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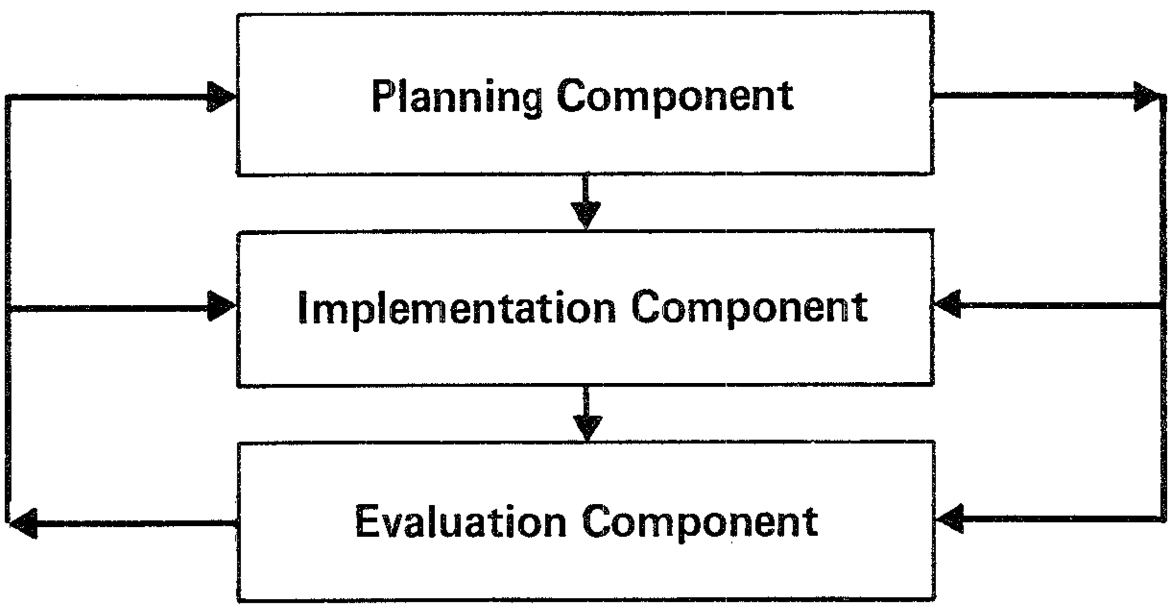
FHWA-TS-81-218

U.S. Department
of Transportation
**Federal Highway
Administration**

# Highway Safety Improvement Program (HSIP)

December 1981

HSIP



## FOREWORD

This user's manual contains guidance to State and local agencies for developing and implementing a highway safety improvement program which best suits their capabilities and needs. The manual should be beneficial to State and local highway engineers and other professionals involved in the highway safety improvement program.

The objectives of this manual are to describe how to:

1. Implement a highway safety improvement program which complies with Federal-Aid Highway Program Manual 8-2-3 and which contains the following components and processes:

   * Planning (collect and maintain data, identify hazardous locations and elements, conduct engineering studies and establish project priorities)

   * Implementation (schedule and implement projects)

   * Evaluation (determine the effect of safety improvements)

2. Select the most appropriate procedures based on an agency's particular goals, objectives, resources, and highway system.

3. Utilize current information concerning reporting requirements, funding sources, and practices of other highway agencies.

The manual was prepared by Goodell-Grivas, Inc. Mr. Charles Zegeer was the Principal Investigator. Mr. Rudolph M. Umbs is the Implementation Manager.

Milton P. Criswell
Director
Office of Development

## NOTICE

U.S. Department of Transportation

Federal Highway Administration

# Memorandum

Subject: Technology Sharing Report FHWA-TS-81-218 "Highway Safety Improvement Program"

Date: April 15, 1982

From: Deputy Chief, Implementation Division
Office of Development
Washington, D.C.

Reply to Attn. of: HDV-21

To: Regional Federal Highway Administrators, Regions 1-10; and Direct Federal Division Engineers

A user's manual titled "Highway Safety Improvement Program" is being distributed as a Technology Sharing Report by this memorandum. This manual is currently being used in a National Highway Institute training course by the same name.

The manual provides guidance to State and local agencies for developing and implementing a highway safety improvement program which best suits their capabilities and needs. The manual should be beneficial to Federal, State, and local highway engineers and other professionals involved in a highway safety improvement program.

The manual describes how to:

1. Implement a highway safety improvement program which complies with Federal-Aid Highway Program Manual 8-2-3 and which contains the following components and processes:

   o Planning (collect and maintain data, identify hazardous locations and elements, conduct engineering studies and establish project priorities)

   o Implementation (schedule and implement projects)

   o Evaluation (determine the effect of safety improvements)

2. Select the most appropriate procedures based on an agency's particular goals, objectives, resources, and highway system.

3. Utilize current information concerning reporting requirements, funding sources, and practices of other highway agencies.

The manual is being distributed in accordance with the Standard Implementation Procedures as amended. A limited number of copies are available from Mr. R. M. Umbs (HDV-21, FTS 426-9211) of the Implementation Division. Copies may also be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. (Stock No. 050-001-00241-8; Price: $7.50.)

This manual is part one of a three part series. The other two publications titled "Highway Safety Evaluation" and "Highway Safety Engineering Studies" will be distributed be separate memoranda. A brochure announcing these publications is being distributed with the "Highway Safety Evaluation" guide.

Information about the training course may be obtained from the National Highway Institute (HHI-2, FTS 426-9141).

John D. Coursey

Attachment

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Washington, D.C. 20402

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# CHAPTER I

## INTRODUCTION

Safety programs administered by the Federal Highway Administration (FHWA) are aimed at reducing human and economic losses on the nation's highway transportation systems. Specific guidelines for highway safety programs were firmly established by the U.S. Congress in the Highway Safety Act of 1966 and later expanded by such legislation as the 1973 Highway Safety Act and the 1978 Surface Transportation Act. The specific safety-related programs which have resulted from this legislation should be carried out by state and local highway agencies in an organized, systematic manner.

The Highway Safety Improvement Program (HSIP) was formally defined in an FHWA regulation titled Federal-Aid Highway Program Manual, Volume 8, Chapter 2, Section 3 (FHPM 8-2-3), dated March 5, 1979. The primary purpose of FHPM 8-2-3 was to establish the policy for the development and implementation of a comprehensive highway safety program in each state.

The policy of FHPM 8-2-3 is: "Each state shall develop and implement, on a continuing basis, a highway safety improvement program which has the overall objective of reducing the number and severity of accidents and decreasing the potential for accidents on all highways."

The HSIP consists of components for the planning, implementation, and evaluation of safety programs and projects. The three components consist of specific processes to be carried out by states and approved by FHWA. A range of appropriate procedures has been defined for use in the administration of the various processes. State highway agencies should work closely with local governments in a spirit of cooperation to obtain the best results from their safety programs.

The purpose of this User's Manual is to provide guidance to state and local highway agencies in implementing a Highway Safety Improvement Program (HSIP) which best suits their capabilities and needs. This User's Manual was developed to be used as a training guide for a 3 1/2-day training course for highway agency managers.

The specific objectives of this manual and course are to:

1. Provide training for the Highway Safety Improvement Program which will include the processes related to:

   - Collecting and Maintaining Data
   - Identifying Hazardous Locations and Elements
   - Conducting Engineering Studies
   - Establishing Project Priorities
   - Scheduling and Implementing Projects
   - Determining the Effects of Safety Improvements

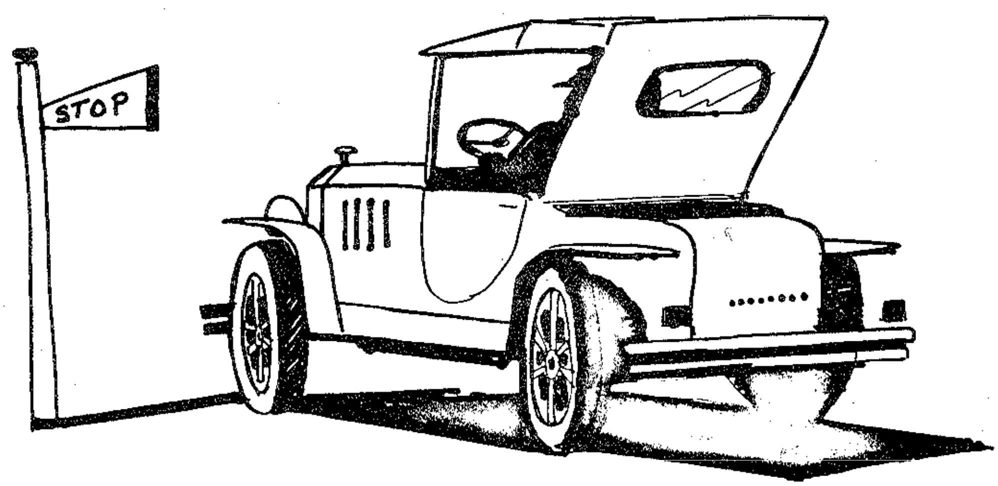
2. Allow for the selection of the most appropriate safety procedures based on a highway agency's particular goals, objectives, resources, and highway system.

3. Provide current information concerning required agency reports and possible funding sources.

4. Provide a list of related articles and publications for use in obtaining more detailed information on topics related to highway safety.

5. Present a summary of current practices by state highway agencies with regards to various safety-related procedures.

This User's Manual is only one of a series of such manuals for FHWA courses related to highway safety. This particular course was intended to provide a general description of an overall highway safety program. Other related courses provide a more detailed description of specific processes within the total HSIP.



## CHAPTER II

## HISTORY OF THE HIGHWAY SAFETY IMPROVEMENT PROGRAM

Highway safety professionals have long recognized the need for an organized approach to the correction of highway safety problems. The concept of organizing a systematic approach appeared in technical papers and government regulations as early as the 1940's and 1950's. It was not until the late 1960's and early 1970's that the importance of a highway safety program was further emphasized through legislation and research. More recently, the private sector expressed a desire for a systemmatic approach to improving highway safety, and similar concerns have been expressed by state and local highway agencies.

As a result of the demonstrated need for improved highway safety methods and the continual increase in annual traffic accident losses in the 1960's and early 1970's, several important Federal programs were initiated. In the mid 1960's, the Federal Highway Administration (FHWA) initiated the Spot Improvement Program. This program attempted to identify "hazardous" locations and provided funds for their correction. Two years later, Congress passed the 1966 Highway Safety Act (23 U.S.C. 402), which set requirements for states to develop and maintain a safety program through the Highway Safety Program Standards. To assist in maintaining a safety program, the American Association of State Highway and Transportation Officials (AASHTO) "Yellow Book" was published in 1967. These sources defined safety design practices and policies. In 1973, categorical funding was made available for specific program areas, such as: pavement marking demonstration programs, rail/highway crossings, high hazard locations, elimination of roadside obstacles, and safer roads demonstration. These actions, in conjunction with other concurrent safety efforts such as vehicle design improvements and highway safety programs and policies of public and private agencies, resulted in a decline in the number and rate of highway fatalities in the late 1960's and 1970's.

The recent emphasis on highway safety has led to the availability of additional funding for the application of new procedures to enhance highway safety efforts at the state and local levels. Among the objectives of these procedures were the efficient use and allocation of available resources and the improvement of techniques for data collection, analysis and evaluation.

With these objectives in mind, the Federal-Aid Highway Program Manual (FHPM) 6-8-2-1, "Highway Safety Improvement Program" was developed and issued. Under this FHPM, a systematic process for organizing a highway safety improvement program was prescribed. This process was refined in FHPM 8-2-3 "Highway Safety Improvement Program", which superceded FHPM 6-8-2-1.

# CHAPTER III

## HIGHWAY SAFETY STANDARDS AND GUIDELINES

The National Highway Safety Act of 1966 (Public Law 89-564) resulted from a national concern to reduce traffic accidents and fatalities. It was enacted by Congress in September, 1966, and was based on the concept that a coordinated approach by all levels of government was the best way to solve the highway safety problem. The Act contains three major provisions:

- Accelerating highway safety programs in each state
- Increasing highway safety research and development
- Establishing the "National Highway Safety Advisory Committee"

The Act requires each state to have an approved program to reduce traffic accidents and the resulting deaths, injuries, and property damage. Each state is required to meet the following conditions to obtain approval of their safety plan:

1. The governor of the state shall be responsible for administering the program.
2. Political subdivisions of the state are authorized to carry out local highway safety programs within their jurisdictions, provided that their programs are approved by the governor and in accordance with uniform standards and the state comprehensive plan.
3. At least forty percent of Federal funds under this section shall be expended by political subdivisions in carrying out local programs.
4. The state and its political subdivisions shall maintain their level of expenditures for highway safety programs.
5. Development and operation of comprehensive driver training programs are required by the state.

### Highway Safety Program Manual

The Highway Safety Program Manual (HSPM) was developed by the U.S. DOT to provide guidance to state and local agencies in conforming with highway safety programs. Volumes comprising the Manual correspond to the Safety Standards and include the following: [1]

0 - Planning and Administration
1 - Periodic Motor Vehicle Inspection
2 - Motor Vehicle Registration
3 - Motorcycle Safety
4 - Driver Education
5 - Driver Licensing
6 - Codes and Laws
7 - Traffic Courts
8 - Alcohol in Relation to Highway Safety
9 - Identification and Surveillance of Accident Locations
10 - Traffic Records
11 - Emergency Medical Services
12 - Highway Design, Construction, and Maintenance
13 - Traffic Engineering Services (Traffic Control Devices)
14 - Pedestrian Safety
15 - Police Traffic Services
16 - Debris Hazard Control and Cleanup
17 - Pupil Transportation Safety
18 - Accident Reporting and Investigation

The Federal Highway Administration's office of Highway Safety currently administers the highway-related safety standards, frequently referred to as the "three-plus standards." These Standards include:

- Standard 9 - Identification and Surveillance of Accident Locations
- Standard 12 - Highway Design, Construction, and Maintenance
- Standard 13 - Traffic Engineering Services
- Standard 14 - Pedestrian Safety (the "plus" in the three-plus standards). The highway related aspects are included in Sections II, V, and jointly in Section VII.

Copies of these volumes should be obtained by agency managers and used routinely as reference guides and as a comparison to their own agency's practices.

A brief description of the requirements of the three-plus standards as they relate to state and local governments follow:

- <u>Standard 9 - Identification and Surveillance of Accident Locations</u>

This Standard requires the development of a program for identifying and maintaining surveillance of locations having high accident experience. After identifying hazardous locations, the state must take appropriate measures to reduce accidents and to evaluate the effectiveness of safety improvements at these locations. Also, a program must be developed to maintain surveillance of the roadway network for potentially high accident locations and for correcting problems at these locations. Each state is required to periodically evaluate their program and provide FHWA with an evaluation summary.

- Standard 12 - Highway Design, Construction, and Maintenance

This Standard requires the development of a highway design, construction, and maintenance program. The program shall include design standards relating to safety features for all new construction or reconstruction, such as sight distance, horizontal and vertical curvature, spacing of decision points, lane widths, etc. Roadway lighting must be provided or upgraded on expressways and other major arterials in urban areas and locations with a high ratio of night-to-day accidents.

Each state must also have a program for resurfacing or other surface treatment on roadway sections with low skid resistance. The systemmatic identification and tabulation of all rail-highway grade crossings is required along with a program to eliminate dangerous crossings. The Standard also calls for roadsides which are clear of obstacles, with breakaway signs, special bridge railings and parapets, and guardrails placed at locations where obstacles cannot be removed or replaced.

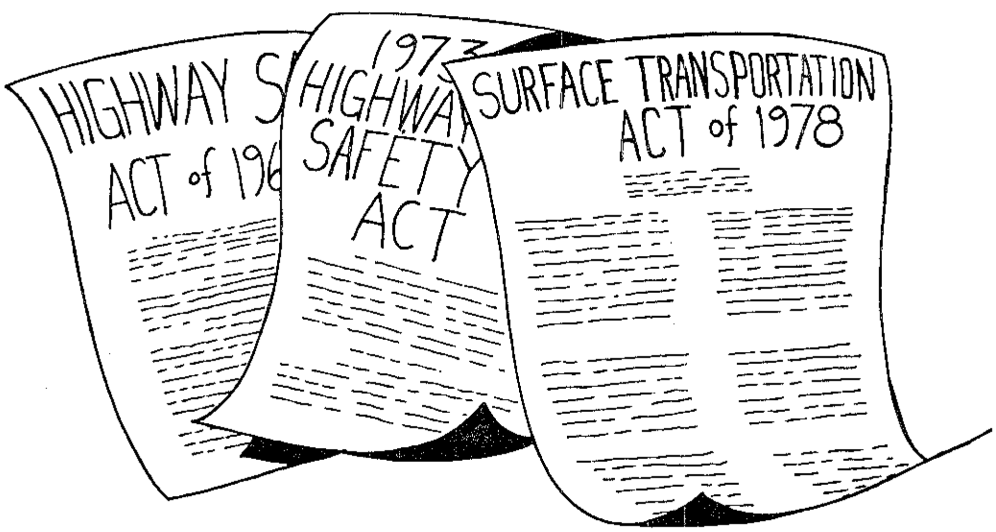
- Standard 13 - Traffic Engineering Services

This Standard requires the application of modern traffic engineering principles and uniform standards for traffic control to reduce the likelihood and severity of traffic accidents. Each state shall have a comprehensive manpower development plan to insure necessary traffic engineering capability to local jurisdictions and provide for upgrading of skills of traffic engineers, subprofessionals, and technicians. A plan should be developed to inventory and maintain traffic control devices according to Federal Standards. An implementation schedule should be developed to utilize traffic engineering manpower to review "operational difficulties", install safety-related improvements, and evaluate the effectiveness of specific traffic control measures.

- Standard 14 - Pedestrian Safety

This Standard requires the development of a statewide inventory of pedestrian-motor vehicle accidents including location, age of pedestrian and other statistics. Procedures should be developed for improving pedestrian protection through development of safe school route handbooks, familiarizing drivers with pedestrian problems, and conducting engineering studies at high hazard locations. The Standard also requires programs to provide training and education for the general public concerning pedestrian safety on or near roads.

The responsibility for Standard 14 (Pedestrian Safety) is shared between FHWA and NHTSA (National Highway Traffic Safety Administration). FHWA is responsible for the highway-related aspects of Volume 14. NHTSA administers the safety program standards pertaining to the automobile and the driver.



# CHAPTER IV

## FRAMEWORK AND OVERVIEW OF THE HIGHWAY SAFETY IMPROVEMENT PROGRAM (HSIP)

The structure of the Highway Safety Improvement Program (HSIP) was established in FHPM 8-2-3 in terms of components, processes, subprocesses, and procedures. Such terms may be defined as follows:

<u>Components</u> - refer to the three general phases of the HSIP: (1) Planning, (2) Implementation, and (3) Evaluation.

<u>Processes</u> - refer to the sequential elements within each component. For instance, the four processes within the Planning Component include; (1) Collect and Maintain Data (2) Identify Hazardous Locations and Elements, (3) Conduct Engineering Studies, and (4) Establish Project Priorities.

<u>Subprocesses</u> - refer to specific activities which are contained within certain processes. For example, under Process 3 of the Planning Component ("Conduct Engineering Studies") the three subprocesses are; (1) Collect and Analyze Data at Hazardous Loctions, (2) Develop Candidate Countermeasures, and (3) Develop Projects.

<u>Procedures</u> - refer to the possible ways in which each of the processes or subprocesses may be attained. For instance, the procedures for identifying hazardous locations and elements (Process 2) include the Frequency Method, Rate Method, Rate Quality Control Method, etc.

