the jurisdiction. This policy should not be unnecessarily restrictive. In particular, installation of unnecessary stop signs must be avoided since this will cause drivers to develop disrespect for all stop signs.

The decision to provide yield signs or stop signs, rather than using no control at a low volume intersection, is based on:

- Sight distances,
- Traffic volumes,
- Vehicle speeds on the approaches,
- Crash experience at the site, and
- Benefits from protecting traffic on designated through streets.

The AASHTO procedures for evaluating intersection sight distances and safe approach speeds must always be used when selecting the type of signs to install at a low volume intersection (refer to Appendix C, HAL Manual). With respect to intersection control, the MUTCD does not contain specific volume and/or crash warrants for yield signs or stop signs, except for multi-way stop signs.

No Control at Intersections

Guidelines:

- Both streets are local streets; or
- One street is a local street and the other is a minor collector; and
- Volume does not exceed 2,000 vehicles per day on the busiest roadway.

DO NOT:

- Use an un-controlled intersection if the busiest roadway has a volume greater than 2,000 vehicles per day.

Comment: Many intersections operating with no control have such low volumes that very few crashes occur, perhaps only one crash every three years. The occurrence of this one crash does not necessarily justify installing yield signs or stop signs. Refer to the following guidelines to determine whether yield signs or stop signs should be installed at a particular intersection. It can also be helpful to consult other sources, such as the AASHTO "Policy on Geometric Design of Highways and Streets".

Yield Signs at Intersections

Guidelines:

- Three or more crashes occur during three years involving vehicles on the minor road; or
- Two or more crashes occur in one year with vehicles on the minor road.

DO NOT:

- Use yield signs to regulate the major traffic flow at an intersection.

Special Instructions for Installation:

- Make sure only the motorists required to yield can view the yield sign. This is especially important if yield signs are used where two roadways meet at an acute angle. Install the signs at an angle or shield the lettering.

Two-Way Stop Signs at Intersections

Guidelines:

- Four or more crashes occur during three years involving vehicles on the minor road; or
- Three or more crashes occur in one year involving vehicles on the minor road.

DO NOT:

- Use a two-way stop sign to regulate the major flow at an intersection.
- Use a stop sign to control speed along a street.
- Use a portable stop sign except for emergency purposes.

Special Instructions for Installation:

- Before installing, complete an on-site field report to determine if some other less restrictive countermeasures could be implemented.
- Make sure only the motorists required to stop can view the stop sign. This is especially important if two-way stop signs are used where two roadways meet at an acute angle. Install the signs at an angle or shield the lettering.

Multi-way (Three-Way or Four-Way) Stop Signs at Intersections

Guidelines:

- Intersection has five or more correctable crashes in one year. (Correctable crashes include right-turn collisions, left-turn collisions, and right-angle collisions.)
- Traffic volumes on all approaches are about equal.

- Traffic volumes are high. (In the case of high traffic volumes, a traffic volume study should be performed to determine if the MUTCD traffic signal warrants have been met.)
- Sight distances at the intersection are inadequate.

Before Installing:

- Evaluate other countermeasures (improving skid resistance, restricting parking at the intersection, e.g.).
- Conduct a traffic volume study if the volume of traffic seems to be high.

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APPENDIX E

ESTIMATED IMPROVEMENT PROJECT COSTS – 1999

The roadway and traffic improvement cost estimates provided below were obtained from the Missouri Department of Transportation and are current for the year 1999. It is possible that local costs could vary from those listed below due to the location and/or project size. Unless otherwise noted, the costs are for installation (materials and labor) only. To account for additional overhead and administrative costs it is suggested that the initial cost of a project be increased by about 30%, or by the percentage deemed appropriate for the jurisdiction.

IMPROVEMENT DESCRIPTION	1999 COST	
ROADWAY CONSTRUCTION/RECONSTRUCTION		
Roadway grading and paving (widening)	$ 3.80	SF*
Roadway grading and paving (reconstruction)	4.66	SF
Median construction (concrete, excluding curbing)	3.50	SF
Curb and gutter (barrier and mountable)	12.50	LF
Barrier curbing	19.00	LF
Shoulder Construction (6” gravel)	4.15	SY
Curb removal	3.50	LF
Curb inlet	443.00	EA
Driveway closure; new curbing installation	19.65	SY
Driveway construction	55.00	SY
Island construction (concrete, excluding curbing)	3.50	SF
PAVEMENT SURFACE TREATMENTS		
Overlay (1-1/2” thick; lime/steel/slag)	1.40	SY
Chip and seal (3/4” thick; with special rock gradation)	1.30	SY
Slurry seal (special stone gradation in suspension)	2.00	SY
Pavement grooving	1.50	SF
Pavement striping (4-inch white or yellow stripe)	0.10	LF
Pavement marking (stop bars, lane use arrows, etc.)	3.50	SF
TRAFFIC SIGNALS AND BEACONS		
Overhead 4-way flashing beacon	2,000.00	EA
Post, signal, 10 feet high	430.00	EA
Mast arm post	2,750.00	EA
Fixed-time controller	5,000.00	EA
Actuated Controller	7,500.000	EA
Junction box	250.00	EA
Detector, loop inductive	3000	EA
Detector, magnetic	371.00	EA

