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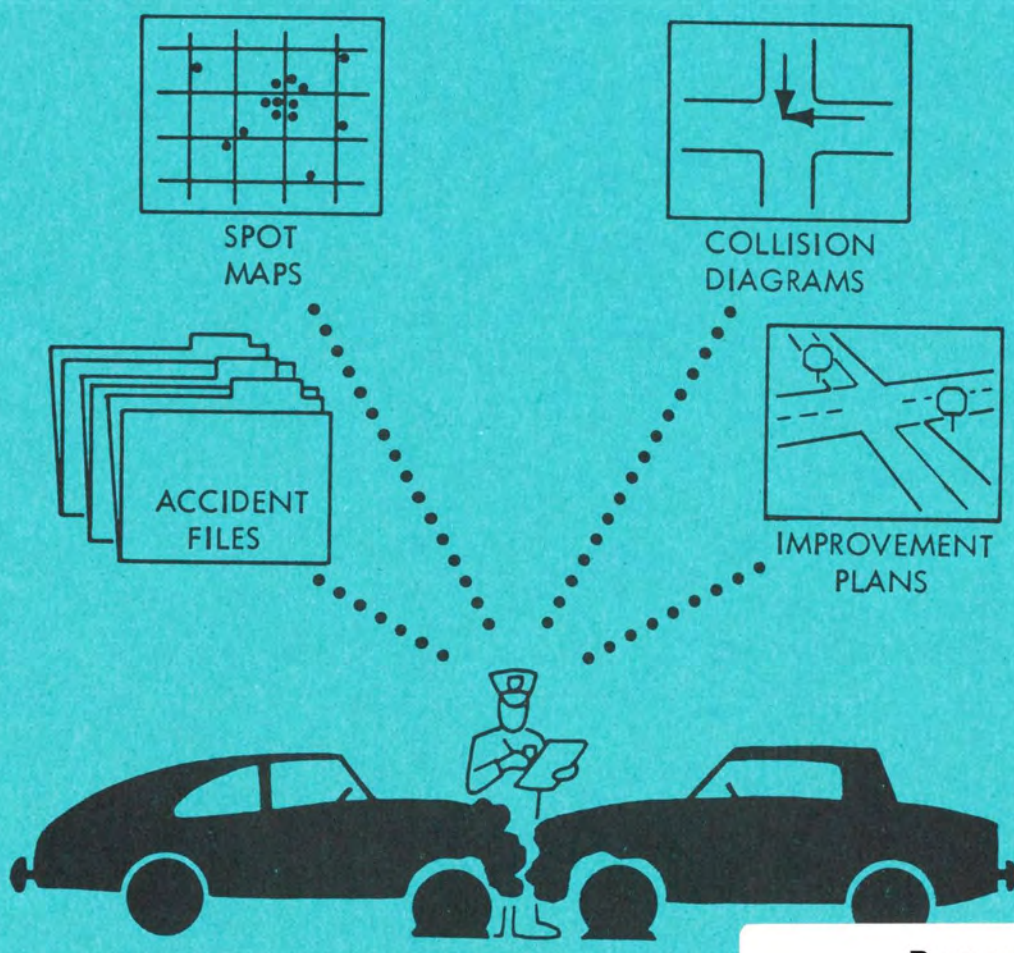
TECHNOLOGY TRANSFER ASSISTANCE PROGRAM

MISSOURI HIGHWAY AND
TRANSPORTATION DEPARTMENT

Manual on

Identification, Analysis and Correction of High-Accident Locations

Second Edition - 1990



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Manual on

IDENTIFICATION, ANALYSIS AND CORRECTION OF HIGH-ACCIDENT LOCATIONS

Second Edition - 1990

Prepared for

Technology Transfer Assistance Program
Missouri Highway and Transportation Department

Prepared by

Department of Civil Engineering
University of Missouri-Rolla

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December 1990

The opinions, findings and conclusions expressed in this publication are not necessarily those of the Federal Highway Administration, U. S. Department of Transportation. This report does not constitute a standard, specification or regulation.

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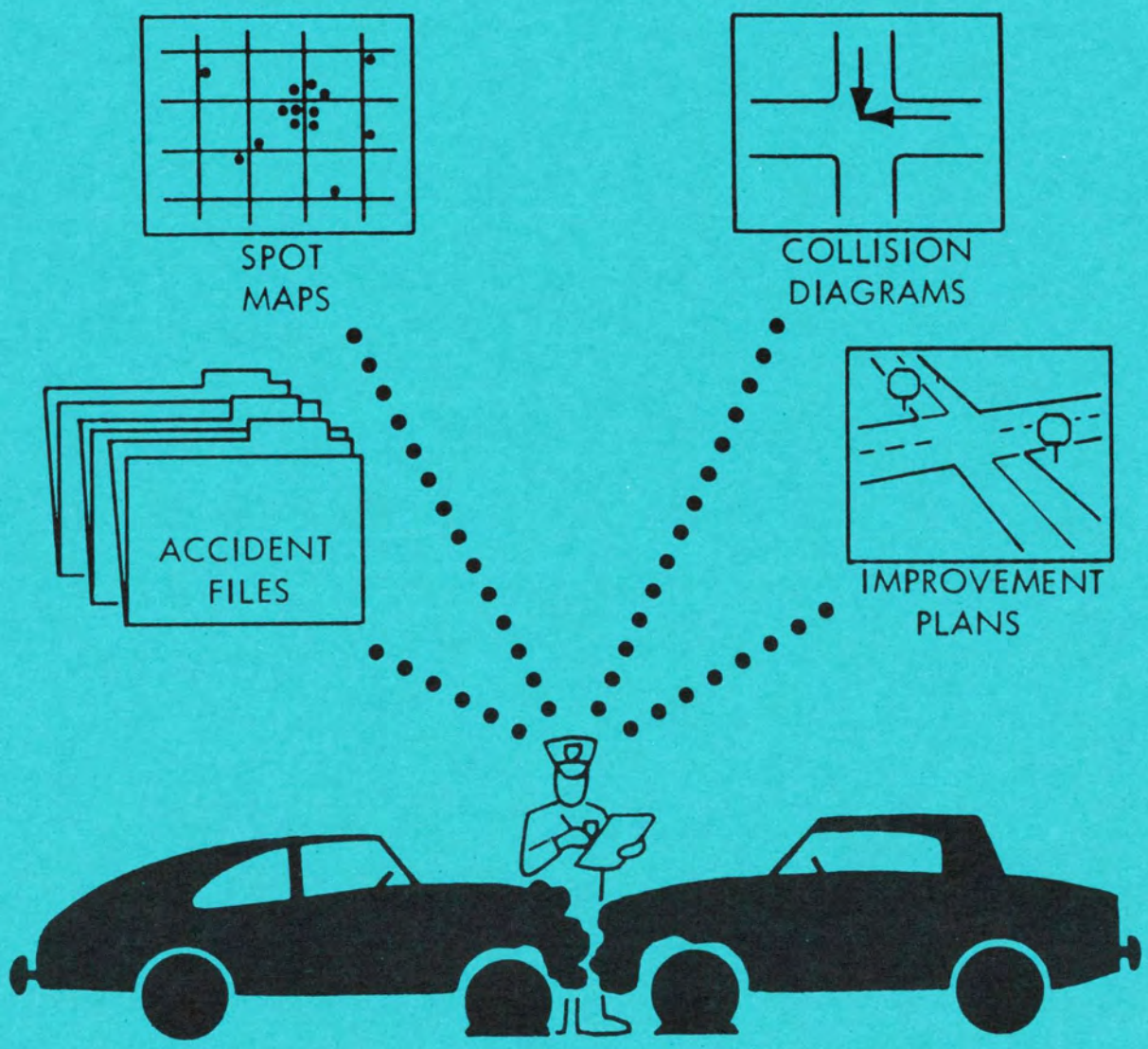
CHAPTER 1 – INTRODUCTION



CHAPTER 1

INTRODUCTION TO THE HAL SYSTEM

Streets and highways are vital to the well-being of all communities. Deficiencies in the street and highway system contribute significantly to human suffering and death, lower productivity, and serious economic loss. Therefore, those charged with the design, construction, and maintenance of streets and highways have the continuing responsibility of making them as safe and efficient as is practical.

Although not all accidents are due to faulty characteristics of the roadway, a concentration of accidents at one location implies there may be a failure in the system. Detailed study of accident records can identify these high-accident locations and further evaluations can then lead to improvements that will reduce the number and severity of future accidents.

PURPOSE AND SCOPE

This manual describes the high-accident location (HAL) analysis system which will allow the user to identify, analyze, and correct high-accident locations. It was prepared for smaller communities in Missouri that do not necessarily have a traffic engineer, but do recognize their need for a local capability to effectively deal with traffic accident problems.

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 traffic safety project results. Using this manual, city personnel in any local jurisdiction should be able to implement a complete high-accident location analysis and improvement program.

ORGANIZATION OF THE MANUAL

This manual has five chapters which are supported by information in several appendices. Chapter 1 introduces the HAL system and explains the benefits it offers a community. Chapters 2 through 5 cover each of the four basic processes of the HAL system as shown in Figure 1.

Chapter 2, "Setting Up the Traffic Records System," describes the requirements for reporting, filing, and summarizing traffic accident data.

Chapter 3, "Identifying High-Accident Locations," describes the Early Warning Analysis and the Annual City-Wide Analysis, two procedures that will identify locations with high numbers of traffic accidents.

Chapter 4, "Analyzing High-Accident Locations," presents methods for interpreting a location's accident experience in order to determine general countermeasures for certain accident patterns. The general countermeasures combined with data from traffic studies may then be used to identify specific improvements for each high-accident location.

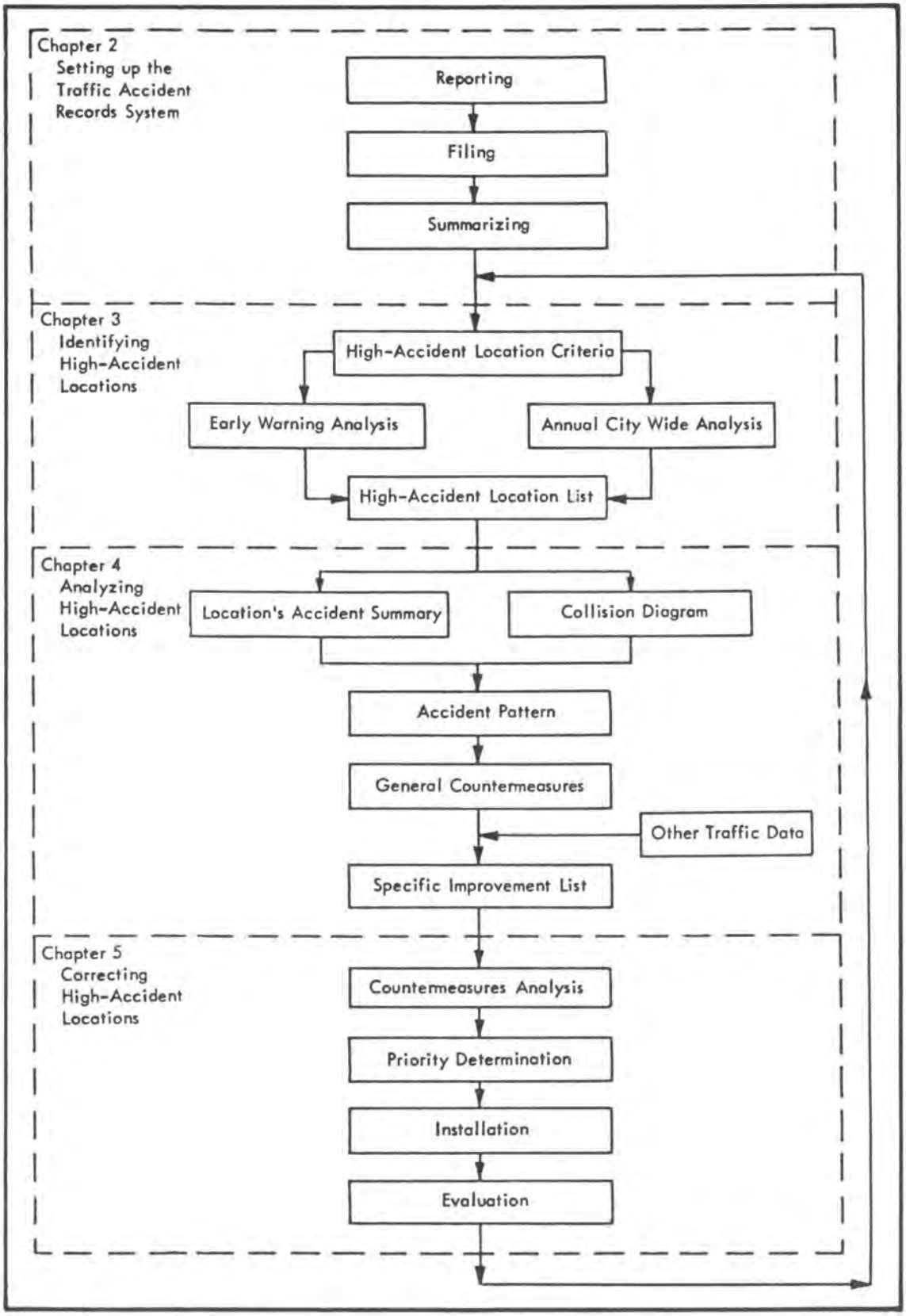


FIGURE 1. THE HIGH-ACCIDENT LOCATION (HAL) ANALYSIS SYSTEM.

Chapter 5, "Correcting High-Accident Locations," describes how alternatives for reducing accident numbers and severity are compared in order to select which improvement or group of improvements to install. Methods for evaluating the improvements installed at a location and evaluating the entire HAL program system are also given in Chapter 5.

HOW TO USE THE MANUAL

Several procedures are used to study high-accident locations. The person in charge of the HAL system should read through the entire manual in order to see how the procedures are related to each other. On the first reading, the procedures in each chapter can be read over quickly. After the four 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-accident locations, it does not contain information concerning improvement design. For this purpose the reader should refer to the Manual on Uniform Traffic Control Devices (MUTCD), the Traffic Control Devices Handbook (TCDH), or one of the other publications listed in the references.

In certain cases, advice on improvement design or construction can be obtained from the Missouri Highway and Transportation Department (MHTD) through their local assistance program known as the Technology Transfer Assistance Program (TTAP). TTAP is located in the MHTD Planning Division; P.O. Box 270; Jefferson City, MO 65102 (Phone: 314-751-0852). Also, a local agency may request assistance by contacting the District Liaison Engineer at the nearest MHTD District Office.

SUPERVISION OF THE HAL SYSTEM

Both the city police department and the engineering department should be involved in analyzing high-accident locations. The police department furnishes the required traffic accident data to the person in charge of traffic engineering functions, which is usually the city engineer.

If the community does not have a city engineer, responsibility for maintaining the HAL system could be given to the chief of police or the police officer in charge of traffic safety, or to the city public works director. In later chapters of this manual, the term "city engineer" will refer to the person in charge of the HAL system.

PURPOSE OF WORKSHEETS

Worksheets are provided for most of the procedures described in the manual. They guide the user through each step of a procedure and provide a record of the HAL analysis. Illustrations of worksheet applications are shown in later chapters, and original worksheets suitable for photocopying are in Appendix I.

BENEFITS AND COSTS OF THE HAL SYSTEM

The goal of reducing the number and severity of traffic accidents requires an investment of time and money on the part of the community. Although the cost of actually setting up the HAL system is negligible, the costs of manpower needed to complete the analysis procedures might become a significant investment since it could involve individuals such as the police chief and the city engineer.

Since the application of the HAL system will most likely result in an investment of community funds, it is appropriate to mention the benefits of the program. The most significant benefits will be reductions in the number and severity of traffic accidents, as indicated in Table 1 by the updated 1990 MHTD traffic accident cost estimates.

TABLE 1. 1990 TRAFFIC ACCIDENT COSTS.

Accident Severity	Accident Cost, in dollars
Fatal Accident	1,900,000 *
Injury Accident	21,100 *
Property-Damage-Only	4,000

* A weighted average cost for combined fatal and injury accidents is recommended for application in economic analysis procedures - refer to Appendix H.

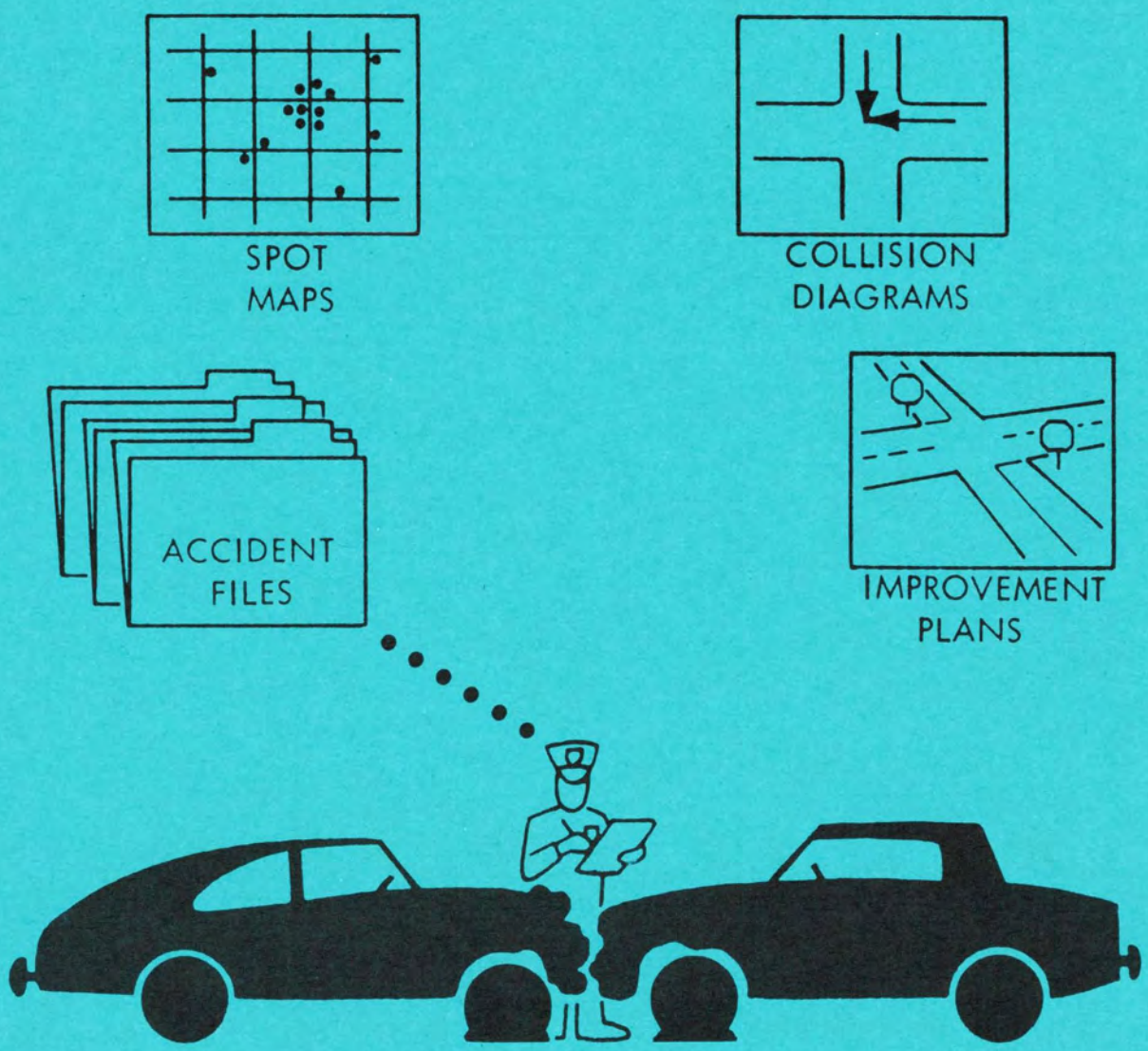
It is apparent from these accident cost estimates that substantial savings could be achieved by having an effective accident reduction program in a community. Property damage losses could be reduced for the motoring public, not to mention the possibility of avoiding needless loss of life and limb. An example will be provided in Chapter 5 to illustrate the benefits of installing safety improvements at a specific location.

The HAL system will assure the best possible use will be made of available traffic accident reports. It is important to realize that although police departments spend considerable time and money collecting and filing accident reports, the true value of those reports is lost if they are not used.

Another benefit of the HAL system is that it would provide easily accessible accident data in the event consultants are hired by the city to perform traffic safety analyses. When accident data are well organized, these professionals can concentrate their efforts on analyzing the causes of the accidents and developing the most effective countermeasures.

The HAL system described in this manual is a powerful traffic safety tool. In the final analysis, it will be the strength of commitment by city officials and civic leaders that determines the extent of benefits to be realized from a traffic safety improvement program.

CHAPTER 2 – SETTING UP THE TRAFFIC RECORDS SYSTEM



CHAPTER 2

SETTING UP THE TRAFFIC RECORDS SYSTEM

Accident data must be complete, accurate, and easily found. Making sure that accident data meet these requirements for an engineering analysis is the first important procedure in using the HAL system. This chapter provides guidelines on reporting, filing, and summarizing accident data.

ACCIDENT RECORDS SYSTEM - BASIC INFORMATION

The Missouri State Highway Patrol furnishes contributing agencies with standard traffic accident report forms, as shown in Figure 2. The accident report form is in a carbon format so each form is filled out in duplicate. The pages are labeled "ORIGINAL" and "STATE." The reporting agency retains the "ORIGINAL" and forwards the "STATE" copy to the Missouri State Highway Patrol. It is critical to the HAL system to have all accident report forms completed in a clear and consistent manner.

The definition of a traffic accident is "any motor vehicle accident that occurs on a roadway or that occurs after the motor vehicle runs off the roadway before the event is stabilized." A roadway is any land area open to the public as a matter of right or custom for moving persons or property from one place to another.

Classification of accident data will enable the city engineer to analyze the data by similarities. Traffic accidents can be classified according to type, severity, or location. The type of accident is based on the characteristics of the first harmful event. Eleven types of accidents are grouped under either collision or noncollision classification headings.

Collision accidents 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:

1. A pedestrian
2. Another motor vehicle in motion
3. A motor vehicle on another roadway
4. A parked motor vehicle
5. A railway train
6. A pedalcyclist
7. An animal
8. A fixed object
9. Other objects

Noncollision accidents involve a motor vehicle in motion and an incident such as:

1. Overturning
2. Other noncollision

MISSOURI UNIFORM ACCIDENT REPORT PAGE OF

1. AGENCY NAME AND ORI | LEFT THE SCENE V1 ☐ V2 ☐ CLEARED YES ☐ NO ☐ | COMPLAINT/REPORT/CASE NUMBER | FOR STATE USE ONLY: ROUTED | CARD | CODE

ACCIDENT CLASSIFICATION: PROPERTY DAMAGE ONLY ☐ | NUMBER INJURED | NUMBER KILLED | NUMBER OF VEHICLES INVOLVED | ACCIDENT DATE | ACCIDENT TIME ☐ AM ☐ PM | TIME NOTIFIED ☐ AM ☐ PM | TIME ARRIVED ☐ AM ☐ PM | INVESTIGATION DATE

2. LOCATION: COUNTY | MUNICIPALITY | BEAT/ZONE | TRP/DIST/PCT | INVESTIGATED AT SCENE ☐ YES ☐ NO

ON | DISTANCE FROM ____ FEET ____ MILES | DIRECTION ☐ N ☐ E ☐ S ☐ W | INTERSECTING STREET OR ROADWAY

LOG POINT | SPEED LIMIT | GEO-CODE | SPEED LIMIT | GEO-CODE

ROAD MAINTAINED BY ☐ 1. STATE ☐ 2. COUNTY ☐ 3. MUNICIPAL ☐ 4. PRIVATE PROPERTY

3. DAMAGE TO PROPERTY OTHER THAN VEHICLES—GIVE NAME, OWNERSHIP, NATURE OF DAMAGE AND DESCRIPTION OF OBJECT(S).

4. DRIVER 1: DRIVER'S FULL NAME (LAST, FIRST, MI) | ADDRESS | CITY | STATE | ZIP | DRIVERS LICENSE NUMBER | STATE | TYPE OF LICENSE ☐ 1. Permit ☐ 2. Chauff ☐ 3. Oper ☐ 4. Unlic ☐ 5. MC (only) | INSURANCE COMPANY | MC Qual ☐ YES ☐ NO

VEHICLE 1: YEAR | MAKE | MODEL | COLOR | VIN | LIC. PLATE NO. | STATE | YEAR | VEHICLE OWNER NAME (LAST, FIRST, MI)/COMMERCIAL CARRIER | ADDRESS | CITY | STATE | ZIP

VEHICLE DAMAGE INITIAL IMPACT # ____ | TOWED ☐ YES ☐ NO | Circle all Damaged Areas | 2 3 4 5 6 7 / 1 15 16 17 8 / 14 13 12 11 10 9 | REAR | 18 - Undercarriage 19 - Windshield 20 - Burned 21 - Injury / No Damage 22 - Towed Unit

5. DRIVER 2: DRIVER'S FULL NAME (LAST, FIRST, MI) | ADDRESS | CITY | STATE | ZIP | DRIVERS LICENSE NUMBER | STATE | TYPE OF LICENSE ☐ 1. Permit ☐ 2. Chauff ☐ 3. Oper ☐ 4. Unlic ☐ 5. MC (only) | INSURANCE COMPANY | MC Qual ☐ YES ☐ NO

VEHICLE 2: YEAR | MAKE | MODEL | COLOR | VIN | LIC. PLATE NO. | STATE | YEAR | VEHICLE OWNER NAME (LAST, FIRST, MI)/COMMERCIAL CARRIER | ADDRESS | CITY | STATE | ZIP

VEHICLE DAMAGE INITIAL IMPACT # ____ | TOWED ☐ YES ☐ NO | Circle all Damaged Areas | 2 3 4 5 6 7 / 1 15 16 17 8 / 14 13 12 11 10 9 | REAR | 18 - Undercarriage 19 - Windshield 20 - Burned 21 - Injury / No Damage 22 - Towed Unit

8. VEHICLE BODY TYPES — AUTOMOBILES / SPECIAL VEHICLES (V1 V2):
1. Passenger Car / Hardtop
2. Passenger Car / Convertible
3. Station Wagon
4. Van
5. Bus
6. School Bus
7. Motorcycle --- ☐ 3 Wh. ☐ 4 Wh. ☐ ATV
8. Moped
9. Bicycle
10. Motor Home/Camper
11. Farm Implements
12. Construction Equipment
13. Other Transport Devices
14. Unknown

A. Vehicle pulling another unit(s)

TRUCKS
15. Single-unit trucks (including pick-up trucks and pick-up cars)
16. Two-unit trucks or truck-tractor with trailer
17. Multi-unit truck or truck-tractor with two or more trailers

LICENSED WEIGHT
A. Up to 12,000 GVW
B. 12,001-26,000 GVW
C. 26,001-54,000 GVW
D. Over 54,000 GVW

HAZARDOUS MATERIALS
A. Gases in bulk
B. Solids in bulk
C. Liquids in bulk
D. Explosives

A. Hazardous materials released/spilled

9. EMERGENCY VEHICLE INVOLVEMENT (V1 V2):
1. Police
2. Fire
3. Ambulance
4. Other (must check A.)

A. Emergency vehicle on emergency run

10. PROBABLE CONTRIBUTING CIRCUMSTANCES (V1 V2; P1 P2):
1. Speed — exceeded limit
2. Too fast for conditions
3. Improper passing
4. Violation signal / sign
5. Wrong side (not passing)
6. Following too close
7. Improper signal
8. Improper backing
9. Improper turn
10. Wrong way (one-way)
11. Improper start / park
12. Improperly parked
13. Vehicle defects
14. Failed to yield
15. Drinking
16. Drugs
17. Physical impairment
18. Inattention
19. None

11. PEDESTRIAN ACTIONS (P1 P2):
INTERSECTION
1. With signal
2. Against signal
3. No signal
4. Diagonally
NOT AT INTERSECTION
5. Behind parked car
6. Walking with traffic
7. Walking against traffic
8. Getting on / off vehicle
9. Standing in road
10. Pushing / working on vehicle
11. Other working
12. Playing in road
13. Other in road
14. Off roadway
15. Crosswalk marked

12. CODES

SEAT LOCATION: XX - Not Known; FR RR, FC RC, FL RL; SV - Occupant - Special Vehicle—bus, truck, motorcycle, station wagon; P - Pedestrian; B - Bicycle

INJURY: 1. Fatal 2. Disabling 3. Evident - not disabling 4. Probable - not apparent 5. None apparent 6. Unknown

EJECTION: 1. No 2. Partially 3. Totally 4. Unknown

SAFETY DEVICES: 1. None 2. Not used 3. Used 4. Child restraint 5. Use unknown 6. Belt failure 7. Helmet used 8. Helmet not used

6. DRIVERS

NAME	ADDRESS	DATE OF BIRTH	SEX	VEH NO.	SEAT LOC.	INJ.	EJECTION	SAF. DEV.	PHONE
DRIVER 1	SAME AS ABOVE			1					
DRIVER 2	SAME AS ABOVE			2					

7. KILLED OR INJURED OTHER THAN DRIVERS

INVESTIGATING AGENCY SEND TO: MISSOURI STATE HIGHWAY PATROL — TRAFFIC DIVISION — P.O. BOX 568 — JEFFERSON CITY, MO 65102

ORIGINAL

FIGURE 2. MISSOURI UNIFORM ACCIDENT REPORT - PAGE 1.

REPORT # _____

PAGE OF

13. WITNESSES

NAME OF WITNESS	ADDRESS	CITY	STATE	ZIP	PHONE

14. TRAFFIC CONTROL
V1 V2
- ☐ ☐ 1. Stop sign
- ☐ ☐ 2. Elec. signal
- ☐ ☐ 3. RR signal gate
- ☐ ☐ 4. Yield sign
- ☐ ☐ 5. Officer Flagman
- ☐ ☐ 6. No passing zone
- ☐ ☐ 7. Turn restrict.
- ☐ ☐ 8. Construct. zone
- ☐ ☐ 9. None

15. LIGHT CONDITION
- ☐ 1. Daylight
- ☐ 2. Dark with street lights on
- ☐ 3. Dark with street lights off
- ☐ 4. Dark - no street lights

16. WEATHER
- ☐ 1. Clear
- ☐ 2. Cloudy
- ☐ 3. Rain
- ☐ 4. Snow
- ☐ 5. Sleet
- ☐ 6. Freezing
- ☐ 7. Fog or Mist

17. ROAD SURFACE
- ☐ 1. Concrete
- ☐ 2. Asphalt
- ☐ 3. Brick
- ☐ 4. Gravel
- ☐ 5. Dirt Sand
- ☐ 6. Multi surface

18. ROAD CONDITION
- ☐ 1. Dry
- ☐ 2. Wet
- ☐ 3. Snow
- ☐ 4. Ice
- ☐ 5. Mud

19. ROAD TYPE 1
- ☐ 1. Straight
- ☐ 2. Curve

20. ROAD TYPE 2
- ☐ 1. Level
- ☐ 2. Hill
- ☐ 3. Crest

21. VISION OBSCURED
V1 V2
- ☐ ☐ 1. Windshield
- ☐ ☐ 2. Load on vehicle
- ☐ ☐ 3. Trees
- ☐ ☐ 4. Building
- ☐ ☐ 5. Embankment
- ☐ ☐ 6. Signboards
- ☐ ☐ 7. Hillcrest
- ☐ ☐ 8. Parked cars
- ☐ ☐ 9. Moving cars
- ☐ ☐ 10. Other
- ☐ ☐ 11. Not obscured

24. VEHICLE ACTION
V1 V2
- ☐ ☐ 1. Going straight
- ☐ ☐ 2. Overtaking
- ☐ ☐ 3. Making right turn
- ☐ ☐ 4. Right turn on red
- ☐ ☐ 5. Making left turn
- ☐ ☐ 6. Making U turn
- ☐ ☐ 7. Skidding
- ☐ ☐ 8. Slowing Stopping
- ☐ ☐ 9. Start in traffic
- ☐ ☐ 10. Start from parked
- ☐ ☐ 11. Backing
- ☐ ☐ 12. Stopped in traffic
- ☐ ☐ 13. Parked
- ☐ ☐ 14. Changing lanes
- ☐ ☐ 15. Avoiding
- ☐ ☐ 16. Crossover median
- ☐ ☐ 17. Crossover centerline

22. ACCIDENT TYPE
COLLISION INVOLVING
- ☐ 1. Animal
- ☐ 2. Bicyclist or Pedalcyclist
- ☐ 3. Fixed object
- ☐ 4. Other object
- ☐ 5. Pedestrian
- ☐ 6. Train
- ☐ 7. MV in transport
- ☐ 8. MV on other roadway
- ☐ 9. Parked MV

NON-COLLISION
- ☐ 10. Overturning
- ☐ 11. Other non-collision
- ☐ 1. On roadway ☐ 2. Off roadway

23. COLLISION DIAGRAM | Going Direction (circle one) **V1** N E S W | **V2** N E S W | Est. Speed - Fatals Only V1 V2

INDICATE NORTH

25. UNIT SYMBOLS
I.T.E. SYMB. MAY BE USED IN LIEU OF STANDARD TEMPLATE
- (1) Vehicle
- (T) Train
- (A) Animal
- (B) Bicycle
- [1] Parked Vehicle
- (F) Fixed Object
- (O) Other Object
- (P) Pedestrian

MOVEMENT DESCRIPTION
- Moving
- Backing
- Moving (Not Involved)
- Out of Control
- Overturn
- (X) Point of Impact

INDICATE ROAD NAMES

DIAGRAM NOT TO SCALE

26. STATEMENT
OFFICER STATEMENT (IF ADDITIONAL ROOM IS NECESSARY, ATTACH A SEPARATE SHEET)

27. ARRESTS & SUMMONS
FIELDS NOT USED ☐

NAME	CHARGE	AR. NO./SUMMONS	COURT	DATE
1.				
2.				

28. REPORTING OFFICER SIGNATURE DSN/BADGE NO. BEAT/ZONE TROOP/DIST/PCT

30. TOW CO. V1 _____
TOW CO. V2 _____

29. REVIEWING OFFICER DSN/BADGE NO.

CHEM. TEST NO ☐ YES ☐

PHOTOS NO ☐ YES ☐ #_____

ORIGINAL

FIGURE 2. MISSOURI UNIFORM ACCIDENT REPORT - PAGE 2.