An overview of the HSIP is given in Figure 1 with respect to the total highway activities of a highway agency. These basic highway activities include:

- Planning and Design
- Construction
- Safety
- Operation and Maintenance

The safety aspect of highways should be handled by maintaining an effective HSIP, consisting of the following three components:

- Planning
- Implementation
- Evaluation

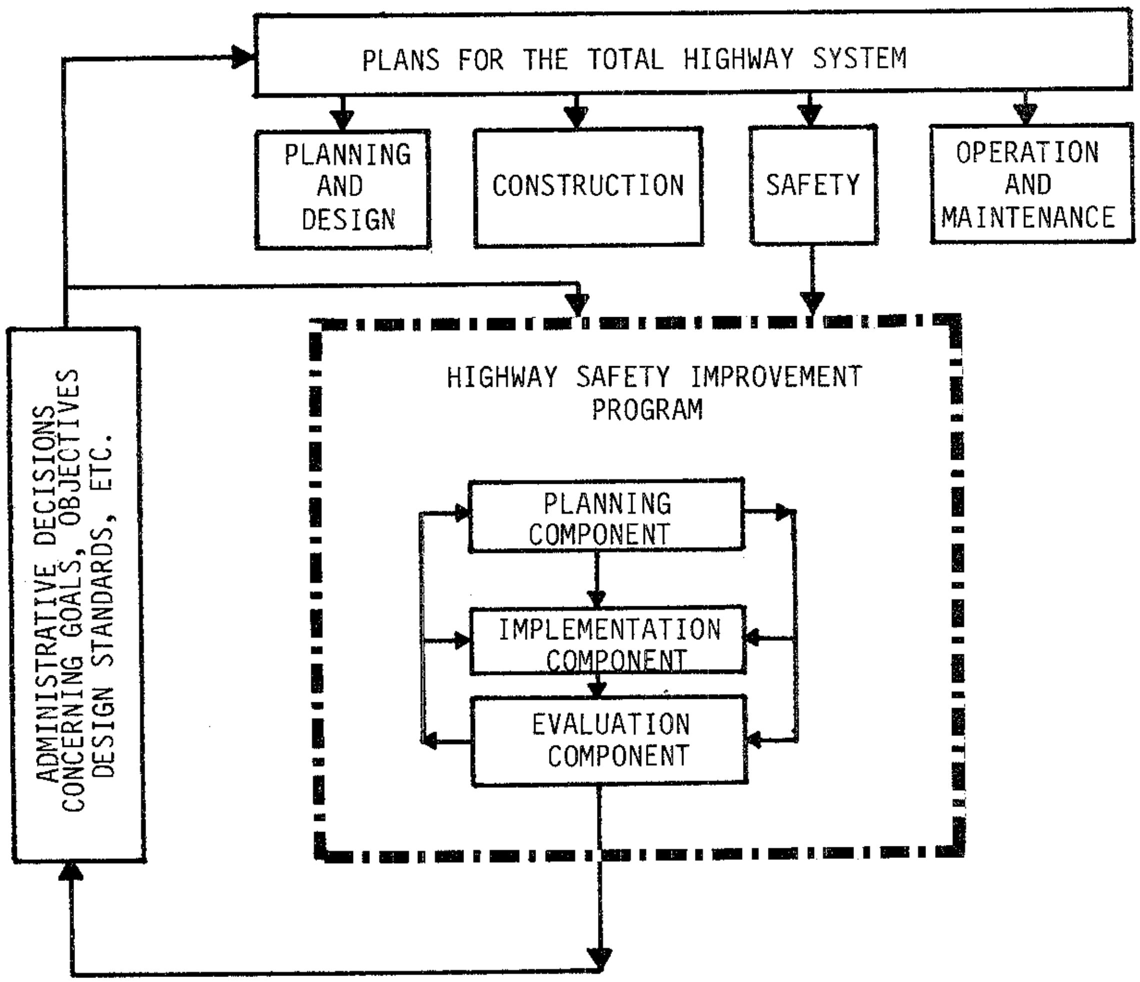



Figure 1. Overview of the Highway Safety Improvement Program.

The relationships between the three components are illustrated in Figure 1, where the arrows indicate the necessary flow of data and information. Note that safety improvements should first be planned, then implemented, and finally evaluated.

The evaluation of highway safety improvements is an essential step in the highway safety program for any highway agency. The results of the Evaluation Component provide necessary information into the planning and implementation of subsequent highway improvements. Beside providing input back into the HSIP, the Evaluation Component provides basic information for use in administrative decisions of a highway agency in terms of:

- Goals of the agency for the future
- Specific agency objectives
- The continuation or modification of local design standards
- The efficiency of various personnel and/or equipment
- The validity of past estimates of required resources for various activities
- Indications of where limited funding should be spent

Such administrative decisions can be used to periodically update and improve total plans for the highway system.

The HSIP at the process level is given in Figure 2, which illustrates the inter-relationships between the six processes. Four processes are defined in under the Planning Component, and the Implementation Component and Evaluation Component each contain one process. The arrows indicate the necessary flow of data and information in order to properly conduct the HSIP.

The subprocess level of the HSIP is shown in Figure 3, where 14 specific subprocesses are defined. The necessary sequence of subprocesses is also illustrated within each process. For example, in Process 3 ("Conduct Engineering Studies"), the collection and analysis of data (Subprocess 1) should be performed before accident countermeasures are developed (Subprocess 2). Projects can be finalized or developed for each highway location (in Subprocess 3) only after the first two subprocesses are completed. The final listing of safety improvement projects is then used as the input into Process 4 ("Establish Project Priorities)

A listing of procedures under each process and subprocess was developed based on:

- Widely accepted practices currently in use by various highway agencies
- Procedures developed and/or used by one or more highway agencies which may offer a useful method under certain conditions

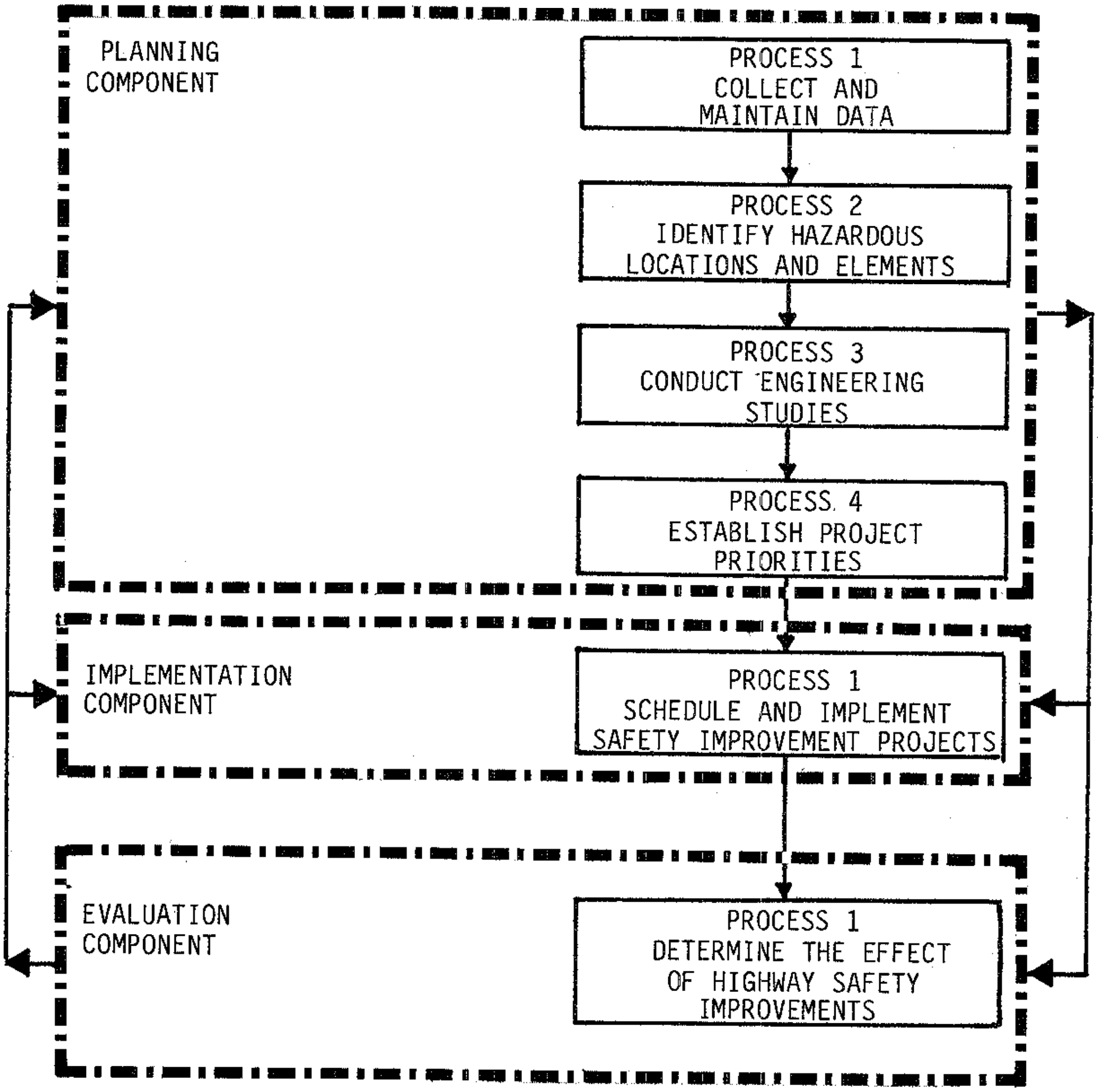



Figure 2. Highway Safety Improvement Program at the process level.

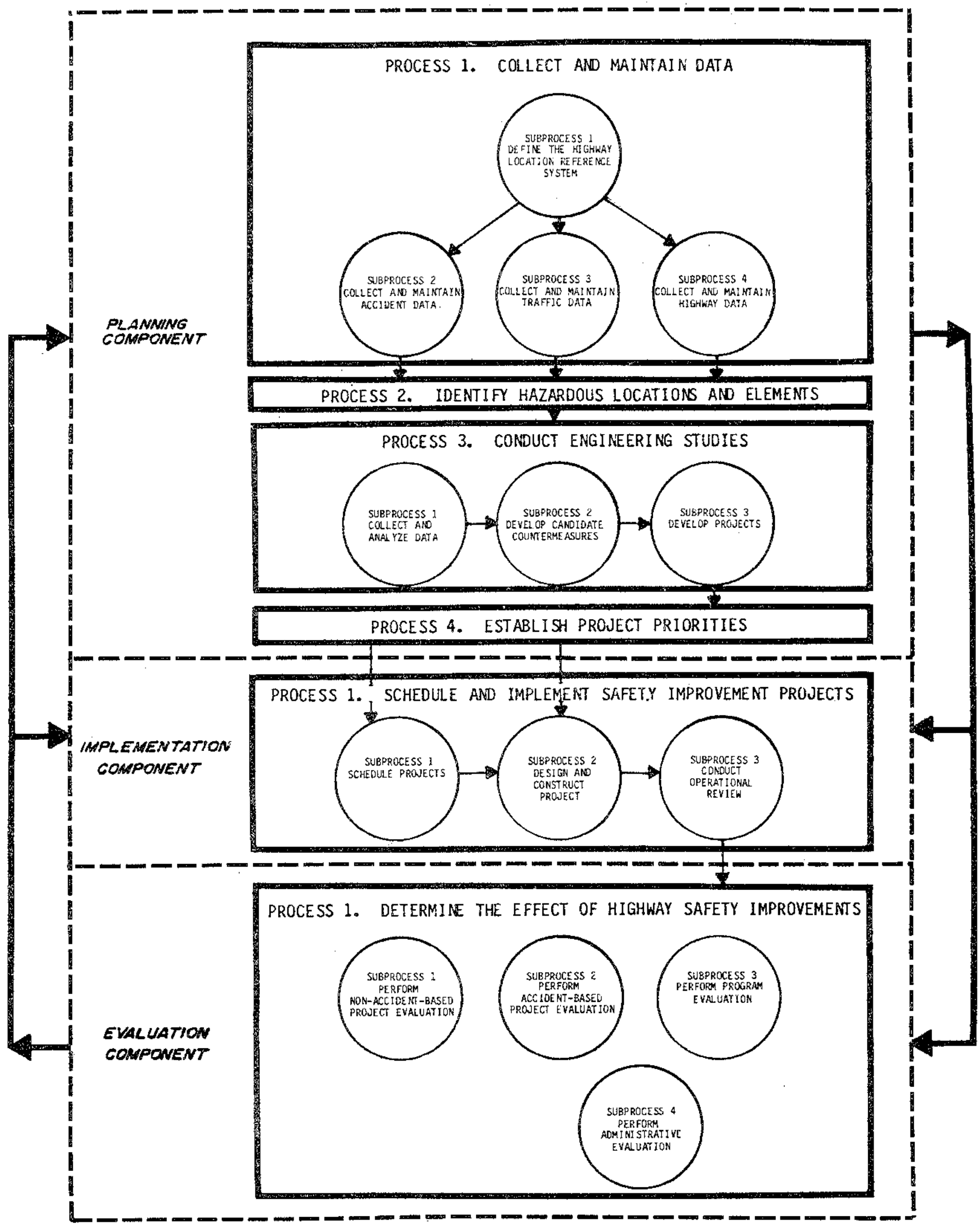



Figure 3. Highway Safety Improvement Program at the subprocess level.

- New or untested concepts reported in the literature which may offer a worthwhile alternative to existing procedures and deserves further testing for possible future use.

A total of 64 specific procedures are listed in Figure 4, as they pertain to the processes and subprocesses of the HSIP.

In this User's Manual, specific categories of highway safety improvements will be discussed on the basis of their complexity and level of aggregation. Highway safety improvements may be arranged in the following hierarchy.

- A countermeasure is a specific activity or set of related activities designed to contribute to the solution of an identified safety problem at a single location. Examples of countermeasures are: (1) an advance warning sign installation, (2) an impact attenuator installation, or (3) left-turn prohibition during peak traffic periods at a signalized intersection.

- A project is one or more countermeasures designed to reduce identified safety deficiencies at a highway location. For example, pavement deslicking may be selected as a single countermeasure to reduce wet-weather accidents at a site, and is termed as a project. Also, the combination of countermeasures at a site, such as shoulder stabilization, edgelining, and fixed-object removal is also considered as a project.

- A program is a group of projects, countermeasures, and/or activities which are implemented to achieve a common highway safety goal. A program may be applied to numerous locations and may include several types of countermeasures which serve the same purpose. For example, a program to reduce wet-weather accidents may be implemented by an agency at five different locations and include various combinations of:

    - Improved signing
    - Longitudinal grooving
    - Deslicking overlay

  The combination of all projects resulting from the HSIP planning component is another example of a program.

PLANNING COMPONENT

Process 1 - Collect and Maintain Data

Subprocess 1 - Define the Highway Location Reference System

Procedure 1 - Milepost Method
Procedure 2 - Reference Point Method
Procedure 3 - Link Node Method
Procedure 4 - Coordinate Method
Procedure 5 - LORAN-C Based Method

Subprocess 2 - Collect and Maintain Accident Data

Procedure 1 - File of Accident Reports by Location
Procedure 2 - Spot Maps
Procedure 3 - Systemwide Computerization of Accident Data

Subprocess 3 - Collect and Maintain Traffic Data

Procedure 1 - Routine Manual Collection of Systemwide Traffic Data
Procedure 2 - Use of Mechanical Volume Counters
Procedure 3 - Permanent Count Stations
Procedure 4 - Maintenance of Traffic Data on Maps or in Files
Procedure 5 - Systemwide Computerization of Traffic Data

Subprocess 4 - Collect and Maintain Highway Data

Procedure 1 - Systemwide Manual Collection of Highway Data
Procedure 2 - Photologging and Videologging
Procedure 3 - Maintenance of Highway Data on Maps or in Files
Procedure 4 - Systemwide Computerization of Highway Data

Process 2 - Identify Hazardous Locations and Elements

Procedure 1 - Frequency Method
Procedure 2 - Accident Rate Method
Procedure 3 - Frequency Rate Method
Procedure 4 - Rate Quality Control Method
Procedure 5 - Accident Severity Method
Procedure 6 - Hazard Index Method
Procedure 7 - Hazardous Roadway Features Inventory

Figure 4. Procedures used in the various processes and subprocesses.

Process 3 - Conduct Engineering Studies

Subprocess 1 - Collect and Analyze Data at Identified Hazardous Locations

Procedures 1-5 - Accident Studies
Procedures 6-14 - Traffic Studies
Procedures 15-20 - Environmental Studies
Procedures 21-24 - Special Studies

Subprocess 2 - Develop Candidate Countermeasure(s)

Procedure 1 - Accident Pattern Tables
Procedure 2 - Fault Tree Analysis
Procedure 3 - Multi-Disciplinary Investigation Team

Subprocess 3 - Develop Projects

Procedure 1 - Cost-Effectiveness Method
Procedure 2 - Benefit-to-Cost Ratio Method
Procedure 3 - Rate-of-Return Method
Procedure 4 - Time-of-Return Method
Procedure 5 - Net Benefit Method

Process 4 - Establish Project Priorities

Procedure 1 - Project Development Ranking
Procedure 2 - Incremental Benefit-to-Cost Ratio
Procedure 3 - Dynamic Programming
Procedure 4 - Integer Programming

IMPLEMENTATION COMPONENT

Process 1 - Schedule and Implement Safety Improvement Projects

Subprocess 1 - Schedule Projects

Procedure 1 - Gantt Charts
Procedure 2 - Program Evaluation and Review Technique (PERT)
Procedure 3 - Critical Path Method (CPM)
Procedure 4 - Multiproject Scheduling System

Subprocess 2 - Design and Construct Projects

Subprocess 3 - Conduct Operational Review

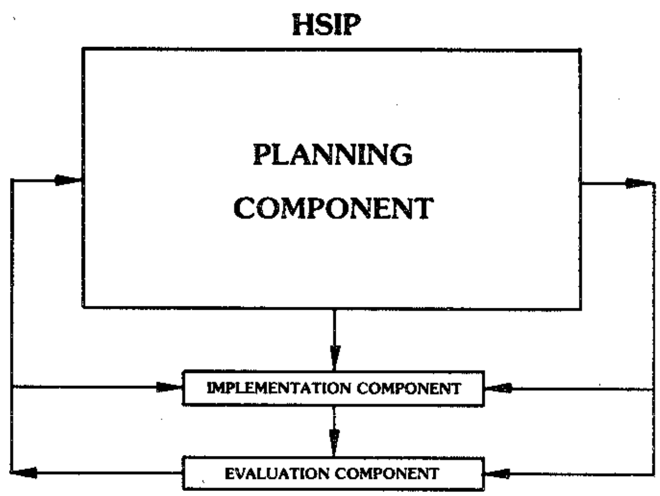
EVALUATION COMPONENT

Process 1 - Determine the Effect of Highway Safety Improvements

Subprocess 1 - Perform Accident-Based Project Evaluation
Subprocess 2 - Perform Non-Accident-Based Project Evaluation
Subprocess 3 - Perform Program Evaluation
Subprocess 4 - Perform Administrative Evaluation

Figure 4. Procedures used in the various processes and subprocesses (continued).

# PLANNING COMPONENT




PURPOSE

The purpose of the Planning Component is to produce the list of highway projects to be implemented.

DESCRIPTION

The Planning Component is the first of the three components in the Highway Safety Improvement Program (HSIP) and involves all activities necessary to determine which safety improvement projects should be implemented. The four processes within the Planning Component are:

Process 1 - Collect and Maintain Data
Process 2 - Identify Hazardous Locations and Elements
Process 3 - Conduct Engineering Studies
Process 4 - Establish Project Priorities

Within these four processes are specific subprocesses and procedures necessary to successfully complete the processes.

## COMPONENT INPUTS AND OUTPUTS

### Management Input

- Goals and objectives for the total highway and transportation network
- Goals and objectives of the Highway Safety Improvement Program

### Resource Input

- Funding
- Manpower
- Equipment

### Data or Informational Input

- Federal, State, and local design standards and guidelines
- Information from the Evaluation Component concerning the effectiveness of prior specific safety projects and programs
- Information from the Evaluation Component concerning past administrative evaluations

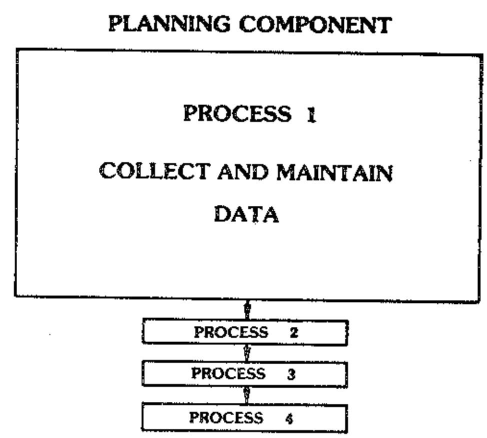
### Output

- A list of the specific highway projects to be implemented

CHAPTER V

# PROCESS 1

# COLLECT AND MAINTAIN DATA




## PURPOSE

The purpose of this process is to supply the necessary data base for the total highway system for use in identifying hazardous locations and elements.

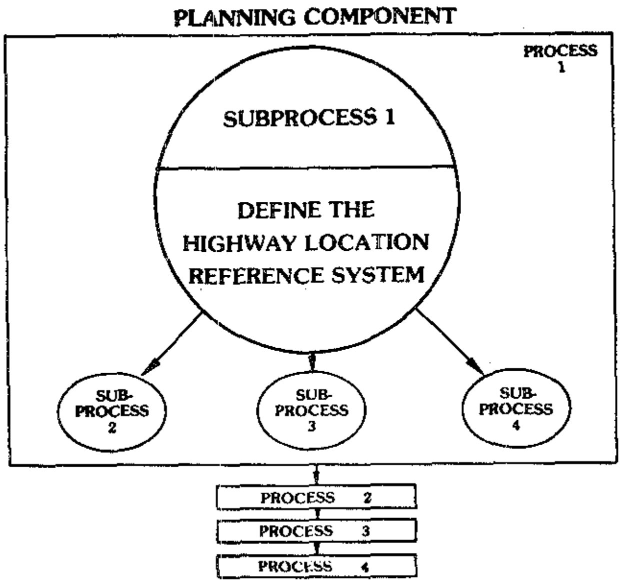
## DESCRIPTION

Four subprocesses have been defined within this process as follows:

Subprocess 1 - Define the Highway Location Reference System
Subprocess 2 - Collect and Maintain Accident Data
Subprocess 3 - Collect and Maintain Traffic Data
Subprocess 4 - Collect and Maintain Highway Data

Within each subprocess are procedures which may be selected by a highway agency to successfully accomplish that subprocess. A description of each subprocess, and the corresponding procedures, is provided in the following pages.