IMPROVEMENT DESCRIPTION	1998 COST	
Detector, pedestrian pushbutton	$ 132.00	EA
Conduit (pushed . . . 2-inch diameter)	25.00	LF
Conduit (trenched . . . 2-inch diameter)	11.00	LF
ROADSIDE FEATURES		
Guardrail: New (Type A)	12.00	LF
Breakaway Cable Terminal (BCT)	700.00	EA
Bridge attachment	700.00	EA
Guardrail, New (Type A) and remove previous guardrail	20.00	LF
Complete lighting unit (1 Pole)	1,600.00	EA
Steel breakaway sign post	25.00	LF
Wood sign post (4-inch by 4-inch)	1.00	LF
Sign (installed . . . stop, yield, warning, etc.)	112.00	EA
Delineators (installed . . . sign and post)	60.00	EA
Remove and reset wood utility pole	160.00 to 750.00	EA
Remove and reset wood telephone poles	330.00 to 4,000.00	EA
Remove and reset road sign and post	50.00	EA
Remove tree(s)	100.00 to 650.00	EA
RAILROAD GRADE CROSSINGS		
Railroad crossing surface improvement (1 track)		
Asphalt	200.00	LF
Concrete	400.00	LF
Timber	300.00	LF
Rubberized	500.00	LF
Railroad crossing automatic gates (per crossing)	100,000.00	TYP
Railroad crossing flashing lights (per crossing)	80,000.00	TYP
MISCELLANEOUS		
Sidewalk removal	4.00	SY
Sidewalk construction	3.41	SF
Sodding	3.41	SY
Blade gravel road approaches (4) at intersection	250.00	TYP
THE FOLLOWING ITEMS INCLUDE MATERIAL COST ONLY:		
Plastic three-lens signal head (12-inch lenses)	195.00	EA
Plastic two-lens pedestrian head (12-inch lenses)	160.00	EA
Optically programmed three-lens signal head	750.00	EA
Plastic back-plate for three-lens signal head	70.00	EA

*Unit Cost Symbols: EA = Each; LF = Lineal Foot; SF = Square Foot; SY = Square Yard; TYP = Typical

APPENDIX F

ESTIMATED IMPROVEMENT PROJECT SERVICE LIFE

The estimated improvement project service lives listed below were obtained from the Missouri Department of Transportation and two other state highway agencies. It should be noted that the service life of an improvement project is somewhat difficult to forecast for several reasons, such as the quality of maintenance the project will receive. Local estimates should be used for service lives whenever they are available. However, there is very little benefit to be gained in stating service lives of an unusual number of years, such as 14 years or 29 years. Such estimates do not have much credibility, and they can make the economic analysis more complicated.

IMPROVEMENT DESCRIPTION	SERVICE LIFE (Years)
ROADWAY CONSTRUCTION/RECONSTRUCTION	
Widen pavement, no lanes added	20
Add lanes, no new median	20
Divide highway, add new median	20
Widen or improve shoulder	10
Flatten, clear side slopes	20
Relocate driveways	20
Flatten entrance slopes	20
Acquire right-of-way	100
Change horizontal alignment	15
Change vertical alignment	15
Change horizontal and vertical	15
STRUCTURES CONSTRUCTION/RECONSTRUCTION	
Widen bridge or major structure	20
Replace bridge or major structure	30
Construct new bridge or major structure	30
Construct minor structure	20
Construct pedestrian over- or under-crossing	30
Construct interchange	35
PAVEMENT SURFACE TREATEMENTS	
Apply skid treatment, groove pavement	10
Apply skid treatment, overlay pavement	6-9
Apply skid treatment, seal coat	3-5

IMPROVEMENT DESCRIPTION	SERVICE LIFE (Years)
PAVEMENT SURFACE TREATEMENTS (cont'd)	
Apply skid treatment, slurry seal	5-7
Apply markings (paint)	1
Apply markings (thermoplastic)	5
Apply edge-line markings (paint)	2
ROADSIDE FEATURES	
Install illumination	15
Install breakaway sign support	10
Install breakaway luminaire support	20
Install guardrail	10
Install median barrier	15
Improve drainage structures	20
Install fencing	10
Install traffic signs	6-8
INTERSECTION-RELATED PROJECTS	
Channelize, add turning lanes	15
Traffic signals	15
Warning flashers	15
Illumination	15
Overhead flashing beacon	10
RAILROAD GRADE CROSSINGS	
Grade separation	30
Crossing relocation	30
Crossing illumination	15
Automatic gates	20
Flashing lights	20
Crossing signs and markings	5
Crossing surface improvement	
Asphalt-timber	10
Timber	5
Rubberized	15
Concrete	20
OTHER IMPROVEMENTS	
Delineators	10
Raised pavement markers	5
Improve sight distance	10 (variable)

REFERENCES FOR SERVICE LIFE ESTIMATES

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APPENDIX G

ESTIMATED CRASH REDUCTION FACTORS

The estimated crash reduction (CR) factors in Table G-1 are based on safety project evaluations performed by a variety of groups and agencies throughout the United States. Due to the variability in traffic crash characteristics and countermeasure effectiveness among sites and regions, differences in CR factors for specific improvements do exist among agencies. Whenever possible, an agency should monitor its traffic safety improvement projects and develop its own CR factors.

CR factors are required for estimating the economic benefits likely to result from feasible countermeasures. Each CR factor indicates the percent crash reduction for a single countermeasure.

When applying CR factors, good engineering judgment and common sense must prevail. It is essential that each CR factor be applied to only those crashes having a reasonable chance of being corrected by the associated countermeasure.

The Estimated Crash Reduction Factor table is organized according to countermeasure category and CR factor group. The countermeasure categories are printed in capital letters in the left column, and the CR factor groups are identified by Roman numerals at the top of the table.

COUNTERMEASURE CATEGORIES

The countermeasure categories are tabled in the following sequence:

- Channelization
- Construction/Reconstruction
- Traffic Signs
- Traffic Signals
- Illumination
- Pavement Treatment
- Pavement Markings
- Regulations
- Roadside Improvement
- Delineation

Within each major countermeasure category, sub-categories are listed. For instance, under the category "REGULATIONS" there are sub-categories such as "Regulate On-Street Parking" and "Prohibit Left Turns."

When several countermeasures are being considered for simultaneous use to correct a crash pattern at one location, the combined effect must be calculated using the procedure in the section entitled "COUNTERMEASURE ANALYSIS" in Chapter 5. If that procedure is not followed, the crash reduction estimate will be incorrect.

CRASH REDUCTION (CR) FACTOR GROUPS

The CR factors are grouped to provide guidance for their proper application. The five groups listed across the top of the table are defined as follows:

GROUP I:	Contains CR factors applicable to "All" crashes.
GROUP II:	Contains CR factors applicable to crashes according to severity level, "Fatal/Injury" or "PDO".
GROUP III:	Contains CR factors applicable to several different types of crashes, such as "Head On" or "Right Angle".
GROUP IV:	Contains CR factors applicable to crashes that occur during "Wet Pavement" conditions.
GROUP V:	Contains CR factors applicable to crashes that occur during "Night" conditions.
GROUP VI:	Contains CR factors applicable to crashes that are train-related.