The severity of accidents can be classified in several ways, with the three most common traffic accident severity categories being:

1. Fatal
2. Injury
3. Property-Damage-Only

A fatal accident results in one or more persons being killed, and may involve one or more injured persons as well as property damage. An injury accident results in one or more persons being injured (no fatalities) and property damage. A property-damage-only accident results in damage to the vehicles involved, but no fatalities and no injuries being reported.

An accident location may be classified either by relating it to an intersection, block address, grid coordinates, or by the MHTD's log point system used on state-maintained roads. For the purposes of summarizing and analyzing accident information in this manual, location will be classified according to "intersection" or "mid-block" categories.

Use of the standard accident report form and standard definitions are essential for the uniform and precise reporting of traffic accidents. An excellent instruction manual entitled "Manual on Collecting and Recording Data on the Missouri Uniform Accident Report Form" is available from:

Missouri State Highway Patrol
Traffic Division
P. O. Box 568
Jefferson City, MO 65102

A helpful supplementary manual entitled "Manual on Classification of Motor Vehicle Traffic Accidents" is available from:

National Safety Council
425 North Michigan Avenue
Chicago, IL 60611

TRAFFIC ACCIDENT REPORTING

Because traffic accident reporting may serve important purposes in addition to the HAL system (such as specifying areas for selective enforcement), the police department must be certain that their accident reporting procedures are monitored for clarity and accuracy. Actual use of accident data in the HAL system is the most effective way to determine if the accident reporting procedures are being correctly followed.

Often the problems with accident reporting involve either how the location is specified or how the accident diagram is drawn and described. It is advisable to periodically check a sample of accident reports to determine if the present accident reports might be faulty, and to improve the way accident reports are made.

The following suggestions for checking accident reports are useful:

1. Check the Location Section of the Report:

   - Is the accident 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.)

2. Check the Collision Diagram:

   - Are directions of travel shown for all involved vehicles?

   - Are the necessary measurements shown in the diagram?

   - Is the location of the accident shown with reference to an intersection or other known landmark?

   - Is the north direction indicated?

3. Check the Officer's Statement:

   - Does it clearly explain what happened?

   - Does it fully identify the relationship of the accident to a nearby intersection? For 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 lined up from the signal at 5th St."

Other problems may concern the extent of accident investigation. For instance, a clear standard on when to make a traffic accident report is very important. Missouri Statutes (RSMO 43:250) require that a report be filed for a vehicle accident resulting in injury or death of a person, or total property damage to an apparent extent of $500 or more to one person, or if a written report is prepared as the result of an investigation. Some city police departments have the policy of filing an accident report for any traffic accident their officers investigate. Also, some departments keep a separate card file for accidents reported on private property.

Inconsistency of accident reporting may also cause confusion when the accident reports are analyzed. An example is the way a street is sometimes referred to by different names. A road that at one time passed through an orchard might have been known as Apple Orchard Lane. Following residential development with construction of many new homes, the road could have been renamed to Regency Drive. If accident reports pertaining to incidents on this road do not use the same street name, they are inconsistent.

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

TRAFFIC ACCIDENT REPORT FILING

Although traffic accident report files are normally kept by the police department, they may also be kept by the engineering department in medium to larger size communities. Within each city a systematic plan must be established for handling accident reports so they can be filed easily, not lost or misfiled, and handled the least number of times. The recommended filing procedure has the following basic steps:

1. Log the report into a chronological list of reports received

2. Check each report for completeness and accuracy

3. Plot the location of each accident on a spot map

4. File the "ORIGINAL" report in an accident location file, or

5. Enter the accident report data into a computerized record system if one is available, and

6. Send the "STATE" copy to the Missouri State Highway Patrol

Step 1 is the initial step in organizing traffic accident information as it arrives. This permanent record should be summarized on a monthly basis and it could include some information concerning the accident such as names of drivers involved, location, severity, and whether or not a summons was issued.

Step 2 is one of the most critical of all steps in the HAL system. It involves checking the officer's accident report forms to assure accuracy and completeness. Standards established for reporting should be carefully followed. For example, measurements taken at an accident scene should be reported with sufficient accuracy to allow a follow-up study to locate the point of impact. All handwriting must be legible and the accident diagram clear. Any contradictions, vagueness, or omissions must be clarified by reviewing the report with the investigating officer as soon as possible.

Steps 3, 4, and 5 involve various ways in which accident data may be retained and summarized. The best procedure to be utilized by a community depends on the total number of traffic accidents experienced during a year, the availability of staff for the HAL effort, and the availability of appropriate computers and computer programs for data management.

If a small community experiences less than 100 traffic accidents per year, a spot map and chronological or numerical accident report file may be satisfactory for record keeping purposes. For more than 100 and up to 200 traffic accidents per year, the accident location file combined with a spot map should be satisfactory for handling accident information. When a city approaches a level of 200 traffic accidents in one year, manual methods for organizing and summarizing accidents become too time consuming. It is strongly recommended for communities experiencing these higher levels of accidents that computerized accident record systems be utilized.

THE LOCATION FILE

In a location file, traffic accident reports are filed alphabetically by location, with street names and house numbers used for indexing. The location file should initially hold a complete year of accident data, with the capability of being expanded to contain three years of data. Materials needed for the location file include a small file cabinet, left tab 1/3-cut guide cards, and center and right tab 1/3-cut file folders.

Starting with the first accident of the year, judge accidents as intersectional or mid-block by the "intersection-related" method. This method does not classify accidents by physical boundaries, but by the direct relationship of the accident to the location. Two examples help explain this method. In the first example, one vehicle rear-ends another vehicle at the end of a long line of traffic waiting at a signalized intersection. This accident is classified as an intersection-related accident and it must be filed with other reports of accidents occurring at this intersection. In the second example, a parked car pulls into traffic from a parking stall close to a corner, and is side-swiped by a car coming from its rear. Despite being close to an intersection, this collision would be classified as a "mid-block" accident.

Filing Intersection-Related Accidents

If the accident is intersection-related, determine which street to use as the primary index. If two municipal streets intersect, use the street name that is first alphabetically as the primary index. For example, as illustrated in Figure 3, the report for an accident occurring at the intersection of Main Street and Wilson Street should be filed behind a left-tab guide card with MAIN STREET as the primary index, and in the right-tab file folder labeled with Wilson Street as the secondary index. Note that primary indexes are typed with all capital letters.

If a numbered route and a municipal street intersect, file the accidents by the highest category of route designation, i.e., Interstate route, U.S. route, State route, County route, municipal street. Also, if possible, include any alternate name such as U.S. 69 (VIVION ROAD) on the index tab. If the city has numbered streets, index those streets as 1st, 2nd, 3rd, etc., and set up their primary index numerically.

In summary, use the following order to determine which street is used as the primary index:

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

For example, at the intersection of U.S. 69 and Ohio Street, use U.S. 69 as the primary index. At the intersection of Ohio Street and 56th Street, use OHIO STREET as the primary index.

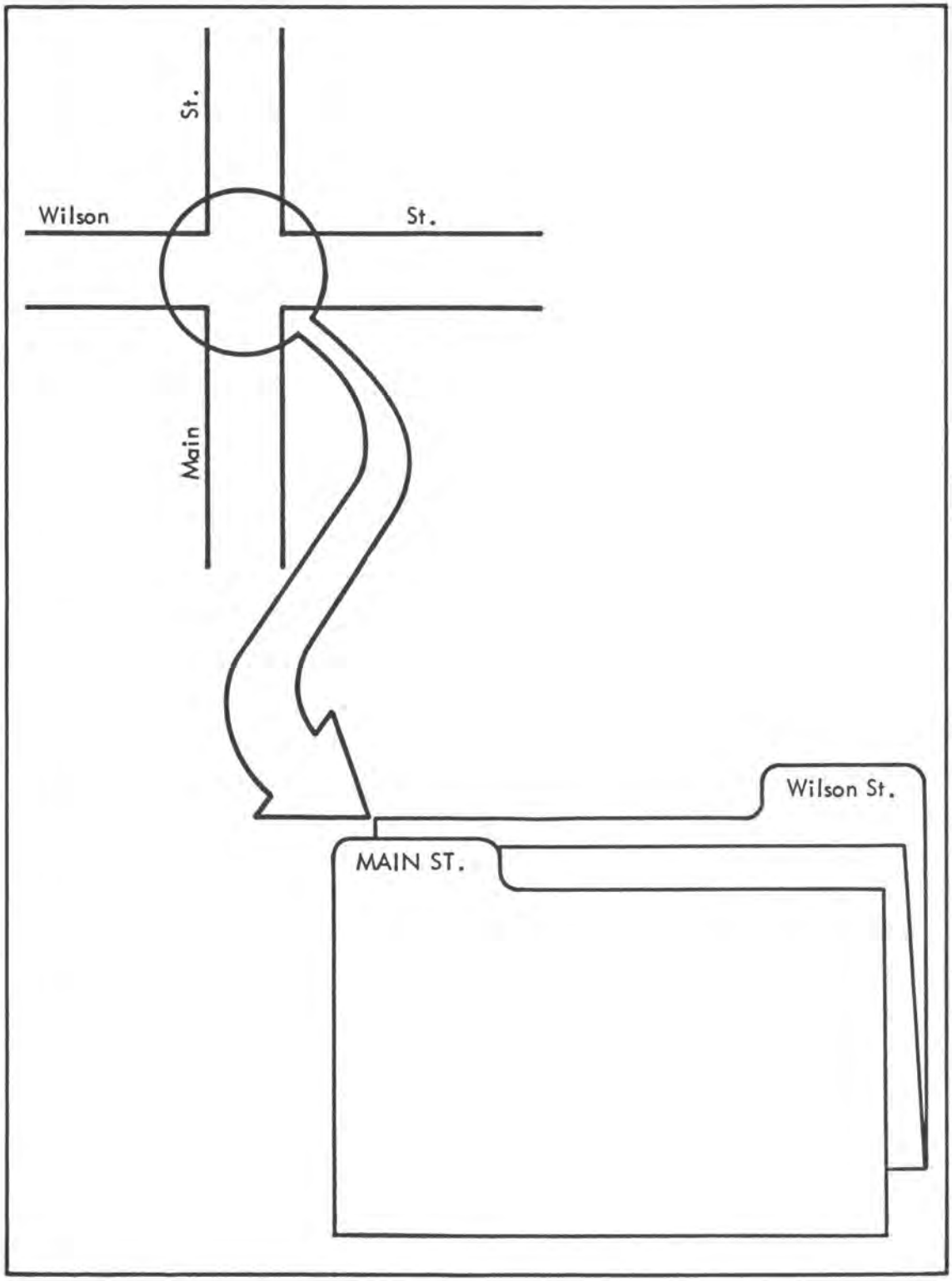


FIGURE 3. FILING AN INTERSECTION-RELATED ACCIDENT REPORT.

Filing Mid-Block Accidents

Classify all accidents that are not intersection-related as mid-block accidents, and use the street name or route number as a primary index and the block number as a secondary index. The number of blocks in a secondary index could be as short as one block or as long as the entire street.

Each street must be divided into sections for indexing according to the number of accidents occurring on each part of the street. When the location file is first established, place the mid-block accidents in a center-tab file folder immediately behind the guide card having the street name as the primary index. When the number of reports in a file reaches 10, divide the street into sections according to accident concentrations. Write section designations in pencil until the entire year's reports are filed, then finalize the file label by typing block numbers on the tabs as in Figure 4. These same sections are used for the next year's file.

General Accident Report Filing Rules

As the accident reports are filed, keep the most recent report at the front of each folder. To save unnecessary work, type labels for primary and secondary indexes only as they are needed for filing purposes. Observe the following rules when filing reports in the location file:

Rule 1: Keep all reports of accidents at the same intersection in one file folder.

Rule 2: Use a separate folder for each individual intersection.

Although these rules seem simple, they are easily misunderstood or violated. For example, filing errors could occur due to peculiarities in a city's road pattern. Referring to the situation shown in Figure 4, the highlighted intersection involves three street names. Ideally, all reports from this location would be filed behind the guide card (primary index) labeled ARTESIAN AVE. and placed in the file folder labeled Rogers St. at Tower St. (secondary index). However, if some investigating officers only enter two of the street names on the report, you might find the accidents filed in one of three <u>incorrect folders</u> as follows:

Folder 1: ARTESIAN AVE. (primary index), Rogers St. (secondary index)

Folder 2: ARTESIAN AVE. (primary index), Tower St. (secondary index)

Folder 3: ROGERS ST. (primary index), Tower St. (secondary index)

If this intersection has a large number of accidents, the problem might not be detected if some of the reports are filed in three other folders. This is a violation of Rule 1 (all accident reports from the same intersection must be in the same folder). Avoid this situation by placing warning cards in folders where the reports could be misfiled.

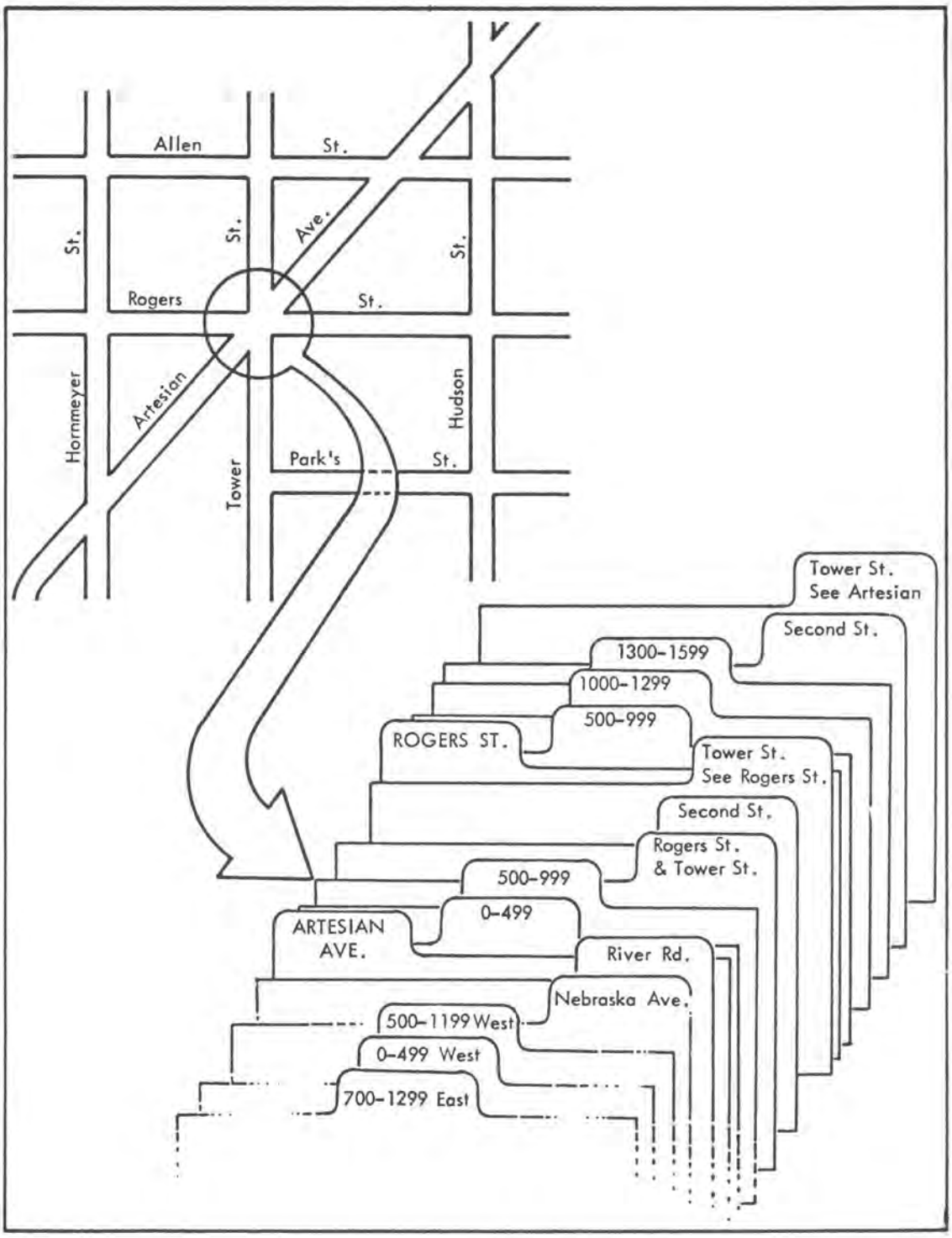


FIGURE 4. FILING REPORTS FROM AN INTERSECTION WITH THREE NAMES.

In Figure 4, warning cards should be placed in all folders where an accident might be misfiled, as ARTESIAN AVE. and Tower St. (file labeled Tower St. See Rogers St.), or ROGERS ST. and Tower St. (file labeled Tower St. See Artesian).

Rule 1 might also be violated if one street has two designations such as a state route number and a street name. For instance, accidents at the intersection of Mo. 1 (Antioch Road) and U.S. 69 (Vivion Road) should be filed in with U.S. 69 as the primary index and Mo. 1 as the secondary index. Errors in filing could occur as:

Folder 1: Mo. 1 (primary index), Vivion Rd. (secondary index)

Folder 2: U.S. 69 (primary index), Antioch Rd. (secondary index)

Folder 3: ANTIOCH RD. (primary index), Vivion Rd. (secondary index)

Again, it is advisable to place warning cards in file folders where accident reports might be misfiled.

Rule 2 might possibly be violated if two intersections have the same name because the two streets intersect more than once, as illustrated in Figure 5. To avoid filing accident reports from both intersections in the same folder, the two intersections must be designated more precisely. In this example, one of the intersections should be called "North" and the other "South."

The potential for misnaming a street also occurs when two routes join on one side of town, proceed together along one street through town, and then separate. In this situation, use the highest category of numbered route for identification purposes. Or, if both routes are in the same category, use the route with the lowest highway number for identification, as Mo. 1. The individual in charge of traffic accident investigations must instruct all investigating officers who fill out accident reports to correctly and clearly identify each accident location.

Although following these rules requires some additional time when setting up the location file, they will save a significant amount of time and confusion later when searching for accident reports related to a particular intersection.

Location File - Time Requirements

Setting up a location file with one year's accident reports will normally take about three days for cities with less than 1,000 accidents per year. After the location file is set up, 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 on classifying accidents as intersection-related or mid-block.

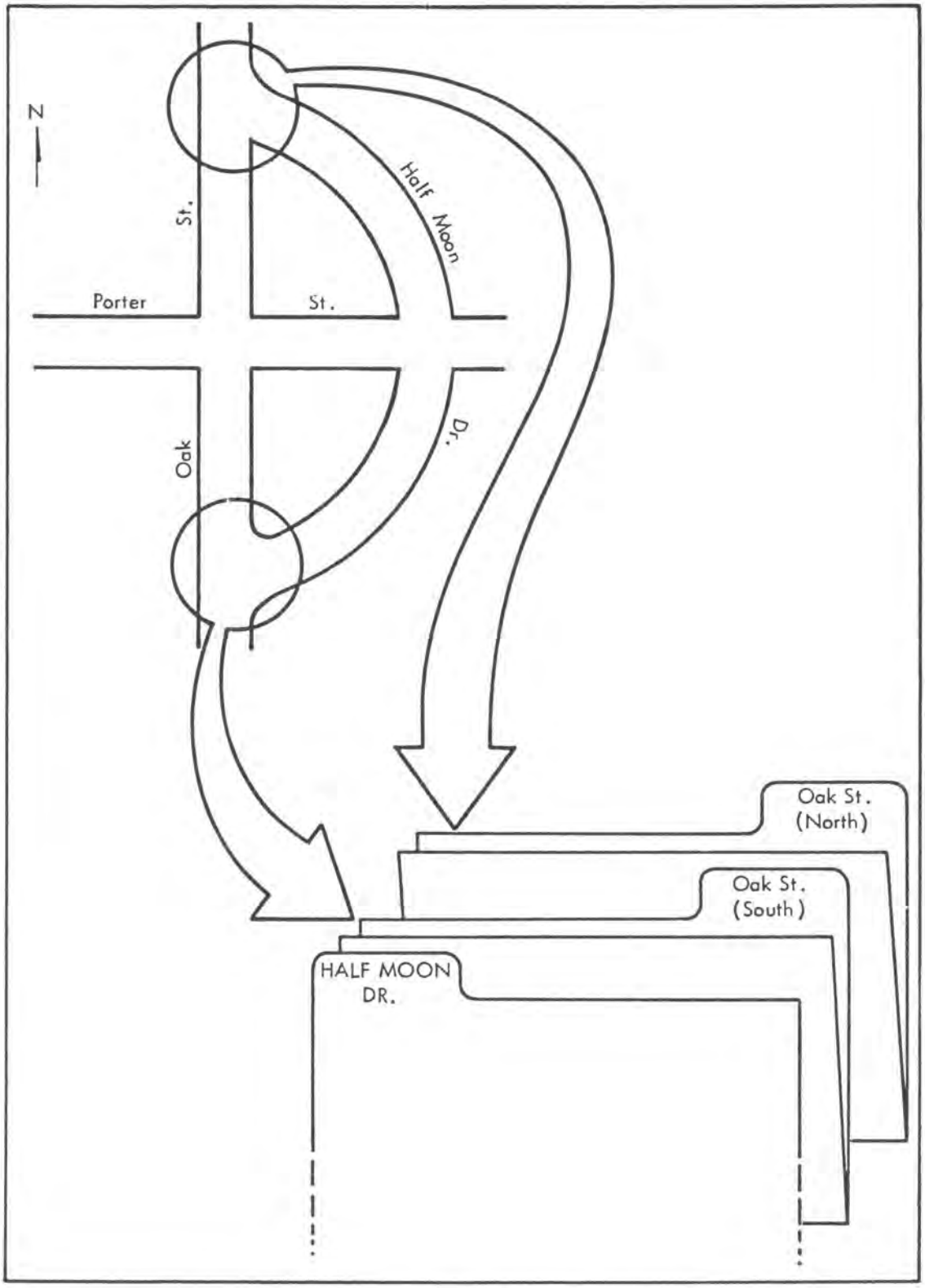


FIGURE 5. FILING REPORTS FROM IDENTICALLY NAMED INTERSECTIONS.

TRAFFIC ACCIDENT DATA SUMMARIES

Summarizing accident data is an important application of a traffic records system because it is the first step in identifying high-accident locations. In cities with 10,000 or more residents, accidents should be summarized monthly and annually. Smaller cities may only need quarterly and annual summaries.

Traffic accident data could be summarized several ways, such as according to accident type, or by mid-block and intersection locations, intersection control type, or accident severity. A recommended summary to supplement analysis of high-accident locations is shown in Figure 6. This summary divides the accidents into intersection-related accidents and mid-block accidents. The intersection accidents are further divided according to whether they occurred on a "major" or "minor" street. Major streets are usually through streets with a volume greater than 2,000 vehicles per day.

Appropriate tallies are placed on the summary sheet when each accident report is filed in the location file. A new summary sheet should be used at the start of each month. At the end of a year the monthly summaries should be combined to provide the annual summary.

Other important sources which assist in providing supplemental traffic safety information, state support services, and accident data tabulations are presented in the following sections of this chapter.

TRAFFIC ACCIDENT SPOT MAPS

A display which provides an impressive visual summary of accident concentrations is the traffic accident "spot map." As shown in Figure 7, this is a city street map with pins inserted to mark the location of each traffic accident. A spot map will reveal which areas of the city might warrant attention; however, the map alone is not sufficient for specifying locations to be selected for improvement projects. The spot map is an excellent supplement to the location file, but it has limitations since it conveys very little information about the accidents which occurred.

A street map or aerial photo ranging in scale from 1 inch = 400 feet to 1 inch = 800 feet is desirable for the traffic accident spot map. Maps containing other information, such as a zoning map, should not be used.

To facilitate the use of pins, the map must be mounted on a backing material that is somewhat soft, yet rigid and non-warping, such as cork. The map or aerial photo must be firmly attached to the backing material with paste or similar adhesive. Pins or "map-tacks" are easily used to mark the accident locations. These pins may be purchased at office supply stores, and they are available in different colors. A recommended practice is to use three different colors of pins defined as:

- Black Pin: Fatal Accident Location
- Red Pin: Injury Accident Location
- Yellow Pin: Property-Damage-Only Accident Location

TRAFFIC ACCIDENT SUMMARY: FROM JAN. 1, 1988 TO DEC. 31, 1988 [Form TAS]

INTERSECTION - RELATED ACCIDENTS

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 ACCIDENTS	96	90	17	10	12	5	26	22	37	7	322

MID - BLOCK ACCIDENTS

	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 6. TRAFFIC ACCIDENT SUMMARY SHEET.

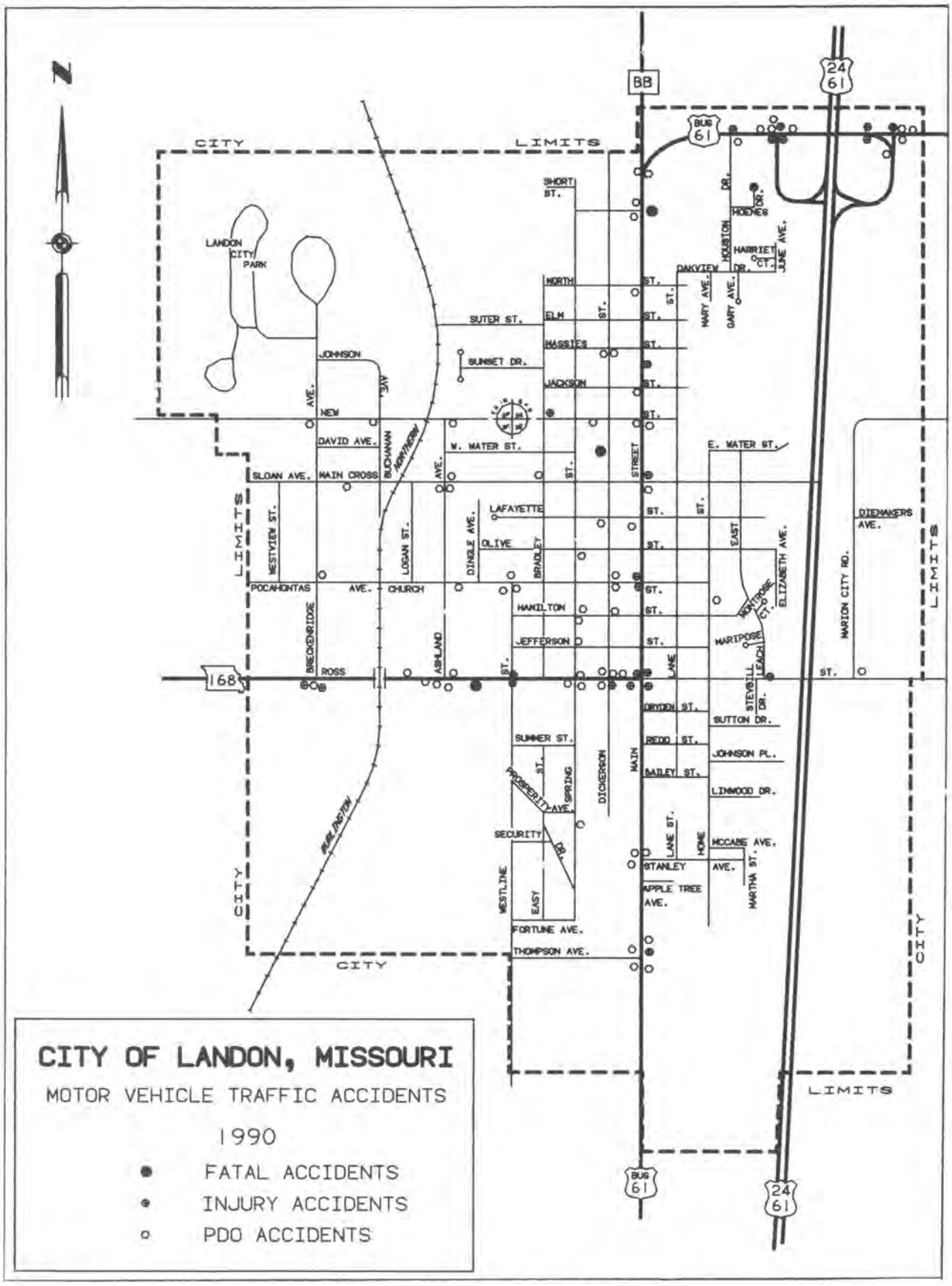


FIGURE 7. TRAFFIC ACCIDENT SPOT MAP.

A spot map must have a legend identifying the area and time period covered by the map and indicating the severity of accident each pin color represents. Space should be provided on or near the map so a small card could be attached listing monthly and cumulative accident data.

The spot map should cover accident 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 a year certain areas on the map (as the central business district) may become too crowded with pins. If this occurs, the solution is to prepare a special map of this crowded area on a much larger scale and use this as a supplementary spot map. The area on the main map for which the special map is prepared should be marked to indicate it is necessary to refer to the supplementary map to view the accident situation.

The best place to mount the spot map is near the location file so accidents can be spotted by the person filing the reports. Some cities also mount a spot map at a highly visible location in a city building so their citizens may become more aware of traffic accident problems.

Use of a spot map is highly recommended for small-to-medium sized communities. It is an informative display and may serve other purposes such as assisting those in the police department responsible for scheduling selective law enforcement efforts.

SUPPLEMENTARY INFORMATION

In addition to the accident files, procedures, and summaries that have been described, it is advisable for the city engineer to record other data that will prove useful for traffic studies, city planning, and activity reports. Examples of supplementary files which should be kept are:

- Date and description of major street and intersection improvements
- Date of opening and description of major new facilities that cause changes in traffic volumes or traffic patterns
- Files on public input and city employee reports

The public input and city employee reports are non-accident-based procedures which are very helpful in identifying a traffic hazard before accidents occur. Public input regarding a hazardous situation could necessitate an immediate response, such as replacing a missing STOP sign. A telephone call reporting a large pothole may be justification to alter the street maintenance schedule.

Traffic safety input should be encouraged from all city employees and officials. This would most definitely include police officers, but should extend to all city employees. Files on public and employee input should include the time when information was received, the nature of the reported hazard, who was assigned the responsibility to investigate the problem, what was done to remedy the situation, and the time when corrective action was completed. Further discussion of this supplemental information system is provided in Appendix A.

ACCIDENT DATA SUPPORT SERVICES AND PROGRAMS

Missouri's programs to increase local capabilities in traffic accident analysis and countermeasure development have been significantly enhanced in recent years through state and local level automated data processing. The following list identifies automated traffic accident data support services currently available to Missouri communities:

1. MOTIS (Missouri Local Traffic Information System): A public domain microcomputer program developed for local agencies experiencing more than 200 and less than 6,000 accidents per year and wanting to encode their own accident and citation data. These two primary data bases assist the community and accident analyst in correlating with citation issuance, as well as providing time and location data for selective enforcement in conjunction with engineering countermeasures. The long-range plan for the MOTIS program will interface all related data bases 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 accident reports on the computer. STARS provides monthly and annual summaries, but they do not include totals on private property or hit-and-run accidents, or enforcement data, which the police department may want to add for its purposes.

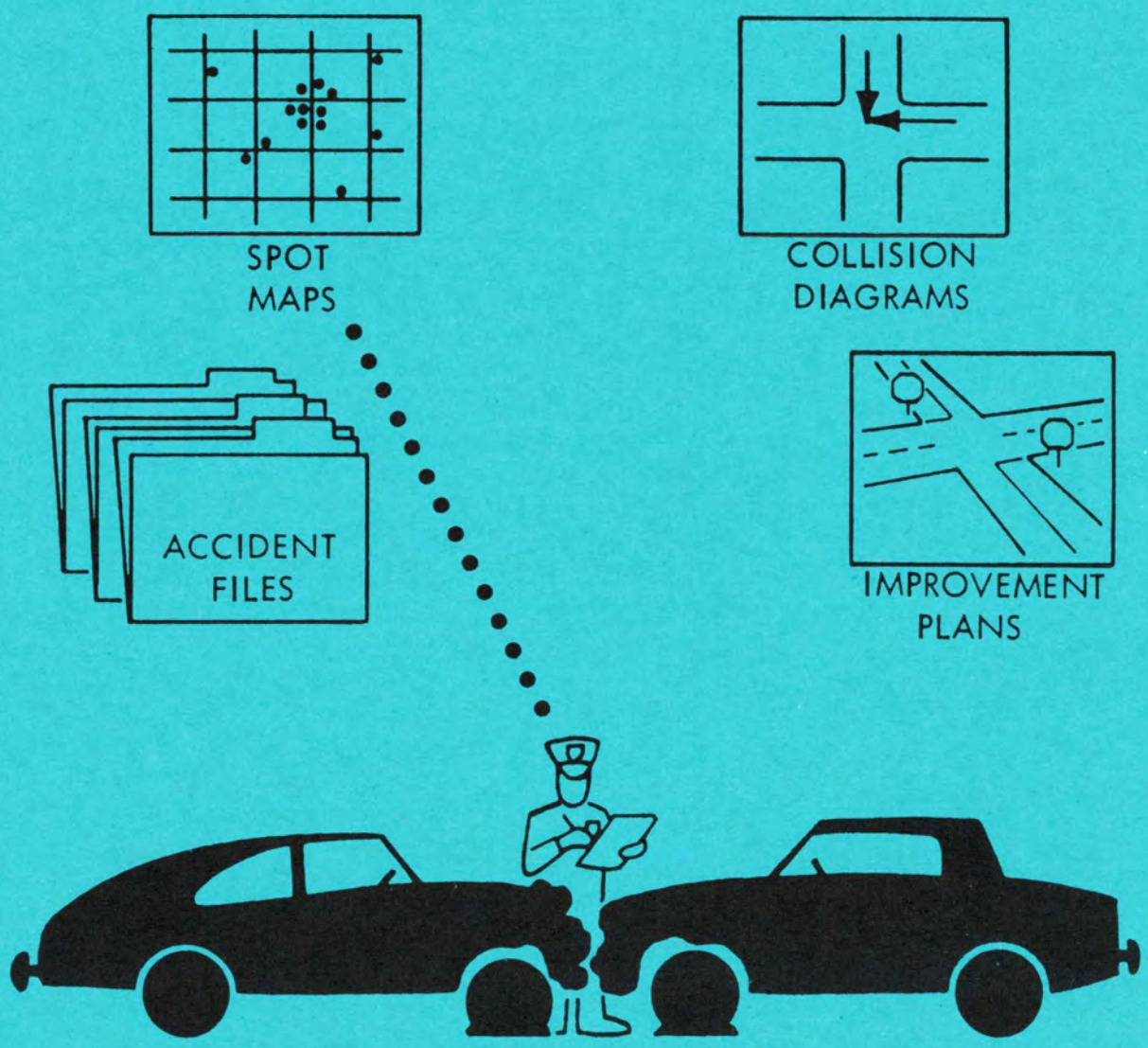
3. TRACE (Traffic Report of Accidents for Countermeasure Establishment): A STARS generated, alpha-order location printout of all accidents in a political subdivision, for a specified time period. The report contains the data elements necessary for engineering analysis to determine the accident pattern and probable cause. Supplemental reports may be obtained for all accidents occurring on a particular route or at a specific intersection.