# PROCESS 1, SUBPROCESS 1
# DEFINE THE HIGHWAY LOCATION REFERENCE SYSTEM




PURPOSE

The purpose of this subprocess is to assign meaningful locational information to highways in the system. This is essential to merge accident, traffic, and highway data to identify and analyze hazardous locations and elements.

DESCRIPTION

According to Volume 9 of the Highway Safety Program Manual [1]: "Each state, in cooperation with county and other local governments, shall have a program for identifying accident locations and for maintaining surveillance of those locations having high accident rates or losses."

The proper identification of such hazardous locations can be accomplished by use of one of several highway location reference systems and methods. A location reference system includes all of the office and field procedures necessary to facilitate highway-related activities, such as planning, safety, and maintenance. A location reference method is a part of an agency's total reference system [2].

The specific methods (procedures) in this subprocess are:

Procedure 1 - Milepost Method
Procedure 2 - Reference Point Method
Procedure 3 - Link Node Method
Procedure 4 - Coordinate Method
Procedure 5 - Loran-C-Based Method

A single highway location reference method is generally adopted throughout a state highway system for practical reasons. However, alternative methods may be used in large cities or by county highway agencies.

## RANGE OF COMPLEXITY AMONG PROCEDURES

The milepost method, reference point method, and link node method are all currently in use and are generally not difficult to implement or utilize. However, the coordinate method and the LORAN-C-Based method are not used widely due to their complexity. The LORAN-C-Based system, in particular, requires considerable investment and manpower training and is appropriate only for large land areas.

## MANAGERIAL CONCERNS

- What is the accuracy of accident reporting using the method?
- What is the manpower required for the method?
- Are adequate funds available for implementing a new method?
- What are the equipment requirements?
- Will growth of the highway system create significant problems in re-numbering of the location reference system?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- A knowledge and understanding of various highway location reference systems

### Resource and Equipment Input

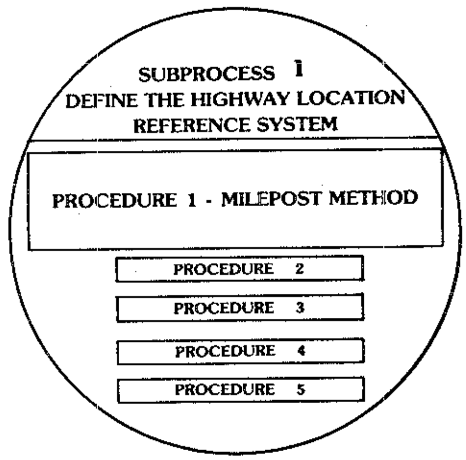
- Manpower
- Equipment (LORAN-C receivers or equipment for installing highway-reference signs)
- Funding

### Data or Information Input

- Highway maps or files containing the appropriate location reference values

## OUTPUT

- A code that uniquely identifies the location of any given spot or section of the highway system



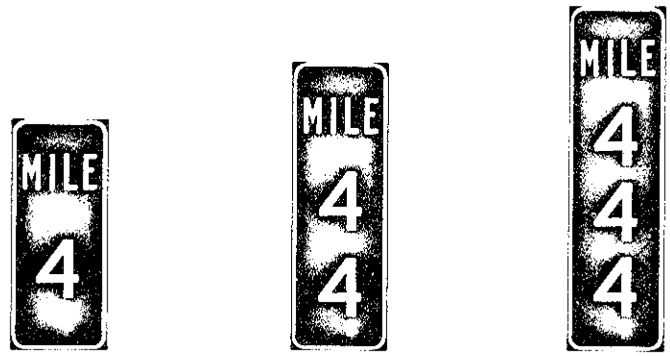

## PROCEDURE 1 - MILEPOST METHOD

## DESCRIPTION

The milepost method uses a numerical value to represent the distance from a base point to any location. This is usually accomplished using milepost markers which indicate the mileage to the point of interest from some zero point on the highway. To identify a location in the field, the distance to the nearest milepost marker is determined and added or subtracted from the number on the milepost. Some states, such as Missouri, utilize a milepost system but without field markers (paper map system). Maps are provided to police officers which identify the milepoint for their use in locating accidents.

Several specific characteristics of the milepost method have been identified by TRB as follows [2]:

- Signs may be placed at any spacing (usually one mile or greater)
- Signs contain the actual milepoints or approximate mileages to the location from a known point (county line, etc.)
- Zero points are usually assigned to route beginnings, at county lines, or at control section limits
- The message on the signs may or may not be readable from a moving vehicle. When readable, they provide useful distance information to motorists. Guides for milepost signs are given in the Manual on Uniform Traffic Control Devices (MUTCD) [3]. A typical milepost marker is shown in Figure 5.




D10–1
10" x 18"

D10–2
10" x 27"

D10–3
10" x 36"

Figure 5. Milepost markers from the MUTCD.

## PROCEDURE APPLICABILITY

The milepost method is generally applicable to highway systems with the following characteristics:

- Rural or suburban highways. In urban areas, intersections are too frequent and street names are more commonly used than route numbers. Also, in urban areas adjacent intersections could have the same milepost number and this could cause confusion in establishing locations of accidents.
- Virtually any size of highway system
- Highway systems which are fairly well established. In growing and newly developing areas, changes in highway lengths and alignments (due to construction or reconstruction) will necessitate changes (or discrepancies) in milepost markers for the routes.

## RESOURCE REQUIREMENTS

- Manpower - A field crew is needed for routine maintenance of milepost signs. Also, office personnel may be required to maintain and modify the maps and/or files to keep the reference system current.
- Funding - A minimum of about $100 per mile is required for the installation of milepost markers (assuming one milepost marker per mile in each direction at about $50 per marker). Also, maintenance funds are needed to maintain and replace damaged markers. Funds are also needed for occasional updating of reference maps or files.
- Equipment - A Sign truck and/or other equipment is needed to install milepost markers.

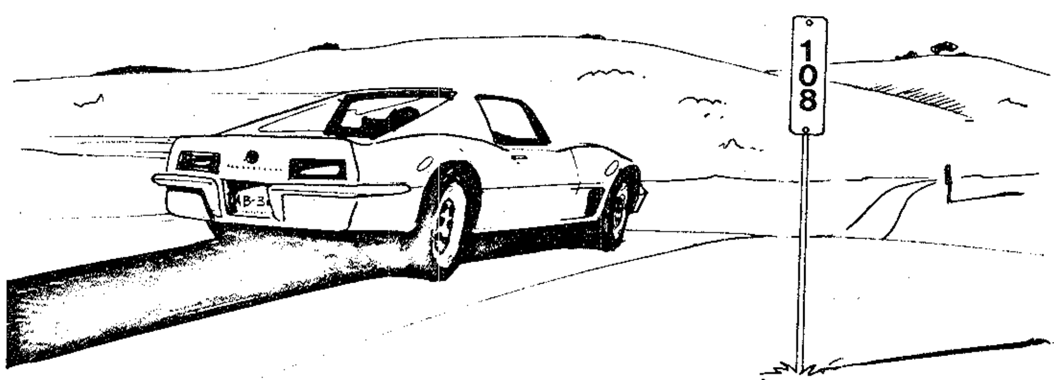
PROCEDURE ADVANTAGES AND DISADVANTAGES

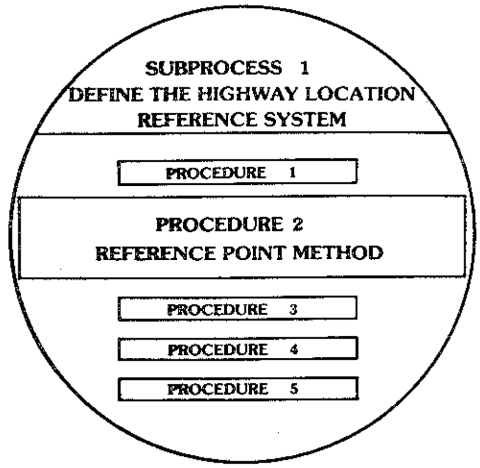
Advantages [2]

- The method can be easily learned by police officers and highway agency personnel.
- Milepost signs provide a chart of progress for motorists along a highway.
- There is usually uniform spacing of milepost markers, so the user (police officer) does not have to proceed more than some fixed distance (such as one-half mile) to find a reference marker.
- The numerical sequence of mileposts provides easy orientation, and many highway users (particularly, truck drivers and other users of CB radios) report accidents, vehicle breakdowns, or other emergencies with reference to posted milepost markers.

Disadvantages [2]

- Changes in route length due to highway construction and incorrect sign placement will result in inaccuracies.
- Where concurrent routes exist (one highway section with two or more route numbers), the numbers on the signs reflect mileage for only one of the routes and this may cause confusion.
- The placement of milepost signs along a road can create maintenance problems; they can also be hit by vehicles.
- Milepost markers which are spaced infrequently (several miles apart, as is common on non-interstate routes) can cause confusion and inaccuracies in the reporting of accident locations by police investigators.






## PROCEDURE 2 - REFERENCE POINT METHOD

### DESCRIPTION

The reference point method uses a fixed, identifiable feature, such as an intersection, railroad crossing or bridge, from which a location can be measured or referenced. Reference point signs may be placed at any spacing, and placement may be at major intersections and jurisdictional boundaries, at fixed uniform intervals, or a combination of these two and at special roadside features.

The true reference point must be recorded in central office records, and such reference numbers do not usually provide highway location information in terms of miles.

Following are important characteristics of the reference point method [2]:

- Signs may be placed at any spacing
- Central office records containing the true milepoint of reference post signs must be kept
- Signs ordinarily contain numbers that are not related to a milepoint. The signs may also include route number and jurisdiction information
- The signs may or may not be in numerical sequence along a route
- The messages on the signs may or may not be readable from a moving vehicle

### PROCEDURE APPLICABILITY

The reference point method is generally applicable to highway systems with the following characteristics:

- Rural or suburban highways. In uban areas, intersections are too frequent and street names and intersections are more commonly used than route numbers.

- Virtually any size of highway system
- Highway systems that are not in newly developing areas. For newly developing areas (more than 5 percent growth expected in the next 10 years) reference points may be assigned after firm plans are developed and approved for new roads.
- For highway systems where inventory information is available concerning the exact location of roadway features/bridges, intersections, changes in number of lanes, etc.

RESOURCE REQUIREMENTS

- Manpower - Field crews needed for routine sign maintenance. Office personnel are required for occasional modification of reference system on maps and/or files.
- Funding - Funds are necessary to develop, maintain, and update the roadway inventory, and maintenance costs for reference signs are required.
- Equipment - Sign installation equipment

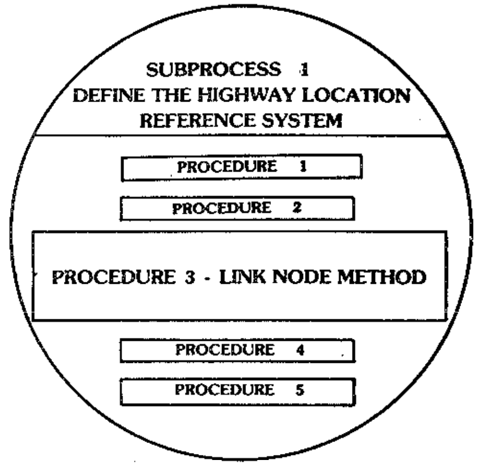
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages [2]

- Changes in route lengths due to construction do not affect the sign placement or the validity of the numbers on them.
- The signs apply to all overlapping routes.
- Spacings of the reference signs are normally of sufficient frequency that users will encounter a sign without travelling great distances.

Disadvantages [2]

- Most reference point signs do not permit motorists to chart their progress along a road.
- The placement of the reference signs on a highway may cause maintenance problems.
- The signs are roadside obstacles which can be hit by motorists.
- There is variability in the accuracy of accident locations, depending on distance from the reference point.




## PROCEDURE 3 - LINK NODE METHOD

### DESCRIPTION

The link-node method (also referred to as the nodal method) is based on assigning node numbers to highway intersections or other selected highway points. It is a document-oriented method, since no signs are installed in the field (in most cases). Generally, the intersection of two major streets (state highways, arterial-collector streets, etc.) is defined as a node. The "link" or highway segment between two nodes may or may not be assigned a unique number.

To use the link-node method, selected intersections are assigned a node number on office maps and/or files. Locations in the field may be identified by recording the name of the street or highway of concern and the name of the nearest intersecting street. The distance to the nearest intersecting street is also normally recorded. Appropriate node (or link) numbers can be assigned either in the field or in the office, using a file or map of node numbers.

Another application of the link-node method involves recording the street names and addresses of the locations of interest. Office personnel then assign the appropriate node number or link number to the location based on this information. While node numbers are normally assigned to intersections, other specific elements (identifiable on maps) may also be assigned node numbers, such as [4]:

- Road ends
- Railroad crossings
- Bridges
- 90-degree turns
- County boundaries
- Ramp terminals
- Grade separated structures

Examples of node maps are given in Figure 6, as developed for Iowa by Goalsby and Yu [4]. These node maps were developed for identifying statewide accident locations based on the U.S. Public Land Survey method for subdivision of land [4].

## PROCEDURE APPLICABILITY

The link-node method is generally applicable to highway systems with the following characteristics:

- Urban, suburban, or rural highways. Can easily conform to various population and highway densities.
- Virtually any size of highway system
- Highway systems with any rate of growth. The link-node method works well, regardless of the increase in highway mileage, since new node numbers can be assigned to new intersections.
- Where detailed updated maps are available, which include all intersections and possibly other observable physical features.

## RESOURCE REQUIREMENTS

- Manpower - Office crews are needed for developing, maintaining and updating the link-node numbers on maps and files.
- Funds - Funds are needed for establishing detailed mapping and roadway inventory (if not already available). Nominal funds are then needed for updating the system.
- Equipment - Mapping and drafting equipment for developing systemwide link-node maps.

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Generally inexpensive to implement, since field referencing signs are not required
- Good correlation can be established with other reference methods in preparing a cross-referencing index
- Relatively easy to understand, since node numbers usually correspond to actual intersections
- Short start-up time for implementation
- Very flexible in complex highway systems, such as interchanges and channelized intersections

### Disadvantages

- Generally undesirable for rural areas, where major intersections are several miles apart, because reporting accuracy may be less than desirable when reporting locations which are not close to any node

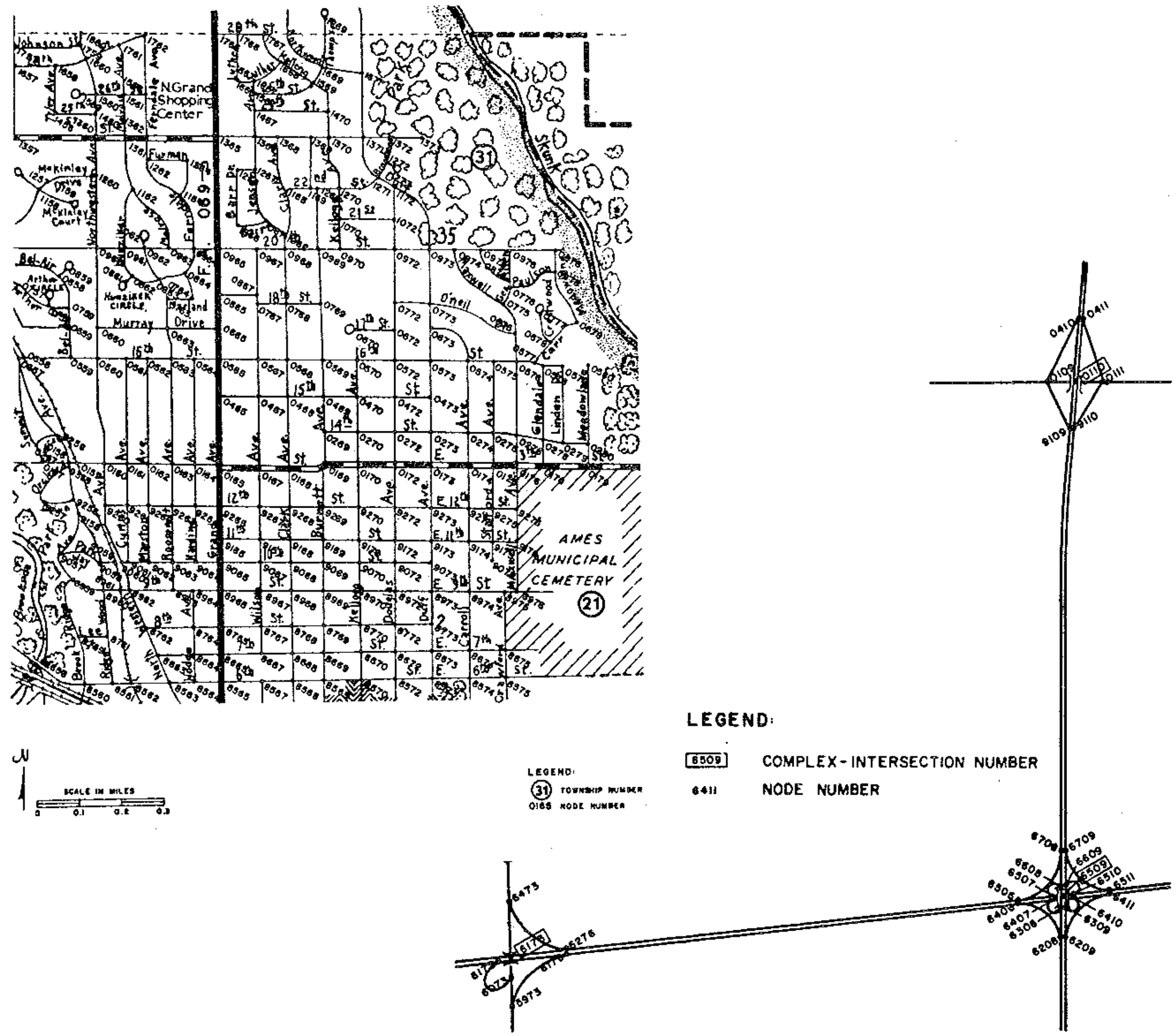
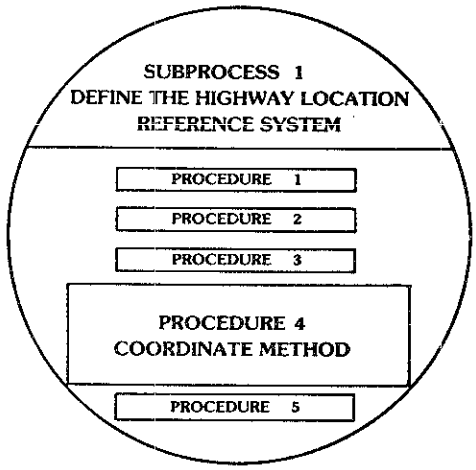



Figure 6. Example of node coding in Iowa for an urban area and a freeway.

(Source: Reference No. 4)

- If the node (or link) numbers are coded in the field for an accident location, the user (police officer) must have a log of node numbers and understand the system
- Entails a cumbersome filing system -- different users may identify the same location in varying ways; more difficult to identify clusters of accidents




## PROCEDURE 4 - COORDINATE METHOD

### DESCRIPTION

The coordinate system involves locating an accident site with a unique set of plane coordinates. The system relies on a complete set of grid coordinate maps and may be applied in several ways. The first may involve printing and distributing a large number of maps to police officers systemwide. The officer must then determine the coordinates of the accident site while he is investigating the accident and directly record these coordinates. The pre-coding of coordinate points on maps would allow the officers to pick such points on the maps while at the site and code them on the report.

The coordinate system is currently in use to only a limited extent, but is in the planning and development stages for possible use by several agencies. The method generally uses U.S. Geodedic Survey (USGS) topographical maps as a base. In most states, such maps are available at a scale of 1 inch = 4000 feet, which corresponds to 50 feet represented by 0.01 inch. In some states, USGS maps are now available at a 7-1/2 min. scale, or 1 inch = 2000 feet (50 ft. is represented by 0.02 inches) [5].

In a few western states, grid-oriented networks of local roads are being used as a basis for a coordinate method. Such roads normally follow section lines and divide the state into squares. Based on some zero point at the southestern corner of the state, a location is identified in terms of the miles east and north of the zero point.

The Indiana Traffic Accident Record System (INTRACS) was intended to be a major statewide effort to geographically locate accidents on highways throughout the state. It is based on a USGS map scale of 1 inch = 2000 feet. The road network file describes the X-Y coordinates of all intersection and alignment points to describe the street and roadway network. The X-Y coordinates are found for each highway point using an electronic digitizer (as shown in Figure 7) for use in a computerized data file. A sample matrix map for the system is shown in Figure 8 [6].

## PROCEDURE APPLICABILITY

The coordinate method is generally applicable to highway systems with the following characteristics:

- Any type of highway system (urban, suburban, or rural) where appropriate maps are available
- Large highway systems and land areas, such as statewide highway systems
- A highway system with any growth rate, as long as new unmapped roads are added to the coordinate maps. The predetermined coordinate identification numbers are permanent.

## RESOURCE REQUIREMENTS

- Manpower - Office personnel are needed to develop and maintain coordinate maps, and also to interpret the coordinate numbers in terms of the actual highway location.
- Funds - Funds are necessary to develop appropriate coordinate maps. Assuming that base maps (USGS) are available, the cost of modification was estimated (in 1969) to be approximately $30 per mile, excluding the costs for modifying the maps to make them useful in urban areas [5].
- Equipment - Appropriate mapping equipment for developing and/or modifying coordinate maps

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages [5]

- A point on the highway identified by coordinates is permanently located in a two-dimensional plane space. Thus, the coordinate number is not affected by changes in the length of the highway.
- The coordinate numbers can easily be correlated with either the milepoint method or the link-node method.
- The use of coordinates to locate accidents may simplify and encourage the use of mechanical plotting equipment.