It is recommended that, for a specific countermeasure, the CR factor(s) to be applied should be selected from only one of the five groups. For example, if the countermeasure is "PAVEMENT TREATMENTS – de-slick pavement" for a high-crash intersection, the engineer should choose the most meaningful application of CR factors from these possibilities:

- From Group I: Apply 13% reduction to All crashes; or
- From Group III: Apply CR factors to specific crash types, as: 10% reduction to Head On; 40% to Rear End, 10% to Right Angle, 10% to Side-Swipe; 10% to Fixed Object; 10% to Pedestrian, and 10% to Run-Off Road crashes; or
- From Group IV: Apply 55% reduction to Wet Pavement crashes.

If CR factors are applied from more than one group for the proposed "De-slicking" countermeasure, the crash reduction may be substantially overestimated. Of course, the ideal situation would be to have CR factors for both wet and dry pavement conditions, for each crash type, and for each level of severity. However, CR factors are seldom available at that level of detail.

For additional access control measures, see appendix D. Table D-3 contains information on crash reduction, in a different format, as a function of ADT.

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
CHANNELIZATION (see also Table D-3 in Appendix D)															
channelize intersection (1)	25														
provide left-turn lane (with signal) (1, 7)	25							45							
- with no left-turn phase	15														
- existing left-turn phase	35														
provide left-turn lane (without signal) (1, 6)	35							50							
- painted lane	32				75										
- protected lane with curb or raised bars	67		62		93										
provide right-turn lane (1)	25								50						
increase turn lane length (1)	15														
install two-way left-turn lane in median (2, 8, 28)	35	20	35		36			33				37			
- two-lane to three-lane	32	59			46		46	46							
- four-lane to five-lane	28	42			40		40	40							
add mountable median (1)	15														
add non-mountable median (1)	25														
CONSTRUCTION/ RECONSTRUCTION															
REALIGNMENT															
construct a more gradual horizontal curve (1,12)	40														
- from 20 to 10 degrees	48														
- from 15 to 5 degrees	63														
- from 10 to 5 degrees	45														

TABLE G-1: ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III										IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
CONSTRUCTION/ RECONSTRUCTION (cont.)															
REALIGNMENT (cont.)															
improve vertical curve (1)	40														
improve horizontal and vertical curve (1)	50														
improve sight distance at intersection (1)	40														
SEPARATING DEVICES															
close median opening (3)				100	50	100	50	100							
install median barrier (1, 2, 5)	5	F:65 I:40										35			
- install a 1 to 12 ft. median		F:75 I:2	-28*												
- install a 13 to 30 ft. median		F:85 I:5	-30*												
install concrete median barrier (5)		F:90 I:10	-10*												
install/improve curbing (9)										50					
replace active warning devices with bridge or tunnel (5)	95		88												

* A crash reduction factor preceded by a (-) sign indicates an increase should be expected for that type of crash.

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
CONSTRUCTION/ RECONSTRUCTION (cont.)															
PAVEMENT WIDENING															
widen pavement (1)	25														
widen shoulder (paved) (10)															
- widen 2 ft.										16		16			
- widen 4 ft.										29		29			
- widen 6 ft.										40		40			
- widen 8 ft.										49		49			
widen shoulder (unpaved) (10)															
- widen 2 ft.										13		13			
- widen 4 ft.										25		25			
- widen 6 ft.										34		34			
- widen 8 ft.										43		43			
pave shoulder (1)	15														
stabilize shoulder (1)	25														
widen lane (10)															
- add 1 ft. to both sides				12			12					12			
- add 2 ft. to both sides				23			23					23			
- add 3 ft. to both sides				32			32					32			
- add 4 ft. to both sides				40			40					40			
ADDITIONAL LANES															
add passing/climbing lane (28)	25	30													
add accel./decel. lane (1)	10														
add lanes (2)	25	F:39 I:23	27	53	32		30					44			

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
CONSTRUCTION/ RECONSTRUCTION (cont.)															
BRIDGES															
widen bridge (general) (1, 2, 4)	45														
- from 18 to 24 ft.	68														
- from 20 to 24 ft.	56														
- from 22 to 24 ft.	36														
- from 18 to 30 ft.	93														
- from 20 to 30 ft.	90														
- from 22 to 30 ft.	86														
replace two-lane bridge (1, 2)	45														
repair bridge deck (1)	15														
INTERSECTION															
increase turning radii (1)	15														
improve sight distance (1, 2, 9)	30			10		21	10	13			10				
PEDESTRIAN															
construct pedestrian bridge or tunnel (1, 13)	5										90				
install sidewalk (1)											65				
DRAINAGE															
provide adequate drainage (1)	20												40		
provide proper superelevation (1)	40														
FREEWAY															
construct interchange (1)	55														
modify entrance/exit ramp (1)	25														
construct frontage road (1)	40														
install glare screen (1)														15	

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
CONSTRUCTION/ RECONSTRUCTION (cont.)															
GUARDRAIL															
install guardrail (1, 2)	5	F:65 I:40										30			
upgrade guardrail (1, 2)	5	F:50 I:35										26			
install at bridge (5)		F:90 I:45	-110*												
install along ditch (5)		26	-19*												
install along embankment (5)		42	-47*												
install to shield trees (5)		F:65 I:51	-90*												
install to shield fixed objects as rocks and steel posts (5)		31	-45*												
TRAFFIC SIGNS															
WARNING SIGNS															
install warning signs (1)	25														
install warning signs in advance of intersections (1, 11) - urban - rural	 30 40														
install warning signs in advance of curves (1, 2, 11)	30	F:55 I:20		29								30			
add signs at railroad crossings (1)															30
install school zone signs (1)	15														
install pavement condition signs (1)													20		

* A crash reduction factor preceded by a (-) sign indicates an increase should be expected for that type of crash.