4. STARS/MULES (Missouri Uniform Law Enforcement System) Interface: An on-line system for MULES participants to query the STARS file, by person's name, to retrieve the location and complaint number of an accident, for in-house hard copy report purposes.

For more information on STARS, contact the Missouri State Highway Patrol, Traffic Division, at (314) 751-3313.

For more information on MOTIS and TRACE, contact the Missouri Division of Highway Safety at (314) 751-5407.

CHAPTER 3 – IDENTIFYING HIGH-ACCIDENT LOCATIONS



CHAPTER 3

IDENTIFYING HIGH-ACCIDENT LOCATIONS

Because the time and money available for community efforts to reduce traffic accidents are often limited, it becomes necessary to concentrate on the locations that should yield the largest accident reductions for each dollar spent. This chapter describes the process of identifying high-accident locations. Relating traffic accidents to the driving environment at those locations and determining the potential for accident reduction are described in Chapters 4 and 5.

An orderly approach to studying accidents greatly improves the odds for bringing about a reduction in both accident numbers and severity. The Annual City-Wide Analysis and Early Warning Analysis procedures described in this chapter are systematic step-by-step methods for identifying high-accident locations. Prior to discussing these procedures, it is advisable to consider how high-accident locations are defined.

HIGH-ACCIDENT LOCATION CRITERIA

A high-accident location may be identified by applying one or more of the standard accident measures or criteria shown in Figure 8.

ACCIDENT NUMBER

ACCIDENT SEVERITY

ACCIDENT RATE

NUMBER-RATE

SEVERITY-RATE

NUMBER-QUALITY-CONTROL

RATE-QUALITY-CONTROL

FIGURE 8. MEASURES OF ACCIDENT EXPERIENCE.

The accident number is the basic measure of accident experience. When using the accident number criteria a location is often judged to be in the high-accident category if 10 or more accidents occur in one year. The value of this number might have to be adjusted occasionally depending on changes in local accident experience. To choose a number that is too low

could provide too many locations to analyze in a reasonable time. To choose a number that is too high might eliminate locations which seriously need improvement. The accident number should not be the only criteria utilized when identifying high-accident locations.

Accident severity measures consist of applying a weighting factor to the number of Fatal (F) and Injury (I) traffic accidents so they are given more importance than Property-Damage-Only (PDO) accidents. For instance, the local policy could be to apply a weighting factor of six to each fatal or injury accident. This means one fatal or injury accident is considered the equivalent of six PDO accidents. The weighted number of fatal and injury accidents, when added to the number of PDO accidents, is called the Equivalent-Property-Damage-Only (EPDO) number. For example, using a weighting factor equal to six at a location with 1 fatal accident, 2 injury accidents, and 9 PDO accidents, the EPDO Number is 27 as calculated below:

F:	1	x	6	=	6
I:	2	x	6	=	12
PDO:	9	x	1	=	9
EPDO Number:				=	27

Another measure used to identify high-accident locations is the accident rate. This is the number of accidents divided by the amount of vehicular exposure at the location. An accident rate accounts for the opportunity for accidents to happen. At an intersection or spot location, an accident rate is found by calculating the annual number of accidents per million vehicles entering the location. For a mid-block section, both the number of vehicles driving through the section and the length of section must be known. Accident rates for mid-block sections are expressed in terms of annual number of accidents per 100 million vehicle miles. Those locations having an accident rate higher than a predetermined level are classified as the high-accident locations.

The number-rate measure combines the accident number and the accident rate to arrive at a standard for identifying high-accident locations which eliminates the weaknesses of the individual measures. The accident number taken alone as a criterion does not account for the exposure of vehicles to potential accidents. On the other hand, the accident rate measure, which does account for vehicle exposure, might identify a low-volume location as a high-accident location with an unreliably low number of accidents. A combination number-rate measure establishes both a minimum accident number and a minimum accident rate for identifying high-accident locations.

The severity-rate measure combines the accident severity and the accident rate to provide a measure for identifying high-accident locations which is often considered to be the most meaningful. The severity-rate measure has the advantages previously stated for the number-rate measure, and it also includes applying a weighting factor to give more importance to the fatal and injury accidents. This measure is calculated by finding the EPDO number and dividing that number by the vehicle exposure at the location, resulting in the EPDO rate.

The two quality-control measures listed in Figure 8 are used to compare a location's accident experience to a local or statewide average. It is possible with statistical tests to determine if a specific accident number or rate is significantly above the average value. These tests rule out locations having somewhat high rates or numbers due to chance.

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

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

ANNUAL CITY-WIDE ANALYSIS

The Annual City-Wide Analysis is a procedure that uses one, two, or three years of accident data to identify high-accident locations. This analysis is initiated as soon as all accidents for a calendar year have been filed in the location file or the MOTIS computer file. 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-accident locations by the Early Warning System.

In addition to information from the accident files, current Average Daily Traffic (ADT) estimates are needed to calculate the accident rates and EPDO rates. If the city does not have recent ADT estimates, contact the MHTD; Planning Division; P. O. Box 270; Jefferson City, MO 65102; to find out if they might have traffic count information available. The Planning Division normally makes counts in cities at one- to five-year intervals and publishes ADT maps for those cities. They can also furnish expansion factors to adjust counts if they are not current. If traffic data are not available from MHTD, the traffic counting and ADT estimating procedures described in Appendix C should be used.

The Annual City-Wide Analysis is comprised of the following steps:

Step 1: For an overview of the accident experience in the community, complete the Annual Traffic Accident Summary Sheet (refer to Figure 6). This summary will reveal the following about the accident situation:

- The most common types of intersection accidents
- The most common types of mid-block accidents
- The need for special studies such as sight distance, pedestrian, railroad crossing, etc.

Step 2: Using the High Accident Location Identification Worksheet as shown in Figure 9, complete the information needed at the top of the form. Always indicate on each page if is being used for intersection accidents or mid-block accidents. Do not mix the analysis of mid-block sections and intersections on a page.

Proceed by listing all intersections with more than three accidents and all mid-block sections with more than five accidents in the past year. These numbers are not necessarily high-accident location criteria, but they should serve as reasonable starting points. It may be necessary to adjust these numbers depending on the level of accident experience in the community from year to year.

Next, for each location, enter the year, number of fatal, injury, and property-damage-only (PDO) accidents, and add these accidents to give a total number of accidents for each year. Numbers and averages using information from earlier years will be considered following Step 3.

Step 3: Calculate required EPDO numbers, annual traffic exposures, accident rates, and EPDO rates for the year by completing each column of the worksheet as follows:

EPDO Number

Intersection or Mid-Block - Add the number of fatal and injury accidents; multiply that total by 6 (the EPDO weighting factor); and add the number of PDO accidents to obtain the EPDO Number.

ADT (Average Daily Traffic)

Intersection - Add the ADT values for all streets leading into the intersection. If the ADT values are for one direction, enter the total; if the ADT values are for two directions, divide the total by 2.

Mid-Block - For mid-block or street sections, calculate the average of the two-way ADT's and use that average as the ADT.

Exposure

Intersection - Multiply the intersection ADT by the duration of the study period in days. For a one-year study, multiply the intersection ADT by 365.

Mid-Block - Multiply the mid-block ADT by the section length in miles; multiply that result by 365.

HIGH - ACCIDENT LOCATION IDENTIFICATION WORKSHEET [Form HALIW]

INTERSECTION [X] or MID-BLOCK SECTION [ ] DATE JAN. 12, 1989 EVALUATED BY JSJ

Location	Year	Number of Accidents				2 and 3 Year Average	EPDO Number*	ADT	Exposure	Accident Rate	EPDO Rate	High-Accident Location	
		Fatal	Injury	PDO	Total							No	Yes
PINE AND SECOND	1988			III	3		3	7,500	2,737,000	1.096	1.096	✓	
TOTALS													
CEDAR AND SECOND	1988			III	3		3	2,150	784,000	3.823	3.823	✓	
TOTALS													
ELM AND THIRD	1988			IIII	4		4	9,670	3,529,550	1.133	1.133	✓	
TOTALS													
ADAMS AND THIRD	1988			~~IIII~~ I	6		6	9,050	3,303,250	1.816	1.816	✓	
TOTALS													
LINCOLN AND THIRD	1988		I	~~IIII~~ II	8		13	3,600	1,314,000	6.088	9.893		✓
TOTALS													
TRUMAN AND SECOND	1988		III	~~IIII~~ I	9		24	7,000	2,555,000	3.523	9.393		✓
TOTALS													

* EPDO Number = (6)x(FATAL + INJURY) + PDO

INTERSECTIONS:

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

Exposure = (ADT)x(365)

Accident Rate = $\frac{\text{(number of accidents)x(1 million)}}{\text{exposure}}$

EPDO Rate = $\frac{\text{(EPDO number)x(1 million)}}{\text{exposure}}$

MID-BLOCK SECTIONS:

The length of each mid-block section must be determined and noted in the location column

ADT = average two-way count of the street

Exposure = (ADT)x(section length)x(365)

Accident Rate = $\frac{\text{(number of accidents)x(100 million)}}{\text{exposure}}$

EPDO Rate = $\frac{\text{(EPDO number)x(100 million)}}{\text{exposure}}$

FIGURE 9. HIGH-ACCIDENT LOCATION IDENTIFICATION WORKSHEET.

Accident Rate

Intersection - Multiply the total number of accidents by one million and divide by the intersection exposure to determine the accident rate expressed in terms of accidents per million vehicles entering the intersection.

Mid-Block - Multiply the total number of accidents by 100 million and divide by the mid-block exposure to determine the accident rate expressed in terms of accidents per 100 million vehicle miles driven on the section.

EPDO Rate

Intersection - Multiply the EPDO number by one million and divide by the intersection exposure to find the EPDO rate for the intersection.

Mid-Block - Multiply the EPDO number by 100 million and divide by the mid-block exposure to find EPDO rate for the section.

Step 4: If accident records are available for one or two years prior to the analysis year, enter information from those years on the worksheet. If it is known that the ADT changed during the analysis years, make the appropriate adjustments to the ADT for each year.

If a location was identified as a high-accident location during an earlier year, note this in the last column of the worksheet.

Step 5: For each previous year of accident data, calculate the total number of accidents, EPDO number, accident rate, and EPDO rate. It will also be necessary to calculate the two- or three-year average for the total number of accidents, average EPDO number, average accident rate, and average EPDO rate.

Step 6: Identify your high-accident locations by reviewing all intersections and all mid-block sections on the analysis worksheets. Those locations having the highest EPDO number and highest EPDO rate are chosen for further countermeasure evaluation. When two or three years of data are available, the two- or three-year averages for EPDO number and EPDO rate should be used.

The high-accident locations are noted by placing a check mark in the "YES" column of the worksheet, by putting a tab on the appropriate folder in the location file, or by running a special list from the computer file.

EARLY WARNING ANALYSIS

The Annual City-Wide Analysis is very effective for identifying high-accident locations on a yearly basis. Another procedure that continuously monitors where accidents are occurring is the Early Warning Analysis. This procedure considers three- or six-month accident numbers and identifies locations with an unusually high short-term number of accidents. The three- or six-month accident numbers are reviewed each time a report is filed. The person maintaining the location file should perform the Early Warning Analysis as follows:

Step 1: When each accident report is placed in a location file, fill out the Accident Location - File Log as shown in Figure 10. This log is a chronological listing of accidents 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 accident experience at a location, and it also serves as a check to assure reports are not missing from the folder.

Step 2: At the time when a report is added to a file log, check for high-accident locations by reviewing the most recent three- or six-month periods. Flag the location as a high-accident location by marking the file folder with a tab if either of the following criteria is met:

Three-Month Criteria

Intersection - Three accidents, of which at least one is an injury or fatal accident; or five PDO accidents.

Mid-Block - Five mid-block accidents in a three-block section.

Six-Month Criteria

Intersection - Five accidents, of which at least one is an injury or fatal accident; or eight PDO accidents.

Mid-Block - Eight mid-block accidents in a three-block section.

These criteria identify locations with an unusually high short-term number of accidents. A sudden increase in accidents at a location could be due to chance causes, or it could be due to unexpected problems arising from recent changes in driver habits or changes in the roadway environment.

The Early Warning Analysis is initiated after the location file has a complete year of accident reports. As soon as a year's reports have been filed by location, the Annual City-Wide Analysis will identify the high-accident locations for the first year. Then, as the second year's accident reports are added to the location file, begin the Early Warning Analysis.

With high-accident locations identified, the task ahead is to analyze the accident experience at each location to find accident patterns that can be corrected, and then to select the most effective countermeasures.

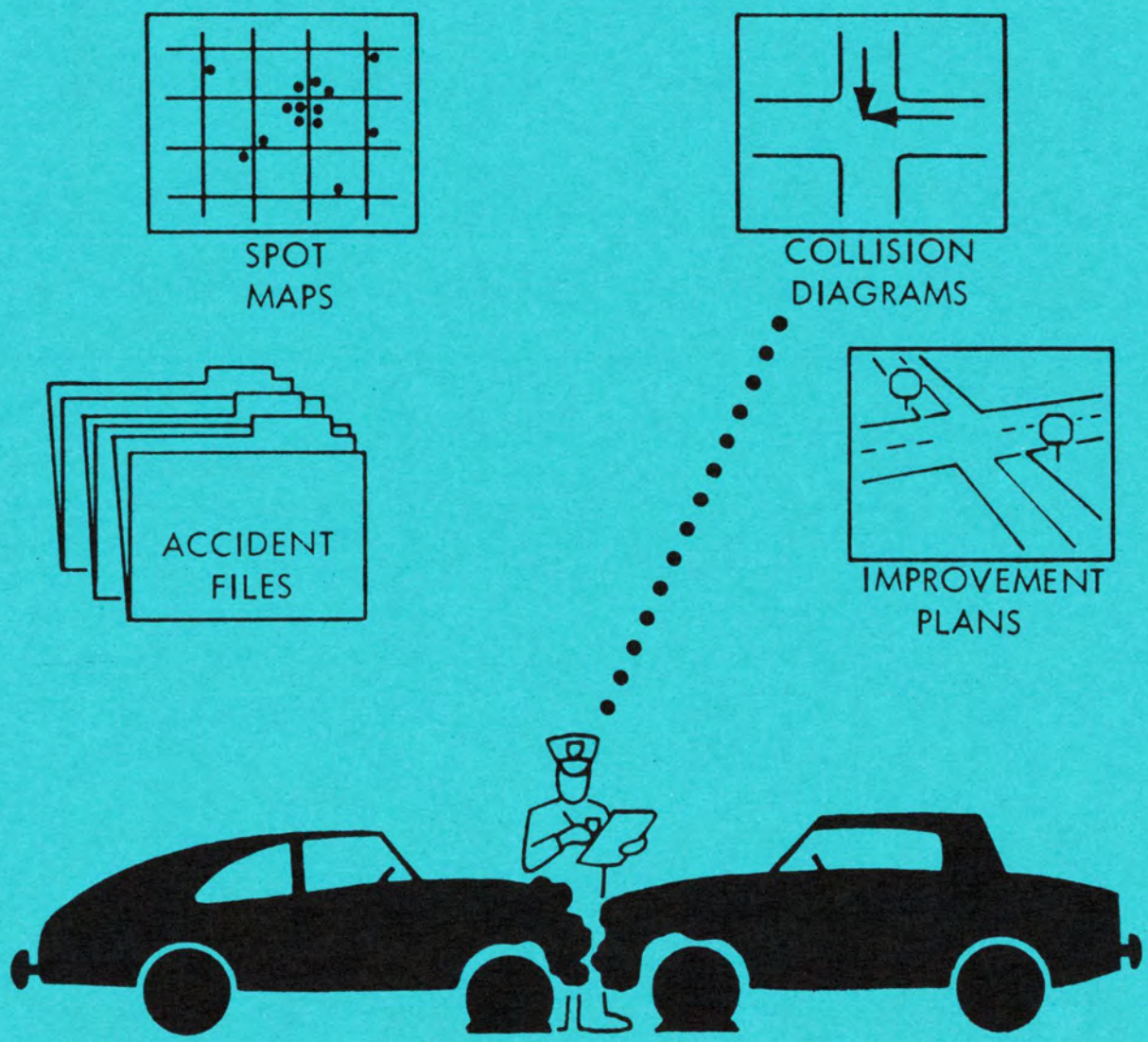
ACCIDENT LOCATION - FILE LOG [Form ALFL]

LOCATION 300 - 800 CLINTON STREET YEAR 1988

ACCIDENT DATE	LOCATION	SEVERITY
1-14-88	426 CLINTON	PDO
2-7-88	545 CLINTON	1 INJURY
5-19-88	50 FT. NORTH OF 4TH ST.	PDO
9-6-88	370 CLINTON	1 INJURY (Ped)
12-3-88	614 CLINTON	PDO
12-17-88	735 CLINTON	PDO

FIGURE 10. ACCIDENT LOCATION - FILE LOG.

CHAPTER 4 – ANALYZING HIGH-ACCIDENT LOCATIONS



CHAPTER 4

ANALYZING HIGH-ACCIDENT LOCATIONS

Analyzing traffic accidents is like solving a Sherlock Holmes mystery. The accidents reported in the previous one to three years provide clues to what aspects of the driving environment are contributing factors. As in a good mystery, the obvious suspect may not always be guilty, and false clues may appear. This is especially true with traffic accidents because they are statistically rare events.

As revealed by the accident rates computed in Chapter 3, intersections may have only a few accidents for every million entering vehicles. The analyst must be careful not to "jump to conclusions" on the basis of these few accidents. Instead, it is necessary to thoroughly study the accident experience to detect accident patterns, and proceed to conduct a detailed investigation to determine exactly what is causing these patterns.

Just as Sherlock Holmes used his magnifying glass and his assistant, Dr. Watson, to help analyze crimes and establish a list of suspects, this chapter describes the Location Analysis Procedures that will help analyze high-accident locations and establish a list of accident countermeasures.

Although the high-accident location analysis procedure is as complete as possible, it will not automatically produce accident countermeasures. It must be recognized that these procedures serve primarily as a tool to guide the analyst through all the steps and assemble all the information needed for achieving the goal of reducing accidents.

This chapter describes the procedures for analyzing the accident patterns at a location to determine the probable causes and appropriate general accident countermeasures (improvements). Then, additional data gathering and analysis procedures are presented that are necessary in order to determine the specific countermeasures for a high-accident location.

LOCATION ANALYSIS

All high-accident locations identified by either the Annual City-Wide Analysis or the Early Warning Analysis are further analyzed by applying the Location Analysis Procedure as follows:

Step 1: Record the location name, date and existing traffic control devices on the Location Analysis Worksheet illustrated in Figure 11.

Step 2: Complete the accident number, rate, and EPDO summary section in Part A. If the location was identified in an Annual City-Wide Analysis, copy the data for Part A from the High-Accident Location Identification Worksheet (refer to Figure 9). If the location was identified during an Early Warning Analysis, complete Part A using the procedure in the Annual City-Wide Analysis discussed in Chapter 3. Then, complete Part B if the location is an intersection, or Part C if it is a mid-block section.

LOCATION ANALYSIS WORKSHEET [Form LAW-1]

LOCATION THIRD STREET AND LINCOLN STREET DATE JUNE 6, 1989

EXISTING TRAFFIC CONTROL TWO-WAY STOP (ON LINCOLN)

PART A - ACCIDENT NUMBER, RATE, AND EPDO SUMMARY

Year	Number of Accidents				2 and 3 Year Average	EPDO Number	ADT	Exposure	Accident Rate	EPDO Rate
	Fatal	Injury	PDO	Total						
1988		1	7	8		13	3,600	1,314,000	6.088	9.893
TOTALS									AVG =	AVG =

PART B - INTERSECTION RELATED ACCIDENTS

	Right Angle	Rear End	Side-Swipe		Head On	Ped	Fixed Object	Right Turn	Left Turn	Other	TOTAL
			Meeting	Passing							
Number of Accidents	4	3							1		8
Percent of Total	50	38							12		100%

PART C - MID BLOCK ACCIDENTS

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

PART D - NUMBER OF ACCIDENTS AND EXISTING CONDITIONS

Time of Day: 6:00 am - Noon 2 6:00 pm - Midnight 2
Noon - 6:00 pm 4 Midnight - 6:00 am

Light Conditions: Day 6 Night 2

Surface Conditions: Dry 3 Wet 5 Snow or Ice

Weather: Cloudy 2 Clear 3 Rain 3 Snow Other

Other:

FIGURE 11. LOCATION ANALYSIS WORKSHEET - PAGE 1.

Step 3: Complete Part D which will provide a summary of several types of conditions associated with the reported accidents. This summary might reveal accident patterns; however, for most evaluations it is recommended that a collision diagram be prepared to assist in detecting patterns. Instructions for preparing collision diagrams are in the next section.

Step 4: Identify the predominant accident pattern if one is evident. Other patterns are classified as secondary. Record the predominant and secondary patterns in Part E, the Accident Analysis Summary section, near the top of the second page of the worksheet.

Step 5: Use the table in Appendix B to determine probable causes of accidents and their general countermeasures. If no predominant accident patterns are identified but a probable cause has been hypothesized, this probable cause is used to identify general countermeasures. List all general countermeasures in Part E of the worksheet.

Step 6: Plan and conduct an on-site observation of the location using the Accident Analysis Summary as a guide for diagnosing problems. Attach the observation report to the Location Analysis Worksheet and place a checkmark by "On-Site Observation Report" in Part E.

Step 7: While conducting the on-site observation study, a location inventory should also be obtained. A location inventory provides a direct measurement of the roadway and other nearby features resulting in a drawing known as the condition diagram. The preparation and use of this diagram should be noted by placing a checkmark by "Condition Diagram" in Part E.

Step 8: From the general countermeasures chosen and the on-site observations, determine what other data or studies are needed in order to identify countermeasures for the location. Instructions for conducting additional traffic studies that might be required are in Appendix C.

Step 9: Check each specific countermeasure that has established warrants to determine if its warrants are satisfied. Warrants are criteria that have been established to indicate when a certain countermeasure or improvement should be considered. Warrants are usually stated in terms of minimum values relating to characteristics at the location, such as the number of accidents per year or the traffic volume.

Step 10: Determine specific countermeasures for the high-accident location and list them toward the bottom of Part E. Identify individual possible countermeasures and all reasonable combinations. The B/C ratio, costs, savings, and priority assigned will have to be entered following preparation of the Countermeasure Analysis Worksheets to be discussed in Chapter 5.

For most improvements, city personnel can develop the design and the cost estimate. Some projects, like traffic signal installation, should be designed by a registered professional engineer. The MHTD offers this type of assistance through its "Traffic Engineering Assistance Program" known as "TEAP." The TEAP service is available for any location not on a state-maintained street and is offered at no cost to the city.

LOCATION ANALYSIS WORKSHEET - PAGE 2 [Form LAW-2]

LOCATION THIRD STREET AND LINCOLN STREET DATE JUNE 6, 1989

PART E - ACCIDENT ANALYSIS SUMMARY

[X] COLLISION DIAGRAM ATTACHED

ACCIDENT PATTERNS IDENTIFIED: Predominant RIGHT ANGLE
Secondary REAR END

PROBABLE CAUSES AND GENERAL COUNTERMEASURES

RESTRICTED SIGHT DISTANCE:
1. INSTALL 4-WAY STOP
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:
- ✓ On-Site Observation Report
- ✓ Intersection Sight Distances
- ✓ Volume/Turning Movement Count
- ___ Other: ___
- ✓ Condition Diagram
- ___ Spot Speed Study
- ___ Traffic Conflict Study

General Conclusions From Supporting Data SIGHT DISTANCE ALL DIRECTIONS FROM LINCOLN IS RESTRICTED BY CARS AND VANS PARKING TOO CLOSE 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. INSTALL SKID-RESISTANT OVERLAY
3. COMBINATION OF 1 AND 2.
4.
5.

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

Best Countermeasure 3 - COMBINATION

Benefit/Cost Ratio 14.1 Implementation Cost 13,300

Average Annual Net Savings 35,779 Priority Assigned 1

FIGURE 11. LOCATION ANALYSIS WORKSHEET - PAGE 2.

The principal aids used in the Location Analysis are the Collision Diagram, the On-Site Observation Report, the Condition Diagram, and the General Countermeasures Table in Appendix B. Other traffic studies and location measurements may also be required.

During the Location Analysis it is especially important to consider all information that was reported by investigating officers on the accident report forms.

COLLISION DIAGRAMS

Step 3 in the analysis is preparing a collision diagram. Just as a spot map shows where accidents are occurring city-wide, a collision diagram quickly shows where accidents are occurring at each high-accident location.

A collision diagram contains much more detail about each accident than does a spot map. And, if the accidents occurring at the location have a repetitive pattern, that pattern will be easily identified on a properly drawn collision diagram.

To prepare a collision diagram, first obtain accidents reports for all accidents at the location during the preceding period of at least one year, and preferably for a three year period. If significant changes (signals, stop signs, construction, etc.,) were made at the location in recent years, do not include reports for accidents that occurred before those changes.

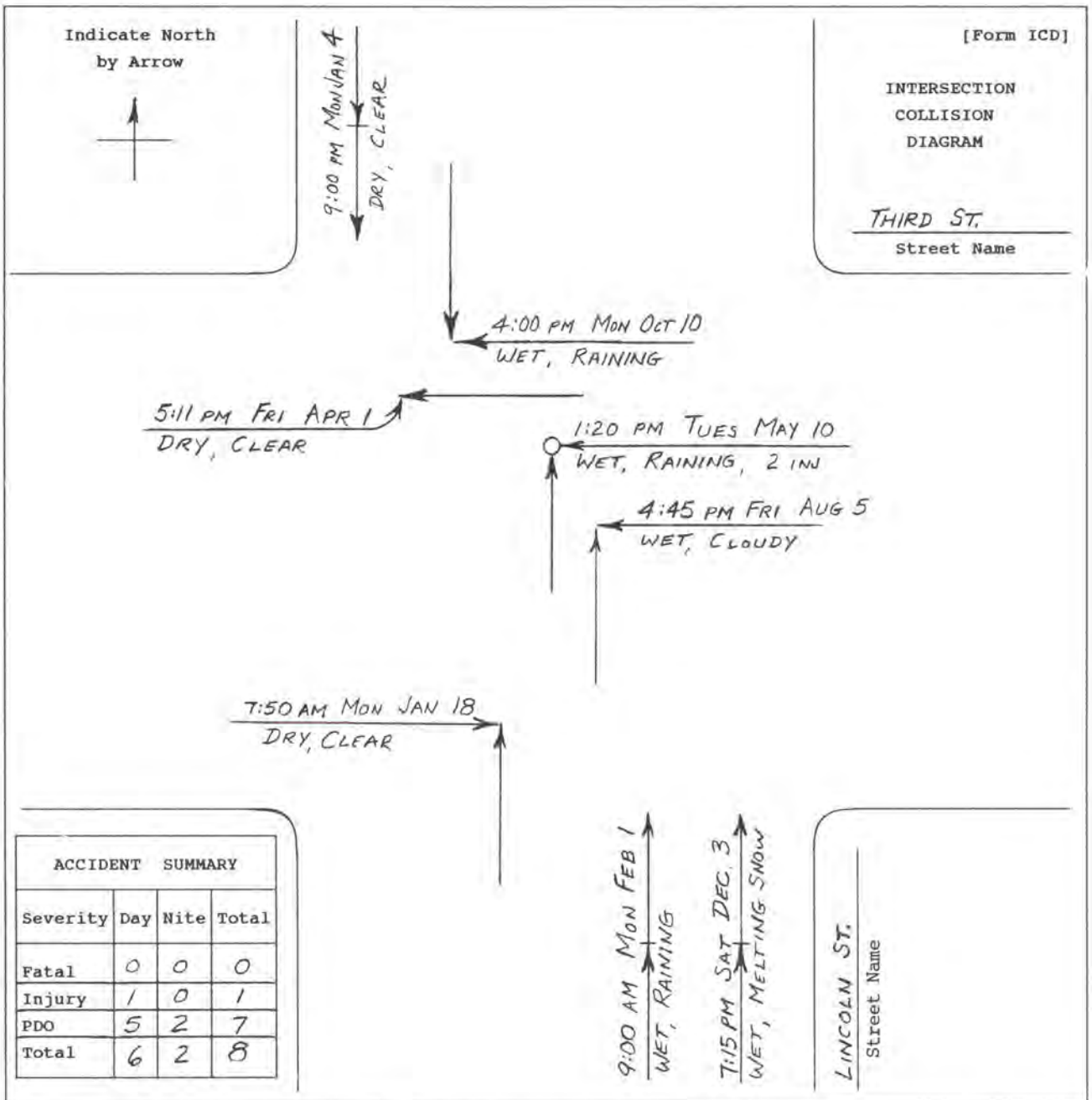
Sketch the collision diagram using a form similar to that provided in Appendix I and include all the information as shown on the example for Third Street and Lincoln Street in Figure 12.

The collision diagram need not be to scale. Allow sufficient room on the drawing to show the path of each vehicle and object involved in an accident. Make certain to identify the type and location of all traffic control devices.

The collision diagram must show the general path of all vehicles involved in each accident, as well as the approximate point of each impact. Use the suggested symbols on the form to show the type and severity of each accident. Write other basic characteristics of each accident on the accident symbols such as:

- Date, day of week, and time of accident
- Light condition (day or night)
- Pavement condition (dry, wet, icy, etc.)
- Number of injuries or fatalities

Also note any special circumstances associated with an accident, especially any driver or investigating officers' comments concerning glare, nonfunctional traffic control devices, poor pavement conditions, or sight obstructions.



ACCIDENT SUMMARY			
Severity	Day	Nite	Total
Fatal	0	0	0
Injury	1	0	1
PDO	5	2	7
Total	6	2	8

SYMBOLS	TYPES OF COLLISIONS	SHOW FOR EACH ACCIDENT
Moving Vehicle	Rear End	1. Approximate location of accident
Backing Vehicle	Head On	2. Type of collision
Non-Involved Vehicle	Side Swipe	3. Time, day, date
Pedestrian	Out of Control	4. Other pertinent factors from accident reports as severity; pavement and weather conditions; etc.
Parked Vehicle	Overturn	
Fixed Object	Left Turn	
Fatal Accident	Right Angle	
Injury Accident		

INTERSECTION THIRD ST. AND LINCOLN ST. DATE MARCH 1, 1989

TIME PERIOD COVERED: FROM JAN. 1, 1988 TO Dec. 31, 1988 PREPARED BY EJD

FIGURE 12. INTERSECTION COLLISION DIAGRAM.

Noninvolved (non-contact) vehicles or pedestrians should also be shown on collision diagrams. 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 noninvolved vehicle since it was not in the actual collision. However, the noninvolved vehicle should have its intended path shown by a dashed line since it was clearly related to the occurrence of the accident.

Step 4 is to identify any accident patterns that are present. Note the types of accidents occurring on each intersection approach or along sections of a street. Summarize the times when accidents occur, the weather and pavement conditions, and enter these summaries in Part D of the Location Analysis Worksheet.

While the collision diagram will reveal the obvious accident patterns, it is helpful to review all information pertaining to the location since this is a critical point in conducting a successful analysis.

GENERAL COUNTERMEASURES

In Step 5, the general countermeasures must be determined. The analysis of a high-accident location should point out the predominant accident pattern at that location, such as a high number of rear-end collisions, or an unusually high percentage of wet pavement accidents.

The general countermeasure tabulation in Appendix B shows feasible countermeasures for typical urban accident patterns. The objective is to choose those general types of improvements which are known to be helpful in reducing accidents of the type occurring at the location being studied.

To use the Appendix B table, first find the predominant accident pattern for the location, then carefully review the associated list of probable causes to see what could have contributed to the accident pattern. For each probable cause, identify all 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 pedestrians crossing, drivers not being aware of the intersection, a slippery surface, or a large turning volume. Knowing the accident pattern and having the accident report information in mind, several general countermeasures should be easily identified.

If there is a secondary accident pattern, identify the probable causes and general countermeasures for it and list them in Part E on the Location Analysis Worksheet.

ON-SITE OBSERVATION

Step 6 consist of conducting an on-site visit and observation at the high-accident location. This is an important step in the analysis since an on-site inspection should provide an excellent perspective from which to choose the best countermeasures.

Rather than a poorly planned field trip, preparations should be carefully made for the on-site visit. Review information concerning the site, including collision diagrams, accident summaries, and traffic counts. Schedule the visit according to any predominant accident characteristics, such as nighttime, during peak volumes, or wet pavement conditions.

A recommended form to assist you in the on-site inspection is shown in Figure 13. Prepare an "On-Site Observation Report" in advance of the field trip by completing the two top lines on the first page.

Upon arriving at the site, drive through the location several times from different directions and pay close attention to how the driver might see the environment. Identify several good vantage points that provide a clear view of traffic from a safe position. Also, the observation points should be located so motorists will not notice the observer. Drivers will act differently if they suspect they are being observed.

Next, complete the "Physical Checklist" to become familiar with features of the location and identify any potential hazards. Place a check mark after items on the list that might create problems or contribute to accidents.

After completing the "Physical 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 check mark following items on the "Operational Checklist" that might be associated with a confusing or hazardous characteristic of the site.

Having observed 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 checked items under the "Comments" section toward the bottom of the second page, using extra pages if necessary.

For each item listed, provide comments and description that could be helpful in identifying any factors contributing to the accident experience. Make each commentary as complete as possible so when they are reviewed later they will provide a useful and valuable documentation of the on-site observations.