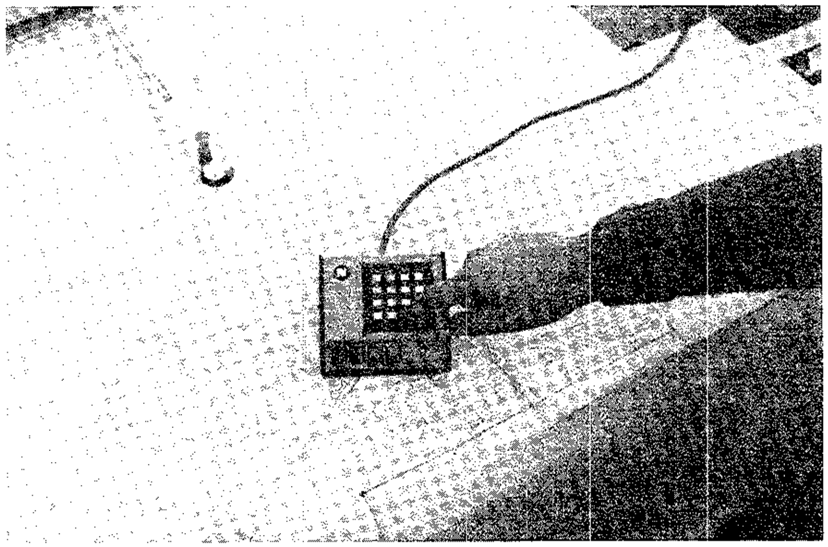


Figure 7. Electronic digitizer.

(Source: Reference No. 6)

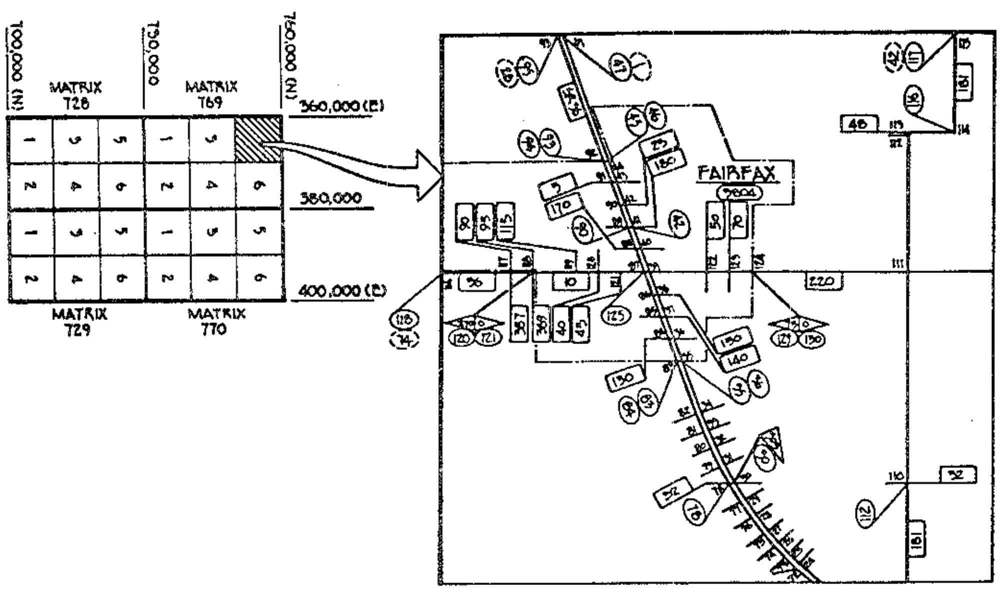
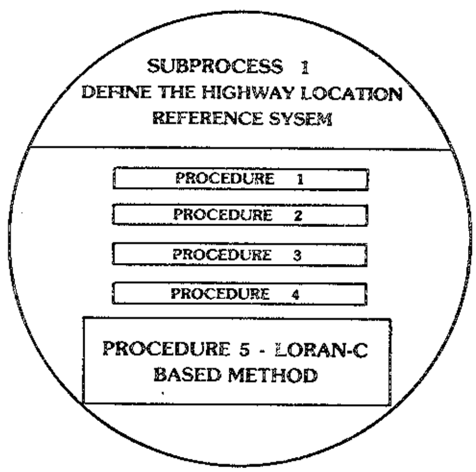



Figure 8. Sample matrix map.

(Source: Reference No. 6)

Disadvantages [5]

- The quantity of data required to uniquely identify a location is considerably more than with other methods. Fourteen digits are currently used to express the coordinate location (plus two or three additional digits for the route numbers). This greater quantity of information results in greater processing costs and is more susceptible to errors in reporting and coding, and such errors are more difficult to detect.
- The availability of costly maps (USGS or other) for sufficient accuracy
- Due to the complexity of the method, the typical accident investigator may have difficulty locating his position on a map and reading the coordinates to the desired accuracy. Under adverse conditions (darkness, rain, snow, fog, in rural areas with few landmarks, etc.) accurate readings may be a problem. Detecting and correcting such errors by office personnel will be very difficult or impossible without supplemental locational information (such as the precise distance and direction from a known intersection, etc.
- A considerable amount of start-up time is required to complete the necessary map work, the printing and distributing of maps, and training the police officers and other users of the coordinate method.
- The cost of modifying and updating maps is expected to be quite high.




PROCEDURE 5 - LORAN C-BASED METHOD

DESCRIPTION

The LORAN-C method is actually a specific application of the coordinate method. It is an electronic, LOng RAnge Navigation system currently operated by the U.S. Coast Guard for marine navigation in U.S. coastal waters. Incidental coverage is provided to over 2/3 of the land area of the continental U.S. LORAN-C can locate a point within one-fourth mile of its true geographic location and will allow a person to return to within about 50-300 feet of that same spot in most cases. By recording readings at locations, the area may be "calibrated" to the 50-300 feet repeatable accuracy. LORAN was developed by the Department of Defense in the 1940's as an aid to marine and aeronautical navigation over large areas of water, and further refined to become the LORAN-C system in the early 1960's.

The LORAN-C system is considered to be a radio system, but is not similar to commercial radio stations. Commercial stations transmit a continuous radio wave from a single antenna, whereas, LORAN-C systems consist of chains of transmitting stations (a master and two or more secondary stations), which are located about 500 miles apart. By broadcasting a group of low-frequency radio pulses, LORAN signals can be transmitted up to 2000 miles with a high degree of accuracy [7].

To apply the LORAN-C system for highway location referencing, a LORAN receiver automatically measures and displays the numerical time difference of arrival between the master its secondary stations. These time differences describe hyperbolic lines of position, the intersection of which describes the exact position of the receiver. Coverage of LORAN-C in the United States is approximately 73 percent as of 1980. Complete coverage of the continental United States will soon be achieved by the installation of three more stations - proposed for Montana, New Mexico, and Texas. All U.S. LORAN transmitting stations are operated and maintained by the U.S. Coast Guard [7].

## PROCEDURE APPLICABILITY

The LORAN-C based method is generally applicable to highway systems with the following characteristics:

- Rural or suburban highways. Distortion in electronic waves can result around tall buildings in urban areas, which can reduce accuracy. However, LORAN-C referencing can be easily cross-referenced with any of the other referencing methods.
- A very large highway system or a large land area. For example, the use of LORAN-C is most practical on a statewide basis. LORAN-C can be tested or implemented in smaller jurisdictions (one county at a time), but an individual city or county should not implement LORAN-C alone, unless it will eventually be part of a statewide system.
- Any rate of system growth, since a LORAN-C number is a permanent unambiguous number, (as are other coordinate numbers) and are not influenced by changes in a highway's length.
- Where accuracy in location referencing is emphasized, the LORAN-C method is desirable, particularly in rural areas.

## RESOURCE REQUIREMENTS

- Manpower - Electronics maintenance personnel are needed for repair of LORAN-C receivers. Also, an office crew is necessary for developing and updating the mapping system as new highway sections are added.

- Funding - Funds are needed for purchase of LORAN-C receivers and also an appropriate mapping system. The basic receiver unit (with no special options) can cost between $425 to $5000, depending on the size of production, as determined by the total available market and the complexity of the receiver (see Table 1) [7].
  The cost of amending existing maps (USGS maps, for example), would be about $200 for the initial calibration of a 450-square-mile area [5]. Subsequent modifications would be less expensive. Office training costs would also be involved.

Table 1. Estimated LORAN-C receiver costs ($).

| RECEIVER OPTIONS | COST RANGE | PRODUCTION RUN QUANTITIES | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 100 | 1,000 | 10,000 | 20,000 | 100,000 |
| Basic | Low | 4,000 | 1,500 | 1,200 | 600 | 540 | 425 |
| | High | 5,000 | 2,500 | 1,900 | 1,000 | 870 | 600 |
| Basic With Coordinate Conversion | Low | 6,000 | 3,000 | 1,700 | 850 | 765 | 600 |
| | High | 10,000 | 3,500 | 2,000 | 1,500 | 1,300 | 900 |
| Including All Of Desired Options | Low | 7,300 | 3,500 | 2,300 | 1,150 | 1,035 | 815 |
| | High | 20,000 | 5,000 | 2,800 | 1,720 | 1,490 | 1,035 |

(From Reference No.7)

- Equipment - LORAN-C receivers for all police officers or other personnel who would need to routinely identify location reference points.

## PROCEDURES ADVANTAGES AND DISADVANTAGES

### Advantages

- Accurate referencing coordinates can often be obtained when compared with other methods, particularly in rural areas.
- The use of field markers is not needed, so no sign installation and maintenance activities are required.
- The method can be easily applied to other highway-oriented or locational uses, such as:

- Location of emergency medical service needs
- Highway inventories
- Traffic enforcement surveillance
- A guide for conducting aerial photography

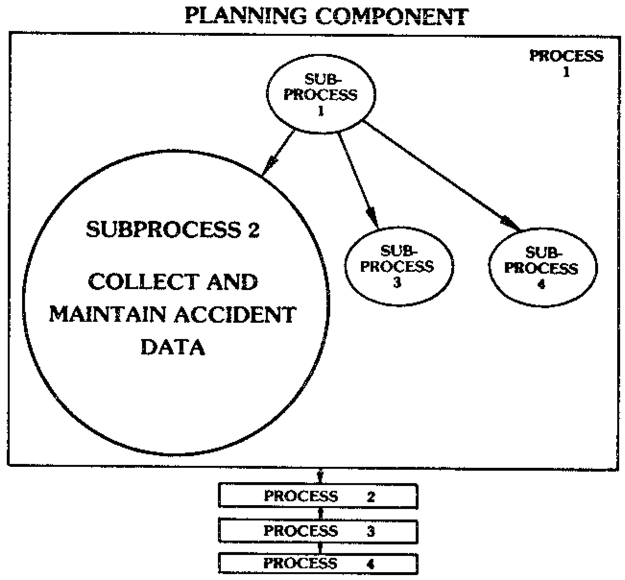
- The recording of location information is very simple, since a numerical code number is recorded from the LORAN-C receiver, and the location can be quickly determined from the LORAN-C-based maps.
- The exact location can be found easily within about 50 feet, if a follow-up site visit is needed.
- The LORAN-C equipment may also be used in conjunction with locating emergency vehicles.

Disadvantages

- Some distortion in the radio waves may result, particularly in urban areas, but may be compensated for. This could reduce the accuracy of the reference number.
- Although a highway location may be located again within about 50 feet, the reference number (with respect to its true geographic location) may be up to 0.25 miles in error until proper calibration is conducted.

# PROCESS 1, SUBPROCESS 2

# COLLECT AND MAINTAIN ACCIDENT DATA




PURPOSE

The purpose of this subprocess is to collect, sort, and process police accident reports for use in the identification and subsequent analysis of high-accident locations.

DESCRIPTION

One of the basic data sources for any agency's traffic record program is the accident data base. The primary source of such accident data is from police-reported accident reports. Supplemental drivers' reports may be used in addition to the police reports.

The reporting level for accidents varies considerably by state. For example, in some states, all traffic accidents must be reported, regardless of cost. In other states, only injury accidents must be reported. Typical accident reporting levels are from $100 to $300 per accident.

The data items on each report form should be carefully selected through cooperation between the police department and highway agency to insure that all necessary data items are included. A uniform statewide report form is currently used by most state highway agencies. Examples of desirable information for an accident report form is shown in Table 2, as given in the ANSI Data Element Dictionary for Traffic Records Systems [1].

Table 2. Recommended data items for an accident report form.

| Data Element Name |
|---|
| ACCIDENT CASE NUMBER* |
| ACCIDENT COUNTY* |
| ACCIDENT DATE AND TIME* |
| ACCIDENT DAY OF WEEK |
| ACCIDENT LOCATION INVESTIGATION |
| ACCIDENT MUNICIPALITY* |
| ACCIDENT RECORD SOURCE |
| ACCIDENT SEVERITY* |
| ACCIDENT VEHICLES |
| BLOOD ALCOHOL CONCENTRATION TEST DATE AND TIME |
| BLOOD ALCOHOL CONCENTRATION TEST RESULTS |
| BLOOD ALCOHOL CONCENTRATION TEST TYPE |
| CAUSE FOR DRIVER/OPERATOR MANEUVER |
| CONTRIBUTING CIRCUMSTANCES, DRIVER |
| CONTRIBUTING CIRCUMSTANCES, ENVIRONMENT |
| CONTRIBUTING CIRCUMSTANCES, OTHER |
| CONTRIBUTING CIRCUMSTANCES, PASSENGER |
| CONTRIBUTING CIRCUMSTANCES, ROAD |
| CONTRIBUTING CIRCUMSTANCES, VEHICLE |
| DIRECTION OF EXTERNAL FORCE |
| DIRECTION OF TRAVEL BEFORE ACCIDENT |
| DRIVER DATE OF BIRTH* |
| DRIVER LICENSE JURISDICTION |
| DRIVER LICENSE RESTRICTION COMPLIANCE |
| DRIVER LICENSE NUMBER* |
| DRIVER LICENSE TYPE COMPLIANCE |
| DRIVER NAME* |
| DRIVER SOCIAL SECURITY NUMBER* |
| EMERGENCY NOTIFICATION* |
| EMERGENCY RESPONSE ARRIVAL TIME* |
| ESTIMATED COLLISION SPEED |
| ESTIMATED TRAVEL SPEED |
| FIRST HARMFUL EVENT |
| INJURED TRANSPORTATION |
| INJURY CLASSIFICATION |
| INJURY DESCRIPTION |
| INSPECTION STICKER NUMBER, CURRENT* |
| INVESTIGATING AGENCY TYPE |
| LIGHTING SYSTEM CONDITION |
| LOCATION OF FIRST HARMFUL EVENT OR OBJECT |
| LOCATION OF SUBSEQUENT HARMFUL EVENT(S) OR OBJECT(S) |
| MILEPOINT* |
| OCCUPANT IDENTIFICATION NUMBER |
| OCCUPANT LOCATION AFTER IMPACT |
| OCCUPANT LOCATION PRIOR TO IMPACT* |
| OCCUPANTS INJURED |
| OCCUPANTS PER VEHICLE |
| ODOMETER READING AT ACCIDENT* |
| PASSENGER AGE |
| PASSENGER RACE AND ETHNICITY |
| PASSENGER SEX |
| PEDALCYCLE ACTION |
| PEDALCYCLE LOCATION PRIOR TO IMPACT |
| PEDALCYCLE VISIBILITY |
| PEDESTRIAN ACTION |
| PEDESTRIAN AGE |
| PEDESTRIAN FATALITIES |
| PEDESTRIAN IDENTIFICATION NUMBER |
| PEDESTRIAN LOCATION PRIOR TO IMPACT |
| PEDESTRIAN RACE AND ETHNICITY |
| PEDESTRIAN SEX |
| PEDESTRIAN VISIBILITY |
| PEDESTRIANS |
| POINT OF IMPACT |
| POLICE ARRIVAL DATE AND TIME |
| POLICE CLEARANCE DATE AND TIME |
| POLICE NOTIFICATION DATE AND TIME |
| PORTION OF VEHICLE CAUSING INJURY |
| PRIMARY CAUSE FACTOR/DRIVER OPINION |
| PRIMARY CAUSE FACTOR/POLICE OPINION |
| PROPERTY DAMAGE AMOUNT |
| PROTECTIVE/RESTRAINT EQUIPMENT USE |
| REGISTRATION PLATE JURISDICTION |
| REGISTRATION PLATE NUMBER* |
| REGISTRATION PLATE YEAR |
| ROAD SURFACE CONDITION |
| ROAD SURFACE DEFECTS |
| ROAD VEHICLE/PEDESTRIAN TYPE* |
| ROADWAYS |
| SUBSEQUENT HARMFUL EVENT(S) |
| TRAFFIC CONTROL DEVICE CONDITION |
| TRAFFIC CONTROL DEVICE TYPE |
| TRAFFICWAY IDENTIFICATION NUMBER |
| TRAFFICWAY IDENTIFIER* |
| VEHICLE DAMAGE AREA/DEFORMITY |
| VEHICLE DAMAGE SEVERITY |
| VEHICLE DEFECTS OBSERVED |
| VEHICLE IDENTIFICATION NUMBER |
| VEHICLE MAKE* |
| VEHICLE MANEUVER |
| VEHICLE MODEL* |
| VEHICLE MODEL YEAR* |
| VEHICLE REMOVAL |
| VEHICLE TRAFFIC UNIT NUMBER |
| VEHICLE USAGE |
| VISIBILITY OBSTRUCTION |
| WEATHER CONDITION |

Source: "Data Element Dictionary - State Model Motorist Data Base", American Association of Motor Vehicle Administrators, 1978

A sample accident report form (State of Michigan) is given in Figure 9.

The specific procedures under this subprocess are:

Procedure 1 - File of Accident Reports by Location
Procedure 2 - Spot Maps
Procedure 3 - Systemwide Computerization of Accident Data

## RANGE OF COMPLEXITY AMONG PROCEDURES

Reports by location and spot maps are very easy to use for relatively small accident data bases. Therefore, these two procedures are more appropriate for local agencies than for state safety agencies. For state agencies and large cities, systemwide computerization is usually more desirable than manual methods. However, many small local agencies currently use systemwide computerization, if computer facilities are available.

## MANAGERIAL CONCERNS

- Are accident reports completed with reasonable care to insure accurate information?
- Are enough accidents reported each year to justify systemwide computerization?
- What percentage of accidents are actually reported?
- Is the reporting level for accidents too high? Too low?
- Can spot maps be produced by computer?
- Should the accident report form be updated or improved to obtain more needed information?
- Will the filing systems and data summaries provide the types of information needed for the identification of hazardous locations?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- A plan for processing accident data for identifying hazardous locations

### Resource and Equipment Input

- Funding
- Manpower (Data Coders)
- Filing system for accident records
- Computer capabilities for summarizing accident data (Procedure 3 - "Systemwide Computerization" only)

### Data or Informational Input

- Accident data by location (From Process 1, Subprocess 1 - "Define the Highway Location Reference System")
- Maps of the highway system for plotting spot maps

Place an "X" on appropriate selection. **ORIGINAL**

UD-10 (Rev. 1-78) **State of Michigan**

**OFFICIAL TRAFFIC ACCIDENT REPORT**

Department Name | LEIN Number | Department Complaint No. | DO NOT USE

**Accident Location:** County Number | City Number | Twp. Number | Day of Week S M T W T F S | Accident Date: Mo/Da/Yr | Time ☐ A.M. ☐ P.M.

Name ON | Route No. | Ft. Mi. N S E W | Intersection | Route Nos.

**Accident Conditions:**

WEATHER: [1] Clear, Cloudy [2] Fog [3] Rain [4] Snow

LIGHT: [1] Day [2] Dawn, Dusk [3] Street Lights [4] Dark

ROAD SURFACE: [1] Dry [2] Wet [3] Snowy, Icy [4] Other

TOTAL LANES | ☐ Divided ☐ Limited Access | [Y] [N] Construction Zone [Y] [N] Investigated at Scene | Total No. Vehicles

**Vehicle Driver No. 1:** State | Driver's License | DOB | Hazardous Action Number | Citation Charge | HBD | HN | Test | Helmet [Y] [N]

Driver's Name: First M. Last | Address | City | State | Age | Sex | Inj.

Year | Make No. | Type | Trailer | Reg. | Yr/State | VIN Number | Removed to/by

[Y] [N] Haz. Citation [Y] [N] Other Citation | *[Y] [N] Driver Re-exam *[Y] [N] Vision Obstruct. | *[Y] [N] Vehicle Defect [Y] [N] Vehicle Drivable | *[Y] [N] Fuel Leakage *[Y] [N] Vehicle Fire | Impact | Severity | Truck Cargo: [Y] [N] Cargo Spillage Cargo Description | Class

Restraints by occupants pos. 1 2 3 4 5 6 | Name | Address | Pos. | Age | Sex | Inj. | Helmet [Y] [N]

Total occupants | Local Use/Owner, Phone | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 1

**Vehicle Driver No. 2:** State | Driver's License | DOB | Hazardous Action Number | Citation Charge | HBD | HN | Test | Helmet [Y] [N]

Driver's Name: First M. Last | Address | City | State | Age | Sex | Inj.