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III										IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
TRAFFIC SIGNS (cont.)															
REGULATORY SIGNS															
install stop sign (2-way) (1)	35														
Change to all-way stop sign from two-way stop sign (1, 26)	55				13	72		20			39				
install yield sign (1)	45														
install lane use signs (27)	30				10		20								
GUIDE SIGNS															
install guide signs (1)	15														
install variable message sign (1)	15														
TRAFFIC SIGNALS															
install signal (general) (1, 24)	25					65									
- from two-way stop	28	43			-46*	74		-92*							
- from two-way stop and add left-turn lane	36	53			8	74		-43*							
SIGNAL UPGRADE															
upgrade signal (1)	20														
install 12-inch lenses (1)	10														
install visors or back-plates (1)						20									
install optically programmed signal lenses (1, 3)	15			20	10	10		10							
upgrade pedestal mounted to mast arm: pre-timed signal (24)															
- no left-turn lane	51	52			24	69		28							
- existing left-turn lane	44	25			35	74		2							
- left-turn lane added	84	87			72	83		87							

* A crash reduction factor preceded by a (-) sign indicates an increase should be expected for that type of crash.

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I All	II Fatal or Injury	 PDO	III Head On	 Rear End	 Right Angle	 Side-Swipe	 Left Turn	 Right Turn	 Fixed Object	 Pedes-trian	 Run-Off Road	IV Wet Pave-ment	V Night	VI Train-Related
TRAFFIC SIGNALS (cont.)															
SIGNAL PHASING															
improve signal phasing (1)	25														
add exclusive left-turn phase (1)	25							70							
add protected/permissive left-turn phase (1)	10							40							
improve timing (1)	10														
install/improve pedestrian signal (1)	25										55				
improve yellow change interval (1)	15					30									
add all-red interval (1)	15					30									
interconnect signals (1, 15)	15	29			20	10		38	36		10				
install traffic actuated signal (33)						10	20	80							
REMOVAL															
remove unwarranted signal (1, 9)	50				90	-30*		-10*			-10*				
FLASHING BEACON															
install flashing beacon (1)	30														
install flashing beacon at intersection (1)	30														
install intersection advance warning flashers (1)	25														
install general advance warning flashers (1)	35														

* A crash reduction factor preceded by a (-) sign indicates an increase should be expected for that type of crash.

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
TRAFFIC SIGNALS (cont.)															
RAILROAD CROSSINGS															
general railroad crossings (1)															70
add flashing lights at railroad crossings (1)															65
add automatic gates at railroad crossings (1)															75
add automatic gates and flashing lights (1)															75
ILLUMINATION															
improve street lighting (1)	25													50	
install/improve lighting at roadway segment (1)	25													45	
install/improve lighting at intersections (1)	30													50	
install/improve lighting at interchanges (1)	25													50	
install/improve lighting at railroad crossings (1)	30													60	60
PAVEMENT TREATMENT															
de-slick pavement (9, 21)	13			10	40	10	10			10	10	10	55		
groove pavement (1)	25												60		
resurface curve with skid-resistant overlay (21)				86									51		
resurface (general) (1)	25												45		
install rumble strips (1, 2)	25														
groove shoulder (1, 2)	25	18	17									27			
make surface improvements at railroad crossings (11)	34		39												

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
PAVEMENT MARKINGS															
add pavement markings (32)	13														
add pavement markings at railroad crossings (1, 2)	48	42	51		58										15
add reflectorized raised pavement markings (1, 9)	10			20			20			10		10	25	20	
add "no passing" striping (1)				40			40								
add centerline markings (1)	35														
add edgeline markings (1, 20)	15	15	8									30			
add/improve pedestrian crosswalk (1)											25				
add wider markings (1)														25	
REGULATIONS															
prohibit on-street parking (1, 9)	35				10	10	30			40	30				
change angle parking to parallel (22)	59														
set appropriate speed limit (1,15)	20		35												
prohibit left-turns (1, 9)	45				30			90			10				
change two-way roadway to one-way roadway (1, 23)															
- intersection crashes	26										46				
- mid-block crashes	43										50				
prohibit right-turn-on-red at signalized intersections (9)					20	30	20				30				
ROADSIDE IMPROVEMENT															
remove fixed objects (1)	30	F:50 I:30													
relocate fixed objects (1)	25	F:40 I:25													

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
ROADSIDE IMPROVEMENT (cont.)															
improve gore area (1)	25														
modify poles/posts with (1) breakaway features	5	F:60 I:30													
install impact attenuators (1)	5	F:75 I:50													
relocate utility poles to increase offset from road (16)															
- from 2 to 6 ft										50					
- from 3 to 8 ft										46					
- from 5 to 10 ft										36					
flatten side-slope (29, 30)															
- from 2:1 to 4:1	6									10		10			
- from 2:1 to 5:1	9									15		15			
- from 2:1 to 6:1	12									21		21			
- from 3:1 to 4:1	5									8		8			
- from 3:1 to 5:1	8									14		14			
- from 3:1 to 6:1	11									19		19			
- from 4:1 to 6:1	7									12		12			
- from 5:1 to 7:1	8									14		14			
install animal fencing (1, 2)	90*	91	61												
eliminate poles by burying utility lines (31)	40														
install object markers (2)	16	F:41 I:17	14									29			

* Applies to animal-related crashes only

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

COUNTERMEASURE	I	II		III									IV	V	VI
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side-Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Run-Off Road	Wet Pave-ment	Night	Train-Related
ROADSIDE IMPROVEMENT (cont.)															
increase roadside clear zone recovery distance (10)															
- add 5 ft										13		13			
- add 8 ft										21		21			
- add 10 ft										25		25			
- add 15 ft										35		35			
- add 20 ft										44		44			
DELINEATION															
install post-mounted delineators on horizontal curve (1, 15)	25													30	
install chevron alignment sign on horizontal curve (15)	35														
install delineation at bridges (5)	40														

TABLE G-1 (CONT'D): ESTIMATED CRASH REDUCTION FACTORS (%)

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30. Zegeer, C. and F. Council, “Safety Relationships Associated with Cross-Sectional Roadway Elements,” Transportation Research Record 1512, Transportation Research Board, December 1995.