Photographs are always useful aids in traffic studies and will be very helpful later in recalling location characteristics. If there is a need to know a dimension related to a feature in a photograph, place an object of known length in the view of the camera, or take a measurement and carefully note it on the rear of the report form along with the photograph number.

In most cases it is advisable to obtain insights from persons residing or working near the location and record their remarks concerning hazardous conditions or dangerous operational characteristics. If added probable causes or general countermeasures are identified during the on-site visit, record them on the Location Analysis Worksheet.

ON-SITE OBSERVATION REPORT [Form OSOR-1]

LOCATION THIRD ST. AND LINCOLN ST. CONTROL DEVICES 2-WAY STOP

OBSERVER EJD DAY TUES DATE 6-5-89 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?	✓
4. Traffic signs are satisfactory as to number, size, message, placement, reflectivity, and visibility. (see MUTCD)	✓
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)	✓
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?	✓
12. Lane and street widths are adequate?	
13. The pavement surface condition is satisfactory? (Consider: potholes, rutting, washboard, edge drop-offs, raveling, bleeding surface, cracking, and poor drainage)	✓
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 13. 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:	✓
B. Straight-through vehicles:	✓
C. Right-turning vehicles:	✓
7. Parked vehicles or parking maneuvers create hazards?	✓
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.

(Continue comments as necessary on additional pages.)

FIGURE 13. ON-SITE OBSERVATION REPORT - PAGE 2.

CONDITION DIAGRAM

Step 7 specifies that a roadway inventory, known as a "Condition Diagram," be prepared for the high-accident location. A condition diagram, as illustrated in Figure 14, is a scaled drawing of the existing roadway, control device locations and major features in the nearby environment. A condition diagram is especially helpful in relating accident 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 to be placed on the diagram is related to the type of improvements being considered. If the location is likely to receive only minor improvements, as installing new warning signs, a sketch of the location showing only a few important measurements would probably be satisfactory. 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 dimensions to all possible line of sight obstructions.

The following items should be shown on a complete condition diagram prepared for a high-accident location:

- Date of diagram preparation
- Observer 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 of view obstructions with height noted (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 location and width
- Road surface materials and significant surface irregularities
- Grade on all approaches
- Corner radii
- General classification of nearby land use and building use

TRAFFIC DATA COLLECTION

Step 8 involves gathering additional traffic data that are required for performing a complete analysis of a high-accident location. Several frequently required studies include traffic counts, spot speed studies, traffic conflicts studies, and sight distance evaluations. These studies are briefly described below, with more complete instructions and additional references provided in Appendix C.

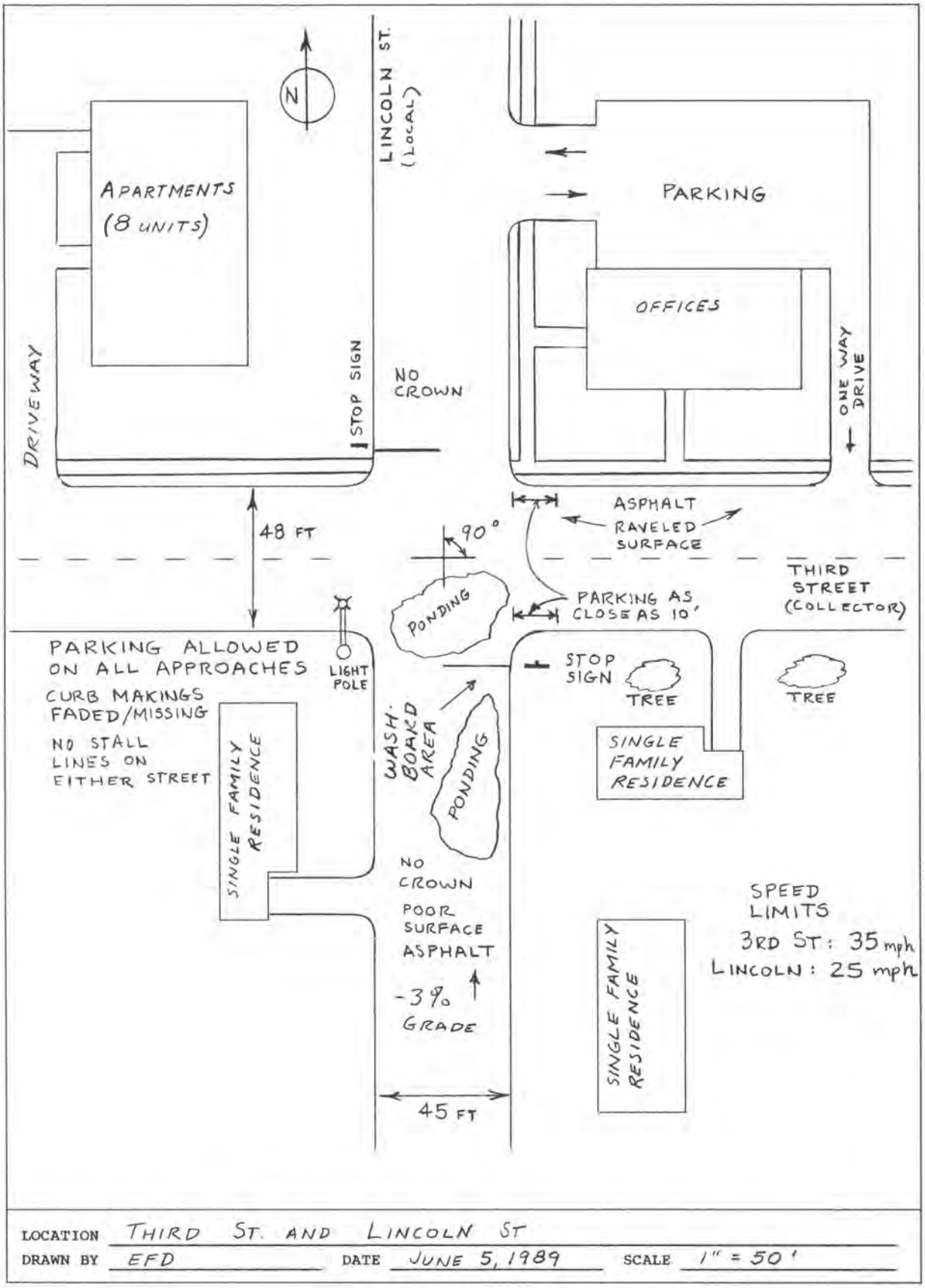


FIGURE 14. CONDITION DIAGRAM

Basic 24-hour traffic volume estimates are required for calculating accident and EPDO rates. Volume counts at an intersection would 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. Traffic counts are usually conducted in four successive 15-minute periods, thereby providing a sample duration of one hour. In urban areas, and especially near schools, pedestrian and bicycle counts may be very helpful for high-accident location analysis.

Speed studies should be conducted if vehicle speed is a possible causative factor in the accident experience. The approach speed at an intersection and the speed on a street are related to the provision of safe stopping distance. Being familiar with prevailing speed characteristics is necessary in order 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 analysis is a method of 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 accidents at the site. It is generally agreed that a traffic conflicts analysis should not be used to replace accident data analysis, but it can be used as a supplementary tool to help identify possible countermeasures. An outline for performing a traffic conflicts analysis is in Appendix C.

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

WARRANTS AND GUIDELINES

Step 9 is concerned with checking countermeasures which might involve warrants. Warrants (e.g., stated minimum values to justify installation) have been developed to prescribe the use of many different types of traffic improvements. 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.

Several guidelines have been developed for installing certain types of countermeasures such as flashing beacons, lighting, and one-way streets. These guidelines are described in Appendix D. Also, this appendix contains general guidelines for the use of guardrail, left-turn channelization, and installation of a continuous median two-way left-turn lane.

It is important to note that even if the warrants for a particular countermeasure are satisfied, alternative improvements should be compared by using the Countermeasure Analysis procedures described in Chapter 5.

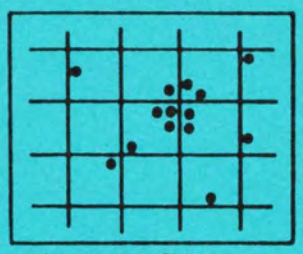
SPECIFIC COUNTERMEASURES

Step 10 is to select specific countermeasures by evaluating the suitability of the general countermeasures for the high-accident location. The specific countermeasure, or countermeasures, chosen for further evaluation must be feasible and warranted. 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.

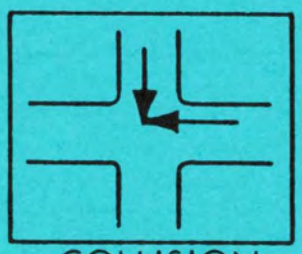
After the feasible countermeasures and all reasonable combinations of those countermeasures have been identified, enter them on the second page of the Location Analysis Worksheet shown in Figure 11. When determining if a countermeasure is economically feasible, project costs and service lifes will have to be estimated. A listing of unit cost estimates is provided in Appendix E and representative service lifes appear in Appendix F.

If a more detailed professional analysis might be required in order to identify feasible countermeasures, consider inquiring about the traffic engineering services available through the TEAP. Details regarding TEAP are available from the nearest MHTD District Office.

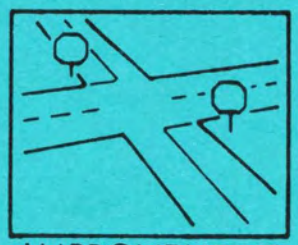
CHAPTER 5 – CORRECTING HIGH-ACCIDENT LOCATIONS



SPOT MAPS



COLLISION DIAGRAMS



IMPROVEMENT PLANS

CHAPTER 5

CORRECTING HIGH-ACCIDENT LOCATIONS

At this point, several countermeasures having the potential to reduce the number and/or severity of accidents at each high-accident location have been identified. The next process consists of selecting the best countermeasure, or set of countermeasures, for each location and establishing the priority ranking for making improvements.

If funds were unlimited, all the countermeasures that promised the most reduction in accidents at each location could be installed. However, with budgets for improvement projects usually being restricted it becomes necessary to obtain the greatest overall benefit from the available funds.

There are several techniques which could be utilized to select the best countermeasures for a site and assist in ranking the various locations to determine their priority for improvement. Four of the economic analysis procedures or techniques most commonly used are the following:

- Benefit/Cost (B/C) Ratio
- Cost/Effectiveness Method
- Net Benefit Method
- Other methods as Incremental B/C Ratio or Dynamic Programming

It is recommended that the benefit/cost ratio be applied for selecting high-accident location countermeasures since it is the practice of many state and local agencies to choose projects by this method. Furthermore, the benefit/cost ratio is a straightforward procedure and its results are meaningful to government officials because they represent an amount saved per dollar spent.

COUNTERMEASURE ANALYSIS

The average annual savings by motorists due to accident reduction achieved by a countermeasure is known as an average annual "benefit." The cost to the public agency of implementing the improvement is considered to be the "cost" and this must be expressed in equivalent annual cost terms.

Generally, for each specific high-accident location, the preferred countermeasure is the one producing the highest benefit/cost ratio. It is also necessary for the best countermeasure to yield a benefit/cost ratio greater than 1.0 in order to be a candidate for acceptance. A benefit/cost ratio equal to 1.0 indicates a borderline project, and a benefit/cost ratio less than 1.0 indicates an undesirable project.

The following steps describe all the calculations and decisions that are necessary when working through a benefit/cost ratio selection process.

Step 1: Starting with the lowest implementation cost countermeasure listed on the Location Analysis Worksheet (refer to Figure 11), record the countermeasure number and description on Figure 15, the Countermeasure Analysis Worksheet.

Step 2: Estimate the improvement(s) service life using Appendix F or from local experience, and record it on the worksheet. (Note: Improvement projects having different service lives must be analyzed on separate pages as explained in Step 6.)

Step 3: Enter the current year ADT for the location. Then estimate the ADT growth factor and calculate the ADT for the year associated with the improvement service life. Contact the MHTD TTAP office if assistance is needed in estimating ADT growth factors.

Step 4: Complete the Estimated Annual Accident Reduction portion of the worksheet by listing each type of accident that will be reduced, the estimated percent (divided by 100) accident reduction, and the average annual number of PDO and fatal or injury accidents of each type. For each accident type compute the estimated accident reduction by multiplying the number of PDO and fatal or injury accidents by the accident reduction factor. Then total the PDO accident reduction estimates and total the fatal or injury accident reduction estimates.

If a combination of countermeasures is being considered at a location, the total percent reduction in accidents cannot be found by simply adding the percent reduction of each countermeasure. For example, if one type of countermeasure is estimated to reduce all accidents by 30% and another by 25%, the total percent reduction that could be expected would be 30% of all accidents plus a 25% reduction of accidents that are uncorrected by the first countermeasure, or 30 + 25(0.70) = 47.5%. When a combination of countermeasures is being evaluated, the total percent accident reduction can be estimated by the following equation:

$$P_T = P_1 + \left(\frac{100 - P_1}{100}\right) P_2 + \left(\frac{100 - P_1}{100}\right)\left(\frac{100 - P_2}{100}\right) P_3 + \ldots$$

where: P_T = total percent reduction in accidents

P_1 = largest percent reduction in accidents due to any one of the countermeasures

P_2 = second largest percent reduction in accidents due to any one of the countermeasures

P_3 = third largest percent reduction in accidents due to any one of the countermeasures

Step 5: Complete the Average Annual Benefits section in Figure 15. Enter the estimated total reduction of PDO accidents on Line 1 and the total reduction of fatal or injury accidents on Line 4. Unless local

COUNTERMEASURE ANALYSIS WORKSHEET [Form CAW-1]

LOCATION THIRD STREET AND LINCOLN STREET DATE JULY 6, 1989
COUNTERMEASURE NUMBER 3 ESTIMATED COUNTERMEASURE SERVICE LIFE 7 YEARS
COUNTERMEASURE DESCRIPTION PAVEMENT OVERLAY & PARKING REMOVAL AT CORNERS

ADT ADJUSTMENT Current Year 1989 ADT 3600 ADT Increase 3 % Annually
Estimated Year 1996 ADT 4428

ESTIMATED ANNUAL ACCIDENT REDUCTION

Accident Type	Estimated % Reduction (÷ 100)	x	Annual Number Accidents of this Type Before Improvement	=	Estimated Annual Reduction for Accidents of this Type
RIGHT ANGLE	.69	x	PDO 2	=	PDO 1.38
		x	F & I 1	=	F & I .69
REAR END	.40	x	PDO 3	=	PDO 1.20
		x	F & I 0	=	F & I 0
		x	PDO	=	PDO
		x	F & I	=	F & I
		x	PDO	=	PDO
		x	F & I	=	F & I

Total Estimated Accident Reduction: PDO 2.58 F & I .69

AVERAGE ANNUAL BENEFITS

1. Enter the estimated reduction of PDO accidents	2.58	
2. Enter the average cost of a PDO accident	4,000	
3. Multiply Line 1 by Line 2 (average annual benefit of reducing PDO accidents)		10,320
4. Enter the estimated reduction of Fatal and Injury accidents	0.69	
5. Enter the average cost of Fatal or Injury accident	35,100	
6. Multiply Line 4 by Line 5 (average annual benefit of reducing Fatal and Injury accidents)		24,219
7. Add Line 6 to Line 3 (average annual benefit from reducing accidents)		34,539

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	4428	
9. Enter the current year 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 accidents with ADT increasing)		38,511

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	38,511

FIGURE 15. COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 1.

estimates of traffic accident costs are available or your analysis is for other than city streets, use the following cost figures: $35,100 for the average cost of a fatal or injury accident; and $4,000 for a PDO accident. Enter these values on Lines 2 and 5. Compute the Average Annual Benefit (for constant ADT) and enter the result on Line 7.

If the ADT is expected to increase during the service life of the improvement, the accidents would increase also if an improvement were not made. Therefore, when ADT is increasing, the benefits due to making an improvement are also increasing. Determine the average annual benefits if the ADT is increasing by completing Lines 8 thru 13.

If secondary annual benefits, such as reduced delay, can be estimated, enter them on Line 14. The total Average Annual Benefit is on Line 15.

Step 6: The Average Annual Costs associated with the improvement must be computed. If a combination of several improvements is being evaluated for a location, and if the service lives for these improvements are not all the same, lines 1 through 9 on Page 2 of the worksheet must be repeated for each of the different lives. For instance, if some improvements have a life of 5 years they must be analyzed on one page; improvements with a life of 2 years must be analyzed on a separate page; etc. The initial costs of the improvement, the terminal value of the improvement, and any additional annual costs should be considered in determining the Average Annualized Costs.

All initial costs and terminal (salvage) values must be adjusted by applying interest factors that consider the time value of money. These factors for typical interest rates are provided in Appendix H, and they are accompanied by several example applications.

Step 7: Next, the Average Annual Net Return is found by subtracting the Average Annual Costs from the Average Annual Benefits. If project costs from Step 6 have been analyzed on several pages due to different service lives, the results from those worksheets must be combined onto one worksheet in order to complete Step 7.

Step 8: The Benefit/Cost Ratio is then determined by dividing the Average Annual Benefits by the Average Annual Costs, and it is entered on the last line of the Countermeasure Analysis Worksheet.

Any improvement with a Benefit/Cost Ratio greater than 1.0 or any improvement with a positive Average Annual Net Return will return more benefit than its cost to the city. Improvements which do not meet these criteria are not economically justified at the time of the analysis.

When the most effective countermeasure, or set of countermeasures, has been identified, enter the countermeasure description, its Average Annual Net Return, its Benefit/Cost Ratio, and its initial cost on the Location Analysis Worksheet (refer to Figure 11).

Figure 15 (Countermeasure Analysis Worksheet-Supporting Computations) on page 50 illustrates several of the calculations used in the example.

COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 2 [Form CAW-2]

LOCATION THIRD STREET AND LINCOLN STREET DATF JULY 6, 1989
COUNTERMEASURE NUMBER 3 ESTIMATED COUNTERMEASURE SERVICE LIFE 7 YEARS
COUNTERMEASURE DESCRIPTION PAVEMENT OVERLAY & 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 *	.20541
3. Multiply Line 1 by Line 2	2,732
4. Enter the terminal (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 *	.10541
6. Multiply Line 4 by Line 5	0
7. Subtract Line 6 from Line 3	2,732
8. Enter any other annual costs associated with the improvement	0
9. Add Line 7 and Line 8 to obtain Average Annualized Costs	2,732

AVERAGE ANNUAL NET SAVINGS

1. Enter the Average Annual Benefits (from Line 15, page 1)	38,511
2. Enter the Average Annualized Costs (from line 9, above)	2,732
3. Subtract Line 2 from Line 1 to obtain Avg Annual Net Savings	35,779

BENEFIT/COST RATIO

1. Enter the Average Annual Benefits (from Line 15, page 1)	38,511
2. Enter the Average Annualized Costs (from Line 9, above)	2,732
3. Divide Line 1 by Line 2 to obtain the Benefit/Cost Ratio	14.1

* The example countermeasure analysis assumes a 10% interest rate. An agency might use a different interest rate and that would require applying factors from an interest table for that rate. Appendix H contains interest factor tables for 6%, 8%, and 10% rates.

FIGURE 15. COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 2.

COUNTERMEASURE ANALYSIS WORKSHEET - SUPPORTING COMPUTATIONS

LOCATION THIRD STREET & LINCOLN STREET DATE JULY 6, 1989

COUNTERMEASURE DESCRIPTION PAVEMENT OVERLAY & PARKING REMOVED

ACCID. REDUCTION ESTIMATES (BASED ON APP G.)

RIGHT-ANGLE COLLISIONS REDUCED BY COMBINED EFFECT OF PAVEMENT OVERLAY AND PARKING REMOVAL (NOTE: 3 RIGHT ANGLE COLLISIONS WERE ON WET PVMT)

PAVEMENT OVERLAY - 1 BLOCK ALL DIRECTIONS

USE 55 % ACCID. REDUCTION FOR WET PVMT ACCID

SIGHT OBSTRUCTION REMOVAL

USE 30 % ACCID. REDUCTION FACTOR

COMBINED EFFECT:

$$P_T = 55 + \left(\frac{100-55}{100}\right) 30 = 55 + 13.5 = 68.5$$

use 0.69

REAR-END COLLISIONS REDUCED BY PVMT OVERLAY

USE 40 % ACCID. REDUCTION FACTOR

INITIAL COST FOR IMPROVEMENTS

OVERLAY 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 15. COUNTERMEASURE ANALYSIS WORKSHEET - SUPPORTING COMPUTATIONS.

PRIORITY OF IMPLEMENTING COUNTERMEASURES

After the most effective countermeasure, or set of countermeasures, has been selected for each high-accident location, it is necessary to determine which location should be improved first, which should be improved second, etc., until all available funds are allocated or there are no further locations to rank.

The priority list of locations should be based on a benefit/cost ratio comparison or an average annual net return comparison. Public agencies often prefer the benefit/cost ratio because it clearly indicates the amount saved per dollar cost. The average annual net return method could be used, however it has the disadvantage of sometimes placing a low priority on low-cost projects that are effective but do not generate a large net benefit.

It is recommended that first priority be given to the location having the proposed countermeasures with the highest benefit/cost ratio. The initial cost of improving this location is subtracted from the available budget, leaving a reduced amount for allocation to other locations.

Continue selecting locations according to the highest remaining benefit/cost ratio, and reduce the available funds by the cost of each successive project, until the remaining funds are insufficient to implement the next ranking improvement. At this point the remaining funds should be spent on lower cost improvements until the budget is expended. These lower cost projects should also be selected according to their respective benefit/cost ratios. When all locations have been selected and priorities determined, enter the results on the Location Analysis Worksheets. It is also advisable to contact the nearest MHTD District Office and inquire if there are special funding sources for the improvement projects selected.

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

INSTALLATION OF IMPROVEMENTS

After the priority listing of improvements has been established, each project must be designed, scheduled and installed. Although the HAL Manual does not cover design of improvements, several sources on this subject are in the reference list. It is very important to remember that design and placement of traffic control devices must conform to the MUTCD.

Project scheduling involves determining when each project should be started and completed. Manpower requirements, as well as the materials and other items to be procured, should be reviewed in developing the project schedule. Consideration should be given to scheduling similar projects at the same time to make more effective use of the workforce and materials. A schedule will also prove to be very useful for alerting the public to road closures or lane closures so they may select alternate routes.

Project installation and all related construction activities must be carried out with full attention given to proper work zone traffic control. This is a critical matter and it must not be overlooked. The safety of the workers and motorists driving through the location 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.

The city engineer should keep good records on all costs of making the improvements in order to improve future countermeasure evaluations. If improvements are done under contract, make an effort to keep the cost of each countermeasure separated so specific costs can be determined.

EVALUATION OF IMPROVEMENTS

Following improvement installation, continue the analysis of accident data to determine the effectiveness of improvements at each location. This effort is essential in order to increase the accuracy of future improvement and countermeasure selections. The most common method of evaluating improvement effectiveness is the Before-After Analysis. These studies compare accident experience at a location for a specified time period "Before" and a comparable time period "After" an improvement is installed. To properly evaluate an improvement or countermeasure, it is necessary to start a documentation file on each improved location with the completed Location Analysis Worksheets.

After the evaluation documentation files have been prepared, the following steps are suggested for proper evaluation:

Step 1: Perform field observations of operations at the location immediately after it has been improved to see if there are any serious problems developing that were not expected. If problems are observed, alter the improvement to eliminate the problems, record the problems and changes that were made, and put this information in the documentation file.

Step 2: Record the project completion date on the Accident Location-File Log so the Early Warning Analysis will be conducted starting three months after the improvement was installed. If the site is again flagged as a high-accident location, immediately reinstate the Location Analysis and conduct appropriate field studies to determine what is causing the unexpected accidents. It might be necessary to develop alterations to the initial improvement from the reinstated Location Analysis.

It is important to realize that a few accidents might occur at an improved site due to "previous habits" of motorists who frequently use the location. For example, installation of a new stop sign does not guarantee all approaching drivers will stop, especially if those drivers have been passing through the location without stopping for many years. If some unexplained accidents 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" period and the "After" period. If a familiarization period is allowed, it should be noted on the Accident Location - File Log and the Countermeasure Evaluation Worksheet.

Step 3: Conduct a Before-After Analysis of the location when the following conditions have been met:

a. "After" accident data are available for a time period comparable to the "Before" period, with a minimum of one year each.

b. ADT data are available for both periods to enable the accident numbers to be adjusted for exposure.

c. The characteristics of the traffic flow are basically unchanged during the two periods.

d. The appropriate "driver familiarization" period has elapsed.

Step 4: Conduct the Before-After Analysis using the Countermeasure Evaluation Worksheet in Figure 16 as follows:

a. Complete the After Accident Analysis section on the first page in a manner similar to the previous Location Analysis Worksheet, using accident data for the period "After" the improvement was installed.

b. If the ADTs of the "After" period are different from the ADTs of the "Before" period, calculate the ADT Ratio by dividing the average "After" ADT by the average "Before" ADT at the top of the second page.

c. Adjust accident numbers in the "After" period by dividing them by the ADT Ratio.

d. Calculate the percent accident reduction for all accident types, accident totals, and accident rates using the following equation:

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

where: P = percent accident reduction

N_B = number of accidents in the before period

N_A = number of accidents in the after period

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

Figure 16 (Countermeasure Evaluation Worksheet-Supporting Computations) on page 56 illustrates several of the calculations used in the example.

COUNTERMEASURE EVALUATION WORKSHEET [Form CEW-1]

LOCATION THIRD STREET AND LINCOLN STREET DATE JAN. 18, 1991

COUNTERMEASURE DESCRIPTION PAVEMENT OVERLAY AND PARKING REMOVED AT CORNER

DATE COUNTERMEASURE INSTALLATION COMPLETED NOV. 20, 1989

PART A - ACCIDENT NUMBER, RATE, AND EPDO SUMMARY

Year	Number of Accidents				2 and 3 Year Average	EPDO Number	ADT	Exposure	Accident Rate	EPDO Rate
	Fatal	Injury	PDO	Total						
1990			4	4		4	3,900	1,423,500	2.81	2.81
TOTALS									AVG =	AVG =

PART B - INTERSECTION RELATED ACCIDENTS

	Right Angle	Rear End	Side-Swipe		Head On	Ped	Fixed Object	Right Turn	Left Turn	Other	TOTAL
			Meeting	Passing							
Number of Accidents	2	1							1		4
Percent of Total	50	25							25		100%

PART C - MID BLOCK ACCIDENTS

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

PART D - NUMBER OF ACCIDENTS AND EXISTING CONDITIONS

Time of day: 6:00 am - Noon 1 6:00 pm - Midnight 1
Noon - 6:00 pm 2 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 16. COUNTERMEASURE EVALUATION WORKSHEET - PAGE 1.

COUNTERMEASURE EVALUATION WORKSHEET - PAGE 2 Form CEW-2]

LOCATION THIRD STREET AND LINCOLN STREET DATE JAN. 18, 1991
COUNTERMEASURE DESCRIPTION PAVEMENT OVERLAY & PARKING REMOVED FROM CORNER
DATE COUNTERMEASURE INSTALLATION COMPLETED NOV. 20, 1989

PART E - AFTER IMPROVEMENT ACCIDENT REDUCTION SUMMARY

___ COLLISION DIAGRAM ATTACHED

ACCIDENT PATTERNS IDENTIFIED: Predominant: NONE
Secondary: _____

ADT RATIO: $\frac{\text{After ADT}}{\text{Before ADT}} = \frac{3900}{3600} = 1.083$

ADJUSTED AFTER IMPROVEMENT NUMBER OF ACCIDENTS:

By Accident Type:

				By Accident Severity:	
Left turn	.92	Skidding		Fatal	
Head on		Wet pavement	.92	Injury	
Rear end	.92	Night		PDO	3.69
Right angle	1.85	RR crossing			
Side swipe		Pedestrian			
Fixed object					
Overturn					
All Accidents:	3.69				

ACCIDENT PERCENT REDUCTION: % Reduction = $\frac{\text{Before - After}}{\text{Before}}$ x 100

By Accident Type:

					By Accident Severity:	
Left turn		%	Skidding		%	Fatal		%
Head on		%	Wet pavement	82	%	Injury	100	%
Rear end	69	%	Night		%	PDO	47	%
Right angle	54	%	RR crossing		%			
Side swipe		%	Pedestrian		%			
Fixed object		%			%			
Overturn		%			%			
All Accidents:	54	%						

FIGURE 16. COUNTERMEASURE EVALUATION WORKSHEET - PAGE 2.

COUNTERMEASURE EVALUATION WORKSHEET - SUPPORTING COMPUTATIONS

LOCATION THIRD STREET & LINCOLN STREET DATE JAN. 18, 1991

COUNTERMEASURE DESCRIPTION PAVEMENT OVERLAY & PARKING RESTRICTED.

PART E:

ADJUSTED "AFTER" NUMBER OF ACCIDENTS:

Left Turn : 1/1.083 = 0.92

Rear End : 1/1.083 = 0.92

Right Angle : 2/1.083 = 1.85

Wet Pvmt : 1/1.083 = 0.92

PDO & All Accidents = 4/1.083 = 3.69

PERCENT REDUCTION:

Left Turn : (no actual reduction)

Rear End : $\frac{3 - 0.92}{3} = 0.693 \approx 69\%$

Right Angle : $\frac{4 - 1.85}{4} = 0.538 \approx 54\%$

Wet Pvmt : $\frac{5 - 0.92}{5} = 0.816 \approx 82\%$

Injury : $\frac{1 - 0}{1} = 1.0 = 100\%$

PDO : $\frac{7 - 3.69}{7} = 0.473 \approx 47\%$

All Accidents : $\frac{8 - 3.69}{8} = 0.539 \approx 54\%$

FIGURE 16. COUNTERMEASURE EVALUATION WORKSHEET - SUPPORTING COMPUTATIONS.

EVALUATION OF THE HAL SYSTEM

As stated in Chapter 1, the identification, analysis and correction of high-accident locations to reduce accident severity and accident numbers does require a commitment of time and money on the part of a city. In this section guidelines for evaluating the benefits of accident countermeasures versus the cost of those countermeasures are presented. It is specifically recommended that the HAL system be evaluated according to the following procedure:

Step 1: For each year that countermeasures are evaluated using the "Before-After" analysis, complete a HAL System Evaluation Worksheet as shown in Figure 17. The year for which the analysis is being performed and number of high-accident locations that qualify for being summarized should be entered at the top of the worksheet.

Step 2: For all improved locations that have been analyzed by the Countermeasure Evaluation during the analysis year, determine the benefit by totaling the average annual number of "Before" and "After" accidents from the Countermeasure Evaluation Worksheets. In order to account for changes in traffic volumes, it is preferred to use accident data for the "After" period that are properly adjusted for ADT changes.

Step 3: Following the instructions on Line 1 through 6, determine the total accident reduction and record it on Line 7. Then refer to Table 2 to determine if there was a significant accident reduction achieved at the improved locations.

In Figure 17, the example indicates 4 fatal or injury accidents were reported during the "Before" period; and only 1 fatal or injury accident during the "After" period. (Note: the 1 accident was adjusted to 0.95 due to a 5% ADT increase). Also, there were 29 PDO accidents reported during the "Before" period; and 12 PDO accidents during the "After" period. (Note: the 12 accidents were adjusted to 11.42 due to a 5% ADT increase). The total accident reduction for entry on Line 7 is found by these computations:

$$4 - 0.95 = 3.05$$

$$29 - 11.42 = 17.58$$

$$3.05 + 17.58 = 20.63$$

The total reduction of 20.63 accidents must be compared to the minimum accident reduction required for statistical significance listed in Table 2. For a total of 33 accidents in the "Before" period, the required reduction is 9.45 accidents. Since the reduction of 20.63 accidents is considerably greater than the required 9.45 accidents, the accident reduction should be regarded as being due to the countermeasures, and not due to chance.

HAL SYSTEM EVALUATION WORKSHEET [Form - HALSEW]

EVALUATION FOR 7 IMPROVED LOCATIONS YEAR 1990 EVALUATED BY AMJ

BENEFITS DUE TO ACCIDENT REDUCTION

1.	Enter the average annual number of "Before" improvement Fatal or Injury Accidents	4
2.	Enter the average annual number of "After" improvement Fatal or Injury Accidents	0.95
3.	Subtract Line 2 from Line 1 (reduction in Fatal or Injury Accidents)	3.05
4.	Enter the average annual number of "Before" improvement PDO Accidents	29
5.	Enter the average annual number of "After" improvement PDO Accidents	11.42
6.	Subtract Line 5 from Line 4 (reduction in PDO Accidents)	17.58
7.	Add Line 6 to Line 3 (total accident reduction)	20.63

WAS ACCIDENT REDUCTION SIGNIFICANT ACCORDING TO TABLE 2? Yes ✓ No ___

8.	Enter the unit cost of Fatal or Injury Accidents	35,100
9.	Multiply Line 3 by Line 8 (the benefit of reducing Fatal and Injury Accidents)	107,055
10.	Enter the unit cost of PDO Accidents	4,000
11.	Multiply Line 6 by Line 10 (the benefit of reducing PDO Accidents)	70,320
12.	Add Line 9 to Line 11 (total benefit due to accident reduction)	177,375

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	177,375
2.	Enter the total cost	19,550
3.	Divide Line 1 by Line 2 to obtain the Benefit/Cost Ratio	9.07

FIGURE 17. **HAL SYSTEM EVALUATION WORKSHEET.**

TABLE 2. ACCIDENT REDUCTION REQUIRED FOR STATISTICAL SIGNIFICANCE.

Number of Accidents Occurring in the "Before" Period	Number of Accidents Reduced from "Before" to "After" Period *	Percent Accidents Reduced from "Before" to "After" Period *
5	3.68	73.6
6	4.03	67.2
7	4.35	62.1
8	4.65	58.1
9	4.94	54.9
10	5.20	52.0
11	5.46	49.6
12	5.70	47.5
13	5.93	45.6
14	6.16	44.0
15	6.37	42.5
16	6.58	41.1
17	6.78	39.9
18	6.98	38.7
19	7.17	37.7
20	7.36	36.8
21	7.54	35.9
22	7.72	35.1
23	7.89	34.3
24	8.06	33.6
25	8.23	32.9
26	8.39	32.3
27	8.55	31.7
28	8.70	31.1
29	8.86	30.6
30	9.01	30.0
31	9.16	29.5
32	9.31	29.1
33	9.45	28.6
34	9.59	28.2
35	9.73	27.8
36	9.87	27.4
37	10.01	27.1
38	10.14	26.7
39	10.27	26.3
40	10.40	26.0
41	10.53	25.7
42	10.66	25.4
43	10.79	25.1
44	10.91	24.8

* Minimum Change Required for Significance at the 95% Level of Confidence.