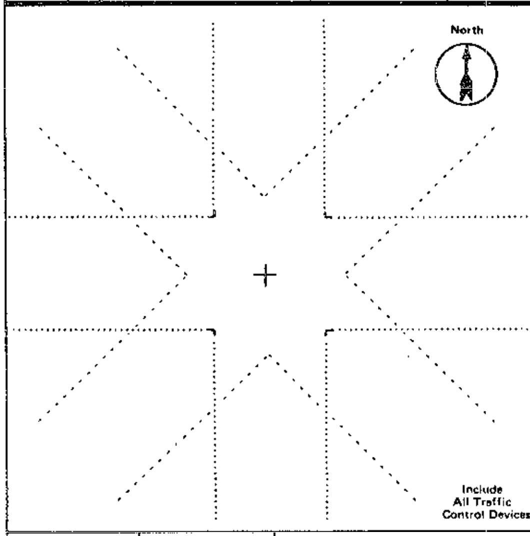
Year | Make No. | Type | Trailer | Reg. | Yr/State | VIN Number | Removed to/by

[Y] [N] Haz. Citation [Y] [N] Other Citation | *[Y] [N] Driver Re-exam *[Y] [N] Vision Obstruct. | *[Y] [N] Vehicle Defect [Y] [N] Vehicle Drivable | *[Y] [N] Fuel Leakage *[Y] [N] Vehicle Fire | Impact | Severity | Truck Cargo: [Y] [N] Cargo Spillage Cargo Description | Class

Restraints by occupants pos. 1 2 3 4 5 6 | Name | Address | Pos. | Age | Sex | Inj. | Helmet [Y] [N]

Total occupants | Local Use/Owner, Phone | Insurance Co. | Agency Address | Injured taken to/by

Driver No. 2




ACCIDENT DESCRIPTION AND REMARKS (*Explain)

Describe all unusual conditions and circumstances

Accident Date | File Class | Department Complaint No.

Date Reported | Time A.M. P.M. | Investigators | Badge No. | Damage Property Other Than Vehicles

Photos by | Complaint Disposition ☐ Open ☐ Closed | Reviewer | Owner | Address

Area | Pseudo | Time | No. Units | No. Inj. | No. Killed | Residence | Test | Intent | Direction | Obj. Hit | Situation | Cont. Cir. | Residence | Test | Intent | Direction | Obj. Hit | Situation | Cont. Cir. | Road Align. | Traffic | Road Loc. | Acc. Type | Where | How | Tags | Road Def. | 1 Veh. Def. | 1 Vision Ob. | 2 Veh. Def. | 2 Vision Ob | MALI | Coder | File

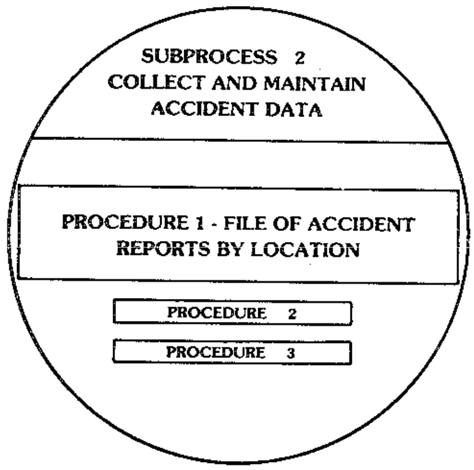
FORWARD COPY TO: Michigan Department of State Police, Safety & Traffic Division 7150 Harris Drive, Lansing, Michigan 48913

*This form is prescribed by Director of Department of State Police pursuant to Section 257.622 of Compiled Laws of 1970, as amended.*

Figure 9. Accident report form - Michigan.

Output

- Summaries of systemwide accident data by location for use in identifying hazardous locations




PROCEDURE 1 - FILE OF ACCIDENT REPORTS BY LOCATION

DESCRIPTION

The manual storage and maintenance of accident reports in files is the most basic method, and may be maintained by the local police department and/or the traffic engineering department. This system is normally found in jurisdictions with relatively small numbers of accidents per year. Accident reports should be filed on a daily basis, if possible, to help maintain organization.

Instead of filing the accident reports themselves, a traffic accident location file should be established, as shown in Figure 10, to help keep a record of high-accident locations. Under each location folder, an accident location index card (Figure 11) will allow for an up-to-date listing of accidents at each site [2]. For each accident, information should include:

- Report number
- Date
- Severity (number killed and injured)
- Type of accident (rear-end, right-angle, pedestrian, etc.)
- Lighting condition (day or night)
- Other information of concern

In urban areas, a location file is generally organized by highway classification (arterial, collectors, local street, alley), or by alphabe-

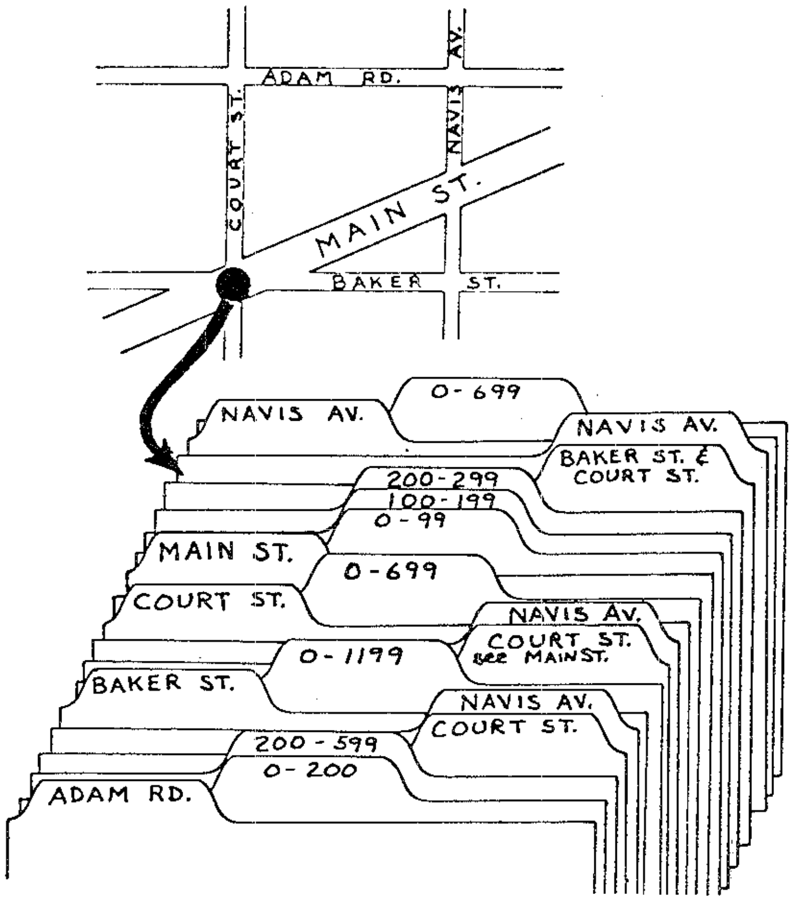



Figure 10. Typical traffic accident location file.
(Source: Reference No. 2)

MAIN STREET — primary street

☒ at Intersection with FIRST STREET — secondary street

☐ from ______ to ______

| Report No. | Date Mo. | Date Day | Date Yr. | Pers. K | Pers. I | Ill. D | Ill. N | Acc. Type | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| A7692 | 2 | 13 | 69 | 0 | 1 | ✓ | | REAR END | W.B ON 1ST ST. PAVMENT ICY |
| A7748 | 4 | 6 | 69 | 0 | 1 | | ✓ | PED. | |
| A7961 | 7 | 30 | 69 | 0 | 0 | ✓ | | FIXED OBJ. | HIT SIGNAL POLE |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Figure 11. Accident location index card.
(Source: Reference No. 2)

tical street name. Accidents between intersections may then be filed in proper order between intersections. For rural locations, filing of locations is normally by route number with intersecting routes or road sections ordered appropriately.

Use of an accident location file will permit easy selection of high accident locations for both enforcement and engineering activities. Spot maps may also be used in conjunction with the accident records file, as will be discussed later. Vertical files, index cards, or punched cards may be employed to file accidents.

## PROCEDURE APPLICABILITY

The filing of accident reports by location is applicable under the following conditions:

- Generally small highway systems (less than about 500 miles). Larger highway systems will usually require computer processing capabilities to properly maintain accident data. The availability of micro computers offers an inexpensive means for small to medium sized communities to file and readily access accident data.
- Highway systems with a relatively small accident data base (less than about 1,000 reported accidents per year)
- Agencies which do not plan to produce periodic systemwide accident summaries

## RESOURCE REQUIREMENTS

- Manpower - File clerks for sorting and filing the accident reports
- Funding - Minimal funds for file cabinets and other material

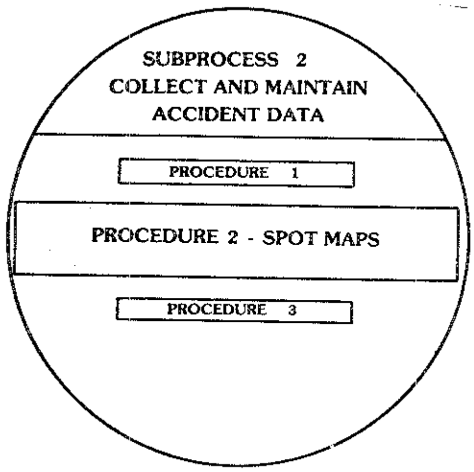
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Very simple method
- Suited for small highway systems with relatively few accidents each year
- Specially trained personnel and computer facilities are not necessary

### Disadvantages

- Does not allow for routine systemwide accident summaries
- Cumbersome for large numbers of accident
- Does not provide a good overview of accident problems, without hand sorting and processing of information




## PROCEDURE 2 - SPOT MAPS

### DESCRIPTION

Spot maps (also called pin maps) are often used by police and other public agencies to provide a quick visual picture of accident concentrations. A street map of the city area is needed and the location of each accident is identified through "spot" marks or pins. It is usually updated on a regular (daily, weekly, or bimonthly) basis for the entire year or analysis period. The cluster of "dots" shows the concentration of accident locations throughout the city. Simple manual plotting of accidents may be desirable for small cities with few high-accident locations. Accidents can usually be placed fairly accurately. However, this method may become quite involved and time consuming for larger cities with thousands of accidents each year.

Spot maps are generally kept for one calendar year. At the end of the year, the map is photographed, and a new map is started. Special spot maps can also be kept for specific accident classes, such as pedestrian accidents, single vehicle accidents, drinking driver accidents, etc.

Computerized spot maps have been successfully used by some agencies to permit quicker and more efficient output, with added flexibility. One such computerized method was developed to plot accidents on an entire street network for any size city. The scale of computerized spot maps is user specified and may be generated in a wide-range of sizes. The entire city may be plotted or specific areas or corridors could be "windowed" for plotting. For more detail, wall-sized enlargements of the plots can be easily obtained, as illustrated in a portion of the plot shown in Figure 12. Color coding by accident severities (or other accident characteristics) is also possible for any computerized spot maps.

The computerized spot map relies on the initial coding of intersection nodes by coordinate, which allows for plotting of the street network.

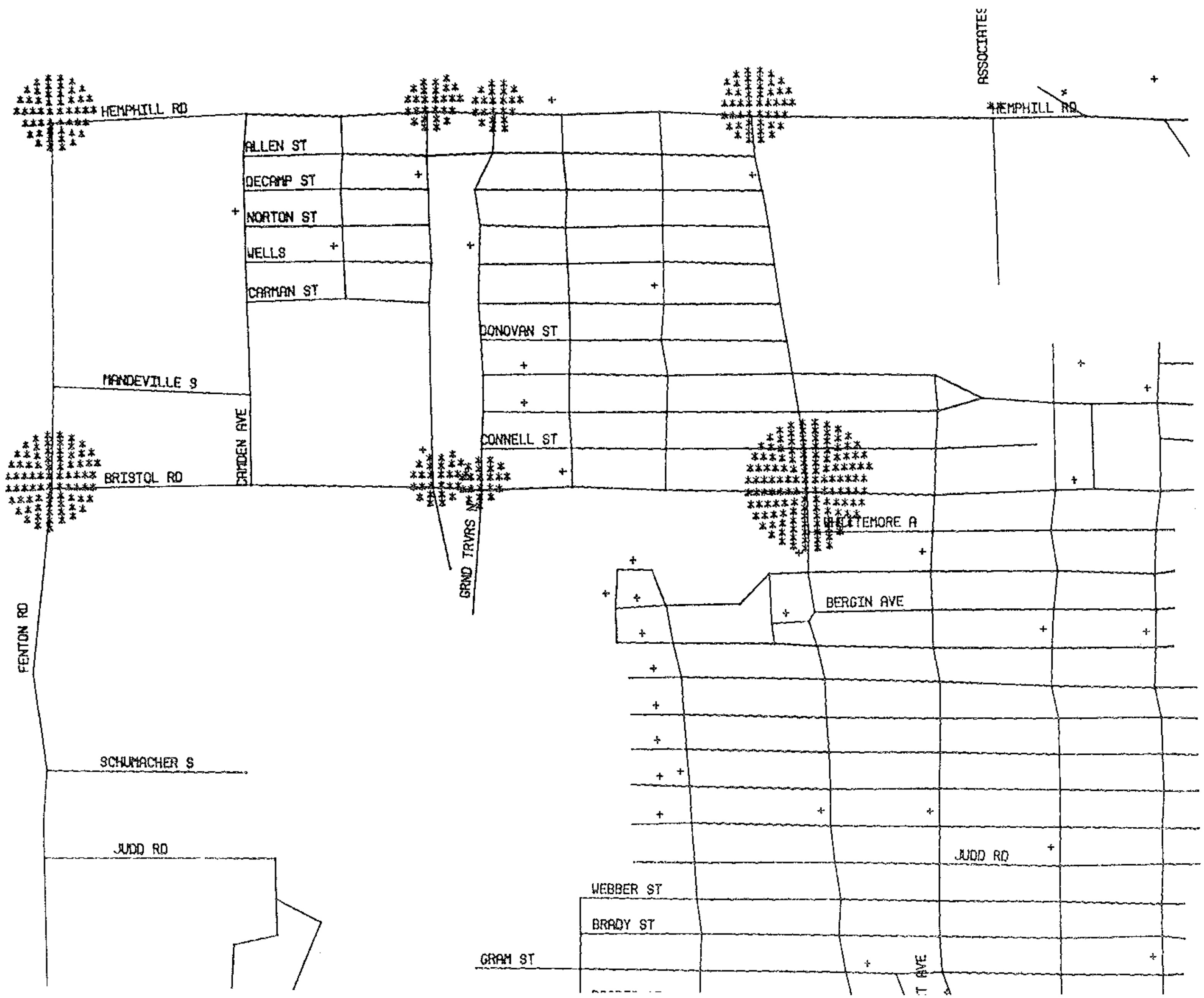



Figure 12. Computerized spot map.

Accidents are then plotted at the appropriate locations. For intersections with numerous accidents, a spiral pattern of dots, circles, or other characters may be used to plot accidents. The locations with the greatest number of accidents will have the largest near-circular patterns and will be easily identified.

PROCEDURE APPLICABILITY

Spot maps are applicable under the following conditions:

- For relatively small highway systems (less than about 2,500 miles) and/or small accident numbers (less than about 5,000 per year) to provide an updated visual display of all traffic accidents. (Efforts should be made to maintain compatibility of accident files between local agencies and the State agency).
- For agencies wanting to supplement their primary systemwide accident summaries and/or visually illustrate accidents of a severe nature (fatal and/or injury accidents only) or special accident types (run-off-road, wet-weather, etc.).

RESOURCE REQUIREMENTS

- Manpower - Technicians or other personnel to update the spot map(s) routinely (daily).
- Funding - Little or none
- Equipment - None required, but computerized spot maps may be produced using computer plotting capabilities.

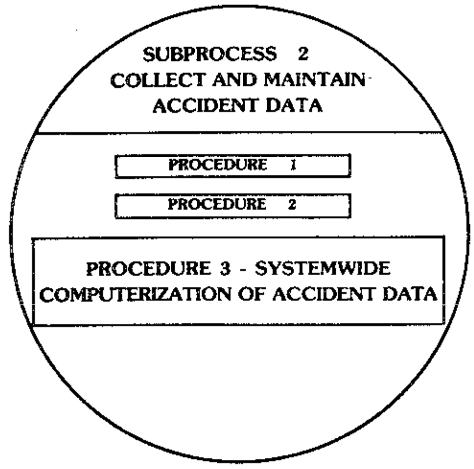
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Provides a visual overview of accidents on the highway system by location
- Is easy to develop and maintain
- Requires a minimal amount of manpower and funds

Disadvantages

- Does not allow for easy systemwide summaries
- Can be very cumbersome for large numbers of accidents
- Is not generally a permanent data source




## PROCEDURE 3 - SYSTEMWIDE COMPUTERIZATION OF ACCIDENT DATA

### DESCRIPTION

A computerized system involves the coding of useful data items for each accident into a permanent computer file for subsequent analysis purposes. Accident data should be easily retrievable by location for use in identifying high-accident spots, intersections, and sections. Computerized accident storage also allows for the quick computation of rates, severity indices, and other such statistics for each location for subsequent priority rankings and further analysis.

Computerized accident storage systems also allow for quick systemwide accident summaries. After accident data are obtained by an agency for a specified time period, accident summaries may be computed to determine the general accident problems for the city, county, or statewide area. Such tables might include summaries by major categories such as:

- Type of area (urban, rural, suburban, etc.)
- Functional classification (state primary, state secondary, county road, local street, etc.)
- Highway type (two-lane, four-lane divided, freeway, etc.)
- Jurisdiction (city, county, etc.)

For specific categories as given above, further summaries of accidents may include such details as:

- Accident severity (number of injury, fatal, and property damage accidents)
- Number of people injured (by degree of injury)
- Temporal summaries (time of day, day of week, month, etc.)
- Weather conditions (rain, sunny, snow, etc.)
- Environmental conditions (dark, dusk, light, wet pavement, dry, icy, construction-related, etc.)

- Driver characteristics (age, sex, residence, etc.)

An example of a citywide computer accident summary table (by accident type and severity) is given in Table 3. In this example, all accidents in the city (one year only) were summarized by day of the week using the SPSS (Statistical Package for the Social Sciences) program battery. For each of the seven days, the absolute frequency is given along with the percentage and cumulative percentage.

Such systemwide accident summaries can be used for comparison with site specific accident summaries. For state highway agencies and large cities, systemwide computerization is strongly recommended for the handling of accident records. Numerous computer software packages have been developed for use in obtaining systemwide accident summaries. Such computer program packages include DART, RAPID, and others [3,4]. Other general statistical packages are available and widely used as well for accident analyses. Figure 13 provides a summary of the available package [5].

PROCEDURE APPLICABILITY

Systemwide computerization of accident data is applicable for the following:

- Virtually any size of highway system, except for very small systems (less than about 100 miles) where computer purchase or rental is not practical
- Highway systems with more than about 1,000 reported accidents per year. For example, an agency with only 100 reported accidents per year could handle them easily without a computer.
- Highway agencies which plan to produce periodic systemwide accident summaries and/or periodic updates of high-accident locations

RESOURCE REQUIREMENTS

- Manpower - Knowledgeable computer programmer(s) and keypunchers available for coding of accident information
- Funding - Funds available for computer rental and operation (range of about $2,000 to $10,000 per month, depending on the size of the accident data base)
- Equipment - Computer facilities

PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Allows for quick and easy systemwide accident summaries for any need
- Requires a relatively small amount of manpower (compared to manual methods) for a large accident data base.