31. Al-Masaeid, H. and K. Sinha, “Analysis of Accident Reduction Potentials of Pavement Markings,” Journal of Transportation Engineering, Vol. 120, No. 5, Sept.- Oct. 1994.

32. “Table 3- Accident Reduction Factors” Nebraska Department of Roads (internal document).

APPENDIX H

ECONOMIC ANALYSIS: COST UPDATES, CRASH COSTS, COMPOUND INTEREST FACTORS, AND THEIR APPLICATIONS

COST UPDATES

The countermeasure costs listed in Appendix E, as well as crash costs used in this edition of the HAL Manual, apply to the State of Missouri for the year 1999. The city engineer or other local official who is responsible for applying the HAL Manual in future years may want to update these costs using one of the following methods:

- Adjust all costs using an annual percentage increase for each type of cost. This would be a tedious process, but it might be necessary due to the rapidly increasing cost of fatal and injury vehicle crashes relative to other cost categories.
- Contact the TTAP office to obtain costs currently used by MoDOT in their high-hazard elimination program.
- Assume a reasonable rate of increase per year for all costs involved, such as 4 or 5 percent per year.
- Use the costs as provided in the HAL Manual, assuming all costs increased in a compatible manner, thereby having little or no effect on the results of the benefit/cost ratio computations.

CRASH COSTS

The crash costs, as stated in Chapter 1 and applied in Chapter 5, assume a 1999 basis and are:

Cost of a Fatal (F) Crash:	$3,390,000
Cost of an Injury (I) Crash:	$ 44,100
Cost of a Property-Damage-Only (PDO) Crash:	$ 3,220

For several reasons, it is not recommended that the cost for a fatal crash be applied directly as the amount shown above. Fatal crashes are infrequent events, and, if the $3,390,000 cost is applied, the chance occurrence of one fatal crash at a site would overwhelmingly influence the selection process. This could result in omitting another site for improvement, which had a larger number of serious injury crashes, but did not experience a fatal crash. Furthermore, reliable crash reduction factors suitable for application to fatal crashes are not readily available due to the infrequency of such events and the difficulty of developing the factors.

To counteract these problems, it is assumed that fatal crashes and injury crashes are events which can each be expressed as a percentage of the total fatal and injury crashes occurring statewide on a specific classification of highway system. The percentages for fatal crashes and injury crashes can be applied to the cost of a fatal crash and to the cost of an injury crash, respectively, to develop a crash category known as "Fatal or Injury Crash." The formula to describe this is:

$$\text{Cost of F+I Crashes} = \frac{(F\%)\ (\text{F Crash Cost}) + (I\%)\ (\text{I Crash Cost})}{(100\%)}$$

For this edition of the HAL Manual, data published by the Missouri State Highway Patrol ("Missouri Traffic Crashes") were used to compute the percentages for fatal crashes and for injury crashes on six classifications of Missouri traffic-ways. These percentages were then applied to the cost of a fatal crash and the cost of an injury crash to yield the weighted cost of a Fatal or Injury Crash, as shown in the last column of Table H-1.

Classification of Traffic-way	Percent Fatal Crashes	Percent Injury Crashes	Weighted Cost of Fatal or Injury Crashes, in $
Interstate	2.812	97.188	138,000
U.S. Numbered	3.062	96.948	147,000
State Numbered	2.835	97.165	139,000
State Lettered	3.875	96.125	174,000
County Road	2.193	97.805	117,000
City Street	0.745	99.255	69,000

TABLE H-1: COST OF FATAL OR INJURY CRASHES OCCURRING ON SIX CLASSIFICATIONS OF TRAFFIC-WAY IN MISSOURI.

Since the HAL Manual is primarily intended to be used as a guide for conducting traffic safety studies in communities, the weighted cost of fatal or injury crashes on city streets ($69,000) is used for the example in Chapter 5.

COMPOUND INTEREST FACTORS

A compound interest rate of 4 percent per year is used in the HAL Manual example computations. Rates other than 4 percent could be used, depending on local policy or on factors such as the interest rate on local bond issues.

To perform an analysis involving interest factors, it is convenient to apply factors that have already been tabulated. The two categories of interest factors needed for most traffic safety analyses are known as the “Capital Recovery Factor” and the “Sinking Fund Factor.” Tabulations of these factors for compound interest rates of 3%, 4%, and 5% are provided in Tables H-2, H-3, and H-4, respectively.

Examples Showing Interest Factor Applications

- Example 1: Paint center-lines, lane lines, crosswalks, and lane use arrows on four approaches at an intersection.

  $200 initial cost
  $0 residual value
  Service life of 1 year
  Determine equivalent uniform annual cost (A) using 4% interest

  A = P(A/P,4%,1) = 200(1.04) = $208 per year

- Example 2: Install 4 regulatory and 4 warning signs at an intersection.

  $720 initial cost
  $50 residual value (for sign materials)
  Service life of 7 years
  Determine equivalent uniform annual cost (A) using 4% interest

  A = P(A/P,4%,7) - F(A/F,4%,7) = 720(0.16661) - 50(0.12661)

  A = 119.96 – 6.33 = $113.63 per year

- Example 3: Install intersection lighting using two poles.

  $3,200 initial cost
  $800 residual value
  Service life of 15 years
  Determine equivalent uniform annual cost (A) using 4% interest

  A = P(A/P,4%,15) – F(A/F,4%,15) = 3200(0.08994) – 800(0.04994)

  A = 287.81 – 39.95 = $247.86 per year

- Example 4: Determine the total equivalent uniform annual cost (A) for a set of three improvements to be made at one location. The three improvements are the items specified in Examples 1, 2 and 3. Use a 4% interest rate.

The three types of improvements for this location have different service lives, which means a special procedure must be followed to find the total equivalent uniform annual cost (A).

First, it is necessary to assume that when each improvement reaches the end of its service life, it will be replaced by an identical item having similar costs. This pattern of replacing items is assumed to continue for a long time.

Next, the equivalent uniform annual cost is calculated for each type of improvement by using the costs associated with the first item in the series of identical replacements.