TABLE 2 (Cont'd). ACCIDENT REDUCTION REQUIRED FOR STATISTICAL SIGNIFICANCE.

Number of Accidents Occurring in the "Before" Period	Number of Accidents Reduced from "Before" to "After" Period *	Percent Accidents Reduced from "Before" to "After" Period *
45	11.03	24.5
46	11.16	24.2
47	11.28	24.0
48	11.40	23.8
49	11.52	23.5
50	11.63	23.3
55	12.20	22.2
60	12.74	21.2
65	13.26	20.4
70	13.76	19.7
75	14.24	19.0
80	14.71	18.4
85	15.17	17.8
90	15.61	17.3
95	16.03	16.9
100	16.45	16.5
105	16.86	16.1
110	17.25	15.7
115	17.64	15.3
120	18.02	15.0
125	18.39	14.7
130	18.76	14.4
135	19.11	14.2
140	19.46	13.9
145	19.81	13.7
150	20.15	13.4
155	20.48	13.2
160	20.81	13.0
165	21.13	12.8
170	21.45	12.6
175	21.76	12.4
180	22.07	12.3
185	22.37	12.2
190	22.67	11.9
195	22.97	11.8
200	23.26	11.6
300	28.49	9.5
400	32.90	8.2
500	36.78	7.4

* Minimum Change Required for Significance at the 95% Level of Confidence.

Step 4: The total monetary benefit achieved due to the reduction in accidents is then estimated by adding Line 9 and Line 11 to give the total shown on Line 12. The total benefit for the example in Figure 17 is:

$ 107,055 + $ 70,320 = $ 177,375

Step 5: Determine the total cost of making the improvements by adding the annual cost of the improvements, the annual cost of work and materials from the engineering and police departments, and any other indirect costs that were involved in implementing the improvements. The total of these costs for the example in Figure 17 is $19,550.

Step 6. Divide the total estimated benefits by the total annual costs for the improvements being evaluated. The resulting ratio will indicate how much benefit was received per dollar spent on making the traffic safety improvements. For the example the benefit/cost ratio is reported on the last line of the HAL System Evaluation Worksheet as 9.07 to 1.0.

IMPORTANCE OF THE HAL SYSTEM EVALUATION

The benefit/cost ratio determined by the above procedure is restricted to showing how the HAL System is benefiting the city for only the locations covered in the specified analysis year. Traffic safety projects completed many years ago are probably not subject to Before-After Analysis, and their continued benefits are not recognized in Figure 17. Thus, a benefit/cost ratio computed according to the procedure in Figure 17 may substantially underestimate the benefits being realized by the city and its motorists.

The HAL System evaluation provides an excellent documentation of the effectiveness of accident 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. Facts should be presented concerning manpower requirements, funds expended, and the benefits realized. Those locations which were improved should be described, and the results of improvements tabulated for easy review. Also, locations which experienced higher than average accident rates, 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.

GLOSSARY

Accident (Traffic Accident) - An unplanned event that results in the occurrence of a fatality, personal injury, and/or property damage.

Accident Rate - The number of accidents which occur during a specified period of time, divided by a measure of the extent of vehicular exposure over the same period; for intersections expressed as accidents per million entering vehicles, for mid-block sections expressed as accidents per 100 million vehicle miles traveled on the section.

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

Accident Severity - A measure of the seriousness of an accident or all accidents at a highway location. Accident severity usually is expressed in terms of number of fatalities, injuries, or property damage accidents.

Accident Type - Classification of the specific accident occurrence as related to the general movements of the involved vehicle(s). Examples of accident types are: right angle, rear-end, head-on, and fixed object.

Annual City-Wide Analysis - A procedure to identify high-accident locations using one to three years of accident 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. Unless otherwise stated, the period is a year.

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 an accident, the type and severity of accident, and any vehicles or pedestrians whose presence might have contributed to the accident. Collision diagrams are not drawn to scale, but represent the approximate accident 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 accident patterns and to relate the accident patterns to the roadway and operational factors.

Correctable Accidents - Accidents which could be reduced by means of 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 accidents.

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

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 cost-effectiveness, or B/C ratio, of a project by comparing the benefits derived and the costs incurred.

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

Eighty-Fifth (85th) Percentile Speed - That 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 accident number giving fatal and injury accidents more importance than property-damage-only accidents.

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

Fatal Accident - An accident event involving at least one fatality.

HAL System - The set of procedures provided in this manual for the identification, analysis and correction of high-accident locations.

Injury Accident - An accident event involving property damage, at least one injury, but no fatalities.

Intersection-Related Accident (Intersection Accident) - An accident that occurs as a result of the operation of an intersection.

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

Mid-Block Accident - An accident that is not related to any operations or events occurring at an intersection.

Non-Correctable Accidents - Accidents of a random nature 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 Accident (PDO) - An accident 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 safe sight distance required for a vehicle to stop along a roadway upon the driver sighting an object which will necessitate that the vehicle stop.

Technology Transfer Assistance Program (TTAP) - A program that provides service and assistance to local transportation agencies, offered by the Missouri Highway and Transportation Department with support from 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, such as a change in direction or speed, that places another user in jeopardy of a collision unless an evasive maneuver is undertaken.

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 accident data with vehicle, driver, and/or highway data to identify the causes of traffic accidents and the means of preventing them.

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

REFERENCES

1. "A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials, 1990.

2. "Roadside Design Guide," American Association of State Highway and Transportation Officials, 1989.

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

4. "AASHTO Maintenance Manual," American Association of State Highway and Transportation Officials, 1987.

5. "Local Highway Safety Studies - Users' Guide," Federal Highway Administration, July 1986.

6. "Local Highway Safety Improvement Program," Federal Highway Administration, July 1986.

7. "The Correction of Hazards on Urban Streets," Informational Report IR-043, Institute of Transportation Engineers, 1986.

8. Revised Statutes of the State of Missouri, Chapter 43, Section 250, (L. 1973 H.B. 536, par. 1; A.L. 1979 H.B. 167), page 217, 1986.

9. "Guidelines for Driveway Location and Design," Recommended Practice, Report RP-006B, Institute of Transportation Engineers, 1986.

10. "Determining Vehicle Change Intervals," ITE Recommended Practice, Report RP-016, Institute of Transportation Engineers, 1985.

11. "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals," American Association of State Highway and Transportation Officials, 1985.

12. "STARS-TRACE Traffic Report of Accidents for Small City Engineering: Users' Manual," Missouri Division of Highway Safety, Department of Public Safety, 1985.

13. "Guide for Erecting Mailboxes on Highways," American Association of State Highway and Transportation Officials, 1985.

14. "An Informational Guide for Roadway Lighting," American Association of State Highway and Transportation Officials, 1985.

15. "Effectiveness of Median Storage and Acceleration Lanes for Left-Turning Vehicles," ITE Informational Report IR-028, Institute of Transportation Engineers, 1984.

16. "Recommended Guidelines for Subdivision Streets," ITE Recommended Practice, Report RP-011A, Institute of Transportation Engineers, 1983.

17. "School Trip Safety Program Guidelines," ITE Recommended Practice Report RP-001-A, Institute of Transportation Engineers, 1984.

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

19. "Highway Drainage Guidelines," American Association of State Highway and Transportation Officials, 1982.

20. "Guide for Development of New Bicycle Facilities," American Association of State Highway and Transportation Officials, 1981.

21. Bunte, W., "Handbook of Traffic Engineering Practice for Small Cities," Missouri State Highway Commission, April 1979.

22. "Standard Highway Signs," FHWA, 1979, (Revised 1985).

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

24. "Guidelines for Skid Resistant Pavement Design," Association of State Highway and Transportation Officials, 1976.

25. J. Graham and J. Glennon, "Manual on Identification, Analysis and Correction of High Accident Locations," Missouri State Highway Commission, November 1975.

26. "Missouri Traffic Crashes," Missouri State Highway Patrol, Department of Public Safety, Annual.

Contact the Appropriate Agency Listed Below for Instructions on Obtaining Traffic Safety References:

American Association of State Highway and
Transportation Officials
444 N. Capitol Street, N.W. Suite 225
Washington, D.C. 20001

Institute of Transportation Engineers
525 School Street, S.W.; Suite 410
Washington, D.C. 20024-2729

Federal Highway Administration
Missouri Division Office
P. O. Box 1787
Jefferson City, Missouri 65102

Technology Transfer Assistance Program
Planning Division
Missouri Highway and Transportation Dept.
P. O. Box 270
Jefferson City, Missouri 65102

APPENDICES

APPENDIX A

SUPPLEMENTARY INFORMATION: NON-ACCIDENT-BASED PROCEDURES

By use of effective non-accident-based procedures, hazardous locations on local streets can often be identified before a large number of accidents occur. These procedures take advantage of information or complaints from individuals who report conditions they regard as needing repair, situations that could contribute to an accident, or suggestions to improve safety.

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. The system could 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.

2. A procedure must exist to prioritize complaints in the event there are numerous contacts 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 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 are: 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. Progress on any required corrective action should be recorded on a form designed to describe the complaint, its location, 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 them of the actions taken. Then, a permanent record should be kept, by location, to supplement the high-accident location countermeasure selection process.

It is important to maintain an effective non-accident-based system in order to have meaningful interactions with members of the community who are genuinely concerned about improving traffic safety. Furthermore, such a system is especially beneficial since it expands the capability of the city to detect traffic safety problems throughout the entire jurisdiction.

In addition to the general public, there are other sources for timely information on roadway problems and traffic safety suggestions. One very important source of this information would be the employees of the city. Not only should the patrol officers in the police department take an active role in this procedure; but in addition, city office personnel, firemen, building inspectors, and sanitation vehicle drivers should all prove to be valuable sources.

REFERENCES

1. "Local Highway Safety Improvement Program - Users' Guide," Federal Highway Administration, July 1986.

2. "Local Highway Safety Studies - Users' Guide," Federal Highway Administration, July 1986.

APPENDIX B

GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSES

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

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

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

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

REFERENCES

1. "Local Highway Safety Studies - User's Guide," Federal Highway Administration, July 1986.
2. "Highway Safety Engineering Studies - Procedural Guide," Federal Highway Administration, Report No. FHWA-TS-81-220, November 1981.
3. P. Box, "Accident Pattern Evaluation and Countermeasures," Traffic Engineering, pp. 38-43, August 1976.

TABLE B-1. GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSES.

ACCIDENT PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Right-angle collisions at unsignalized intersections	Restricted sight distance	Remove sight obstructions Restrict parking near corners Install warning signs * Install yield signs * Install stop signs * Install overhead flashing beacon * Channelize intersection Reconstruct approach to improve crossing angle at intersection Install/improve street lighting Install signals * Reduce speed limit on approaches **
	Large total traffic volume at location	Install stop signs * Install signals * Add traffic lanes Reroute through traffic
	High approach speed	Reduce speed limits on approaches ** Install rumble strips Install overhead flashing beacon *
Right-angle collisions at signalized intersections	Restricted sight distance	Remove sight obstructions Restrict parking near corners Install warning signs * Reduce speed limit on approaches **
	Poor visibility of traffic signals	Remove sight obstructions Install 12-inch signal lenses * Install signal visors or back plates Install advance warning devices * Install overhead or added signals * Reduce speed limit on approaches **
	Inadequate traffic signal timing or type of signal	Adjust yellow change interval Provide all-red clearance interval Adjust phase times and cycle time Install multi-dial controller Install traffic actuated signal Adjust minimum green or extension time Provide/improve progression through a set of signalized intersections Install signal speed sign *

* Refer to Manual on Uniform Traffic Control Devices for proper application and warrants.

** Spot speed study should be conducted to justify speed limit reduction.

TABLE B-1 (Cont'd). GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSE.

ACCIDENT PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Rear-end collisions at unsignalized intersections	Pedestrians crossing roadway	Improve crosswalk markings and/or signs* Illuminate crosswalk Relocate crosswalk
	Driver not aware of intersection	Install/improve warning signs * Install overhead flashing beacon *
	Slippery surface	Overlay pavement (friction course) Chip and seal or slurry seal approaches Groove pavement Provide adequate drainage and/or crown Reduce speed limit on approaches ** Use "SLIPPERY WHEN WET" sign (temporary)*
	Large volume of vehicles turning	Increase curb radii Construct left-turn or right-turn lanes Prohibit turns
Rear-end collisions at signalized intersections	Poor visibility of traffic signals	Remove sight obstructions Install/improve advance warning devices Install 12-inch signal lenses * Install signal visors and/or back plates Install additional/overhead signals * Reduce speed limits on approaches **
	Inadequate traffic signal timing	Adjust yellow change interval Provide all-red clearance interval Adjust phase time and cycle time Install multi-dial controller Install traffic-actuated signal Adjust minimum green or extension time Provide/improve signal progression
	Pedestrians crossing roadway	Improve crosswalk markings/signs * Provide pedestrian "WALK" phases Improve/install lighting at crosswalks
	Slippery surface	Overlay pavement (friction course) Chip and seal or slurry seal approaches Groove pavement Provide adequate drainage and/or crown Reduce speed limit on approaches ** Use "SLIPPERY WHEN WET" sign (temporary)*
	Unwarranted signals	Remove signals *
	Large volume of vehicles turning	Increase curb radii Construct left-turn or right-turn lanes Prohibit turns

* Refer to Manual on Uniform Traffic Control Devices for proper application and warrants.

** Spot speed study should be conducted to justify speed limit reduction.

TABLE B-1 (Cont'd). GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSE.

ACCIDENT PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Left-turn collisions at intersections	Large volume of left-turn traffic	Channelize intersection Install "STOP" signs * Provide signal with left-turn phase * Reroute left-turn traffic Prohibit left-turns Create one-way streets
	Restricted sight distance	Remove sight obstructions Install warning signs * Reduce speed limit on approaches **
Right-turn collisions at intersections	Inadequate turning path	Increase curb radii
	Restricted sight distance	Remove sight obstructions Add "NO TURN ON RED" signs if signalized* Reduce speed limit on approaches **
Pedestrian accidents at intersections	Sight distance inadequate	Remove sight obstructions Improve/install pedestrian crossings * Improve/install pedestrian crossing signs * Reroute pedestrian path/mid-block crossing
	Inadequate protection for pedestrians	Add pedestrian refuge islands Install pedestrian signals * Install pedestrian overpass or underpass
	Inadequate traffic signals	Add pedestrian "WALK" phase * Improve timing of pedestrian phase
	School crossing area	Remove parking from crosswalk location Remove sight obstructions Install school zone markings * Install school crossing signs * Install school speed limit signs * Install school crossing signals * Use school crossing guards Revise school route plan map * Construct overpass or underpass
Pedestrian accidents at locations between intersections	Driver has inadequate warning of frequent mid-block crossings	Prohibit parking Install warning signs * Reduce speed limit **
	Pedestrians walking on road or jay-walking	Install sidewalks Install "CROSS ONLY AT CROSSWALK" signs * Install pedestrian barriers
	Distance too long to nearest crosswalk	Install additional crosswalks and signs * Install pedestrian actuated signals *

* Refer to Manual on Uniform Traffic Control Devices for proper application and warrants.

** Spot speed study should be conducted to justify speed limit reduction.

TABLE B-1 (Cont'd). GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSE.

ACCIDENT PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Fixed object collisions	Objects located too near the roadway	Remove or relocate large objects Install object marker * Modify poles/posts with breakaway feature Eliminate poles by burying utility lines Install barrier curbs or guardrail
Fixed object collisions and/or vehicles running off road	Slippery pavement	Overlay pavement (friction course) Chip and seal or slurry seal approaches Groove pavement surface Provide adequate drainage or improve crown Reduce speed limit ** Use "SLIPPERY WHEN WET" sign (temporary)*
	Roadway design is no longer adequate for traffic conditions	Widen lanes and/or shoulders Relocate or remove islands Flatten side slopes Provide proper superelevation on curve Construct more gradual horizontal curve
	Poor delineation	Improve/install pavement markings Install roadside delineators or chevron alignment signs *
	Driver has inadequate warning of roadway alignment change	Install curve or turn warning sign * Install advisory speed plate on curve or turn warning sign * Install large arrow warning sign *
Sideswipe or head-on collisions between vehicles traveling opposite directions	Roadway design is no longer adequate for traffic conditions	Install/improve center line markings * Channelize intersections Widen lanes and/or shoulders Remove constriction as parked vehicles Install median divider Create one-way streets
Lane change, sideswipe or turning collisions between vehicles traveling in the same direction	Roadway design is no longer adequate for traffic conditions	Widen lanes and/or shoulders Remove constrictions as parked vehicles Channelize intersections Provide turning bay for high volume driveway Install continuous two-way left-turn lane Reduce speed limit **
	Inadequate traffic control devices	Improve/install pavement lane lines * Install advance route identification or street name signs *

* Refer to Manual on Uniform Traffic Control Devices for proper application and warrants.

** Spot speed study should be conducted to justify speed limit reduction.

TABLE B-1 (Cont'd). GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSE.

ACCIDENT PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Collisions with parked vehicles or vehicles being parked	High rate of parking turnover	Change from angle to parallel parking Provide short-term off-street parking Prohibit parking Restrict parking during rush hours Reroute through traffic Create one-way streets
	Roadway design is not adequate for traffic conditions	Widen lanes Change from angle to parallel parking Prohibit parking Restrict parking during rush hours Reroute through traffic Reduce speed limit on traveled way *
Collisions at driveways	Improperly located driveway	Regulate minimum spacing of driveways Regulate minimum corner clearance Move driveway to side street Combine adjacent driveways
	Left-turn vehicles	Install median divider Install continuous two-way left-turn lane Install protected left-turn bays
	Right-turn vehicles	Provide right-turn lanes Restrict parking near driveways Increase driveway width Widen through lanes Increase driveway curb radii
	Large volume of through traffic	Move driveway to side street Construct a local service road Reroute through traffic
	Large volume of driveway traffic	Signalize driveway Provide acceleration and/or deceleration lanes Widen and/or channelize driveway Construct additional driveway Change to one-way driveways
	Inadequate sight distance	Remove sight obstructions Restrict parking near driveway Install/improve lighting at driveway Reduce speed limit*
Pedestrian accidents at driveways	Sidewalk too close to roadway	Move sidewalk laterally away from street

* Spot speed study should be conducted to justify speed limit reduction.

TABLE B-1 (Cont'd). GENERAL COUNTERMEASURES FOR ACCIDENT PATTERNS AND THEIR PROBABLE CAUSE.

ACCIDENT PATTERN	PROBABLE CAUSE	GENERAL COUNTERMEASURE
Wet pavement accidents	Slippery pavement	Overlay pavement (friction course) Chip and seal or slurry seal roadway Groove pavement surface Reduce speed limit ** Use "SLIPPERY WHEN WET" sign (temporary)*
	Water ponding on roadway	Provide adequate drainage Improve roadway crown Remove turf or other drainage impediments from shoulder
	Inadequate pavement markings	Install raised/reflectorized pavement markers
Night accidents	Poor visibility	Improve/install street lighting Improve/install reflectorized signs Improve/install reflectorized pavement markers Remove distracting commercial lighting or other sources of glare
Collisions at railroad grade crossings	Inadequate sight distance	Remove sight obstructions Improve/install advance warning signs * Improve/install pavement markings * Install train actuated signals * Install overhead flashing lights * Install automatic crossing gates * Reconstruct crossing to provide improved crossing angle Construct grade separation
	Poor visibility	Improve/install crossing lighting Install larger reflectorized signs
	Slippery approaches	Improve drainage Install skid resistant surface
	Excessive speed	Reduce speed limits on approaches ** Reduce train speed through community

* Refer to Manual on Uniform Traffic Control Devices for proper application and warrants.

** Spot speed study should be conducted to justify speed limit reduction.

APPENDIX C

COLLECTION OF TRAFFIC DATA

I. INTERSECTION VOLUME STUDIES AND ENTERING ADT ESTIMATES

Intersection traffic counts are conducted for several reasons, one of the more important being to provide the information needed to estimate the entering Average Daily Traffic (ADT). When conducting an intersection traffic count, it is recommended practice to record the vehicle entering and departing paths at the location. Occasionally, it is necessary to classify vehicles by type, and to count pedestrians and cyclists.

Due to manpower and cost constraints, the counting period duration is limited and the counts are samples of the actual traffic volumes. The sampling period may range from 1 hour to 12 hours. Although mechanical or automated equipment is available for many counting applications, the HAL Manual emphasizes manual procedures.

A. WHAT TO COUNT

1. Unless otherwise directed, only vehicles entering the intersection are counted. When required, pedestrians and cyclists are tallied.

2. Each vehicle is tabulated according to the direction from which it approaches the intersection; and whether it turns right or left, or goes straight. A pedestrian is counted each time a crosswalk is used.

3. U-turns are counted as left turns.

4. Vehicle classifications that should be used are:

   a. Cars, vans, smaller trucks, pickup trucks, and motorcycles are usually counted as passenger vehicles.

   b. Larger trucks (six tires or more), semi-trailer or combination trucks, are counted as trucks.

   c. Buses (commercial) and school buses are noted separately.

Guidelines for detailed vehicle classification studies are available from the TTAP office. The TTAP office can also provide information on the MHTD community traffic counting program and community traffic maps.

B. TALLY SHEET

Vehicle volume and turning movement counts at intersections can be recorded manually using the Traffic Count Field Sheet shown in Figure C-1. The tally sheet has 12 rectangles for recording vehicle movements and 4 squares for recording pedestrian crossing activity.

INTERSECTION TRAFFIC COUNT FIELD SHEET [Form ITCFS]

N/S STREET LINCOLN DAY TUES DATE 5-23-89
E/W STREET THIRD TIME START 4:30 pm END 4:45 pm
OBSERVER JSJ WEATHER

P or (~~IIII~~): Passenger cars, pickups, vans
T: Trucks with six or more tires
B: Buses SB: School buses

North Arrow:

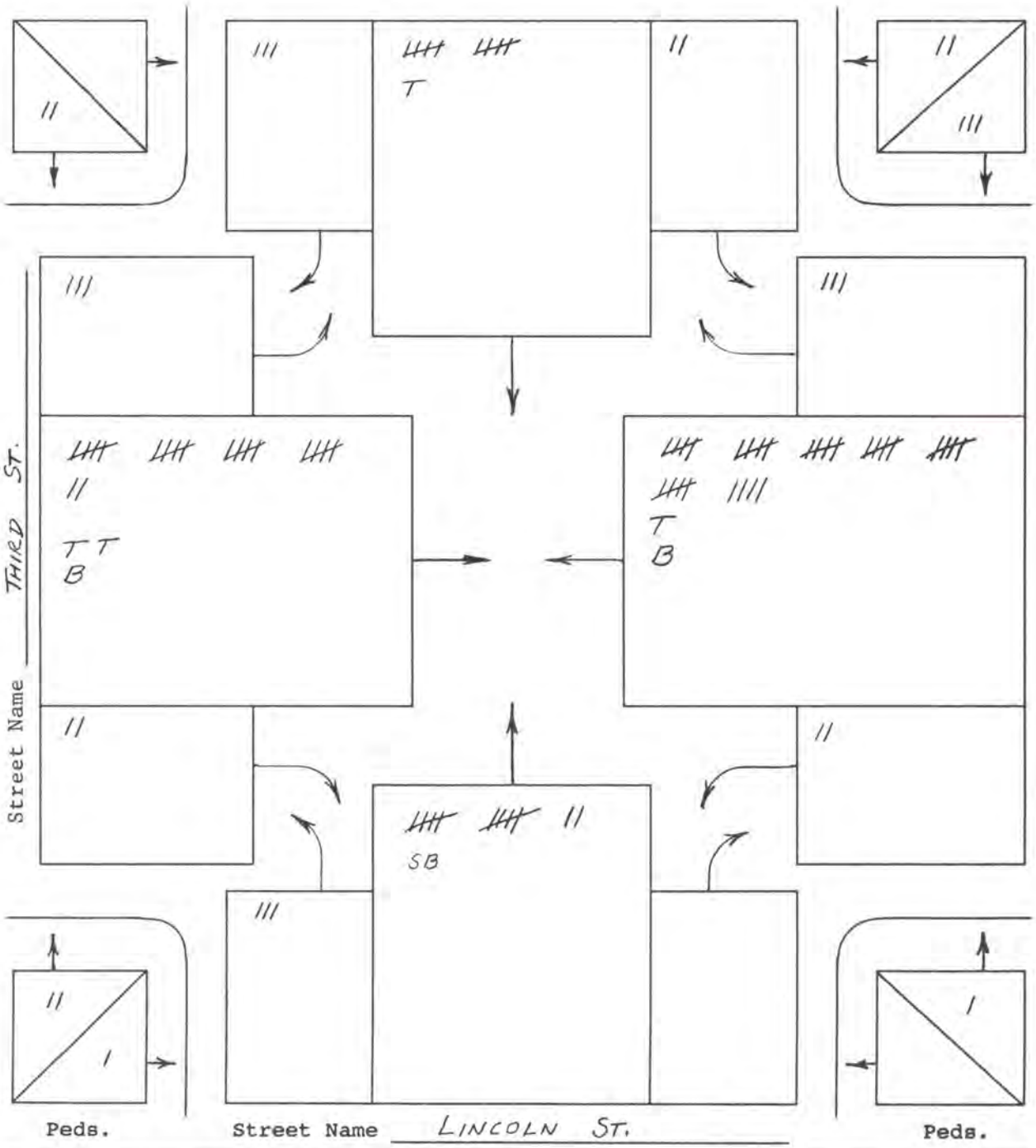


FIGURE C-1. INTERSECTION TRAFFIC COUNT FIELD SHEET.

Before starting the counts enter the street names, date, time, and other related information on the 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 a study.

To record pedestrians and vehicles use a tally system consisting of four vertical marks with every fifth mark placed diagonally across 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.

If any unusual events affect the traffic flow during the counting period, you must note these events and their duration. If an incident occurs that substantially disrupts traffic flow, the count should be stopped and conducted at another time.

C. SUGGESTED EQUIPMENT

- A watch with second hand
- Several pencils with erasers
- A pencil sharpener
- A clip board
- An accumulating register (optional)

D. PROCEDURES

A low-volume intersection can usually be counted by one observer. For most intersection counts two observers are required. When two persons are counting traffic at a four-leg intersection, they should be positioned in diagonally opposite quadrants. Each observer should tally vehicles entering on two approaches. The observers must be inconspicuous so traffic operations will not be affected by their presence.

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. It is recommended that data not be gathered on a weekend, a Friday, the day of a special event, or holiday.

E. COUNT SUMMARIES

The 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 Street and Third Street.

In this example, the counts were taken during a Tuesday evening peak hour. To arrive at the intersection entering ADT estimate, 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 are summed to form the "Intersection ADT Estimate."

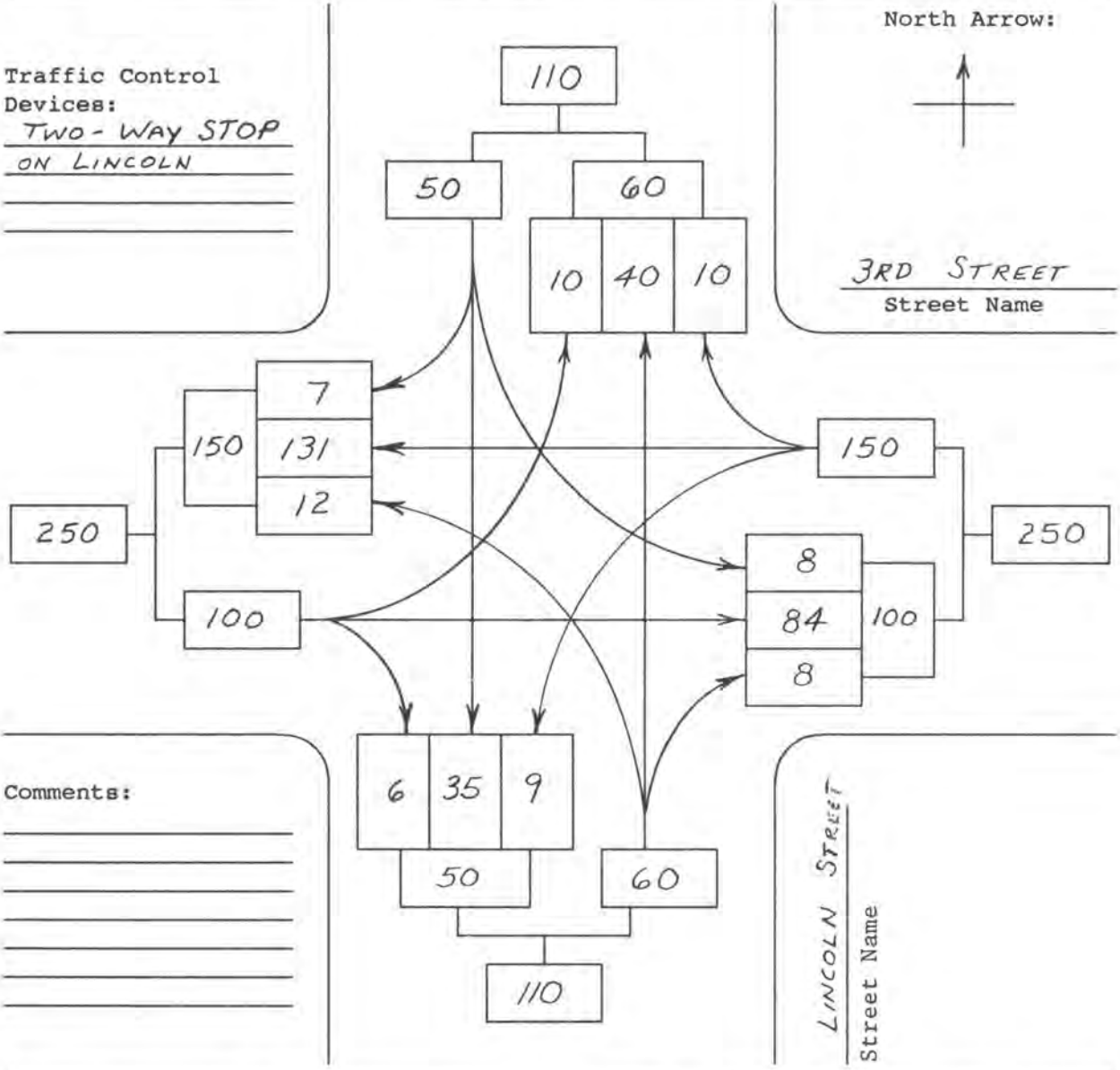
VEHICLE TURNING COUNT SUMMARY AND ADT ESTIMATE [Form TCSAE]

LOCATION 3RD STREET & LINCOLN OBSERVER JSJ

DAY TUES. DATE 5-23-89 TIME 4:30-5:30 PM WEATHER CLEAR

Traffic Control Devices:
TWO-WAY STOP ON LINCOLN

North Arrow:



Comments:

INBOUND APPROACH STREET NAME AND DIRECTION	INBOUND COUNT	ADJUSTMENT FACTOR *	AVERAGE DAILY TRAFFIC ESTIMATE
EASTBOUND ON 3RD	100	10	1,000
WESTBOUND ON 3RD	150	10	1,500
NORTHBOUND ON LINCOLN	60	10	600
SOUTHBOUND ON LINCOLN	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.

II. CONDUCTING SPOT SPEED STUDIES AND SETTING SPEED LIMITS

A spot speed study involves measuring 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.

A spot speed study should be performed when determining the appropriate speed limit, or when evaluating sight distance problems at intersections and other critical locations.

A. SELECTION OF STUDY LOCATION AND TIME

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

Spot speed studies should be performed in good weather and with normal traffic conditions. Usually, speed studies are conducted during off-peak hours. One method that is recommended is to sample for one or two hours at three times during the day. The three studies should be conducted between 9:00 am and 11:30 am; 1:30 pm to 4:00 pm; and 7:00 pm to 10:00 pm.

B. STUDY PROCEDURE

At least 100 vehicle speeds, and preferably more, should be measured during a spot speed study. On low-volume roads, observations might have to be obtained on more than one day to have the required minimum sample size.

Vehicles to be measured should be selected at random or according to a predetermined pattern so the data are not biased. The vehicle selection pattern should be decided before starting a field study. For instance, every third or fourth vehicle could be measured whenever possible.

Only the speeds of free-flowing vehicles should be recorded. Free-flowing vehicles are those whose speed is not influenced by preceding vehicles. Trucks should be selected for speed observation in proportion to their presence in traffic.

Observers should be careful to avoid the temptation to measure only the fastest vehicles. The recording of observations should be done by tallying the number of vehicle speeds that occur within a certain speed interval, such as a two-mph interval.

C. DATA ANALYSIS

Traffic speed data may be summarized for analysis purposes as shown in Table C-1. The example speed data in this table contains 120 observations. The observations are grouped into 2-mph intervals, and the intervals range from 20 mph to 41.9 mph, as listed in the first column.

TABLE C-1. SPOT SPEED STUDY DATA ANALYSIS.

Speed Interval in mph	Number Observed	Cumulative Number Observed	Percent Observed	Cumulative Percent Observed	10-mph Pace
20.0 to 21.9	3	3	2.5	2.5	
22.0 to 23.9	3	6	2.5	5.0	
24.0 to 25.9	6	12	5.0	10.0	
26.0 to 27.9	12	24	10.0	20.0	12
28.0 to 29.9	18	42	15.0	35.0	18
30.0 to 31.9	27	69	22.5	57.5	27
32.0 to 33.9	24	93	20.0	77.5	24
34.0 to 35.9*	13	106	10.8	88.3*	13
36.0 to 37.9	8	114	6.7	95.0	
38.0 to 39.9	4	118	3.3	98.3	
40.0 to 41.9	2	120	1.7	100.0	

* The 85th percentile is in the interval from 34.0 to 35.9 mph.

The number of vehicle speeds observed in each interval is recorded in the second column, while the cumulative number of observations appears in the third column. The fourth column shows the percent of observations recorded in each 2-mph speed interval. The fifth column is the cumulative percent of observations, with the last percent being 100%.

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

The 85th percentile speed is the speed below which 85% of the observed vehicles travel. The 85th percentile speed is given primary importance in speed zoning practice for communities. Traffic engineers generally adopt this criteria assuming that the majority of reasonable drivers will travel at a speed that is safe and proper for existing conditions. This practice does recognize that a few drivers will be operating somewhat in excess of the speed considered appropriate by a large majority of drivers.