Disadvantages

- Requires computer facilities

Table 3. SPSS summary and histogram by day of week

VAR004 DAY OF THE WEEK

| CATEGORY LABEL | CODE | ABSOLUTE FREQ | RELATIVE FREQ (PCT) | ADJUSTED FREQ (PCT) | CUM FREQ (PCT) |
|---|---|---|---|---|---|
| SUNDAY | 1. | 1 | 2.4 | 2.4 | 2.4 |
| MONDAY | 2. | 4 | 9.5 | 9.5 | 11.9 |
| TUESDAY | 3. | 5 | 11.9 | 11.9 | 23.8 |
| WEDNESDAY | 4. | 9 | 21.4 | 21.4 | 45.2 |
| THURSDAY | 5. | 7 | 16.7 | 16.7 | 61.9 |
| FRIDAY | 6. | 7 | 16.7 | 16.7 | 78.6 |
| SATURDAY | 7. | 9 | 21.4 | 21.4 | 100.0 |
| | TOTAL | 42 | 100.0 | 100.0 | |

VAR004 DAY OF THE WEEK

```
 CODE
       I
    1. ****** (     1)
       I  SUNDAY
       I
       I
    2. ********************* (     4)
       I  MONDAY
       I
       I
    3. ************************** (     5)
       I  TUESDAY
       I
       I
    4. ********************************************** (     9)
       I  WEDNESDAY
       I
       I
    5. ************************************ (     7)
       I  THURSDAY
       I
       I
    6. ************************************ (     7)
       I  FRIDAY
       I
       I
    7. ********************************************** (     9)
       I  SATURDAY
       I
       I.........I.........I.........I.........I.........I
       0         2         4         6         8        10
       FREQUENCY
```

**(1) Biomedical Programs (BMD & BMDP)**
Health Sciences Computing Facility
CHS Bldg. AV-111
University of California
Los Angeles, California 90024

**(2) Box-Jenkins Univariate, Bivariate Time Series Program (Batch Version)**
David Park
Ohio State University
Columbus, Ohio 43210

**(3) Box-Jenkins Univariate, Bivariate Time Series Programs**
(Interactive Version)
National CSS, Inc.
300 Westport Avenue
Norwalk, Connecticut 06851

**(4) Data Text**
Rand Corporation
1700 Main Street
Santa Monica, California 90406

**(5) International Mathematical and Statistical Librarian (IMSL) Package**
IMSL, Inc.
Sixth Floor, GNB Bldg.
7500 Bellaire Boulevard
Houston, Texas 77036

**(6) Osiris III**
Institute of Social Research
University of Michigan
Ann Arbor, Michigan 48105

**(7) P-Stat**
Princeton University Computing Center
Princeton University
Princeton, New Jersey 08540

**(8) Table Producing Language (TPL)**
Bureau of Labor Statistics
441 G Street, N.W. - Room 2518
Washington, D.C., 20212

**(9) Statistical Analysis System**
SAS Project
Institute of Statistics
North Carolina State University
P.O. Box 5457
Raleigh, North Carolina 27607

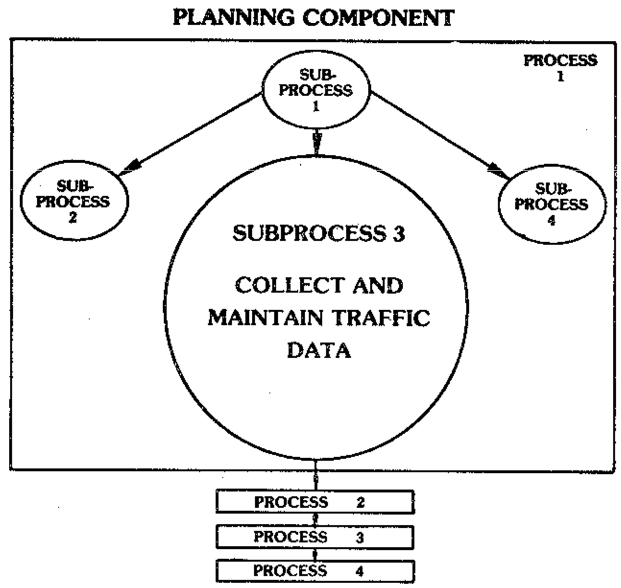
**(10) Statistical Package for the Social Sciences (SPSS)**
National Opinion Research
University of Chicago
6030 South Ellis Avenue
Chicago, Illinois 60637

Figure 13. Statistical Analyses Programs Available

Source: The Evaluation of Highway Traffic Safety Programs, USDOT, 1977.

# PROCESS 1, SUBPROCESS 3

# COLLECT AND MAINTAIN TRAFFIC DATA




PURPOSE

The purpose of this subprocess is to routinely collect and maintain all types of systemwide traffic-related data needed for use in the identification of hazardous highway locations.

DESCRIPTION

The routine collection and maintenance of traffic data on a systemwide basis should include any traffic data considered necessary for use in identifying hazardous locations. The types of data needed from this subprocess as input into Process 2 ("Identify Hazardous Locations and Elements") is basically traffic volume (AADT and traffic mix) information. Such information is needed to compute accident rates for use in rate related identification methods. For use in other more complex methods (Hazard Index method for example), such traffic data as vehicle speeds, erratic maneuvers, and traffic conflict data may also be needed. The collection of train traffic data is also important in identifying hazardous rail/highway grade crossings.

The traffic data from this subprocess should be used to establish systemwide averages. Traffic volume data can be used to compute average accident rates for specific highway types. Such information is often used for setting criteria to identify high-accident locations. For example, one of the necessary inputs for the Rate-Quality Control method is the average accident rate for particular highway types. After hazardous locations are identified in Process 2 ("Identify Hazardous Locations and Elements"), it may be desirable to collect additional traffic data for the Engineering Studies of Process 3 ("Collect and Analyze Data").

The procedures defined under this subprocess include:

Procedure 1 - Systemwide Manual Collection of Traffic Data
Procedure 2 - Use of Mechanical Volume Counters
Procedure 3 - Permanent Count Stations
Procedure 4 - Maintenance of Traffic Data on Maps or in Files
Procedure 5 - Systemwide Computerization of Traffic Data

## RANGE OF COMPLEXITY AMONG PROCEDURES

This subprocess involves two types of activities related to traffic data:

- Field Data Collection
- Data Storage, Maintenance and Retrieval

The first three procedures center on data collection. Systemwide Manual Collection of Traffic Data (Procedure 1) and Use of Mechanical Volume Counters (Procedure 2) are relatively simple to conduct. More detailed information is normally collected at Permanent Count Stations (Procedure 3) often these data are used for systemwide traffic projections -- e.g., determining seasonal factors for computing ADT data, detailed vehicle classification counts, lane distribution counts, vehicle volumes by time of day, etc.

The other two procedures refer to the storage, maintenance and retrieval of traffic data. The Maintenance of Traffic Data on maps or in files (Procedure 4) is the simplest method; Systemwide Computerization of Traffic Data (Procedure 5) is generally more complex, although it can provide an excellent means for managing large quantities of traffic data.

## MANAGERIAL CONCERNS

- Is manpower being wasted needlessly on the manual collection and/or storage of traffic-related data?
- Is the traffic data of sufficient accuracy for use in identifying hazardous locations?
- Is traffic data being collected at enough (or too many) locations?
- Are the proper types of traffic data being collected routinely?
- Can existing computer facilities be utilized to store and retrieve traffic data?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- An understanding of traffic data needs for use in identifying hazardous locations

Resource and Equipment Input

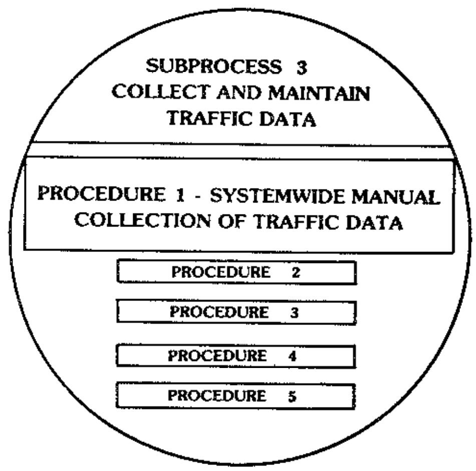
- Funding
- Mechanical data collection equipment
- Trained personnel for data collection

Data or Information Input

- A defined highway location system (From Subprocess 1 - "Define the Highway Location Reference System")
- A listing of traffic data needs

Output

- A file of systemwide traffic data needed for use in identifying hazardous locations




PROCEDURE 1 - SYSTEMWIDE MANUAL COLLECTION OF TRAFFIC DATA

DESCRIPTION

This procedure includes the use of technicians or other trained personnel for collection of traffic-related data at preselected highway locations. Manual data collection on a systemwide basis can be very expensive if a large number of sites are chosen. Traffic volume data are often taken routinely on certain highway sections for use in many highway agency functions (planning, environmental studies, etc.). Routine traffic speed data may also be needed for use in various studies. Traffic volume data should be collected manually by small agencies which cannot afford mechanical traffic counters. Manual volume counts are often more practical than mechanical counters for short periods of time (two hours or less), or for pedestrian counts.

## PROCEDURE APPLICABILITY

The use of routine manual collection of traffic data is applicable under the following conditions:

- Virtually any size of highway system, except that the quantity of data becomes unmanageable for large systems
- When mechanical volume counters are not available
- When an agency has a supply of available manpower for such data collection
- When more detailed traffic mix and/or traffic volume data are required than can be obtained from mechanical counters

## RESOURCE REQUIREMENTS

- Manpower - Personnel trained in the collection of traffic data (particularly volume data, turning movements, and speed data)
- Funding - Funds to purchase radar equipment, counting boards, and travel costs for data collectors
- Equipment - Radar equipment, counting boards, etc.

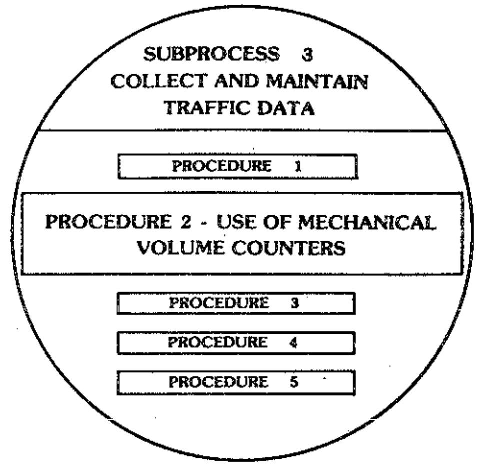
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Does not require the purchase or maintenance of mechanical volume counters
- Does not require the costs of establishing a permanent count station
- Provides flexibility in data collection, since data collectors can be sent to specific sites and can modify the types of data collected to conform to existing needs and resources
- Allows for the collection of data which are impractical using mechanical methods such as:
    - pedestrian volume data
    - vehicle delay data
    - vehicle classification data

### Disadvantages

- May require considerable manpower, depending on number of sites and types of data collected
- Not practical for long-term collection of data at a site




## PROCEDURE 2 - USE OF MECHANICAL VOLUME COUNTERS

### DESCRIPTION

The use of mechanical volume counters is often preferred over manual data collection techniques when data are to be collected over long periods of time. This is because mechanical volume counters:

- Have a relatively low cost per hour of counting
- Can provide counts for an extended period of time
- Are reliable, when maintained properly

The most commonly used mechanical counters are:

- Battery-operated, with rubber-tube or other detectors
- Magnetic loop detectors

Because of their flexibility, the battery-operated counters are more widely used. Mechanical techniques are also available to obtain other traffic operational information, such as vehicle delay and speed.

### PROCEDURE REQUIREMENTS

- Manpower - Personnel knowledgeable in the installation and maintenance of mechanical volume counters
- Funding - Funds ($1000 - $1500 per unit) for the purchase and maintenance of mechanical volume counters
- Equipment - Mechanical volume counters

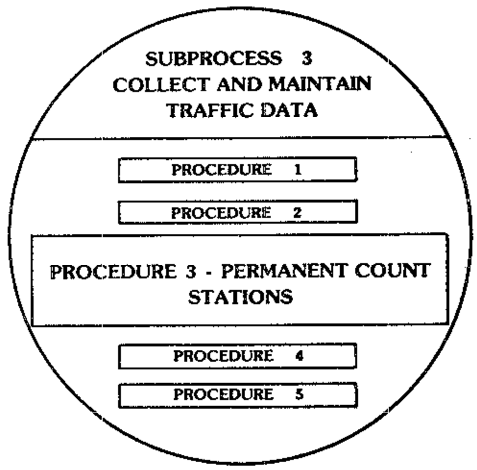
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Takes the place of one or more data collectors and are economical to use
- Allows for data collection over extended time periods and in adverse weather conditions
- Some types of counters are portable and can be moved easily

### Disadvantages

- Initial purchase costs
- Do not provide some types of data which may be desired, such as pedestrian volumes




## PROCEDURE 3 - PERMANENT COUNT STATIONS

### DESCRIPTION

Permanent count stations generally refer to the long-term monitoring of traffic data at specific locations of interest either by manual or mechanical surveys (or both). Permanent count stations are often established for monitoring of traffic volume data and vehicle speeds over several years. Continuous volume data from these stations can be used to determine volume fluctuations by time of day, day of week, month, etc. Then adjustment factors can be developed for computing Average Annual Daily Traffic (AADT) values at other locations where only short-term volume data are available. Traffic data may also be obtained where permanent traffic detectors are installed for computerized traffic signal systems.

In addition to traffic volume by time, detailed information on the following items may be available:

- Volumes by specific vehicle classifications
- Lane distribution data
- Speeds of various vehicle types

PROCEDURE APPLICABILITY

The use of permanent count stations is applicable under the following conditions:

- For states or other large highway agencies (over about 500 miles) wishing to obtain long-term traffic data at a limited number of sites for use in making projections of traffic data at other sites
- Agencies desiring detailed systemwide traffic data for general or unspecified uses

RESOURCE REQUIREMENTS

- Manpower - Personnel to establish and maintain long-term count stations
- Funding - Funds to purchase and maintain all necessary equipment
- Equipment - Mechanical volume counters, radar meters, and other data collection equipment appropriate for the desired type of traffic data

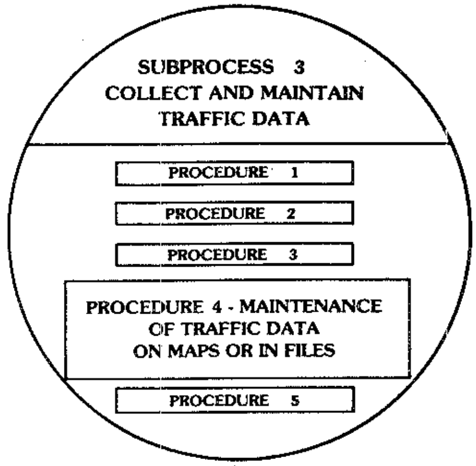
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Can provide detailed traffic-related data at a few desired sites
- Important in developing adjustment factors and trends for sites with limited available traffic data

Disadvantages

- Relatively expensive, compared to other methods
- Can only be applied at a limited number of sites
- Not portable




## PROCEDURE 4 - MAINTENANCE OF TRAFFIC DATA ON MAPS OR IN FILES

### DESCRIPTION

After traffic data are collected, efficient storage and maintenance of such data is very important. In the absence of computer capabilities, the systematic filing of information will make the data more readily accessible. For small highway agencies, volume data can be written directly on highway maps or filed by location. The use of color-coded ADT maps is a common practice by many state highway agencies.

### PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Any type or size of highway system
- A highway agency which does not have access to computer facilities
- A highway agency which does not plan to compute systemwide traffic volume summaries

### RESOURCE REQUIREMENTS

- Manpower - Office personnel to routinely update traffic data files or maps
- Funding - Funds for purchasing appropriate maps of the highway system, files, printing ADT maps, etc.
- Equipment - Drafting equipment and filing facilities

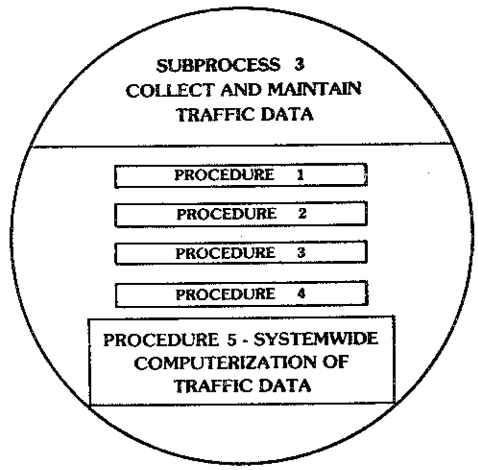
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Does not require computer facilities
- Can be inexpensive and easy to use for small highway systems

Disadvantages

- Does not allow for easy systemwide data summaries
- Cumbersome to handle for large highway systems




PROCEDURE 5 - COMPUTER STORAGE AND RETRIEVAL OF TRAFFIC DATA

DESCRIPTION

Computerized storage and retrieval of traffic data (particularly volume data) is desirable for state and local agencies with a large amount of such data to maintain. Computerized traffic data systems allow for quick computations for such purposes as calculating accident rates for large numbers of locations. To compute systemwide travel or average ADT's on particular highway types, a computerized data file is highly desirable.

PROCEDURE APPLICABILITY

Computer storage and retrieval of traffic data is preferred under the following conditions:

- Highway systems larger than about 100 miles, where considerable traffic volume data are available
- For agencies which plan to compute systemwide summaries of traffic data by highway type, etc., for integration with accident records
- Agencies which have access to computer facilities

## RESOURCE REQUIREMENTS

- Manpower - Office personnel for keypunching, and one or more computer programmers
- Funding - Funds for computer rental and operation (range of $2000 to $10,000 per month, depending on required capabilities)
- Equipment - Access to computer facilities

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

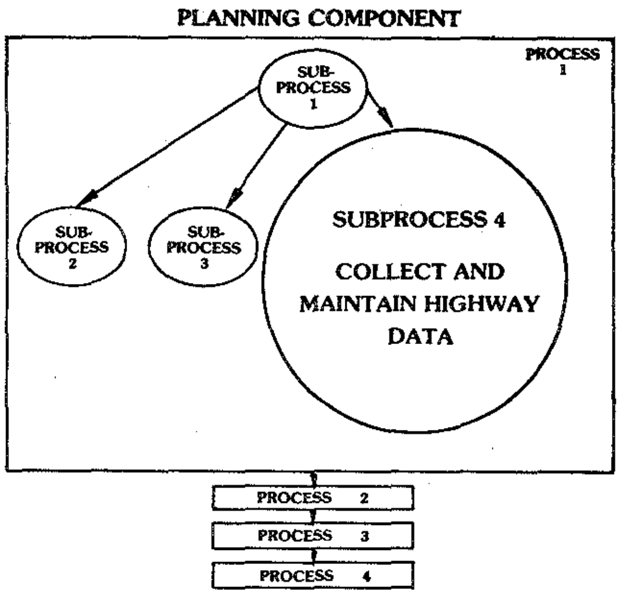
- Allows for efficient development of systemwide traffic summaries, with a minimum of manpower
- Can allow for easy merging with computerized accident information for computing accident rates

### Disadvantages

- Requires computer facilities, which may not be available to some agencies

# PROCESS 1, SUBPROCESS 4

# COLLECT AND MAINTAIN HIGHWAY DATA




PURPOSE

The purpose of this subprocess is to provide a method for the collection, storage, and maintenance of highway-related information for use in identifying hazardous locations.

DESCRIPTION

The collection and maintenance of highway-related data is important for several specific purposes, including:

- Hazardous highway features data is needed as an input into Procedure 7 ("Hazardous Roadway Features Inventory") under Process 2 ("Identify Hazardous Locations and Elements").

  In some cases, hazardous features can be identified by location or section, such as:

  - Blunt end guardrail terminals
  - Slippery pavement sections
  - Narrow lanes or shoulders
  - Non-breakaway sign supports
  - Rigid light pole supports
  - Other fixed objects within the clear zone

- Inadequate vertical or horizontal curves
- Poor sight distance
- Non-uniform or inadequate traffic control devices

- Other useful systemwide highway data may provide information needed in hazard rating formulas. For example, the inputs for the Hazard Index method include such factors as sight distance, volume-to-capacity ratio, driver expectancy rating, and a rating of information system deficiencies.

- Highway classification information is needed in order to properly classify the highway system into similar groupings for use in the Rate-Quality Control Method (Procedure 4) or other procedures under Process 2 ("Identify Hazardous Locations and Elements"). Highway information required for such classifications may include:

  - Number of lanes (2,3,4, greater than 4, etc.)
  - Divided or undivided
  - Access control (full, partial, none)
  - Type of area (urban, rural, suburban, etc.)
  - Functional classification (Urban or Rural; Major Arterial, Minor Arterial, Collector, or Local).

  Thus, when identifying hazardous locations, specific accident criteria can be established separately for each location type. For example, the accident criteria (in terms of accident rates, numbers, severity, etc.) for rural intersections should be different than the criteria for urban intersections.

- Detailed highway-related characteristics data are also very useful for all sections, intersections, and on bridges within the highway system. This type of information can be used for several purposes, including:

  - Computation of sufficiency (adequacy) ratings for long-range planning of improvements
  - Consideration of combinations of features which may cause safety problems. For example, a sharp horizontal curve with narrow shoulders and numerous roadside obstacles on a rural road may be a good candidate for further investigation for possible improvement.

The procedures currently in use for the collection and maintenance of systemwide highway data include:

Procedure 1 - Systemwide Manual Collection of Highway Data
Procedure 2 - Photologging and Videologging
Procedure 3 - Maintenance of Highway Data on Maps or in Files
Procedure 4 - Systemwide Computerization of Highway Data

## RANGE OF COMPLEXITY AMONG PROCEDURES

The first two procedures involve the collection of highway data and the last two procedures involve the maintenance, storage, and retrieval of that data. Thus, an agency which collects systemwide highway data would need to utilize at least two of the four procedures. The four procedures can all be relatively simple, depending on the nature of the highway data collected. However, the computerized storage and retrieval of highway data (Procedure 4) requires one or more trained programmers. Photologging and videologging may be done by the agency or by a qualified consulting firm.