Finally, the total equivalent uniform annual cost is found by adding the annual costs for the first item from each of the three types of improvements. Since the equivalent uniform annual cost has already been calculated for each improvement project, the total equivalent uniform annual cost in Example 4 is found by adding together the previous results:

$$A = 208 + 113.63 + 247.86 = \$569.49 \text{ per year}$$

REFERENCES FOR ECONOMIC ANALYSIS

Grant, E., W. Ireson, and R. Leavenworth, "Principles of Engineering Economy," John Wiley & Sons, New York, New York, 8th Edition, 1990.

"A Manual on User Benefit Analysis of Highway and Bus-Transit Improvements," American Association of State Highway and Transportation Officials, 1977.

"Missouri Traffic Crashes," Missouri State Highway Patrol, Department of Public Safety, published annually.

"Motor Vehicle Accident Costs," Federal Highway Administration Technical Advisory, T-7570.1, June 30, 1988. Attachment: A. Bailey, "Accident Costs – Are We Using Them Correctly?"

Service Life in Years (n)	Uniform Series Capital Recovery Factor (A/P, 3%, n)	Uniform Series Sinking Fund Factor (A/F, 3%, n)
1	1.03000	1.00000
2	0.52261	0.49261
3	0.35353	0.32353
4	0.26903	0.23903
5	0.21835	0.18835
6	0.18460	0.15460
7	0.16051	0.13051
8	0.14246	0.11246
9	0.12843	0.09843
10	0.11723	0.08723
11	0.10808	0.07808
12	0.10046	0.07046
13	0.09403	0.06403
14	0.08853	0.05853
15	0.08377	0.05377
20	0.06722	0.03722
25	0.05743	0.02743
30	0.05102	0.02102
40	0.04326	0.01326
50	0.03887	0.00887
100	0.03165	0.00165

Symbols:

"n" is the number of years for the improvement service life.

"P" is the initial cost to install or construct the improvement at the beginning of its service life.

"F" is the salvage value or the residual value at the end of the service life for an inprovement.

"A" is the uniform annual amount that is equivalent to the "P" value for an improvement; "A" should include the effect of a salvage or residual value "F" if that value is available.

TABLE H-2: INTEREST FACTORS – 3 PERCENT COMPOUNDED ANNUALLY

Service Life in Years (n)	Uniform Series Capital Recovery Factor (A/P, 4%, n)	Uniform Series Sinking Fund Factor (A/F, 4%, n)
1	1.04000	1.00000
2	0.53020	0.49020
3	0.36035	0.32035
4	0.27549	0.23549
5	0.22463	0.18463
6	0.19076	0.15076
7	0.16661	0.12661
8	0.14853	0.10853
9	0.13449	0.09449
10	0.12329	0.08329
11	0.11415	0.07415
12	0.10655	0.06655
13	0.10014	0.06014
14	0.09467	0.05467
15	0.08994	0.04994
20	0.07358	0.03358
25	0.06401	0.02401
30	0.05783	0.01783
40	0.05052	0.01052
50	0.04655	0.00655
100	0.04081	0.00081

Symbols:

"n" is the number of years for the improvement service life.

"P" is the initial cost to install or construct the improvement at the beginning of its service life.

"F" is the salvage value or the residual value at the end of the service life for an inprovement.

"A" is the uniform annual amount that is equivalent to the "P" value for an improvement; "A" should include the effect of a salvage or residual value "F" if that value is available.

TABLE H-3: INTEREST FACTORS – 4 PERCENT COMPOUNDED ANNUALLY

Service Life in Years (n)	Uniform Series Capital Recovery Factor (A/P, 5%, n)	Uniform Series Sinking Fund Factor (A/F, 5%, n)
1	1.05000	1.00000
2	0.53780	0.48780
3	0.36721	0.31721
4	0.28201	0.23201
5	0.23097	0.18097
6	0.19702	0.14702
7	0.17282	0.12282
8	0.15472	0.10472
9	0.14069	0.09069
10	0.12950	0.07950
11	0.12039	0.07039
12	0.11283	0.06283
13	0.10646	0.05646
14	0.10102	0.05102
15	0.09634	0.04634
20	0.08024	0.03024
25	0.07095	0.02095
30	0.06505	0.01505
40	0.05828	0.00828
50	0.05478	0.00478
100	0.05038	0.00038

Symbols:

"n" is the number of years for the improvement service life.

"P" is the initial cost to install or construct the improvement at the beginning of its service life.

"F" is the salvage value or the residual value at the end of the service life for an inprovement.

"A" is the uniform annual amount that is equivalent to the "P" value for an improvement; "A" should include the effect of a salvage or residual value "F" if that value is available.

TABLE H-4: INTEREST FACTORS – 5 PERCENT COMPOUNDED ANNUALLY

APPENDIX J

CRASH DATA SUPPORT SERVICES AND PROGRAMS

Missouri's programs to assist local communities in traffic crash analysis and countermeasure development have been significantly enhanced in recent years through automated data processing at both the state and local levels. The following list identifies automated traffic crash data support services currently available to Missouri communities. Contact information for the agencies is listed in Appendix K.

1. MOTIS (Missouri Local Traffic Information System): MOTIS is a public domain microcomputer program developed for local agencies experiencing between 200 and 6,000 crashes per year and wanting to encode their own crash and citation data. These two primary databases assist the community and crash analyst in correlating the data with citation issuance. The databases also provide time and location data for selective enforcement and engineering countermeasures. The long-range plan for the MOTIS program will interface all related databases relative to a crash, including traffic control devices, street lighting, and roadway geometrics.
2. STARS (Statewide Traffic Accident Records Systems) Monthly reports: The Missouri State Highway Patrol prepares the STARS reports by summarizing a contributing agency's crash reports on the computer. STARS provides monthly and annual summaries. However, these summaries do not include totals on crashes occurring on private property, hit-and-run crashes, or enforcement data. Police departments may want to add this information for their purposes.
3. TRACE (Traffic Report of Accidents for Countermeasure Establishment): TRACE is a STARS generated, alpha-order location printout of all crashes in a political subdivision for a specified time-period. The report contains the data necessary to determine the crash pattern and probable cause. Supplemental reports may be obtained for all crashes occurring on a particular route or at a specific intersection.
4. STARS/MULES (Missouri Uniform Law Enforcement System) Interface: This interface is an on-line system for MULES participants to query the STARS file by the crash victim's name, the crash location, or the complaint number of the crash.