For the data in Table C-1, the 85th percentile speed 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 upper limit of the 32.0 to 33.9 mph interval was reached; however 88.3 % of the observations were accumulated when the upper limit of the 34.0 to 35.9 mph interval was reached. This provides a good indication that a 35 mph speed limit would be appropriate.

The 10-mph pace is the 10-mph range of speeds which 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.

The last column in Table C-1 identifies the 10-mph pace. For this speed study the 10-mph pace is between 26.0 mph and 35.9 mph since that 10-mph range contains the highest number of vehicles:

$$12 + 18 + 27 + 24 + 13 = 94 \text{ vehicles in 10-mph pace}$$

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

Occasionally, studies such as vehicle test runs along the street or highway are performed in order to establish a proper speed limit. Several other factors to consider when setting speed limits are:

- Accident experience
- Presence of restricted sight distances
- Design speed
- Roadway surface characteristics
- Presence of driveways
- Extent of turning movements
- Parking conditions
- Large numbers of pedestrians

It is important that a speed limit not be established at too high or at too low of a speed. Also, speed limits must be posted in increments of 5 miles per hour using speeds such as 30, 35, or 40 mph, and NOT at unusual limits as 34 mph.

REFERENCES

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

2. Bunte, W., "Handbook of Traffic Engineering Practice for Small Cities," Missouri State Highway Commission, 1979.

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

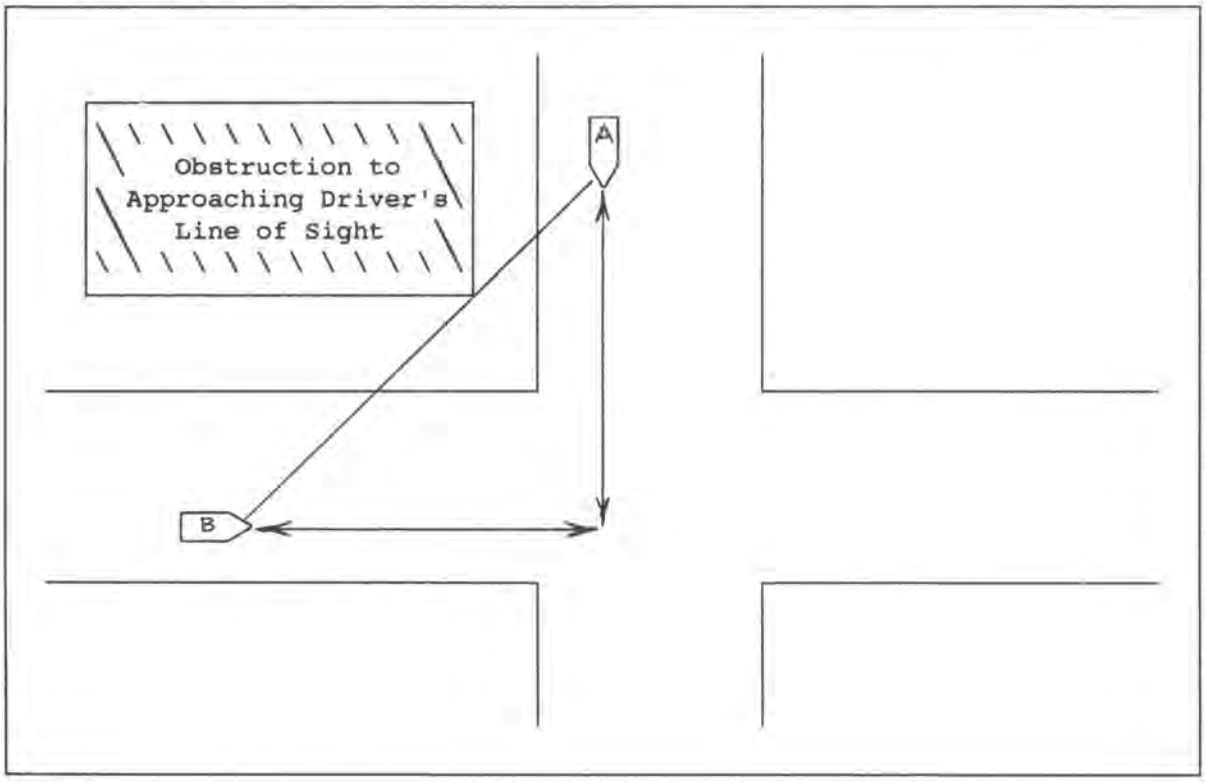
III. INTERSECTION SIGHT DISTANCE STUDIES

A. SIGHT DISTANCE STUDIES FOR INTERSECTIONS WITH YIELD SIGNS OR NO CONTROL

Sight distance studies for intersections with YIELD signs or no control are essentially sight triangle analyses. A vehicle driver approaching an intersection where directional priority is not assigned (no control) should have an unobstructed view of the entire intersection and sufficient lengths along the cross road to avoid a collision. Therefore, it is necessary that an unobstructed line of sight be provided that allows a driver to detect any vehicle approaching on a conflicting path.

The required sight distances for safe operation when approaching an intersection are those 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.



The determination of the safe distances for the respective speeds of approaching vehicles should be based on required stopping sight distances listed in Table C-2. For example, if the 85th percentile speed of Vehicle A was 30 mph, and that of Vehicle B was 45 mph, then the line of sight drawn in Figure C-3 must be unrestricted when Vehicle A is 200 feet from the intersection and Vehicle B is 385 feet from the intersection.

TABLE C-2. RECOMMENDED STOPPING SIGHT DISTANCES.

Posted Speed, 85th Percentile Speed, or Design Speed, in mph	Stopping Sight Distance, in feet
20	110
25	150
30	200
35	250
40	315
45	385
50	465
55	540

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

1. Determine the minimum required stopping sight distance from Table C-2 for all intersecting roadways using the largest of either the 85th percentile speed, the speed limit, or the design speed on each approach.

2. Provide an observer with a sighting rod that is 3.5 feet high (represents driver eye height) and an assistant with a target rod 4.25 feet high represents top of a car). The observer and assistant should position themselves on different approaches at the appropriate stopping distance from the intersection.

3. With both rods held vertically on the road at the respective stopping distances, the observer sighting over the top edge of the sighting rod should determine if the top of the target rod is visible. If the target rod is visible, the visibility triangle is satisfactory for that 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 does become visible to the observer. This position should be marked and the distance to the intersection measured. The safe speed for that approach can then be determined by referring to the stopping distances listed in Table C-2.

5. The intersection sight triangle study should be repeated for all approach legs, considering traffic approaching from both the left and the right.

6. Sight distance measurements should be conducted during, or at least with consideration given to, possible short-term adverse conditions. Trees, shrubs, and parked cars are examples of these special factors.

7. In those circumstance where 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, the speed of one or both roadways should be reduced to be compatible with the safe approach speed, or a STOP sign installed.

B. SIGHT DISTANCES ON CONTROLLED APPROACHES

Instructions for locating intersection traffic control devices such as STOP signs or YIELD signs are provided in the MUTCD. In the event that the visibility of a STOP sign or YIELD sign at any 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 sight 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 signs are primarily for the benefit of the driver who is unacquainted with the road, it is important that care 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.

TABLE C-3. A GUIDE FOR ADVANCE WARNING SIGN PLACEMENT.

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 obstructions.

C. DEPARTURE FROM TWO-WAY STOP CONTROL INTERSECTION APPROACHES

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 while not risking a collision with a vehicle that may appear just after the driver decides to proceed.

A car waiting at a STOP sign may be assumed to be positioned so the vehicle front bumper is 10 feet back from the near edge of pavement on the cross road. When making field observations to determine if the line of sight from a stopped car is adequate, sight distance must be measured from a driver eye height of 3.50 feet to the top of an object representing an oncoming car that is 4.25 feet above the pavement. A sighting rod 3.50 feet high and a target rod 4.25 feet high should be used when performing these measurements. The sight distances required for a passenger car to safely turn onto or cross a two-lane highway are in Table C-4.

TABLE C-4. SIGHT DISTANCES REQUIRED FOR A PASSENGER CAR STOPPED AT AN INTERSECTION TO CROSS OR TURN ONTO A 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 design speed to 85% of design speed.

If it is determined that a safe sight distance does not exist along a certain approach, then corrective measures should be taken to improve the sight distance, provide warnings to approaching drivers, or to reduce the major roadway traffic speeds.

REFERENCES

1. "Local Highway Safety Studies - Users' Guide," Federal Highway Administration, July 1986.

2. "A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials, 1990.

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

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

IV. 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 a change in direction or speed, causes the other user to make a sudden evasive maneuver, as swerving or braking, to avoid a collision.

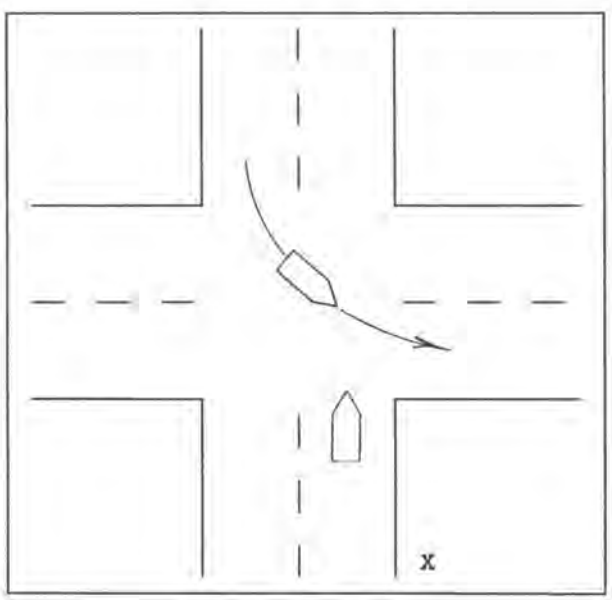
A secondary traffic conflict occurs when the second vehicle makes an evasive maneuver, placing another road user (a third vehicle) in danger of a collision. Generally, the road users are motorists, but pedestrians and cyclists may also be included.

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 not dealt with in a timely and appropriate manner, the result of a traffic conflict is frequently an accident. It is important to recognize that "near-miss" situations occurring without braking or evasive maneuvers are also considered traffic conflicts.

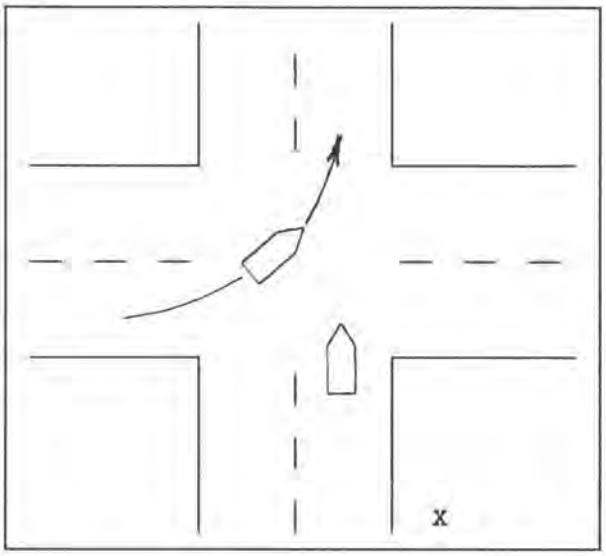
A. TRAFFIC CONFLICT TYPES

A general knowledge of traffic conflict types is necessary before an observer conducts an on-site conflicts study. The illustrations in this appendix show examples and provide definitions pertaining to the types of traffic conflicts most likely to be observed. In each illustration, the letter "X" is used to identify the position of the observer.



OPPOSING LEFT-TURN CONFLICT:

Occurs when an oncoming vehicle makes a left turn, placing a another vehicle going in the opposing direction in danger of a head-on or broadside collision.

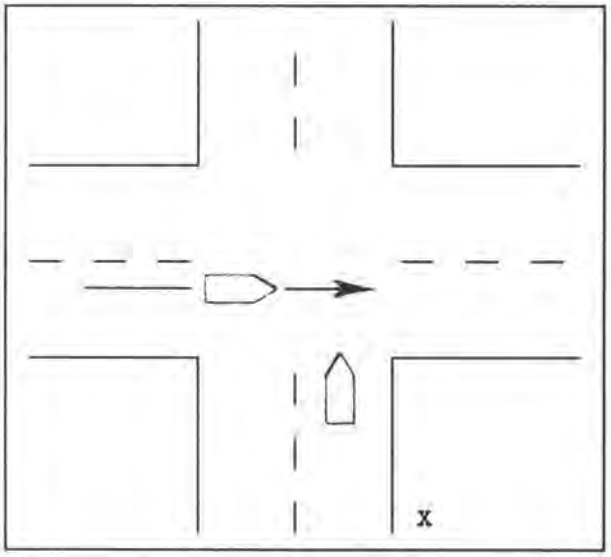


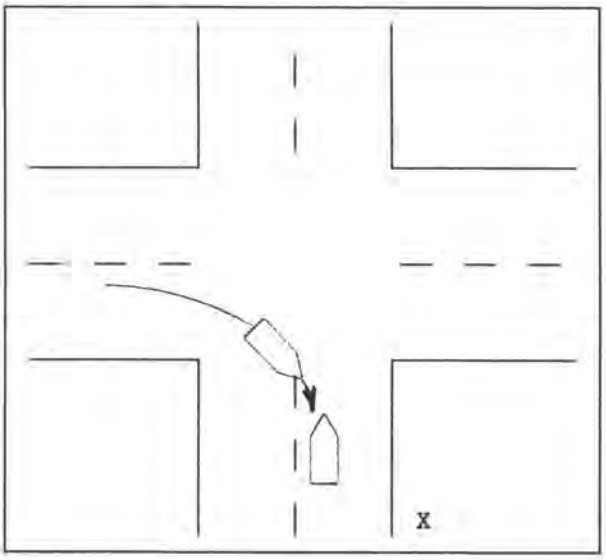
LEFT-TURN, CROSS-TRAFFIC
FROM LEFT CONFLICT:

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.

THROUGH, CROSS-TRAFFIC
FROM LEFT CONFLICT:

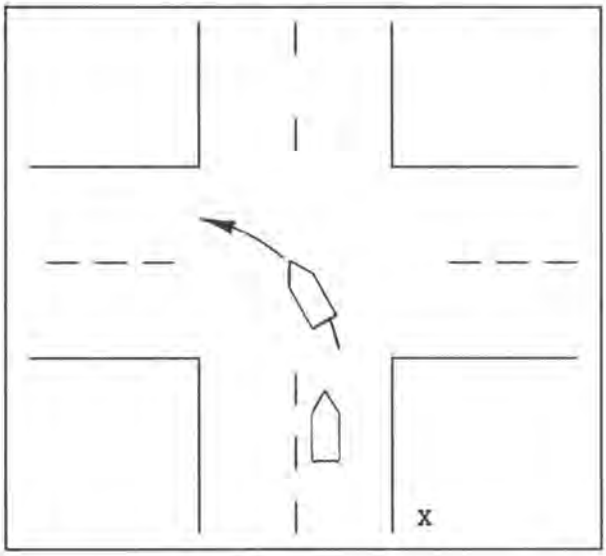
Occurs when a vehicle on the left hand cross street crosses in front of a second vehicle on the main street placing it in danger of a broadside collision.





RIGHT-TURN CROSS-TRAFFIC
FROM LEFT CONFLICT:

Occurs when a vehicle on the left hand cross street turns right across the center of the main street roadway and into an opposing lane, placing the vehicle in that lane in danger of a collision. Note, the first driver must cross the centerline for a conflict to exist.

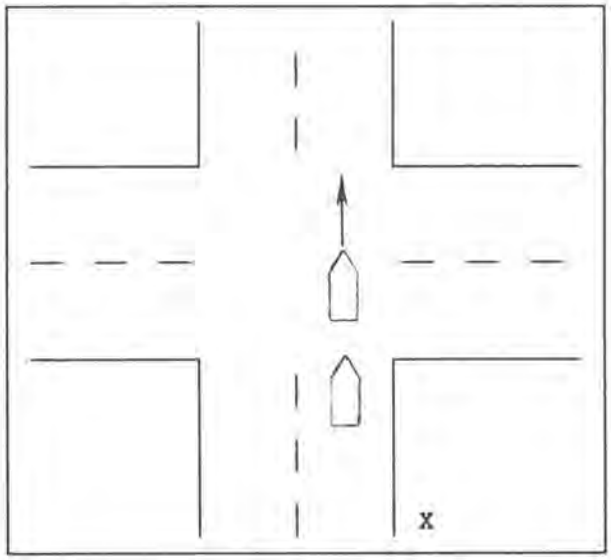


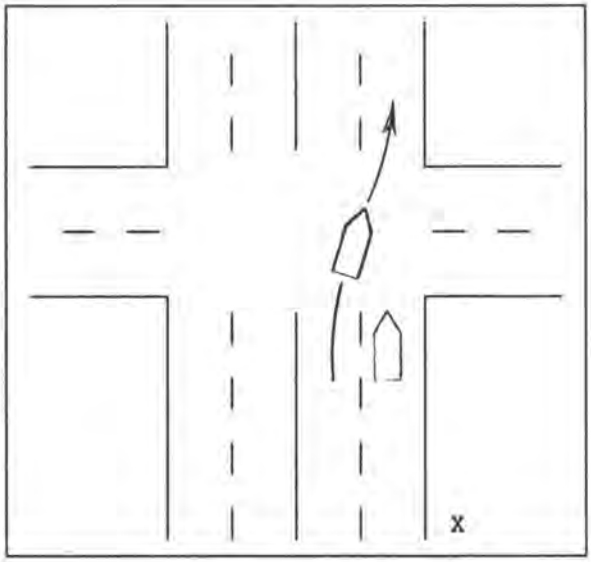
LEFT-TURN, SAME-DIRECTION CONFLICT:

Occurs when the first vehicle slows to make a left turn thus placing a second, following vehicle in danger of a rear-end collision.

SLOW VEHICLE, SAME-DIRECTION CONFLICT:

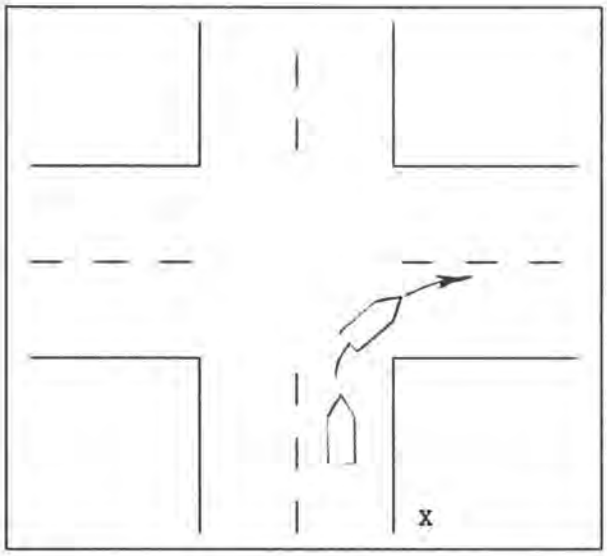
Occurs when the first vehicle slows while approaching or passing through an intersection, placing a second, following vehicle in danger of a rear-end collision.





LANE-CHANGE, SAME-DIRECTION CONFLICT:

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.

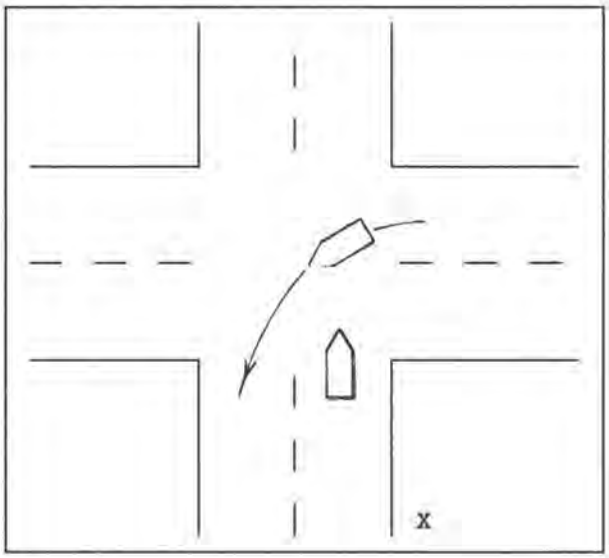


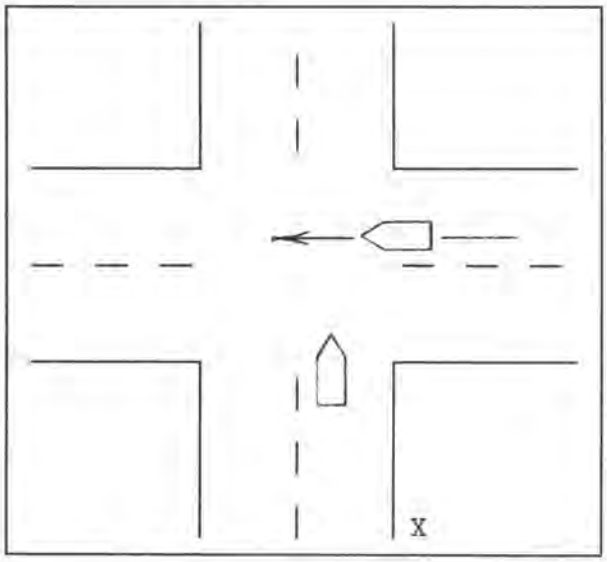
RIGHT-TURN SAME-DIRECTION CONFLICT:

Occurs when the first vehicle slows to make a right turn, thus placing the second, following vehicle in danger of a rear-end collision.

LEFT-TURN, CROSS-TRAFFIC FROM RIGHT CONFLICT:

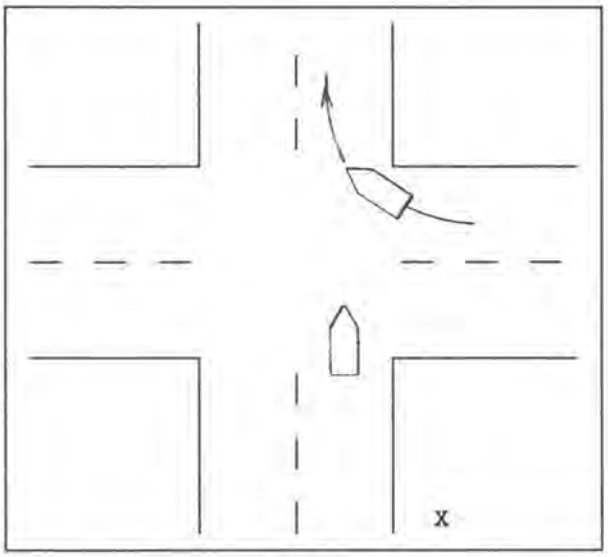
Occurs when a vehicle on the right hand cross street makes a left turn, placing a second vehicle in danger of having a broadside collision with the turning vehicle.





THROUGH, CROSS-TRAFFIC FROM RIGHT CONFLICT:

Occurs when a 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.

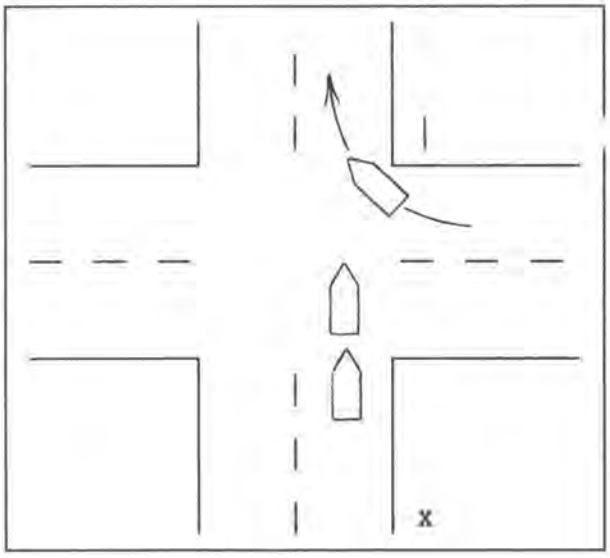


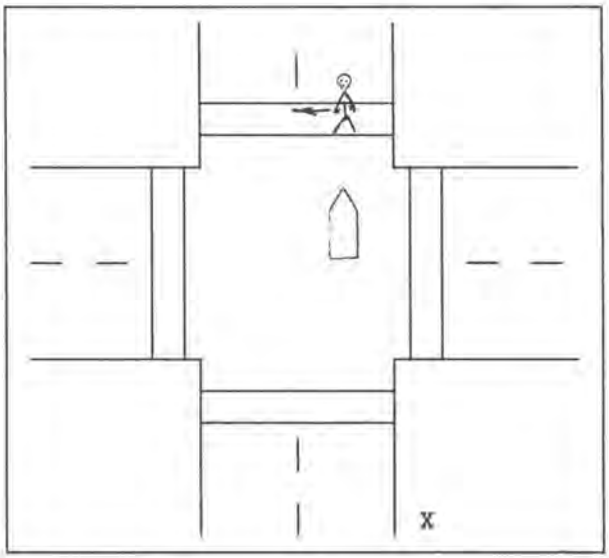
RIGHT-TURN, CROSS-TRAFFIC FROM RIGHT CONFLICT:

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.

SECONDARY TRAFFIC CONFLICT EXAMPLE: RIGHT-TURN CROSS-TRAFFIC FROM RIGHT

Same as above, except a third vehicle is involved and it is in danger of colliding with the rear end of the vehicle it is following.





PEDESTRIAN CONFLICT:

Occurs when a pedestrian crosses in front of a vehicle creating a possible collision situation. 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 pedestrians have the right-of-way as on a "WALK" phase.

B. THE TRAFFIC CONFLICT SUMMARY SHEET

The traffic conflict sheet in Figure C-4 is a general purpose form that may be used for recording and summarizing conflict counts. Each conflict classification has a separate column for recording observations. The last column is provided for conflicts with pedestrians, cyclists, or vehicles emerging from access points near the intersection.

All heading information should be filled out prior to beginning the conflicts study. The diagram in the upper right hand corner displays the approach leg numbering system. For example, traffic approaching the site from the north is on leg 1, traffic from the east is on leg 3, etc. A separate form should be used for each leg observed at the intersection.

C. COORDINATING THE TRAFFIC CONFLICT STUDY

A traffic conflict study includes making conflict counts along with collecting other data needed to make a complete study of the location. This auxiliary data may include: intersection condition diagram, on-site observation report, traffic volume counts, and sight distance studies.

D. TRAFFIC CONFLICT STUDY TEAM

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

E. OBSERVER LOCATIONS

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

Since conflicts are identified by braking and weaving actions it is necessary to place the conflicts observer sufficiently far back on the approach so all possible braking and weaving movements will be seen. A distance of 200 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 street whenever 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 to oncoming motorists. In all instances, the observers must not use a vehicle that could be recognized as a police or other official car.

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.

LOCATION _____ DATE _____

OBSERVER _____ DAY _____ LEG NUMBER _____

[C = CONFLICT SC = SECONDARY CONFLICT] TIME OF STUDY: FROM _____ TO _____

8 1=N 2
7 3
6 5 4

TIME	OPPOSING		FROM LEFT						SAME DIRECTION								FROM RIGHT						OTHER CONFLICTS	
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
____																								
____																								
____																								
____																								
TOTAL																								
TOTAL C + SC																								

COMMENTS _____

FIGURE C-4. INTERSECTION TRAFFIC CONFLICT SUMMARY.

F. 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 is a 10-hour counting day extending from 7:30 am to 12:00 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, the initial 20 minutes are allocated to data gathering and the remaining 10 minutes are available for summarizing data, adding any helpful notations to the forms, and changing observation positions.

G. 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 accident patterns for the location. The traffic conflict data can then be used to answer safety and operational problems, to recommend corrective measures, or to show the effectiveness of improvements already implemented.

REFERENCES

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

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

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

APPENDIX D

GENERAL GUIDELINES FOR SEVERAL TRAFFIC SAFETY IMPROVEMENTS

Appendix D contains general guidelines for the use of traffic safety improvements frequently considered by local jurisdictions. This appendix is not intended to be a substitute for a thorough evaluation of possible improvements at any high-accident location. Prior to discussing these guidelines for safety improvements, the differences between "Warrants" and "Guidelines" will be reviewed, and comments will be presented on accident reduction factors and consistency of traffic control device applications.

WARRANTS

Warrants are specific criteria that are typically applied in reaching decisions on the use of traffic control devices or certain types of safety improvements. The MUTCD provides warrants for several types of devices, such as the conditions justifying traffic signal installation. Warrants may be based on accident experience, but other factors like traffic volume are frequently involved.

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 substantial engineering judgment is required for decisions to implement improvements. Guidelines reflect previous experiences where specific improvements have proven to be beneficial to motorists and cost-effective under the prevailing conditions.

Several guidelines in Appendix D include suggested thresholds for improvements based on accident experience. It must be remembered that the accident experience at a site is due to several factors and any improvement being considered is only one of many that might possibly be implemented.

An economic analysis should be performed to determine the feasibility of a potential improvement. The guideline serves only to indicate the general suitability of the improvement.

ACCIDENT REDUCTION FACTORS

The Guidelines on Access Control in Appendix D, as well as Appendix G in the HAL Manual, contain accident reduction factors. Accident reduction factors are used to estimate the change in accident experience to be expected from installing a specific improvement.

Most accident reduction factors listed in the HAL Manual are based on studies or evaluations of improvements at locations that were identified as high-accident locations. If these accident reduction factors are applied to improvements being considered for locations having no unusually high accident experience, it is unlikely that there will be any significant reduction in the accident experience at the location.

CONSISTENCY

Changes in the driving environment must be implemented with considerable forethought and a high degree of caution. Often, the application of a countermeasure results in a "spot improvement" focused on deficiencies that have lead to the location experiencing many accidents. Spot improvements often will improve roadway and control device consistency by eliminating local inconsistencies that may have existed for many years.

A countermeasure could be a traffic control device that is not very frequently used. If the countermeasure is applied consistently according to MUTCD standards, there should be little or no difficulty with acceptance by motorists. 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.

I. ACCESS CONTROL IMPROVEMENTS

As major streets and highways in a community experience increasing traffic volumes, the land immediately next to the roadway becomes more and more attractive for commercial and business development. Each of these developments attempts to achieve the most convenient access it can possibly obtain to the street. Often this results in construction of a large number of poorly spaced and inadequately designed driveways. This is inevitably followed by serious negative consequences in terms of traffic delays, disruptions to the traffic stream, and accidents on the major road.

The presence of numerous driveways along a major street creates a situation which generally worsens as the volume grows and driveway use increases. Vehicles intending to use the driveways create substantial speed differentials in the traffic flow as they decelerate or stop unexpectedly in a through lane. Rear-end collisions increase noticeably due to this speed differential. Furthermore, accidents involving vehicles turning left to enter or exit the driveways occur more frequently.

Access control, or management of access to roadside developments, involves the application of both roadway and driveway improvements. These improvements are usually preferred rather than resorting to the highly expensive alternative of relocating the roadway as a by-pass to avoid the congested area.

One category of access control improvements consists of modifications to the roadway and its median. Left-turn channelization, the installation of a continuous two-way left-turn median lane, and median barriers are examples of this category.

The other category of access control improvements pertains to the design and spacing of driveways, as well as changes in the type of traffic control devices to be used at the driveway. These improvements involve widening driveways, converting to one-way driveways, combining driveways, or improving traffic control.

Accident levels which indicate the need for access improvements are available, but they should not be regarded as being applicable to all situations. Each roadway, or specific location, must be evaluated with due consideration given to highway function, traffic speeds, placement of driveways relative to each other, and available sight distances.

Tables D-1 and D-2 contain minimum accident rates and numbers which, if exceeded, would justify a detailed evaluation of accident data and a review of possible route or point improvements. If the existing roadway and driveway volumes are high, or if the accident experience is high at a particular driveway, the MUTCD warrants for traffic signal installation should also be reviewed.

The accident reduction to be expected from several types of access control improvement is shown in Table D-3. This table describes the countermeasure, its general effects, and the accident reduction that may be anticipated. Table D-3 clearly shows that the accident reduction factors for access improvements cover a wide range of values 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 below.

REFERENCES ON ACCESS CONTROL IMPROVEMENTS

1. J. Glennon, et.al., "Technical Guidelines for the Control of Direct Access to Arterial Highways," Federal Highway Administration, Report Nos. FHWA-RD-76-85 thru 87, August 1975.

2. H. Marks, "Protection of Highway Utility," Transportation Research Board, NCHRP Report 121, 1971.

3. V. Stover, et.al., "Guidelines for Medial and Marginal Access Control on Major Roadways," Transportation Research Board, NCHRP Report 93, 1970.

4. J. Flora and K. Keitt, "Access Management for Streets and Highways," Federal Highway Administration, Report No. FHWA-IP-82-3, June 1982.

5. "Guidelines for Driveway Design and Location," Institute of Transportation Engineers, 1985.

6. V. Stover and F. Koepke, "Transportation and Land Development," Institute of Transportation Engineers, 1988.

TABLE D-1.

ACCESS CONTROL: ACCIDENT THRESHOLDS FOR ROUTE IMPROVEMENTS.

Density of Roadside Development (Driveways per Mile)	Annual Number of Accidents per Mile		
	Highway Volume (ADT)		
	Less than 5000	5000 to 15000	More than 15000
Less than 30	3.8	7.4	11.0
30 to 60	11.3	22.1	32.9
More than 60	18.8	36.8	54.8

TABLE D-2.

ACCESS CONTROL: ACCIDENT THRESHOLDS FOR DRIVEWAY IMPROVEMENTS.

Driveway Volume (ADT)	Annual Number of Accidents		
	Highway Volume (ADT)		
	Less than 5000	5000 to 15000	More than 15000
Less than 500	0.26	0.45	0.62
500 to 1500	0.63	1.10	1.50
More than 1500	0.97	1.70	2.30

TABLE D-3.

ACCIDENT REDUCTION ESTIMATES FOR ACCESS CONTROL AND CHANNELIZATION COUNTERMEASURES.