## MANAGERIAL CONCERNS

- Can the existing highway data be computerized to improve the usage of the data?
- Are highway data being collected for the most important data variables?
- Are resources available for the collection of more detailed highway information?
- Is basic highway classification information available for the total highway system?
- Are the data of sufficient accuracy?
- Would the use of photologging or videologging provide useful information which is not currently available?
- Can highway information be merged with traffic and/or accident information to form one comprehensive highway data base?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- An understanding of highway data needs for use in identifying hazardous locations

### Resource and Equipment Input

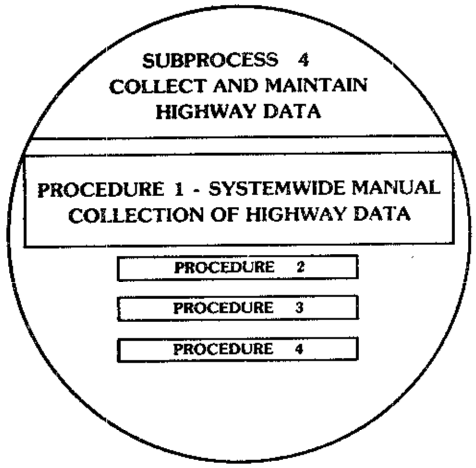
- Maps or files for data storage
- Appropriately trained personnel for data collection
- Funding

### Data or Informational Input

- A defined highway location system (From Process 1, Subprocess 1 - "Define the Highway Location Reference System")
- A listing of highway data needs

### Output

- A file of systemwide highway data needed for use in identifying hazardous locations




## PROCEDURE 1 - SYSTEMWIDE MANUAL COLLECTION OF HIGHWAY DATA

### DESCRIPTION

The manual collection of data on a systemwide basis is desirable for agencies with sufficient manpower to perform such field inventories. The manpower requirement is a direct function of the highway mileage in the system. Each agency must determine what highway data elements are needed to properly conduct their highway improvement program at the appropriate level. Virtually every state highway agency currently collects various highway-related data for use in planning future highway construction projects, using some adequacy rating scheme. Such a program is usually the responsibility of a state's planning division, but necessary highway data can often be made available for use in highway safety program.

### PROCEDURE APPLICABILITY

The systemwide manual collection of highway data is generally applicable under the following conditions:

- Virtually any size of highway agency, if sufficient manpower are available for such data collection
- Where an agency does not need photographic information
- Where an agency plans to use only a limited number of highway variables in its highway safety improvement program

### RESOURCE REQUIREMENTS

- Manpower - Field crews for manual data collection
- Funding - Training costs and travel expenses for data collectors

If manpower are not available for such data collection, funds for hiring a Consultant (to collect data) are needed.

- Equipment - Little or none in most cases. However, collection of certain highway-related data variables (skid resistance, for example) will require appropriate equipment (skid trailers, etc.).

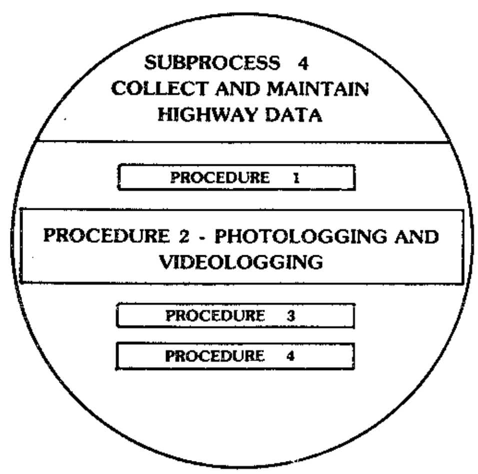
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- For most data variables, requires little or no data collection equipment
- When manpower are available, information of interest can be collected

Disadvantages

- Requires considerable money and manpower for extensive data collection programs
- Does not provide a photographic record of the highway system




PROCEDURE 2 - PHOTOLOGGING AND VIDEOLOGGING

DESCRIPTION

Photologging is a technique that involves taking photographs of the highway and its environment at equal increments of distance from a moving vehicle. This results in a visual inventory of the highway and roadside. A camera is normally used that incorporates the use of a dual lens system. The primary lens provides a view of the highway, and a secondary lens enables the addition of information such as date, route description, direction, and milepoint across the top or bottom of each picture.

Many different uses have been made of highway photolog information. For example, a large state agency might use photologs to review high accident locations, confirm the location of utility crossings, extract physical measurements for inventories, or perhaps document the location of roadside obstacles. A small city agency might be interested in a computerized inventory system that would require film documentation of the number and condition of traffic control devices. Photolog data may also be useful by a highway agency in litigation cases.

Videologging tapes can be substituted for photologging film, but its suitability depends on the required uses. High quality video equipment is more expensive than comparable photographic equipment. Also, video tape pictures are not as sharp as photologs, and do not present as stable an image when displayed in the "still" mode on the video monitor. However, video tape can be reused, does not require processing, and sound can be incorporated on the tape at the time of recording.

## PROCEDURE APPLICABILITY

The use of photologging and/or videologging for collecting highway data is applicable under the following conditions:

- Virtually any size of highway system (except the equipment investment may not be justified for systems of less than 100 miles)
- Agencies desiring a comprehensive photographic record of roadway information for office viewing and/or developing a computerized roadway inventory

## RESOURCE REQUIREMENTS

- Manpower - Personnel trained in highway photologging and/or videologging
- Funding - Costs for hiring a consultant to photolog or videolog the highway system and develop the inventory file, or funds to purchase the van, camera, film, develop film, etc.
- Equipment - Photologging or videologging equipment (cameras, van, etc.)

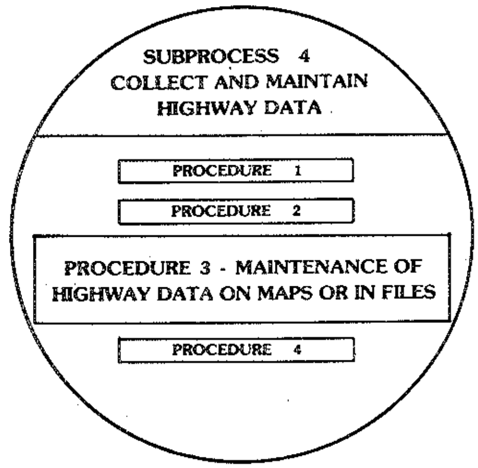
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Provides a film record of the highway system for office viewing
- Provides capabilities for development of a computerized highway inventory system
- Useful in litigation cases

## Disadvantages

- Can be relatively expensive, depending on the number of data items to be inventoried, although the filming alone is relatively inexpensive




## PROCEDURE 3 - MAINTENANCE OF HIGHWAY DATA ON MAPS OR IN FILES

### DESCRIPTION

The processing and storage of the highway data can be adequately handled in most cases with the use of simple data files or special highway maps. Color-coding of highways is one effective way of presenting some types of highway data on maps. Systemwide summaries of highway data can be quite difficult when all data are located on maps or in files, however. In such cases, the summaries must be developed manually each time changes are made in the highway system. This can be expensive and may require extensive manpower. For agencies with larger data requirements, the use of computerized data files may be more efficient.

### PROCEDURE APPLICABILITY

The use of maps or files for maintenance of highway data is applicable under the following conditions:

- Highway systems with less than about 2500 miles, since large quantities of highway data can generally be handled more efficiently by using a computer
- Highway agencies with no plans to produce routine systemwide summaries of highway data
- Agencies with a need to simply maintain an organized record or file of highway information

RESOURCE REQUIREMENTS

- Manpower - Office clerks or technicians for maintaining data on maps or in files
- Funding - Funds to purchase maps, files, etc.
- Equipment - Little or none

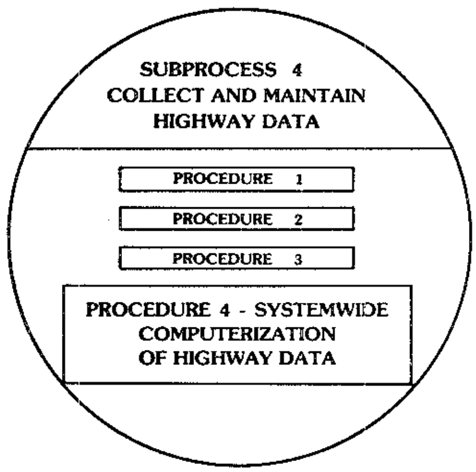
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Requires no computer facilities
- Can be handled by technicians or file personnel
- Inexpensive for small quantities of data

Disadvantages

- Does not allow for systemwide highway data summaries




PROCEDURE 4 - SYSTEMWIDE COMPUTERIZATION OF HIGHWAY DATA

DESCRIPTION

Computerization of highway information is warranted when it is necessary to process a large amount of data. For state, large city, or county agencies, highway data on capacity, sight distance, lane width, etc., may be handled more efficiently in this manner. A number of adequacy rating programs utilize computerized storage and retrieval of highway data. Some agencies have developed computerized files which integrate highway, traffic, and accident records.

PROCEDURE APPLICABILITY

The computerized storage and retrieval of highway data is applicable under the following conditions:

- Agency has access to computer facilities
- Agency has a desire to utilize highway data for systemwide summaries of geometric and/or deficient highway features for Procedure 7 ("Hazardous Roadway Features Inventory") of Process 2 ("Identify Hazardous Locations and Elements")

RESOURCE REQUIREMENTS

- Manpower - Computer programmers
- Funding - Funds for computer rental and operation (approximately $2000 to $10,000 per month, depending on required capabilities)
- Equipment - Access to computer facilities

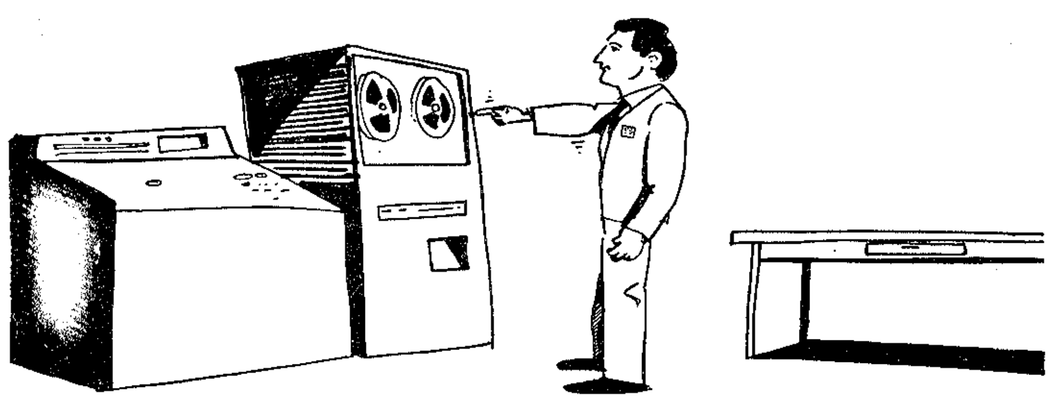
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Permits systemwide summaries of highway information (such as numbers of miles of each highway type)
- Permits summaries of deficient highway features

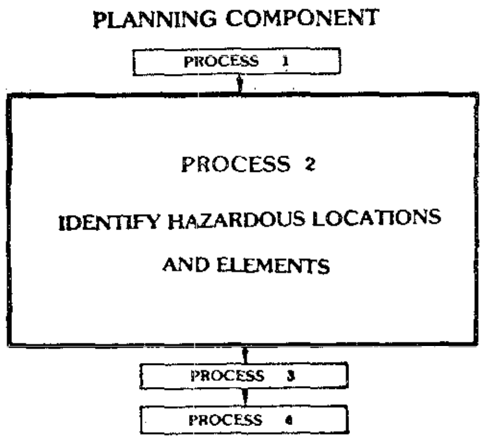
Disadvantages

- Requires computer facilities and programmers



# PROCESS 2

# IDENTIFY HAZARDOUS LOCATIONS AND ELEMENTS




## PURPOSE

The purpose of this process is to identify hazardous spots, sections, and elements based on the accident, traffic and highway data obtained from Process 1 ("Collect and Maintain Data").

## DESCRIPTION

This process includes the following procedures:

Procedure 1 - Frequency Method
Procedure 2 - Accident Rate Method
Procedure 3 - Frequency Rate Method
Procedure 4 - Rate Quality Control Method
Procedure 5 - Accident Severity Methods
Procedure 6 - Hazard Index Method
Procedure 7 - Hazardous Roadway Features Inventory Methods

Hazardous highway locations may or may not be high-accident locations. Many locations with narrow bridges, slick pavements, numerous rigid roadside obstacles, etc., have a high accident potential but may not yet have a history of high-accident occurrence. Therefore, it is important for a highway agency to also consider the identification of locations with a potential for high-accident numbers or severity.

Of the seven procedures listed above, the first five involve the use of accident data for identifying high-accident locations. The Hazardous Roadway Features Inventory primarily involves the use of physical roadway information (i.e., non-accident data) for identifying potentially hazardous locations, and the Hazard Index method may involve the use of both accident data and physical roadway information.

## Time Considerations

A period of time must be established for the analysis period. Current practice includes a wide range of time periods. The following should be considered when selecting the appropriate time period [1]:

- The time period should be as short as possible to identify locations where sudden changes in accident patterns have occurred.
- The time period should be long enough to assure reliability in identifying hazardous locations. It has been shown that reliability increases with longer time periods, up to about 3 or 4 years.
- Multiples of one year are preferred to avoid seasonal influences on accident patterns.

The first two items are contradictory and care should be taken to try to account for both. Dual analysis using different time intervals may be used, with one shorter period to "insure responsiveness to sudden changes in accident patterns," and one longer period to "insure maximum reliability" [1]. If a single time period is used, three years of data have been found to be desirable [2].

## Segment Length Considerations

Segment lengths must also be specified prior to the identification process. Each segment length may be defined as:

- Spot (short roadway length)
- Section (long roadway length)

Whether the segment is a spot or a section, it should have consistent characteristics of [3]:

- Geometrics
- Traffic volumes
- Condition

Several items need to be considered to determine the appropriate spot (short roadway) length. The appropriate spot length should [1]:

- Be no smaller than the minimum distance increment for reporting accident locations. For example, if accidents are reported to the nearest 0.1 mile, the minimum spot length can be no less than 0.1 mile.

- Accommodate errors that occur in reporting accident locations due to the locations of reference markers. Accidents should be located accurately to the nearest 0.1 mile (or better) whenever possible.
- Be capable of accounting for the area of influence of the roadway hazard, since the hazard may contribute to accidents occurring over a range of several hundred yards.
- Attempt to maximize reliability of identifying hazardous locations. It has been shown that reliability increases as spot length increases, although too large a spot length may create difficulty in identifying the specific hazard.

Spots may be considered as either fixed or floating locations. For example, if the spot length is taken as 0.3 mile, one spot would be identified as the interval along a route from 9.0 to 9.3 miles from the reference point. The next spot would then be located from 9.3 to 9.6 miles, and so on. Hazards located near the boundaries of these fixed spots may create locational problems, with some related accidents being assigned to one spot and some assigned to another spot. This problem can be alleviated by the use of floating locations instead of fixed locations. Spots would then be defined as 0.3 mile segments beginning at points 9.0, 9.1, and 9.2 miles from the reference point.

Section (long roadway) lengths vary widely in current practice, although a section length of one mile appears to be an accepted minimum. It is recommended that the sections [1]:

- Have a constant section length to avoid complications in the interpretation of accident data which may arise from the use of a variable length
- Be allowed to "float" to minimize the incompatibilities between section designation and the physical features of the roadway

For some agencies, the section length is defined as within the range of two to five miles.

### Early Warning Techniques

As a supplement to the identification process, short-term analyses may be conducted to aid in identifying locations which might require further investigation. Early warning analysis should be conducted routinely to identify locations which have a sudden increase in accidents or accident potential. Sudden increases in accident potential may be noticed by observing a rash of skid marks, erratic maneuvers, dents in guardrail, or other such indicators at a location [4].

## RANGE OF COMPLEXITY AMONG PROCEDURES

The seven procedures vary widely in complexity. The Number Method is the simplest to use and requires the least amount of data (only accident numbers by location). The most complex method is the Hazard Index Method, which requires numerous data items and may involve extensive manpower and cost to examine a large number of highway locations.

## MANAGERIAL CONCERNS

- What percentage of accidents are being reported?
- Are the reports complete and accurate?
- What additional information, if any, is needed?
- Are some hazardous locations being overlooked?
- What section (or spot) length is most appropriate?
- What analysis time period is most appropriate?
- What costs are going to be incurred?
- What is the availability of data and manpower?
- Is the complexity of the procedure appropriate for the size, type, and capabilities of the agency?
- Is the procedure appropriate for the highway type to which it is being applied?

## PROCESS INPUTS AND OUTPUTS

### Management Input

- An understanding of the appropriate identification procedure for the agency size, manpower, data availability, available funding, and other constraints
- Goals of the agency in terms of types of locations and elements to be included in the identification process

### Resource and Equipment Input

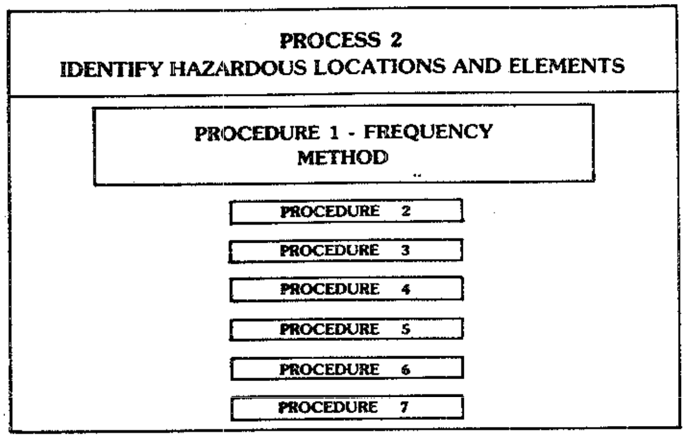
- Manpower
- Computer Facilities (Optional)
- Funding

### Data Input

| | Procedure | | | | | | |
|---|---|---|---|---|---|---|---|
| | Freq. | Acc. Rate | Freq. Rate | Rate Qual. Con. | Acc. Sev. | Haz. Index | Haz. Road. Feat. |
| Accident Summaries | X | X | X | X | X | X | |
| Traffic Volume Data | | X | X | X | | X | |
| Accident Severity | | | | | X | X | |
| Avg. Accident Experience | X | X | X | X | X | X | |
| Statistical Constants | | | | X | | | |
| Other Locational Data | | | | | | X | |
| Roadway Features | | | | | | | X |

### Output

- A listing of hazardous locations and elements for futher analysis




## PROCEDURE 1 - FREQUENCY METHOD

### DESCRIPTION

The Frequency Method is used to identify and rank locations on the basis of the number of accidents. The location with the highest number of accidents will rank first, then the location with the second highest number of accidents, and so on. This method is the easiest to apply and does not require the use of traffic volume data. Many agencies use the frequency method to select an initial group of high accident locations for further analysis. Then some other method is often applied to rank the locations in order of priority.

A critical value must be established for location selection (such as 9 or more accidents per year). If the number of accidents at a location equals or exceeds the critical value, the location is designated as a high-accident site. The critical value should be set such that the number of locations identified can reasonably be studied by the agency.

### PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Highway systems of 2500 miles or less (larger systems need more comprehensive methods)
- Systemwide accident data available (as a minimum)
- Technician level personnel (as a minimum)
- Objective of reducing accident numbers

This procedure is most applicable and efficient for street systems in small cities and local street systems within larger cities [5]. These systems are normally low volume and are not monitored for traffic volumes on a regular basis.

RESOURCE REQUIREMENTS

- Manpower - Requires minimum manpower. Technicians and/or engineers for listing hazardous locations based on accident frequencies
- Funding - Relatively low cost
- Equipment - None (Computer may be used to select hazardous locations from computerized accident files)

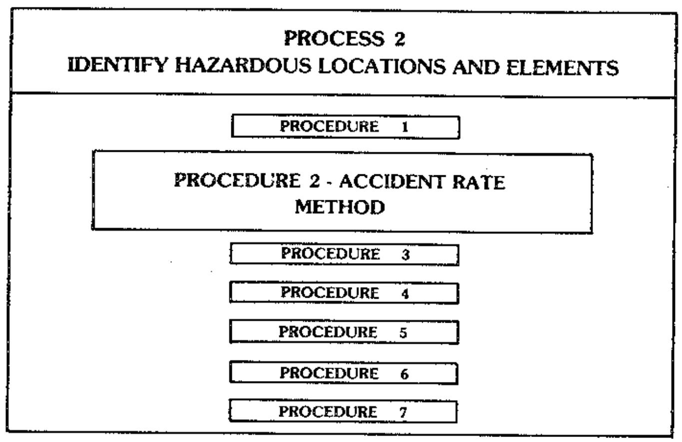
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Effective as a tool for providing continuous monitoring of the accident situation in an area
- Provides a simple, direct method for identifying hazardous locations

Disadvantages

- No consideration of exposure (i.e., traffic volumes) to the hazard
- Does not account for accident severity
- Does not give consideration to locations with a high potential for accidents, but with no past accident experience




PROCEDURE 2 - ACCIDENT RATE METHOD

DESCRIPTION

This method combines the accident frequency with the vehicle exposure, i.e., the volume of traffic. The accident frequency is divided by the exposure factor to provide "accidents per million vehicles" for intersections (and other spots) or "accidents per million vehicle- miles of travel" for highway sections. The locations are then ranked in descending order by accident rate.

The equation for computing accident rate for a spot location is as follows:

$$R_{sp} = (A)(1{,}000{,}000)/(365)(T)(V)$$

Where: $R_{sp}$= Accident rate at a spot in accidents per million vehicles,

A = Number of accidents for the study period,

T = Period of study (years or fraction of years),

V = Average Annual Daily Traffic (AADT) during the study period. For intersections, V equals the sum of the entering volumes on all approach legs.