For more information on STARS, contact the Missouri State Highway Patrol, Traffic Division. For more information on either MOTIS or TRACE, contact the Missouri Division of Highway Safety.

APPENDIX K

CONTACT INFORMATION

Many organizations are listed in this manual as resources for local agencies needing assistance with the HAL program. Addresses and phone numbers for these offices are listed in the tables below.

MoDOT OFFICES				
ABBREV.	FULL NAME	ADMINISTRATING AGENCY AND/OR ADDRESS	PHONE #	FAX #
---	MoDOT Web Page	www.modot.state.mo.us	---	---
Dist. 1	Northwest Area	3602 North Belt Highway P.O. Box 287 St. Joseph, MO 64502	(816) 387-2350 (888) ASK-MODOT	(816) 387-2359
Dist. 10	Southeast Area	201 North Main Street P.O. Box 160 Sikeston, MO 63801	(573) 472-5333 (888) ASK-MODOT	(573) 472-5342
Dist. 2	North Central Area	US Route 63 P.O. Box 8 Macon, MO 63552	(660) 385-3176 (888) ASK-MODOT	(660) 385-4195
Dist. 3	Northeast Area	1711 S. Route 61 P.O. Box 1067 Hannibal, MO 63401	(573) 248-2490 (888) ASK-MODOT	(573) 248-2469
Dist. 4	Kansas City Area	5117 East 31st Street Kansas City, MO 64128	(816) 889-3350 (888) ASK-MODOT	(816) 889-3369
Dist. 5	Central Area	1511 Missouri Blvd. P.O. Box 718 Jefferson City, MO 65102	(573) 751-3322 (888) ASK-MODOT	(573) 527-6891
Dist. 6	St. Louis Area	1590 Woodlake Drive Chesterfield, MO 63017	(314) 340-4100 (888) ASK-MODOT	(314) 340-4119
Dist. 7	Southwest Area	3901 East 32nd Street P.O. Box 1445 Joplin, MO 64802	(417) 629-3300 (888) ASK-MODOT	(417) 629-3140
Dist. 8	Springfield Area	3025 East Kearney Street P.O. Box 868 Springfield, MO 65801	(417) 895-7600 (888) ASK-MODOT	(417) 895-7711

MoDOT OFFICES (cont'd)				
Dist. 9	South Central Area	910 Springfield Road P.O. Box 220 Willow Springs, MO 65793	(417) 469-3134 (888) ASK-MODOT	(417) 469-4555
TTAP	Technology Transfer Assistance Program	MoDOT Research Development and Technology Division P.O. Box 270 Jefferson City, MO 65102	(573) 751-3002	(573) 526-4337
TEAP	Traffic Engineering Assistance Program	MoDOT Traffic Division P.O. Box 270 Jefferson City, MO 65102	(573) 526-0117	(573) 526-0120

OTHER OFFICES			
NAME	ADDRESS	PHONE #	FAX # / WEB ADDRESS
Missouri State Highway Patrol	Dept. of Public Safety Missouri State Highway Patrol 1510 East Elm St. P.O. Box 568 Jefferson City, MO 65102-0568	(573) 751-3313	(573) 751-9419
Missouri State Highway Patrol, Traffic Div.	Dept. of Public Safety Missouri State Highway Patrol 1510 East Elm St. P.O. Box 568 Jefferson City, MO 65102-0568	(573) 751-3313	(573) 751-9419
Missouri Division of Highway Safety	1719 Southridge Dr. P.O. Box 104808 Jefferson City, MO 65110	(573) 751-5407	(573) 634-5977
National Safety Council	425 North Michigan Avenue Chicago, IL 60611	(630) 775-2056 or (800) 621-7619	www.nsc.org

INTERSECTION TRAFFIC COUNT FIELD SHEET [Form ITCFS]

N/S Street: ______________________________ Day________ Date ___________

E/W Street: ______________________________ Time Start __________ End __________

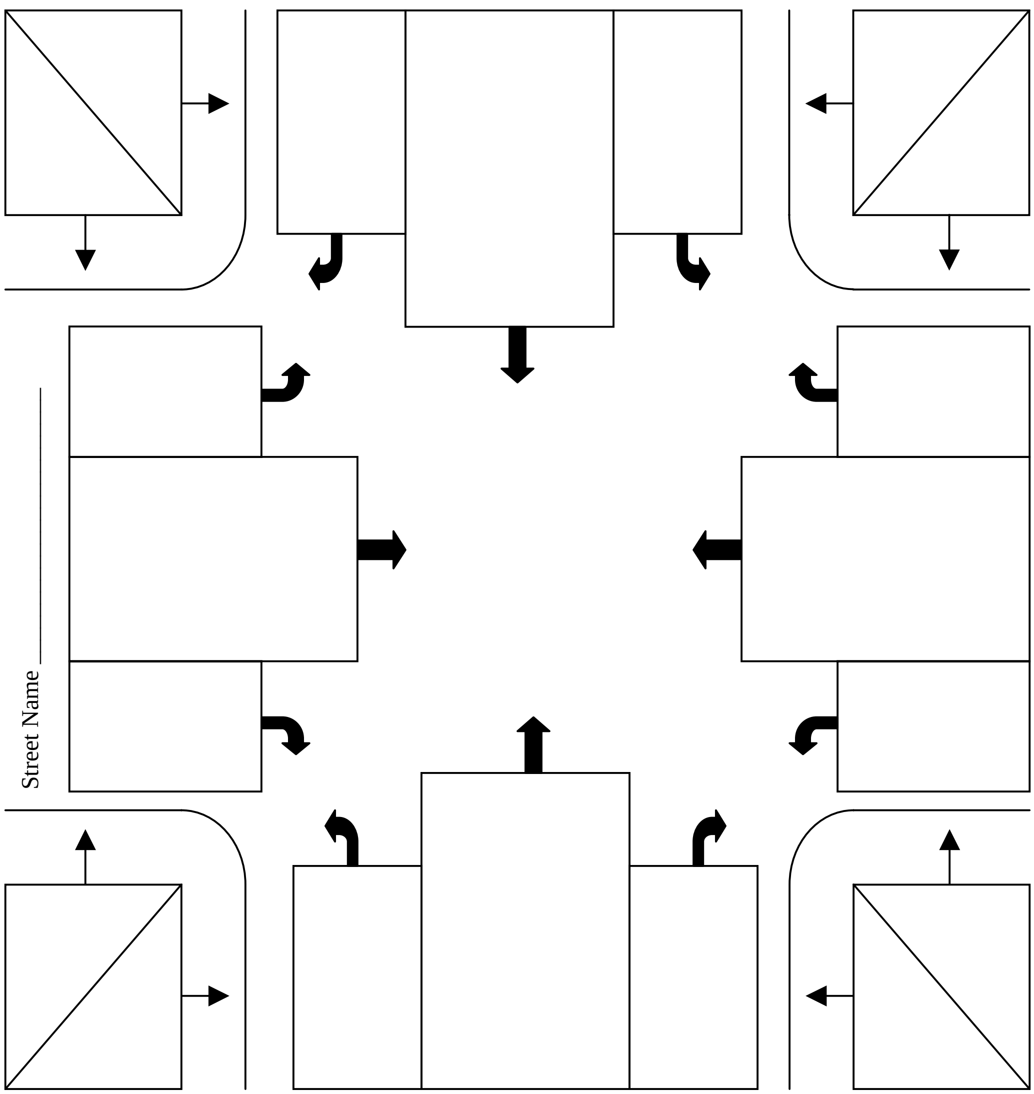
Observer: ______________________________ Weather _________________