COUNTERMEASURE	EFFECTS	ACCIDENT REDUCTION FACTORS			
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 cause circuitous travel to reach some destinations.	Annual Accident Reduction per Mile			
			Highway Volume (ADT)		
		Number of Commercial Driveways per Mile	Less than 5000	5000 to 15000	More than 15000
		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 accidents. This countermeasure is very effective on roadways that have closely spaced drives with a somewhat uniform density of left turns.	Annual Accident Reduction per Mile			
			Highway Volume (ADT)		
		Number of Commercial Driveways per Mile	Less Than 5000	5000 to 15000	More than 15000
		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	A deceleration lane will reduce rear-end collisions since right-turn vehicles may reduce speed after leaving the through lane. An acceleration lane will allow right turn vehicles leaving the drive to merge with through traffic at a more compatible speed.	Annual Accident Reduction per Driveway			
			Highway Volume (ADT)		
		Driveway Volume (ADT)	Less than 5000	5000 to 15000	More than 15000
		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

TABLE D-3 (Continued).

ACCIDENT REDUCTION ESTIMATES FOR ACCESS CONTROL AND CHANNELIZATION COUNTERMEASURES.

COUNTERMEASURE	EFFECTS	ACCIDENT REDUCTION FACTORS
Improve Sight Distance at Driveway Exits by Removing Parking from Traveled Way, Either Totally or Partially	Adequate sight distance at exits will provide drivers with an improved view of oncoming traffic and will make it easier for them to select a safe gap for entry onto the roadway. Physical sight obstructions such as shrubbery should also be removed.	Annual Accident Reduction per Mile of Parking Removed

Number of Commercial Driveways per Mile	Highway Volume (ADT) Less than 5000	5000 to 15000	More than 15000
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 accidents. Driveways must be marked and signed properly to avoid wrong-way use.	Annual Accident Reduction per Driveway

Driveway Volume (ADT)	Highway Volume (ADT) Less Than 5000	5000 to 15000	More than 15000
Less than 500	0.28	0.50	0.68
500 to 1500	0.70	1.22	1.66
More than 150	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 and thereby protects them from rear-end collisions. The closing of a median opening is a restrictive measure that should be used only if the driveway left-turn demand is low, as less than 100 vehicles per day.	Annual Accident Reduction per Driveway

Driveway Volume (ADT)	Highway Volume (ADT) Less than 5000	5000 to 15000	More than 15000
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

II. FLASHING BEACONS

A Flashing Beacon is a supplementary traffic control device that may be used with other devices for additional warning 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
- Intersection Control Beacon

A. HAZARD IDENTIFICATION BEACON

A Hazard Identification Beacon flashes only yellow indications and it shall be used only to supplement an appropriate warning or regulatory sign or marker. Typical applications of a Hazard Identification Beacon are:

- Where obstructions are in or immediately adjacent to the roadway
- Supplemental to advance warning signs
- At midblock crosswalks
- At intersections where warning is required
- To supplement certain regulatory signs

B. SPEED LIMIT SIGN BEACON

A Speed Limit Sign Beacon flashes only yellow indications and is used with either a fixed or variable speed limit sign. A flashing speed limit beacon (with an appropriate accompanying sign) may be used emphasize that the speed limit shown on the sign is in effect.

C. STOP SIGN BEACON

A Stop Sign Beacon flashes only red indications and it is mounted above the STOP Sign. The Stop Sign Beacon may be especially helpful in locations where surrounding developments and/or commercial lights divert motorists attention away from the STOP Sign. This type of beacon should also be considered where a STOP Sign is not immediately visible to the approaching driver due to vertical or horizontal roadway alignment.

D. INTERSECTION CONTROL BEACON

An Intersection Control Beacon is suspended over the center of an intersection so it is visible from all approaches. At an intersection with 4-way stop control the beacon flashes red to all approaches. At an intersection with 2-way stop control the beacon flashes red to the minor approaches, while flashing yellow to the major approaches that are not required to stop. Intersection Control Beacons are intended for use at intersections where volumes or physical conditions do not yet justify conventional traffic signals, but where high accident rates indicate a special hazard exists. The MUTCD does not state warrants for use of an

Intersection Control Beacon. However, a previous report (Ref. 1) provides the following suggested warrants for considering flashing beacons at 4-leg intersections:

1. Four or more left-turn plus right angle accidents in one year, or

2. Six or more left-turn plus right angle accidents in two years.

When one of the above warrants is satisfied, the type of intersection control can then be determined from the following:

1. If the minor road entering volume divided by the major road entering volume gives a result of 0.50 or less, a red-yellow flashing beacon with 2-way stop control should be considered.

2. If the minor road entering volume divided by the major road entering volume gives a result greater than 0.50, a red-red flashing beacon with 4-way stop control should be considered.

A recent study (Ref. 2) of Intersection Control Beacon installations presented the following important suggestions concerning this type of traffic control device:

1. 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.

2. 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 cross road traffic does not stop.

It is recommended that an Intersection Control Beacon be installed only after a proper traffic engineering study has been performed. This service may be requested through your nearest MHTD District Office as a part of the Traffic Engineering Assistance Program.

REFERENCES ON FLASHING BEACONS

1. "Evaluation of Minor Improvements: Part 1 - Flashing Beacons," Traffic Department, State of California Transportation Agency, 2nd Ed., 1967.

2. J. Hammer and E. Tye, "Overhead Yellow-Red Flashing Beacons," Division of Traffic Engineering, California Department of Transportation, Report No. FHWA/CA/TE-87/01, 1987.

3. "Synthesis of Safety Research Related to Traffic Control and Roadway Elements," FHWA-TS-82-232, Federal Highway Administration, 1982.

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

III. LEFT-TURN CHANNELIZATION

Channelization on streets and highways involves the application of pavement markings, or the construction of raised curbs and traffic islands to more effectively and safely guide drivers through a location. There are many possible ways in which channelization might be utilized, but the two applications that are often found in smaller communities are:

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

Other examples of channelization are right-turn lanes, channelization to improve the angle of intersection between crossing traffic streams, and islands shaped to deter wrong-way turns at intersections.

Each location being considered for a channelization project should be carefully studied before 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 means of sandbags temporarily placed on the roadway to represent curbs or pavement markings.

A. LEFT-TURN LANES

The provision of a lane dedicated to exclusive left-turn movements on an approach at a signalized or unsignalized intersection has several safety advantages. The left-turn lane allows a vehicle to be removed from the through lane as it waits for an opportunity to turn. This separation significantly reduces the danger of rear-end and sideswipe collisions from vehicles passing on the right side of the turning vehicle. Furthermore, with left-turn lanes opposing each other and left-turn vehicles waiting on opposing lanes, these vehicles will be in a direct line with each other, thereby providing both drivers a better line of sight to detect opposing straight through traffic.

Left-turn lane construction should be considered for intersections having a substantial number of left-turn-involved accidents. These accidents include rear-end collisions with vehicles waiting to turn left, same direction sideswipe collisions, and left-turn angle collisions. The exact number of left-turn related collisions to justify a left-turn lane varies depending on several factors such as the occurrence of injury or fatal accidents.

The criteria listed in Table D-4 are suggested as being appropriate for considering left-turn lane installation.

TABLE D-4.

MINIMUM ACCIDENT EXPERIENCE FOR LEFT-TURN LANE CONSIDERATION.

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

B. 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. Traffic using the numerous driveways that provide access to these developments can create extensive delays and serious midblock accident problems on the through lanes of the street. Rear-end collisions and sideswipes occur as vehicles frequently stop in traffic to wait for an opportunity to turn left into a driveway. Also, vehicles attempting to turn left from a driveway must often wait so long that they attempt to force an entry to the through lanes.

An effective countermeasure for reducing these midblock accidents 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.

A CTWLTL extends for at least several blocks, and must have signs and markings (see MUTCD) permitting median lane use for left-turns only. It has been found that a CTWLTL not only improves safety for vehicles turning left to enter and exit driveways, but it also separates vehicles traveling in opposite directions, thus reducing the chance for head-on collisions and opposite direction sideswipe collisions.

The seriousness of the midblock accident problem usually depends on the number of driveways present, the volume and composition of traffic, and the volume of traffic using the driveways. Exact guidelines for when to consider such a major street modification as a CTWLTL are not currently available.

However, estimates for accident rates along commercially developed streets are available, and an example of these rates is provided below. If a two-lane undivided or four-lane undivided roadway has an accident rate higher (say 1.2 times higher) than those listed in Table D-5, the CTWLTL installation should be considered.

TABLE D-5.

TYPICAL ANNUAL ACCIDENT RATES PER MILE FOR NON-INTERSECTION ACCIDENTS IN URBAN COMMERCIAL AREAS.*

Roadway Category	Number of Driveways per Mile	Average Daily Traffic 7000 to 10000	10000 to 15000	15000 to 20000
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	20.0

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

REFERENCES ON LEFT TURN CHANNELIZATION

1. D. Harwood, "Multilane Design Alternatives for Improving Suburban Highways," Transportation Research Board, NCHRP Report 282, 1986.

2. T. Neuman, "Intersection Channelization Design Guide," Transportation Research Board, NCHRP Report 279, 1985.

3. "Accident Reduction Factors for Highway Safety Projects," in Safety Evaluation Instructions, California Department of Transportation, 1975.

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

5. "Design Criteria for Left-Turn Channelization," Technical Council Informational Report, Institute of Transportation Engineers, ITE Journal, February 1981, pp. 38-43.

IV. SAFETY LIGHTING

The primary purpose of roadway lighting, or illumination, is to increase the visibility of the pavement and its surroundings, thereby providing the driver a chance for earlier detection of potentially hazardous situations. Many studies have been performed which agree that the installation of roadway lighting is highly beneficial in terms of improved safety.

Several suggested warrants for intersection lighting were evaluated in an extensive study (Ref. 1) of minor safety improvements. The following accident experience levels were suggested as warrants for intersection lighting:

> "It is recommended that safety lighting be considered at locations which experience 4 night accidents in one year or 6 or more night accidents in two years."

This study also found the intersection accidents most susceptible to correction by lighting were single-vehicle accidents (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 accidents should be about equal to the rate for daytime accidents. The ideal situation would be a ratio of 1.0:1.0 which would indicate the accident rate at night is the same as the accident rate during daylight conditions.

Using the decision criteria developed in Transportation Research Board NCHRP 152 (Ref. 2), a ratio of nighttime accidents to daytime accidents of 1.5:1.0 is somewhat high, but not unusual. However, a ratio of 2.0:1.0 or greater indicates night visibility is inadequate and lighting should be considered for the location.

REFERENCES ON SAFETY LIGHTING

1. T. Tamburri, et. al., "Evaluation of Minor Improvements," Highway Research Board, Highway Research Record Number 257, 1968.

2. N. Walton and N. Rowan, "Warrants for Highway Lighting," Transportation Research Board, NCHRP Report 152, 1974.

3. "Synthesis of Safety Research Related to Traffic Control and Roadway Elements," FHWA-TS-82-233, Federal Highway Administration, 1982.

4. "Roadway Lighting Handbook," Federal Highway Administration, Implementation Package 78-15, December 1978 and Addendum September 1983.

V. 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 accidents by as much as 10% to 50% on the affected streets. The accident types usually reduced the most are sideswipe accidents with opposite direction vehicles, head-on collisions, parking accidents, right-angle collisions, rear-end collisions, turning collisions, and pedestrian accidents. Another important benefit of a conversion to one-way operation is the likely reduction in the percentage of injury or fatal involvements.

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 accident category. However, one-way operation might be highly desirable if there is the possibility of noticeably improving safety along an entire corridor.

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

1. It is clear that a specific traffic problem will be alleviated and overall efficiency of the street system will be improved,

2. One-way operation is more desirable and cost-effective than the alternate solutions,

3. A parallel street of suitable width, preferably not more than a block away, does exist or can be constructed,

4. The parallel and adjacent streets are continuous in that they carry traffic through and beyond the congested areas,

5. There exists a sufficient number of intersecting streets of satisfactory design to permit circulation of traffic,

6. Safe transition to two-way operation can be provided at the end points of the one-way sections,

7. Proper public transit services can continue to be provided on the one-way pair of streets,

8. The proposed one-way streets are compatible with the community master plan and adjacent land uses, and

9. 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 are most usually attained without adverse financial impact on adjacent businesses.

ADVANTAGES OF ONE-WAY STREETS

- Capacity is increased as a result of reduced conflicts and more efficient operation of traffic control devices,
- 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 accidents is reduced by eliminating the hazardous head-on accidents and reducing several types of intersection conflicts,
- An odd number of traffic lanes may be used fully on streets that did not lend themselves to division into an even number of lanes of suitable width with two-way operation, and
- 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 may be increased for certain destinations due to having to take an "around-the-block" route,
- One-way streets may be confusing to strangers,
- Emergency vehicles may be blocked at intersections by vehicles waiting in all lanes on an approach, and
- Additional signs and markings must be installed and must be carefully maintained (see MUTCD).

Technical assistance for a thorough evaluation of a possible change to one-way streets should be obtained from traffic engineering professionals. It is possible for Missouri communities that do not have a traffic engineer on their staff to arrange for these services through the MHTD Traffic Engineering Assistance Program.

REFERENCES ON ONE-WAY STREETS

1. "Transportation and Traffic Engineering Handbook," 2nd Edition, Institute of Transportation Engineers, Prentice-Hall, Inc., 1982.

2. "Synthesis of Safety Research Related to Traffic Control and Roadway Elements," FHWA-TS-82-232, Federal Highway Administration, 1982.

3. "A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials, 1990.

VI. 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 or not 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 are 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 their vehicle until it travels to the bottom of the embankment. A critical slope is greater than 3:1. It is on a critical slope that a vehicle is most likely to overturn.

If a critical embankment exists along an urban street, errant vehicles should be intercepted by a barrier such as a guardrail 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 nontraversable 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. Relocate the obstacle so it is less likely to be struck.

3. Reduce impact severity by using a breakaway device.

4. Redirect a vehicle by installing a barrier or crash cushion.

5. Delineate the obstacle if above alternatives are not appropriate.

While Alternatives 1 and 2 are highly preferred, they are not always practical in urban areas. Items such as signs, signals, and light poles must be located near the road in most cities; and this practice often makes it difficult to achieve a safe roadside.

Properly designed breakaway supports for sign posts and light poles, as suggested in Alternative 3, are easily provided and extremely beneficial in reducing vehicle occupant injuries. Breakaway utility poles are still in the developmental stage. However, the alternative may exist to bury the utility line and thereby eliminate an entire series of poles.

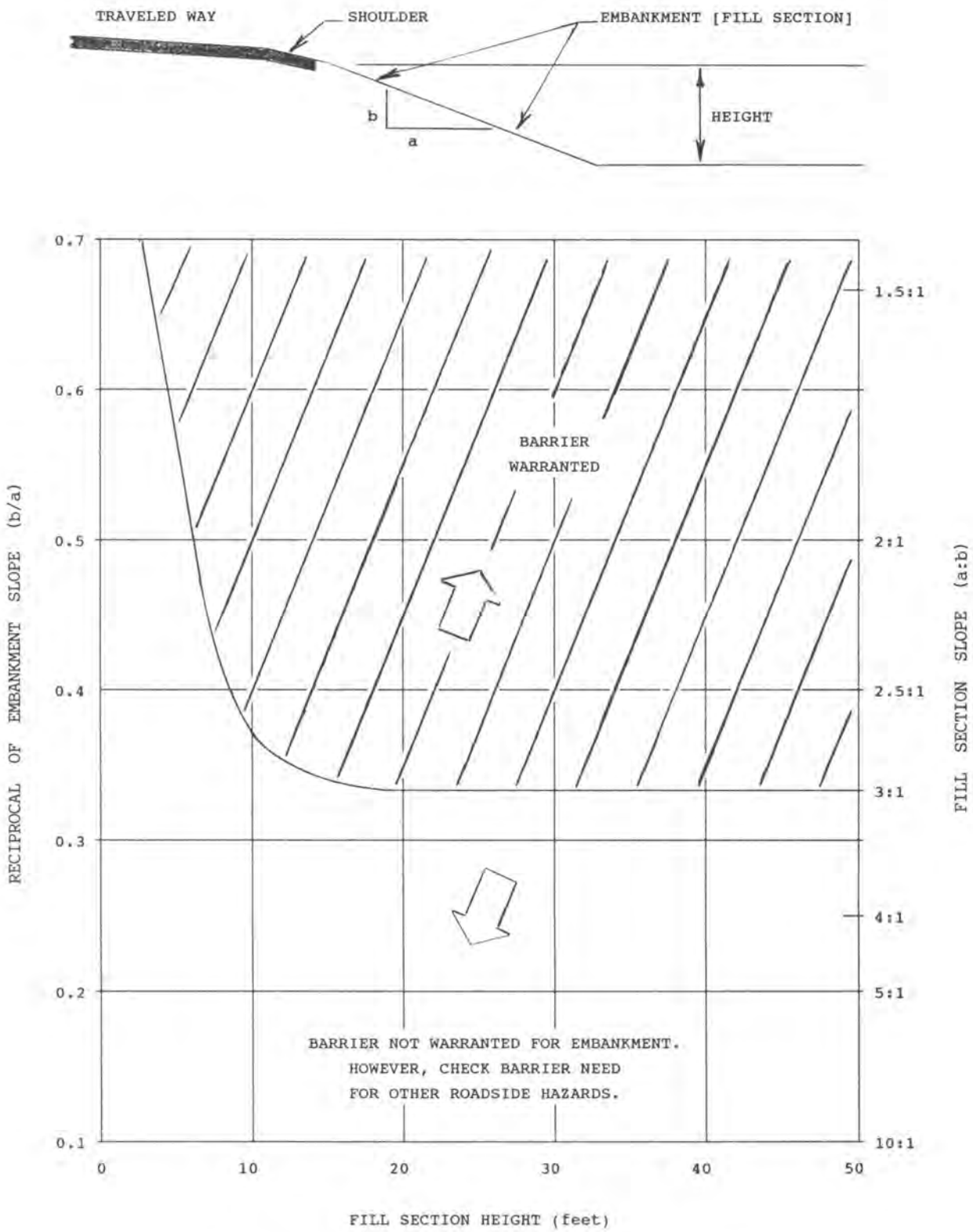


FIGURE D-1. COMPARATIVE RISK WARRANTS FOR EMBANKMENTS.
[Adapted from AASHTO Roadside Design Guide.]

Alternative 4 requires consideration of warrants for roadside barriers (such as 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 accident resulting from hitting the unshielded object. Although no specific number of accidents may be related to the need for installing a barrier, general guidelines do exist for their use as shown in Table D-6. Specific roadside barrier designs depend on the function the barrier must perform, as well as the speed and size of the involved vehicle. The barrier should be placed as far from the traveled way as conditions permit. The length of barrier must be determined based on the length of the hazard and the vehicle approach path. The lateral offset of the barrier from the fixed object must be sufficient to allow for barrier deflection.

Alternative 5 involves alerting the motorist to presence of hazardous objects using markers recommended in the MUTCD.

Several types of roadside hazards are especially prevalent in urban areas, namely: trees, mailboxes and drainage features.

Trees: A tree with a trunk diameter greater than 6 inches is considered a fixed object. Trees located along curves are a greater hazard than trees along straight sections. For streets with design speed of 50 mph or more, the minimum setback to a tree should be 30 feet from the edge of traveled lane; for design speeds less than 45 mph the setback should be in the range of 7 to 18 feet. If these distances are impractical for a community, then a priority listing of trees to be gradually removed should be developed.

Mailboxes: Roadside mailbox installations result in an object being placed very close to the traveled path, with the mailbox typically being vehicle windshield height. The important guidelines for roadside mailboxes are:

1. 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.

2. Mailbox-to-post attachments should ideally prevent mailboxes from separating from their supports when hit by an errant vehicle.

Drainage Features: Drainage features such as culverts, inlets, headwalls, and ditches are serious traffic hazards if they are not properly designed and located. The following guidelines pertain to drainage structures:

1. Eliminate non-essential drainage structures.

2. Design or modify drainage structures so they are traversable or present a minimal hazard to an errant vehicle.

3. If a major drainage feature cannot be redesigned or relocated, it should be shielded by a suitable traffic barrier.

TABLE D-6. GUIDELINES FOR ROADSIDE BARRIERS.

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, Pipes, 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

Source: AASHTO Roadside Design Guide, 1989, page 5-5.

4. Roadside hardware (as posts) should not be in or near a ditch bottom.

5. Drop inlets on the roadway should be installed flush with the pavement surface and designed for safe passage of bicycle tires.

6. Drop inlets located off the traveled way should be installed flush with the ditch bottom or slope on which they are located.

REFERENCES ON ROADSIDE SAFETY FEATURES

1. "Roadside Design Guide," American Association of State Highway and Transportation Officials, 1989.

2. "A Guide for Erecting Mailboxes on Highways," American Association of State Highway and Transportation Officials, 1984.

3. "A Guide for Accommodating Utilities Within Highway Right-of-Way," American Association of State Highway and Transportation Officials, 1985.

4. "Guide to Management of Roadside Trees," FHWA-IP-86-17, Federal Highway Administration, December 1986.

5. "Traffic-Safe and Hydraulically Efficient Drainage Practice," Highway Research Board, NCHRP Synthesis of Highway Practice, No. 3, 1969.

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

VII. TRAFFIC CONTROL AT LOW-VOLUME INTERSECTIONS

The decision to provide YIELD signs or STOP signs, rather than using no control at a low volume intersection, is based on several factors, as:

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

The AASHTO procedures for evaluating intersection sight distances and safe approach speeds should be used when selecting the type of signs to install at a low volume intersection (refer to Appendix C). With respect to intersection control, the MUTCD does not contain specific volume and/or accident warrants for YIELD signs or STOP signs, except for multiway STOP signs.

A community should adopt a signing policy for low-volume intersections that can be applied with a high degree of consistency throughout the jurisdiction. It is important that the community not use an unnecessarily restrictive intersection signing practice. In particular, installation of unnecessary STOP signs must be avoided since the unnecessary signs will cause drivers to develop a sense of disrespect for all STOP signs.

NO CONTROL AT INTERSECTIONS

No control could be appropriate for intersections up to a volume of about 2,000 vehicles per day on the busiest roadway. No control is usually satisfactory at intersections where both streets are local streets, or where one street is a local street and the other is a minor collector.

Many intersections operating with No control have such low volumes that very few accidents occur, perhaps only one accident every three years. The occurrence of this one accident does not necessarily justify installing YIELD signs or STOP signs. However, if an intersection with no control experiences two or more correctable accidents in one year, YIELD signs or STOP signs should be considered.

YIELD SIGNS AT INTERSECTIONS

A reasonable guideline for installing YIELD sign control could be that an intersection has three or more accidents during three years involving minor road vehicles, or that it has two or more accidents in one year involving minor road vehicles.

YIELD signs generally should NOT be placed to regulate the major traffic flow at an intersection. If YIELD signs are used where two roads meet at an acute angle, the signs should be installed at an angle, or shielded, so their message is out of view of traffic to which it does not apply.

TWO-WAY STOP SIGNS AT INTERSECTIONS

A reasonable guideline for installing two-way STOP sign control could be that an intersection has four or more accidents during three years involving minor road vehicles; or that it has three or more accidents in one year involving minor road vehicles. Prior to installing the STOP signs, an on-site field report should be completed to determine if some other less restrictive countermeasures could be implemented.

With a two-way STOP sign installation the signs generally should NOT be placed to regulate the major flow at an intersection. Portable STOP signs shall not be used except for emergency purposes.

STOP signs should not be used to attempt speed control along a street. If two-way STOP signs are used where two roadways meet at an acute angle, the signs should be installed at an angle, or shielded, so their message is out of view of the traffic to which it does not apply.

MULTIWAY (THREE-WAY OR FOUR-WAY) STOP SIGNS AT INTERSECTIONS

If an intersection has five or more accidents of a correctable type in one year, multiway STOP signs should be considered. Multiway STOP sign control is effective for reducing accidents at intersections where traffic volumes on all approaches are about equal, and at locations with inadequate sight distances. Accidents susceptible to correction by multiway STOP signs include right-turn and left-turn collisions, as well as right-angle collisions.

Prior to installing multiway STOP signs, other countermeasures should be evaluated. It is possible that improving pavement skid resistance or installing warning signs may reduce the accident experience. If the traffic volumes appear to be high at the location, a traffic volume study should be performed to determine if the MUTCD traffic signal warrants have been met.

REFERENCES ON INTERSECTION CONTROL

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

2. "A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials, 1990.

3. W. Stockton, et. al., "Stop, Yield, and No Control at Intersections," Federal Highway Administration, Report No. FHWA-RD-81/084, June 1981.

4. H. McGee and M. Blankenship, "Guidelines for Converting Stop to Yield Control at Intersections," Transportation Research Board, NCHRP Report 320, 1989.

APPENDIX E

ESTIMATED IMPROVEMENT PROJECT COSTS - 1990

The roadway and traffic improvement cost estimates provided below were obtained from the MHTD and are current for the year 1990. It is possible that local costs could vary from those listed below due to being in a particular location and/or the 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 whatever percentage is determined to be appropriate for the jurisdiction.

IMPROVEMENT DESCRIPTION	1990 COST
ROADWAY CONSTRUCTION/RECONSTRUCTION	
Roadway grading and paving (widening)	$ 3.25 SF*
Roadway grading and paving (reconstruction)	4.30 SF
Median construction (concrete, excluding curbing)	3.00 SF
Curb and gutter (barrier and mountable)	15.00 LF
Barrier curbing	16.25 LF
Shoulder Construction (6" gravel)	3.60 SY
Curb removal	2.50 LF
Curb inlet	525.00 EA
Driveway closure; install new curbing	19.65 SY
Driveway construction	30.00 SY
Island construction (concrete, excluding curbing)	3.50 SF
PAVEMENT SURFACE TREATMENTS	
Overlay (1-1/2" thick; lime/steel/slag)	1.36 SY
Chip and seal (3/4" thick; with special rock gradation)	1.25 SY
Slurry seal (special stone gradation in suspension)	2.00 SY
Pavement grooving	1.50 SF
Pavement striping (4-inch white or yellow stripe)	0.03 LF
Pavement marking (stop bars, lane use arrows, etc.)	3.00 SF
ROADSIDE FEATURES	
Guardrail: New (Type A)	14.50 LF
Breakaway Cable Terminal (BCT)	700.00 EA
Bridge attachment	625.00 EA
Guardrail, New (Type A) and remove previous guardrail	17.50 LF
Complete lighting unit (1 Pole)	1,600.00 EA
Steel breakaway sign post	21.00 LF
Wood sign post (4-inch by 4-inch)	0.80 LF
Sign (installed ... stop, yield, warning, etc.)	90.00 EA
Delineators (installed ... sign and post)	30.00 EA
Remove and reset wood utility pole	160.00 to 750.00 EA
Remove and reset wood telephone pole	330.00 to 4,000.00 EA
Remove and reset road sign and post	40.00 EA
Tree removal	100.00 to 650.00 EA

IMPROVEMENT DESCRIPTION	1990 COST
TRAFFIC SIGNALS AND BEACONS	
Overhead 4-way flashing beacon	$ 2,000.00 EA
Post, signal, 10 feet high	350.00 EA
Mast arm post	2,500.00 EA
Fixed-time controller	5,000.00 EA
Actuated Controller	7,000.00 EA
Junction box	250.00 EA
Detector, loop inductive	2.00 LF
Detector, magnetic	450.00 EA
Detector, pedestrian pushbutton	50.00 EA
Conduit (pushed ... 2-inch diameter)	6.00 LF
Conduit (trenched ... 2-inch diameter)	22.00 LF
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	2.75 SF
Sodding	4.00 SY
Blade gravel road approaches (4) at intersection	250.00 TYP
THE FOLLOWING ITEMS INCLUDE MATERIAL COST ONLY:	
Plastic three-lense signal head (12-inch lenses)	195.00 EA
Plastic two-lense pedestrian head (12-inch lenses)	160.00 EA
Optically programed three-lense signal head	750.00 EA
Plastic backplate for three-lense 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 MHTD 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, as 14 years or 29 years. Such estimates do not have that much credibility, and they can make the economic analysis more complicated.

IMPROVEMENT DESCRIPTION	SERVICE LIFE (Years)
ROADWAY CONSTRUCTION/RECONSTRUCTION	
Pavement widening, no lanes added	20
Lanes added, no new median	20
Highway divided, new median added	20
Shoulder widening or improvement	10
Flattening, clearing side slopes	20
Relocate driveways	20
Flatten entrance slopes	20
Right-of-way acquisition	100
Horizontal alignment changes	15
Vertical alignment changes	15
Horizontal and vertical changes	15
STRUCTURES CONSTRUCTION/RECONSTRUCTION	
Widen bridge or major structure	20
Replace bridge or major structure	30
New bridge or major structure	30
Minor structure	20
Pedestrian over- or under-crossing	30
Construct Interchange	35
PAVEMENT SURFACE TREATMENTS	
Skid treatment, pavement grooving	10
Skid treatment, pavement overlay	6-9
Skid treatment, seal coat	3-5
Skid treatment, slurry seal	5-7
Markings (paint)	1
Markings (thermoplastic)	5
Edgeline markings (paint)	2

IMPROVEMENT DESCRIPTION	SERVICE LIFE (Years)
ROADSIDE FEATURES	
Illumination	15
Breakaway sign support	10
Breakaway luminaire support	20
Guardrail	10
Median barrier	15
Improve drainage structures	20
Fencing	10
Traffic signs	6-8
INTERSECTION RELATED PROJECTS	
Channelization, 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

1. Missouri Highway and Transportation Department, Correspondence dated April 4, 1990, Jefferson City, Missouri.

2. University of Alabama, "Accident Identification & Surveillance Documentation Manual," TSM Report 112-88, September 1988.

3. J. McCoy, "Safety Improvement Economic Analysis," Iowa Department of Transportation, Memo Reference No. 590, November 27, 1985.

APPENDIX G

ESTIMATED ACCIDENT REDUCTION FACTORS

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

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

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

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

COUNTERMEASURE CATEGORIES

The countermeasure categories are tabled in the following sequence:

- ACCESS CONTROL
- BRIDGES
- CHANNELIZATION
- CONSTRUCT/RECONSTRUCT
- DELINEATION
- FIXED OBJECTS
- FLASHING BEACONS
- GUARDRAIL
- ILLUMINATION
- PAVEMENT MARKINGS
- PAVEMENT TREATMENTS
- RAILROAD CROSSINGS
- REGULATIONS
- SIGHT DISTANCE
- SIGNALS
- SIGNS

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 an accident 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 accident reduction estimate will be incorrect.

ACCIDENT REDUCTION (AR) FACTOR GROUPS

The reason for grouping the AR factors is to provide guidance to the HAL Manual user in their proper application. The five groups listed across the top of the table are defined as follows:

GROUP I: Contains AR factors applicable to "All" accidents

GROUP II: Contains AR factors applicable to accidents according to severity level, "Fatal/Injury" or "PDO" being specified

GROUP III: Contains AR factors applicable to several different types of accidents, as "Head On" or "Right Angle"

GROUP IV: Contains AR factors applicable to accidents that occur during "Wet Pavement" conditions

GROUP V: Contains AR factors applicable to accidents that occur during "Night" conditions

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

1. From Group I: Apply 13% reduction to All accidents; or

2. From Group III: Apply AR factors to specific accident 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 Ran Off Road accidents; or

3. From Group IV: Apply 55% reduction to Wet Pavement accidents.

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

TABLE G-1. ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I*	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
ACCESS CONTROL														
Close Median Opening [A]**				100	50	100	50	100						
BRIDGES														
Widen Bridge or Replace Two-Lane Bridge [B]														
From 18 to 24 feet	68													
From 20 to 24 feet	56													
From 22 to 24 feet	36													
From 18 to 30 feet	93													
From 20 to 30 feet	90													
From 22 to 30 feet	86													
Install Guardrail [C]		F: 90 I: 45	-110***											
Install Delineation [C]	40													

* Roman numerals designate accident reduction factor groups.

** Capital letters in brackets, such as [A], refer to the accident reduction factor sources which are listed at end of Appendix G.

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

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
CHANNELIZATION														
Install Painted or Raised Median [C]	10													
Add Left-Turn Lane Where No Existing Signal [D]														
Painted Lane	32				75									
Protected Lane with Curb or Raised Bars	67		62		93									63
Install Left-Turn Lane at Signalized Intersection [E]														
With No Left-Turn Phase	15													
Existing Left-Turn Phase	35													
Install Continuous Two-Way Left-Turn Lane in Median [F]														
Two Lanes to Three Lanes	32	59			46		46	46						
Four Lanes to Five Lanes	28	42			40		40	40						

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
CONSTRUCT/RECONSTRUCT														
Install Curbing [G]										50				
Install Concrete Median Barrier [C]		F: 90 I: 10	-10**											
Lane Widening * [H]														
Add 1 Foot to Both Lanes				12			12					12		
Add 2 Feet to Both Lanes				23			23					23		
Shoulder Widening * [H]														
Add 2 Feet to Both Sides										13		13		
Add 4 Feet to Both Sides										25		25		
Add 6 Feet to Both Sides										35		35		
Add 8 Feet to Both Sides										43		43		
Increase Roadside Clear Zone Recovery Distance * [H]														
Add 5 Feet										13		13		
Add 8 Feet										21		21		
Add 10 Feet										25		25		
Add 15 Feet										35		35		
Sideslope Flattening * [H]														
From 2:1 to 4:1										7		7		
From 2:1 to 6:1										15		15		
From 3:1 to 4:1										6		6		
From 3:1 to 6:1										14		14		

* Conditions for use: 2-lane highway, ADT 100-10,000; Lanes 8-12 feet wide; shoulders 0-12 feet wide.