P or ( ): Passenger cars, pickups, vans

T: Trucks with six or more tires

B: Buses SB: School Buses

North Arrow:



Peds. Street Name ______________________________ Peds.

INTERSECTION TRAFFIC COUNT FIELD SHEET [Form ITCFS]

N/S Street: ______________________________ Day________ Date __________

E/W Street: ______________________________ Time Start _________ End _________

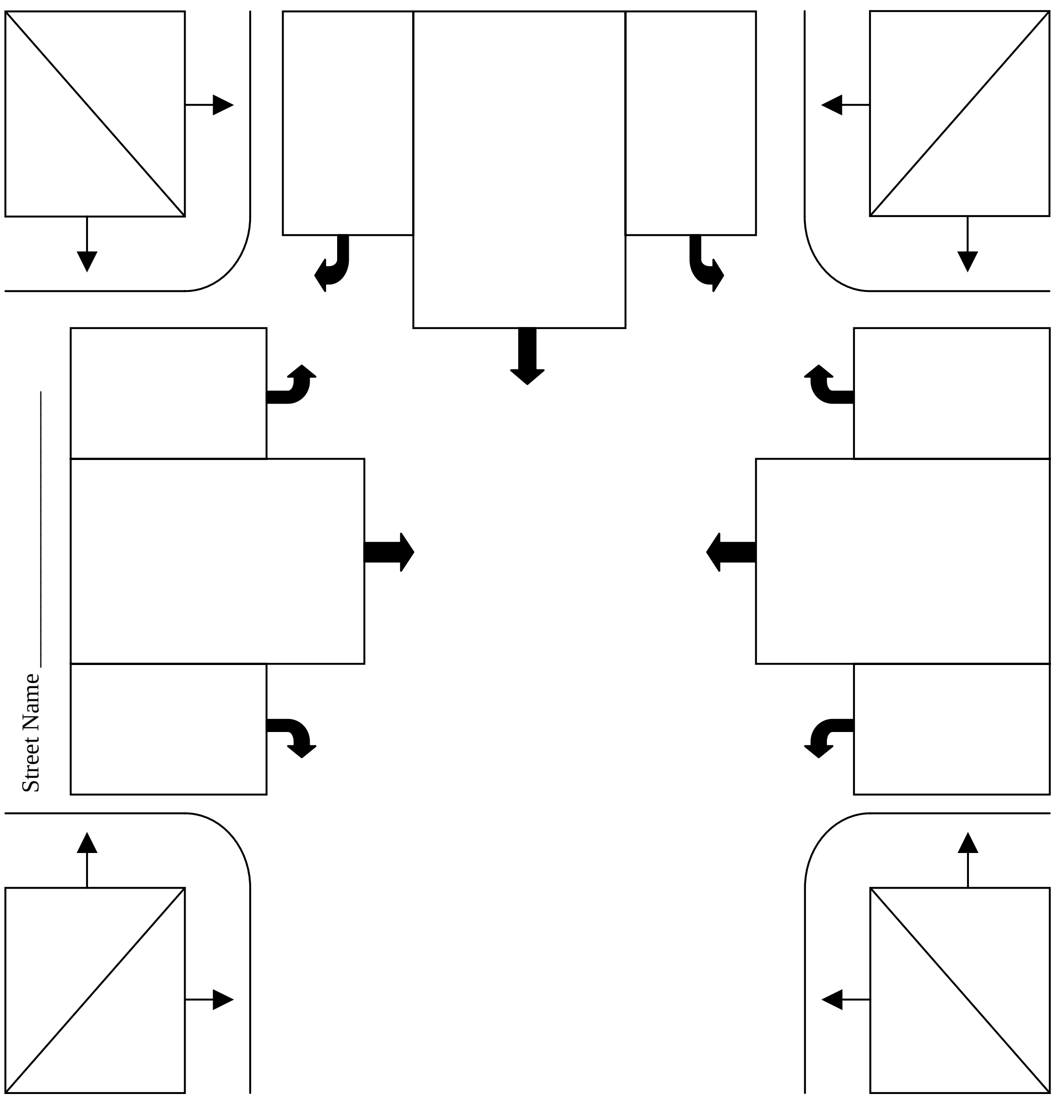
Observer: ______________________________ Weather ________________

P or (||||): Passenger cars, pickups, vans

T: Trucks with six or more tires

B: Buses SB: School Buses

North Arrow:



Peds. Street Name ____________________________ Peds.