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

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
CONSTRUCT/RECONSTRUCT (Continued)														
Reduce Sharpness of Curve For Horizontal Curve [J]														
From 20 to 10 Degrees	48													
From 15 to 5 Degrees	63													
From 10 to 5 Degrees	45													
Improve Vertical Curve [I]	45													
Improve Horizontal and Vertical Alignment [I]	50													
Install Pedestrian Grade Separation [K]	5										95			
Add Accel. or Decel. Lane [I]	10													
Improve Intersection Approach Angle [L]	35													
DELINEATION														
Install Post Mounted [M] Delineators on Horiz. Curve	25													
Install Chevron Alignment Sign on Horiz. Curve [M]	35													

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
FIXED OBJECTS														
Remove Fixed Objects [I]		F: 50 I: 15												
Relocate Fixed Objects [I]		F: 40 I: 15												
Relocate Utility Pole to Increase Offset from Road [N]														
From 2 to 6 feet										50				
From 3 to 8 feet										46				
From 5 to 10 feet										36				
FLASHING BEACONS														
With Warning Sign [D]														
Before Curve	54											57		62
Before Intersection	24													
Overhead Yellow-Red at 4-Leg Intersection [O]	36	15	50											33
Overhead Red-Red at 4-Leg Intersection [O]	50	40	55											46
Overhead Yellow-Red at 3-Leg Intersection [O]	39	7	54											63

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
GUARDRAIL														
Median Barrier [C]														
1 to 12 ft. Median		F: 75 I: 2	-28*											
13 to 30 ft. Median		F: 85 I: 5	-30*											
Install Along Ditch [C]		26	-19*											
Install Along Embankment [C]		42	-47*											
Install at Fixed Objects as Rocks & Steel Posts [C]		31	-45*											
Install at Trees [C]		F: 65 I: 51	-90*											
ILLUMINATION														
Intersections [D]														
3-Leg														69
4-Leg. 2-Lane														53
4-Leg, 4-Lane														62
Bridge Approaches [P]														50
Underpasses [P]														10

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

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
PAVEMENT MARKINGS														
Center Double Yellow [A]	5													
Add Centerline [Q]	30													
Add Edgeline [R]	11	15	8									11		16*
No Passing Striping [I]	40													
Reflectorized Raised Pavement Markings [G]				20			20			10		10	31	26
PAVEMENT TREATMENTS														
Deslicking [S, G]	13			10	40	10	10			10	10	10	55	
Resurface Curve with Skid-Resistant Overlay and Improve Superelevation [S]				86									51	
Groove Pavement Parallel to Centerline [C]													75	

* Applies to Ran Off Road at Night Accidents Only.

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
RAILROAD CROSSINGS														
Add Pavement Markings [I]	10													
Add Markings and Signs [I]	27	20	31											
Surface Improvements [I]	34		39											
Add Flashing Lights from Crossbucks [C]														
Urban	57													
Rural	74													
Add Automatic Gates from Crossbucks [C]														
Urban	79													
Rural	87													
Add Automatic Gates from Flashing Signal [C]														
Urban	68													
Rural	63													
Replace Active Warning Devices with Grade Separation [C]	95		88											

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASRURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
REGULATIONS														
Prohibit On-Street Parking [G]	90*				10	10	30			40	30			
Change Angle Parking to Parallel [T]	59													
Adjust Speed Limit Increase or Decrease [M]	20		35											
Change Two-Way Streets to One-Way Streets [U]														
Intersection Accidents	26										46			
Mid-Block Accidents	43										50			
Prohibit Right-Turn-On-Red at Signalized Intersection [G]					20	30	20				30			
Prohibit Left Turns [G]					30			90			10			
SIGHT DISTANCE														
Improve Sight Distance at Urban Intersections [G]				10		30	10	10			10			

* Applies to parking accidents only.

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
SIGNALS														
Install New Signal [V]														
From Two-Way Stop	28	43			-46*	74		-92*						
From Two-Way Stop and add Left-Turn Lane	36	53			8	74		-43*						
Install New Signal and New Left-Turn Lane With [V]														
No Left-Turn Phase	53	49			44	73		14						
Protected Left-Turn Phase	49	66			26	56		70						
Protected/Permitted Left-Turn Phase	58	61			45	44		69						
Upgrade Pedestal Mounted to Mast Arm Mount: Pretimed [V]														
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						
Install 12-inch Lenses [Q]	10													
Install Pedestrian Signal [Q]											60			
Add All-Red Interval [W]						31								

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

TABLE G-1 (Cont'd). ESTIMATED ACCIDENT REDUCTION FACTORS (Percent).

COUNTERMEASURE	I	II		III									IV	V
	All	Fatal or Injury	PDO	Head On	Rear End	Right Angle	Side Swipe	Left Turn	Right Turn	Fixed Object	Pedes-trian	Ran Off Road	Wet Pave-ment	Night
SIGNS (Continued)														
Regulatory Signs														
Yield from No Control [K]	59													
Two-Way Stop from Yield Control [K]	48													
Four-Way Stop from Two-Way Stop [X]	47				13	72		20			39			
Lane Use Signs [Y]	30				10		20							
Install Guide Signs [Q]	15													

REFERENCES FOR ESTIMATED ACCIDENT REDUCTION FACTORS

A. J. Graham and J. Glennon, "Manual on Identification, Analysis and Correction of High Accident Locations," Missouri State Highway Commission, November 1975.

B. "A Study of Motor Vehicle Traffic Accidents at Bridges on the Colorado State Highway System," Colorado State Department of Highways, Planning and Research Division, June 1973.

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APPENDIX H

ECONOMIC ANALYSIS: COST UPDATES, ACCIDENT COSTS, COMPOUND INTEREST FACTORS AND THEIR APPLICATION

I. COST UPDATES

The countermeasure costs listed in Appendix E, as well as accident costs used in the Second Edition of the HAL Manual, apply to the State of Missouri for the year 1990. The city engineer or other local official who may be responsible for applying the HAL Manual in future years may desire to update these costs using one of the following methods:

1. 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 accidents relative to other cost categories.

2. Contact the TTAP office to obtain costs currently used by the MHTD in their high-hazard elimination program.

3. Assume a reasonable rate of increase per year for all costs involved, such as 4 or 5 percent per year.

4. 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.

II. ACCIDENT COSTS

The accident costs stated in Chapter 1 and applied in Chapter 5 assume a 1990 basis and they are the following amounts:

Cost of a Fatal (F) Accident:	$ 1,900,000
Cost of an Injury (I) Accident:	21,100
Cost of a Property-Damage-Only (PDO) Accident	4,000

For several reasons, it is NOT RECOMMENDED that the cost for a fatal accident be applied directly as the amount shown above. Fatal accidents are infrequent events, and the chance occurrence of one fatal accident at a site overwhelmingly influences the improvement selection process to favor that site if the $1,900,000 cost is applied. This could result in omitting another site for improvement which had a larger number of serious injury accidents, but did not experience a fatal accident. Furthermore, reliable accident reduction factors suitable for application to fatal accidents are not readily available due to the low rate of occurrence of such events and the difficulty of developing the factors.

To counteract these problems, it is assumed that fatal accidents and injury accidents are events which can each be expressed as a percentage of the total fatal and injury accidents occurring statewide on a specific classification of highway system. The percentages for fatal accidents and injury accidents can be applied to the cost of a fatal accident and to the cost of an injury accident, respectively, in order to develop a weighted cost for an accident category know as "Fatal or Injury Accident." The formula (Ref. 1) which must be applied is:

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

For this edition of the HAL Manual, data published by the Missouri State Highway Patrol (Ref. 2) were used to compute the percentages for fatal accidents and for injury accidents on six classifications of Missouri trafficways. These percentages were then applied to the cost of a fatal accident and the cost of an injury accident to yield the weighted cost of a Fatal or Injury Accident as shown in the last column of Table H-1.

TABLE H-1. COST OF FATAL OR INJURY ACCIDENTS OCCURRING ON SIX CLASSIFICATIONS OF TRAFFICWAY IN MISSOURI.

Classification of Trafficway	Percent Fatal Accidents	Percent Injury Accidents	Weighted Cost of Fatal or Injury Accidents, in $
Interstate	2.812	97.188	73,900
U.S. Numbered	3.062	96.948	78,600
State Numbered	2.835	97.165	74,400
State Lettered	3.875	96.125	93,900
County Road	2.193	97.805	62,300
City Street	0.745	99.255	35,100

Since the HAL Manual is primarily intended as a guide for conducting traffic safety studies in communities, the weighted cost of fatal or injury accidents on city streets ($35,100) is used for the example in Chapter 5.

III. COMPOUND INTEREST FACTORS

A compound interest rate of 10 percent per year is used in the HAL Manual example computations. Rates other than 10 percent could be used depending on local policy, or 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 are provided in Tables H-2 through H-4 at the end of this appendix, and sample applications of the "Capital Recovery Factor" and the "Sinking Fund Factor" are provided in the next section.

IV. 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 10% interest

A = P(A/P,10%,1) = 200(1.100) = $ 220 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 10% interest

A = P(A/P,10%,7) - F(A/F,10%,7) = 720(0.20541) - 50(0.10541)

A = 147.90 - 5.27 = $ 142.63 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 10% interest

A = P(A/P,10%,15) - F(A/F,10%,15) = 3200(0.13147) - 800(0.03147)

A = 420.70 - 25.18 = $ 395.52 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 10% 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 only with the <u>first item</u> 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, as:

A = 220.00 + 142.63 + 395.52 = $ 758.15 per year.

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TABLE H-2. INTEREST FACTORS: 6 PERCENT COMPOUNDED ANNUALLY.

Service Life in Years (n)	Uniform Series Capital Recovery Factor (A/P,6%,n)	Uniform Series Sinking Fund Factor (A/F,6%,n)
1	1.06000	1.00000
2	0.54544	0.48544
3	0.37411	0.31411
4	0.28859	0.22859
5	0.23740	0.17740
6	0.20336	0.14336
7	0.17914	0.12914
8	0.16104	0.10104
9	0.14702	0.08702
10	0.13587	0.07587
11	0.12679	0.06679
12	0.11928	0.05928
13	0.11296	0.05296
14	0.10758	0.04758
15	0.10296	0.04296
20	0.08718	0.02718
25	0.07823	0.01823
30	0.07265	0.01265
40	0.06646	0.00646
50	0.06344	0.00344
100	0.06018	0.00018

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 improvement.

"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: 8 PERCENT COMPOUNDED ANNUALLY.

Service Life in Years (n)	Uniform Series Capital Recovery Factor (A/P,8%,n)	Uniform Series Sinking Fund Factor (A/F,8%,n)
1	1.08000	1.00000
2	0.56077	0.48077
3	0.38803	0.30803
4	0.30192	0.22192
5	0.25046	0.17046
6	0.21632	0.13632
7	0.19207	0.11207
8	0.17401	0.09401
9	0.16008	0.08008
10	0.14903	0.06903
11	0.14008	0.06008
12	0.13270	0.05270
13	0.12652	0.04652
14	0.12130	0.04130
15	0.11683	0.03683
20	0.10185	0.02185
25	0.09368	0.01368
30	0.08883	0.00883
40	0.08386	0.00386
50	0.08174	0.00174
100	0.08004	0.00004

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 improvement.

"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: 10 PERCENT COMPOUNDED ANNUALLY.

Service Life in Years (n)	Uniform Series Capital Recovery Factor (A/P,10%,n)	Uniform Series Sinking Fund Factor (A/F,10%,n)
1	1.10000	1.00000
2	0.57619	0.47619
3	0.40211	0.30211
4	0.31547	0.21547
5	0.26380	0.16380
6	0.22961	0.12961
7	0.20541	0.10541
8	0.18744	0.08744
9	0.17364	0.07364
10	0.16275	0.06275
11	0.15396	0.05396
12	0.14676	0.04676
13	0.14078	0.04078
14	0.13575	0.03575
15	0.13147	0.03147
20	0.11746	0.01746
25	0.11017	0.01017
30	0.10608	0.00608
40	0.10226	0.00226
50	0.10086	0.00086
100	0.10001	0.00001

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 improvement.

"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.

APPENDIX I

HAL SYSTEM WORKSHEETS

Appendix I contains the worksheets and traffic data forms which are described and used with the example in the HAL Manual. The forms have been designed to assist city engineers and local traffic safety analysts in their implementation of the HAL System. Each form is coded according to its title and appears in this appendix in the order listed below.

FORM CODE	FORM NAME
TAS	Traffic Accident Summary
HALIW	High-Accident Location Identification Worksheet
ALFL	Accident Location - File Log
LAW-1	Location Analysis Worksheet - Page 1
LAW-2	Location Analysis Worksheet - Page 2
ICD	Intersection Collision Diagram
OSOR-1	On-Site Observation Report - Page 1
OSOR-2	On-Site Observation Report - Page 2
CAW-1	Countermeasure Analysis Worksheet - Page 1
CAW-2	Countermeasure Analysis Worksheet - Page 2
CEW-1	Countermeasure Evaluation Worksheet - Page 1
CEW-2	Countermeasure Evaluation Worksheet - Page 2
HALSEW	High-Accident Location System Evaluation Worksheet
ITCFS	Intersection Traffic Count Field Sheet
TCSAE	Vehicle Turning Count Summary and ADT Estimate

TRAFFIC ACCIDENT SUMMARY: FROM _____ TO _____ [Form TAS]

INTERSECTION - RELATED ACCIDENTS

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											
4-Way Stop											
Traffic Signal											
MAJOR - MINOR Yield Sign											
2-Way Stop											
4-Way Stop											
SUBTOTAL											

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											
Yield Sign											
2-Way Stop											
4-Way Stop											
SUBTOTAL											
TOTAL INTERSECTION ACCIDENTS											

MID - BLOCK ACCIDENTS

	Vehicle Striking							Non-Collision		
	Vehicle on Street	Parked Car	Vehicle at Drive	Fixed Object	Ped.	Train	Other	Over-Turn	Other	TOTAL
Major Street										
Minor Street										
Alleys										

HIGH - ACCIDENT LOCATION IDENTIFICATION WORKSHEET [Form HALIW]

INTERSECTION ☐ or MID-BLOCK SECTION ☐ DATE _____ EVALUATED BY _____

Location	Year	Number of Accidents				2 and 3 Year Average	EPDO Number*	ADT	Exposure	Accident Rate	EPDO Rate	High-Accident Location	
		Fatal	Injury	PDO	Total							No	Yes
TOTALS													
TOTALS													
TOTALS													
TOTALS													
TOTALS													
TOTALS													

* EPDO Number = (6)x(FATAL + INJURY) + PDO

INTERSECTIONS:

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

Exposure = (ADT)x(365)

$$\text{Accident Rate} = \frac{(\text{number of accidents})\text{x}(1\text{ million})}{\text{exposure}}$$

$$\text{EPDO Rate} = \frac{(\text{EPDO number})\text{x}(1\text{ million})}{\text{exposure}}$$

MID-BLOCK SECTIONS:

The length of each mid-block section must be determined and noted in the location column

ADT = average two-way count of the street

Exposure = (ADT)x(section length)x(365)

$$\text{Accident Rate} = \frac{(\text{number of accidents})\text{x}(100\text{ million})}{\text{exposure}}$$

$$\text{EPDO Rate} = \frac{(\text{EPDO number})\text{x}(100\text{ million})}{\text{exposure}}$$

ACCIDENT LOCATION - FILE LOG [Form ALFL]

LOCATION _____ YEAR _____

ACCIDENT DATE	LOCATION	SEVERITY

LOCATION ANALYSIS WORKSHEET [Form LAW-1]

LOCATION _____ DATE _____

EXISTING TRAFFIC CONTROL _____

PART A - ACCIDENT NUMBER, RATE, AND EPDO SUMMARY

Year	Number of Accidents				2 and 3 Year Average	EPDO Number	ADT	Exposure	Accident Rate	EPDO Rate
	Fatal	Injury	PDO	Total						
TOTALS									AVG =	AVG =

PART B - INTERSECTION RELATED ACCIDENTS

	Right Angle	Rear End	Side-Swipe		Head On	Ped	Fixed Object	Right Turn	Left Turn	Other	TOTAL
			Meeting	Passing							
Number of Accidents											
Percent of Total											100%

PART C - MID BLOCK ACCIDENTS

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

PART D - NUMBER OF ACCIDENTS AND EXISTING CONDITIONS

Time of Day: 6:00 am - Noon _____ 6:00 pm - Midnight _____

Noon - 6:00 pm _____ Midnight - 6:00 am _____

Light Conditions: Day _____ Night _____

Surface Conditions: Dry _____ Wet _____ Snow or Ice _____

Weather: Cloudy _____ Clear _____ Rain _____ Snow _____ Other _____

Other: _____

LOCATION ANALYSIS WORKSHEET - PAGE 2 [Form LAW-2]

LOCATION _____ DATE _____

PART E - ACCIDENT ANALYSIS SUMMARY

__ COLLISION DIAGRAM ATTACHED

ACCIDENT PATTERNS IDENTIFIED: Predominant _____
Secondary _____

PROBABLE CAUSES AND GENERAL COUNTERMEASURES _____

OPERATIONAL AND PHYSICAL DATA ANALYSIS

Supporting Data Attached:
- ___ On-Site Observation Report
- ___ Intersection Sight Distances
- ___ Volume/Turning Movement Count
- ___ Other: _____
- ___ Condition Diagram
- ___ Spot Speed Study
- ___ Traffic Conflict Study

General Conclusions From Supporting Data _____

COUNTERMEASURE SELECTION

Specific Countermeasures:

1. _____
2. _____
3. _____
4. _____
5. _____

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

Best Countermeasure _____

Benefit/Cost Ratio _____ Implementation Cost _____

Average Annual Net Savings _____ Priority Assigned _____

Indicate North
by Arrow

[Form ICD]

INTERSECTION
COLLISION
DIAGRAM

Street Name

ACCIDENT SUMMARY			
Severity	Day	Nite	Total
Fatal			
Injury			
PDO			
Total			

Street Name

SYMBOLS	TYPES OF COLLISIONS	SHOW FOR EACH ACCIDENT
Moving Vehicle	Rear End	1. Approximate location of accident
Backing Vehicle	Head On	2. Type of collision
Non-Involved Vehicle	Side Swipe	3. Time, day, date
Pedestrian	Out of Control	4. Other pertinent factors from accident reports as severity; pavement and weather conditions; etc.
Parked Vehicle	Overturn	
Fixed Object	Left Turn	
Fatal Accident	Right Angle	
Injury Accident		

INTERSECTION _____ DATE _____

TIME PERIOD COVERED: FROM _____ TO _____ PREPARED BY _____

ON-SITE OBSERVATION REPORT [Form OSOR-1]

LOCATION _____ CONTROL DEVICES _____

OBSERVER ____ DAY ____ DATE _____ TIME _____ WEATHER _____

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?	_____
4. Traffic signs are satisfactory as to number, size, message, placement, reflectivity, and visibility. (see MUTCD)	_____
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)	_____
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?	_____
12. Lane and street widths are adequate?	_____
13. The pavement surface condition is satisfactory? (Consider: potholes, rutting, washboard, edge drop-offs, raveling, bleeding surface, cracking, and poor drainage)	_____
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?	_____

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:	_____
B. Straight-through vehicles:	_____
C. Right-turning vehicles:	_____
7. Parked vehicles or parking maneuvers create hazards?	_____
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)

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Continue comments as necessary on additional pages.)

COUNTERMEASURE ANALYSIS WORKSHEET [Form CAW-1]

LOCATION _____ DATE _____

COUNTERMEASURE NUMBER _____ ESTIMATED COUNTERMEASURE SERVICE LIFE _____ YEARS

COUNTERMEASURE DESCRIPTION _____

ADT ADJUSTMENT Current Year _____ ADT _____ ADT Increase _____ % Annually

Estimated Year _____ ADT _____

ESTIMATED ANNUAL ACCIDENT REDUCTION

Accident Type	Estimated % Reduction (÷ 100)	x	Annual Number Accidents of this Type Before Improvement	=	Estimated Annual Reduction for Accidents of this Type
		x	PDO _____	=	PDO _____
_____	_____	x	F & I _____	=	F & I _____
		x	PDO _____	=	PDO _____
_____	_____	x	F & I _____	=	F & I _____
		x	PDO _____	=	PDO _____
_____	_____	x	F & I _____	=	F & I _____
		x	PDO _____	=	PDO _____
_____	_____	x	F & I _____	=	F & I _____
			Total Estimated Accident Reduction:		PDO _____ F & I _____

AVERAGE ANNUAL BENEFITS

1. Enter the estimated reduction of PDO accidents _____
2. Enter the average cost of a PDO accident _____
3. Multiply Line 1 by Line 2 (average annual benefit of reducing PDO accidents) _____
4. Enter the estimated reduction of Fatal and Injury accidents _____
5. Enter the average cost of Fatal or Injury accident _____
6. Multiply Line 4 by Line 5 (average annual benefit of reducing Fatal and Injury accidents) _____
7. Add Line 6 to Line 3 (average annual benefit from reducing accidents) _____

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 _____
9. Enter the current year ADT _____
10. Add Line 9 to Line 8 _____
11. Divide Line 10 by 2 (average ADT during service life) _____
12. Divide Line 11 by Line 9 (ADT growth factor) _____
13. Multiply Line 7 by Line 12 (average annual benefits from reducing accidents with ADT increasing) _____

14. Enter secondary annual benefits from improvement (if known) _____
15. If ADT is constant add Line 14 to Line 7 } Average Annual Benefits _____
    If ADT is increasing add Line 14 to Line 13 }

COUNTERMEASURE ANALYSIS WORKSHEET - PAGE 2 [Form CAW-2]

LOCATION _____ DATE _____

COUNTERMEASURE NUMBER _____ ESTIMATED COUNTERMEASURE SERVICE LIFE _____ YEARS

COUNTERMEASURE DESCRIPTION _____

AVERAGE ANNUALIZED COST

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

AVERAGE ANNUAL NET SAVINGS

1. Enter the Average Annual Benefits (from Line 15, page 1) _____
2. Enter the Average Annualized Costs (from line 9, above) _____
3. Subtract Line 2 from Line 1 to obtain Avg Annual Net Savings _____

BENEFIT/COST RATIO

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

* The example countermeasure analysis assumes a 10% interest rate. An agency might use a different interest rate and that would require applying factors from an interest table for that rate. Appendix H contains interest factor tables for 6%, 8%, and 10% rates.

COUNTERMEASURE EVALUATION WORKSHEET [Form CEW-1]

LOCATION _____ DATE _____

COUNTERMEASURE DESCRIPTION _____

DATE COUNTERMEASURE INSTALLATION COMPLETED _____

PART A - ACCIDENT NUMBER, RATE, AND EPDO SUMMARY

Year	Number of Accidents				2 and 3 Year Average	EPDO Number	ADT	Exposure	Accident Rate	EPDO Rate
	Fatal	Injury	PDO	Total						
TOTALS									AVG =	AVG =

PART B - INTERSECTION RELATED ACCIDENTS

	Right Angle	Rear End	Side-Swipe		Head On	Ped	Fixed Object	Right Turn	Left Turn	Other	TOTAL
			Meeting	Passing							
Number of Accidents											
Percent of Total											100%

PART C - MID BLOCK ACCIDENTS

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

PART D - NUMBER OF ACCIDENTS AND EXISTING CONDITIONS

Time of day: 6:00 am - Noon _____ 6:00 pm - Midnight _____

Noon - 6:00 pm _____ Midnight - 6:00 am _____

Light Conditions: Day _____ Night _____

Surface Conditions: Dry _____ Wet _____ Snow or Ice _____

Weather: Cloudy _____ Clear _____ Rain _____ Snow _____ Other _____

Other: _____

COUNTERMEASURE EVALUATION WORKSHEET - PAGE 2 Form CEW-2]

LOCATION _____ DATE _____

COUNTERMEASURE DESCRIPTION _____

DATE COUNTERMEASURE INSTALLATION COMPLETED _____

PART E - AFTER IMPROVEMENT ACCIDENT REDUCTION SUMMARY

___ COLLISION DIAGRAM ATTACHED

ACCIDENT PATTERNS IDENTIFIED: Predominant: _____

Secondary: _____

ADT RATIO: $\frac{\text{After ADT}}{\text{Before ADT}}$ = _____ =

ADJUSTED AFTER IMPROVEMENT NUMBER OF ACCIDENTS:

By Accident Type:

Left turn	_____	Skidding	_____	Fatal	_____
Head on	_____	Wet pavement	_____	Injury	_____
Rear end	_____	Night	_____	PDO	_____
Right angle	_____	RR crossing	_____		
Side swipe	_____	Pedestrian	_____		
Fixed object	_____	_____			
Overturn	_____	_____			

By Accident Severity:

All Accidents: _____

ACCIDENT PERCENT REDUCTION: % Reduction = $\frac{\text{Before - After}}{\text{Before}}$ x 100

By Accident Type:

Left turn	_____	%	Skidding	_____	%	Fatal	_____ %
Head on	_____	%	Wet pavement	_____	%	Injury	_____ %
Rear end	_____	%	Night	_____	%	PDO	_____ %
Right angle	_____	%	RR crossing	_____	%		
Side swipe	_____	%	Pedestrian	_____	%		
Fixed object	_____	%	_____		%		
Overturn	_____	%	_____		%		

By Accident Severity:

All Accidents: _____ %

HAL SYSTEM EVALUATION WORKSHEET [Form - HALSEW]

EVALUATION FOR _____ IMPROVED LOCATIONS YEAR _____ EVALUATED BY _____

BENEFITS DUE TO ACCIDENT REDUCTION

1. Enter the average annual number of "Before" improvement Fatal or Injury accidents _____
2. Enter the average annual number of "After" improvement Fatal or Injury accidents _____
3. Subtract Line 2 from Line 1 (reduction in Fatal or Injury accidents) _____

4. Enter the average annual number of "Before" improvement PDO accidents _____
5. Enter the average annual number of "After" improvement PDO accidents _____
6. Subtract Line 5 from Line 4 (reduction in PDO accidents) _____

7. Add Line 6 to Line 3 (total accident reduction) _____

WAS ACCIDENT REDUCTION SIGNIFICANT ACCORDING TO TABLE 2? Yes____ No____

8. Enter the unit cost of Fatal or Injury accidents _____
9. Multiply Line 3 by Line 8 (the benefit of reducing Fatal and Injury accidents) _____

10. Enter the unit cost of PDO accidents _____
11. Multiply Line 6 by Line 10 (the benefit of reducing PDO accidents) _____

12. Add Line 9 to Line 11 (total benefit due to accident reduction) _____

IMPROVEMENT COSTS

1. Enter the total annual cost of improvements _____
2. Enter the annual cost to engineering department _____
3. Enter the annual cost to police department _____
4. Enter other cost _____

5. Add Lines 1, 2, 3, and 4 (total cost of making improvements) _____

BENEFIT/COST RATIO

1. Enter the total benefit _____
2. Enter the total cost _____
3. Divide Line 1 by Line 2 to obtain the Benefit/Cost Ratio _____

INTERSECTION TRAFFIC COUNT FIELD SHEET [Form ITCFS]

N/S STREET _____ DAY _____ DATE _____

E/W STREET _____ TIME START _____ END _____

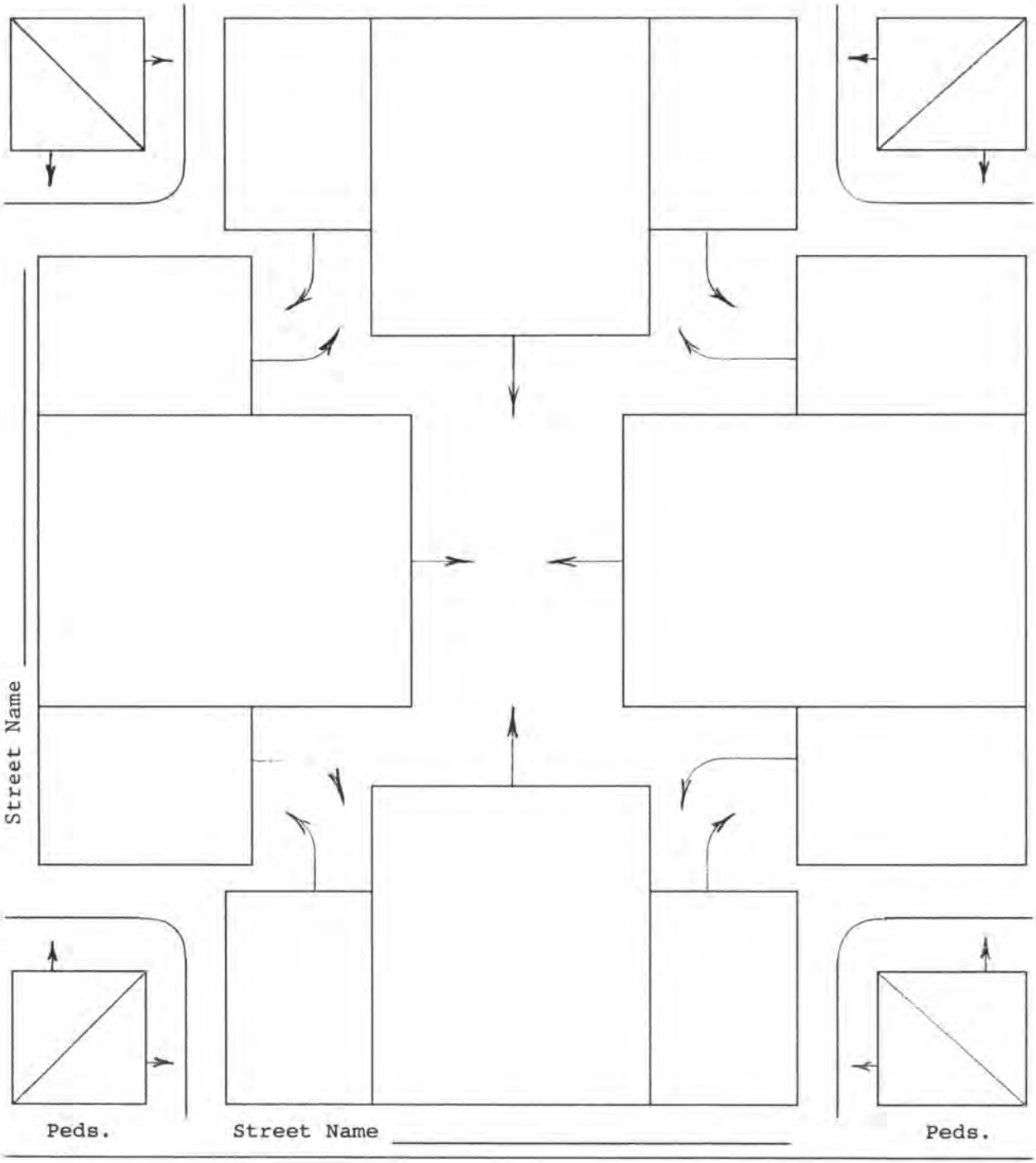
OBSERVER _____ WEATHER _____

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

T: Trucks with six or more tires

B: Buses SB: School buses

North Arrow:



VEHICLE TURNING COUNT SUMMARY AND ADT ESTIMATE [Form TCSAE]

LOCATION _____ OBSERVER _____

DAY _____ DATE _____ TIME _____ WEATHER _____

Traffic Control Devices:

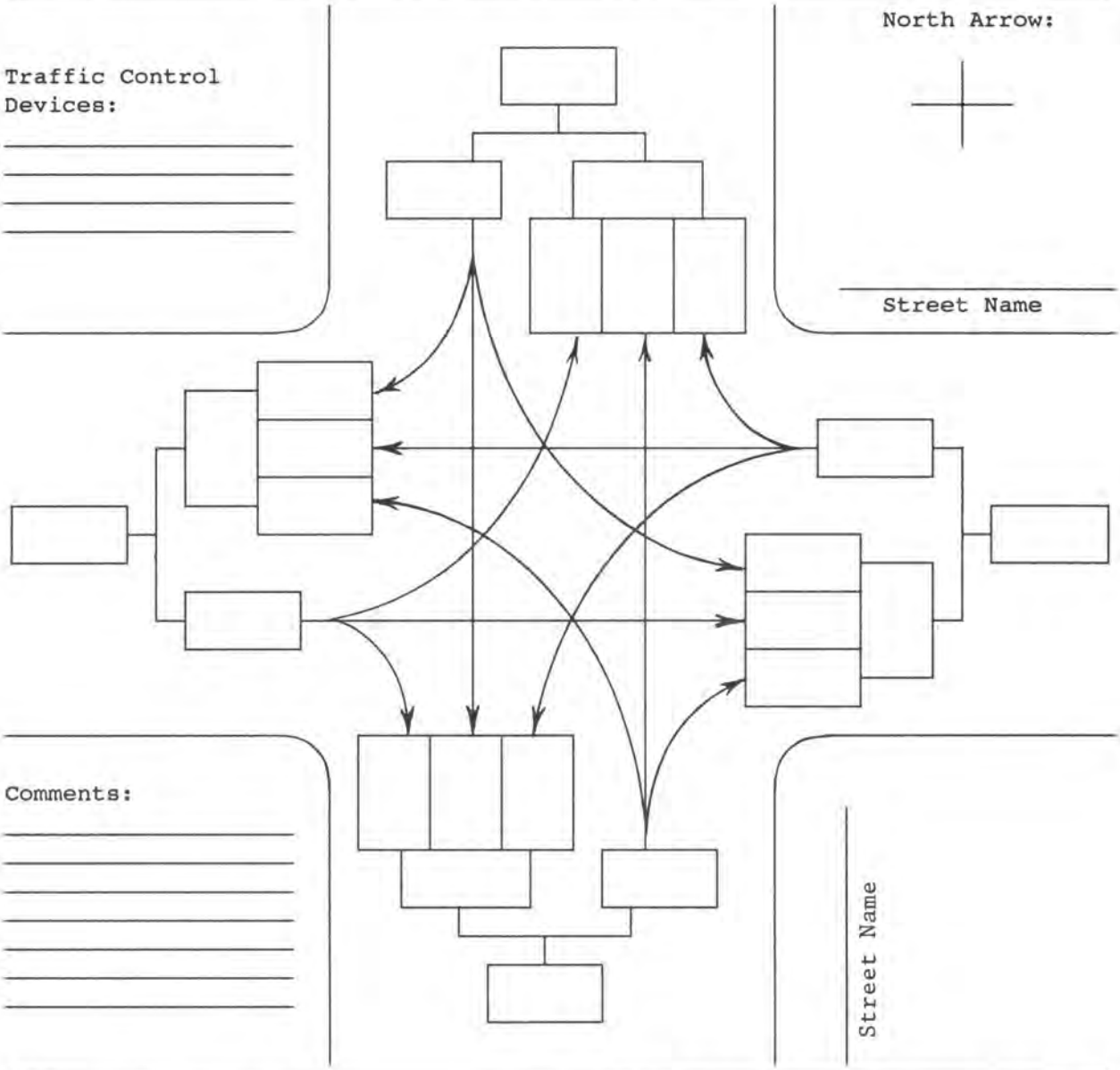
_____

_____

_____

_____

North Arrow:



Comments:

_____

_____

_____

_____

_____

_____

_____

INBOUND APPROACH STREET NAME AND DIRECTION	INBOUND COUNT	ADJUSTMENT FACTOR *	AVERAGE DAILY TRAFFIC ESTIMATE

INTERSECTION ADT ESTIMATE (TOTAL ENTERING VEHICLES PER DAY): _____

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

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