A spot location is generally defined as a location about 0.3 miles or less in length.

For roadway sections, length becomes a consideration, and the equation becomes:

$$R_{se} = (A)(1{,}000{,}000)/(365)(T)(V)(L)$$

Where: $R_{se}$ = Accident rate of the section in accidents per million vehicle miles of travel,

L = Length of the section (in miles). Roadway segments of less than one-half mile should not be considered as sections.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Highway systems of 10,000 miles or less (larger systems need a more comprehensive method)
- Technician level personnel (as a minimum)
- Agencies with systemwide traffic accident and volume data available
- Objective to reduce accident rates

## RESOURCE REQUIREMENTS

- Manpower - Requires very little manpower per location. Technicians and/or engineers for computing accident rates, and listing hazardous locations based on accident rate. A programmer may also be necessary if computer is used.
- Funding - Higher cost than frequency method due to manpower and/or

computer time necessary to compute accident rates, but less expensive than most other methods in Process 2.
- Equipment - None required. Computer is optional for computing accident rates.

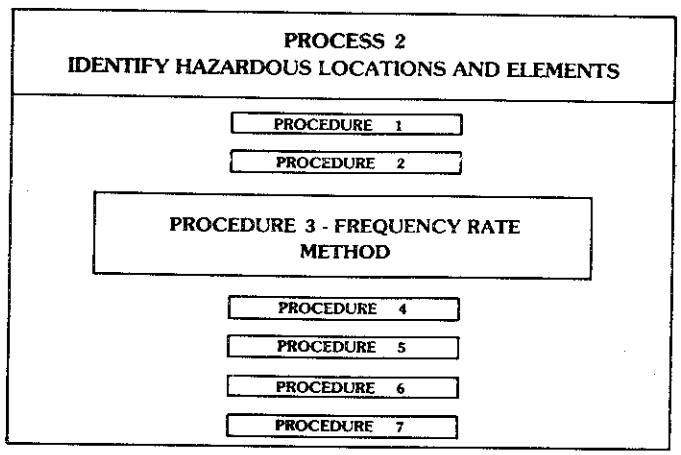
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Combines the use of an exposure factor (traffic volumes) and a frequency factor
- Remains a relatively simple, direct method

### Disadvantages

- May overrepresent hazard at locations with very low traffic volumes
- Requires additional data (i.e., traffic volumes) compared to the frequency method
- Does not account for accident severity
- Does not give consideration to locations with a high potential for accidents, but with no past accident experience




## PROCEDURE 3 - FREQUENCY RATE METHOD

### DESCRIPTION

The Frequency Rate Method is normally applied by first selecting a large sample of high accident locations based on a "number of accidents" criteria (i.e., the Frequency Method). Then, accident rates are computed and the locations are priority ranked by accident rate.

A somewhat different procedure was developed to compare the dual influence of frequency and rate in a matrix pattern [6]. Using this procedure, accident frequency is plotted on the horizontal axis and accident rate on the vertical axis for use in ranking high accident links and intersections. Each accident location can be categorized by this method into matrix cells representing a given level of accident frequency and accident rate. Each cell includes two-dimensional boundaries. An example of a frequency-rate matrix is given in Table 4.

Listed in each cell of a frequency-rate matrix is the number of intersections or links with the particular cell characteristics. The upper right-hand corner denotes the more hazardous locations. As one proceeds downward and to the left, decreasing levels of hazard are indicated.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Highway systems of any size
- Technician level personnel (as a minimum)
- Systemwide accident and volume data must be available
- Objectives to reduce accident numbers and rates

## RESOURCE REQUIREMENTS

- Manpower - Technicians and engineers are required for the purpose of computing rates, and developing the frequency-rate matrix. A programmer may be necessary if a computer is used (recommended).
- Funding - Manual methods may require considerable funding, depending on the size of highway system.
- Equipment - None required. Computer is optional (recommended)

## PROCEDURE ADVANTAGES AND DISADVANTAGES

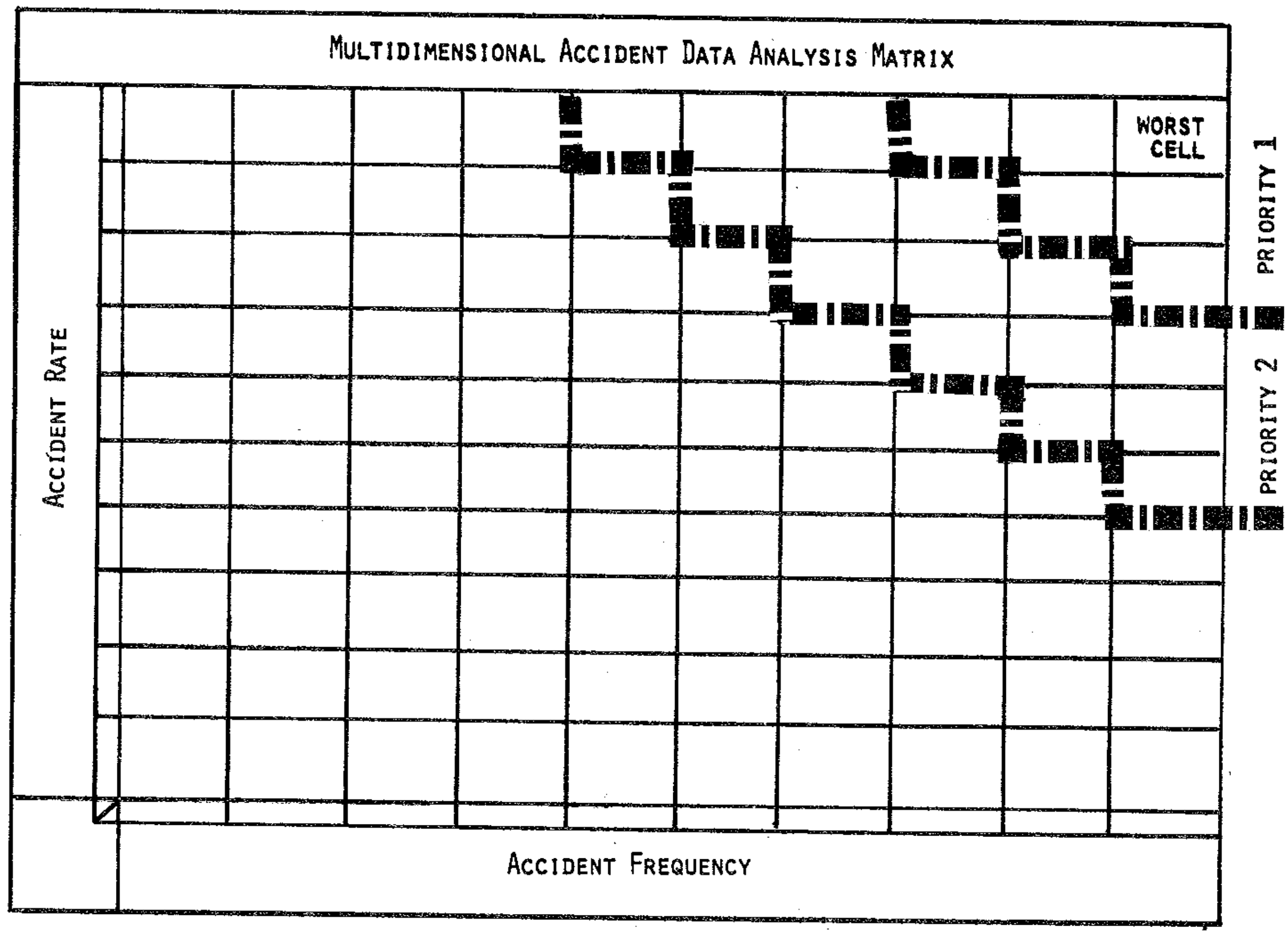
### Advantages

- Alleviates the need to calculate rates at every accident location
- Uses both frequencies and rates to assess hazard
- Reduces the exaggerated effect of the accident rate on low volume roads and the exaggerated effect of high frequencies at high-volume intersections

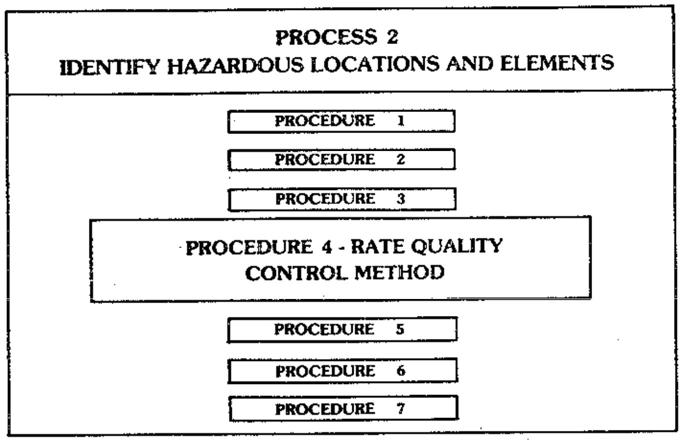
### Disadvantages

- May require considerable funds and manpower for manual application
- More complex than frequency method or rate method. May require personnel with experience in highway safety
- Does not account for accident severity
- Does not give consideration to locations with a high potential for accidents, but with no past accident experience

Table 4. Frequency/Rate matrix.




(Source: Reference No. 6)




## PROCEDURE 4 - RATE QUALITY CONTROL METHOD

### DESCRIPTION

This method utilizes a statistical test to determine whether the accident rate at a particular location is significantly higher than a predetermined average rate for locations of similar characteristics. The statistical tests are based on the commonly accepted assumption that the occurrence of accidents approximates the Poisson distribution. In this method, the accident rate at a location is compared to a "critical rate", which is based on the average systemwide accident rate for the highway type. The equation for calculating the critical rate is as follows [7]:

$$R_c = R_a + K\sqrt{R_a/M} + 1/(2M)$$

Where,

$R_c$ = Critical accident rate for a spot (accidents per million vehicles) or section (accidents per million vehicle-miles).

$R_a$ = Average accident rate for all spots of similar characteristics or on similar road types.

$M$ = Millions of vehicles passing over a spot in the study period, or million vehicle miles of travel on the section during the study period.

$K$ = A probability factor determined by the desired level of significance for the equation.

The K value is determined by the probability, P, that an accident rate is sufficiently large that it cannot be reasonably attributed to random occurrences. Selected values of K are:

| P (Probability) | .005 | 0.0075 | 0.05 | .075 | .10 |
|---|---|---|---|---|---|
| K - value | 2.576 | 1.960 | 1.645 | 1.440 | 1.282 |

The most commonly used K values are 2.576 (P = .005) and 1.645 (P = .05).

Two sets of curves were developed for using this method in Kentucky. A set of critical rate curves is given for rural highways in Kentucky for each highway classification (2-lane, 4-lane divided, etc.) in Figure 14. Hazardous locations were also identified based upon their critical accident rates as related to the AADT and city population in Figure 15. For example, a location with an AADT of 10,000 in city population group 6 (2500-5000 population) would be considered hazardous if the accident rate is 1.5 or higher, as shown in Figure 15. The location would be considered safe if the accident rate is less than 1.5. This example is based on average accident rates on urban streets in Kentucky and may not represent highway accident levels in other states.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Highway systems greater than about 2500 miles (smaller systems need less complex methods)
- Junior level engineers on staff (minimum)
- Systemwide accident rates by highway classification available
- Objectives to reduce rates and compare locations to systemwide average

## RESOURCE REQUIREMENTS

- Manpower - Requires more manpower than methods described previously, particularly for manual application. At least one or more junior engineers are needed for computing actual and critical rates, and developing listings based on a comparison of actual vs. critical rate. Programmer may also be required if computer is used (recommended).
- Funding - Relatively moderate cost. Manual methods may require considerable funds.
- Equipment - Computer is optional (recommended for large numbers of locations to be processed).

## ADVANTAGES AND DISADVANTAGES

### Advantages

- Reduces the exaggerated effect of the accident rate on low-volume roads and the exaggerated effect of high frequencies at high-volume urban intersections
- Flexible enough to accommodate changing accident patterns
- Allows for statistical reliability in identifying locations

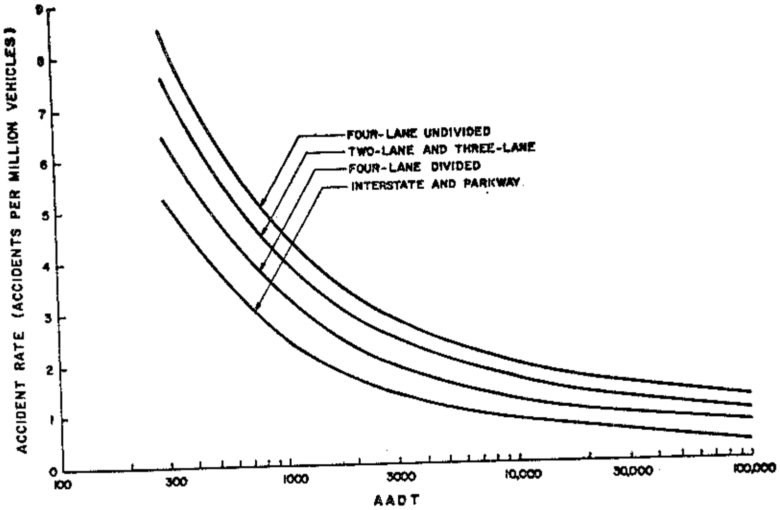



Figure 14. Rate quality control curves for rural roads in Kentucky.

(Source: Reference No. 1)

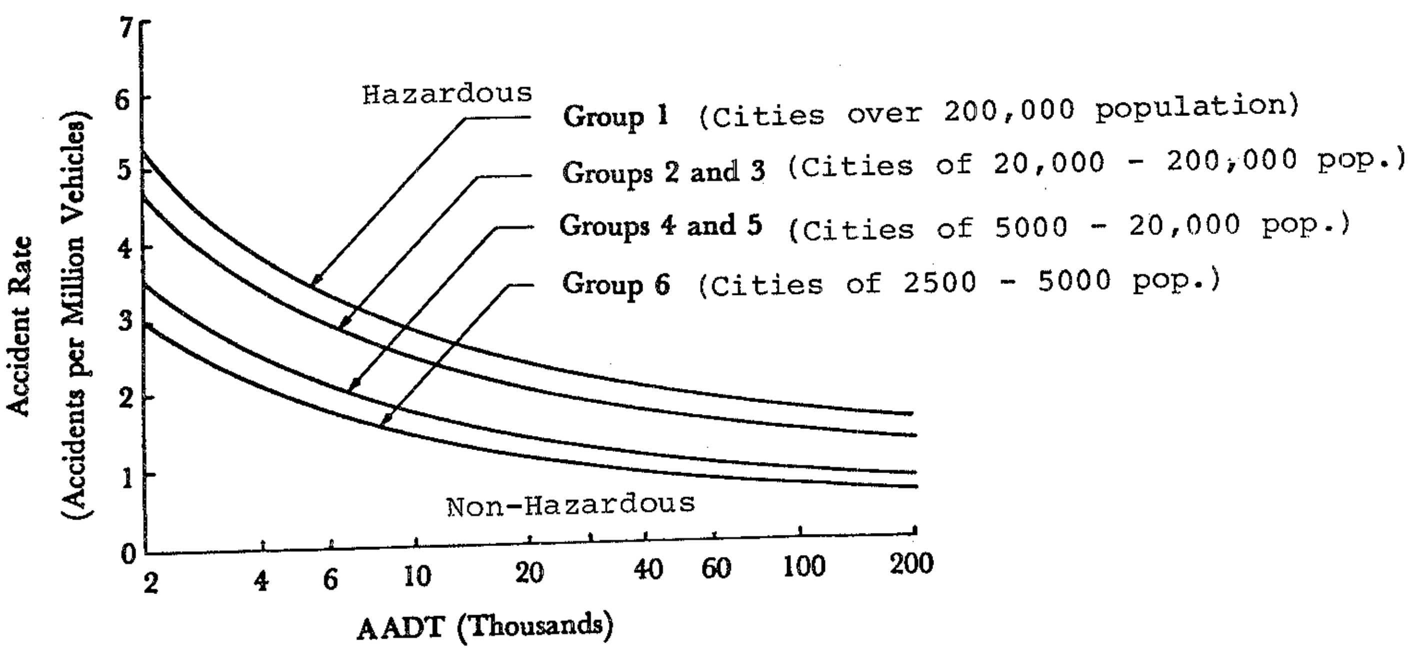
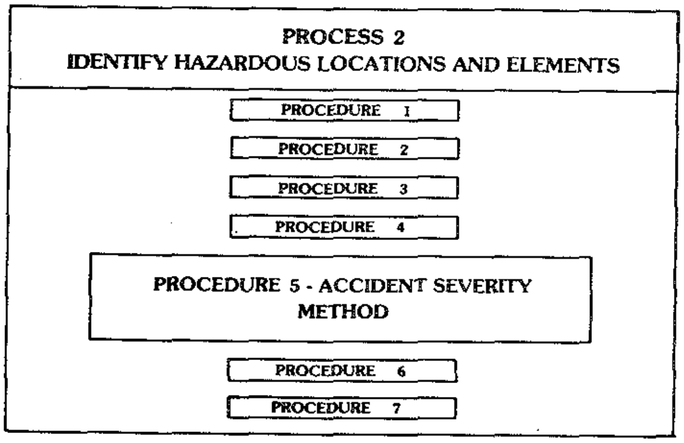



Figure 15. Rate quality control curves for urban streets in Kentucky.

(Source: Reference No. 8)

Disadvantages

- Relatively complex
- Manual application is time consuming and expensive
- Does not take severity of accidents into account
- Does not give consideration to locations with a high potential for accidents, but with no past accident experience




PROCEDURE 5 - ACCIDENT SEVERITY METHOD

DESCRIPTION

Accident Severity Methods are used in various states to identify and priority-rank high-accident locations. Some states consider only injury and fatality accidents in identifying hazardous locations. Other states apply weighting factors to accidents based on their severity and then compute some form of Severity Index or Severity Number.

Accident severities are often classified (by the National Safety Council and many States) within the following five categories:

- Fatal Accident - One or more deaths
- A - Type Injury Accident - Bleeding wound, distorted member, or person carried from scene (incapacitating)
- B - Type Injury Accident - Bruises, abrasions, swelling, limping, (non-incapacitating)
- C - Type Injury Accident - Involving no visible injuries but complaint of pain (probable injury)
- PDO Accident - Propery damage only accident

One of the many severity methods is called the Equivalent Property Damage Only (EPDO) Method. The equivalency factors vary by state -- the formula given below is used in Kentucky [1]:

$$EPDO = 9.5(F+A) + 3.5(B+C) + PDO$$

Where:

F = Number of fatal accidents
A = Number of A-type injury accidents
B = Number of B-type injury accidents
C = Number of C-type injury accidents
PDO = Number of PDO accidents

To be included in this equation, each accident is classified by the most severe injury which occurred, and an accident is counted only once in the equation. Locations are then ranked based on their computed EPDO number.

Another severity method involves the determination of an average Relative Severity Index (RSI) for each location [9]. RSI values for various accident types (Table 5) are dependent on accident type, area type (urban, rural) and accident cost by severity, i.e.,

The following steps should be used to determine average RSI values for each individual location:

1. Classify each accident at the location under one of the categories listed in Table 5.
2. Multiply the total accidents under each category (type of accident) by its corresponding cost (unit RSI value) to determine the total RSI values for each accident type occurring at the location.
3. The total RSI value for the location is obtained by summing the total RSI values for each accident type at the location.
4. The average RSI value is determined by dividing the total RSI value for the location by the total number of accidents at the location.
5. Repeat steps 1 through 4 for each location.
6. Rank the hazardous locations by average RSI value.

As an example, suppose Location A is an urban intersection where there were five opposing left-turn, three right-angle, and two rear-end accidents. Location B is a rural intersection with three right-angle and two run-off-the-road accidents. The total RSI value for Location A would be:

$$5(4,400) + 3(4,300) + 2(3,800) = \$42,500$$

Similarly for Location B, the total RSI value is:

$$3(14,400) + 2(12,300) = \$67,800$$

Table 5. Sample relative severity index values.

| Type of Accident | RSI Urban | RSI Rural |
|---|---|---|
| **Multi-Vehicle, At Intersection** | | |
| Entering at angle | $ 4,300 | $14,400 |
| From same direction -- both going straight | 2,800 | 5,100 |
| From same direction -- one turn, one straight | 2,500 | 5,100 |
| From same direction -- one stopped | 3,800 | 5,200 |
| From same direction -- all others | 2,000 | 6,300 |
| From opposite direction -- both going straight | 4,000 | 20,000 |
| From opposite direction -- one left turn, one straight | 4,400 | 15,400 |
| From opposite direction -- all others | 2,700 | 3,800 |
| Not stated | 3,800 | 5,200 |
| **Multi-Vehicle, Non-Intersection** | | |
| Going opposite direction -- both moving | $ 4,400 | $19,600 |
| Going same direction -- both moving | 2,900 | 8,100 |
| One car parked | 1,600 | 2,400 |
| One car stopped in traffic | 4,200 | 6,800 |
| One car entering parked position | 1,900 | 2,300 |
| One car leaving parked position | 1,200 | 2,700 |
| One car entering alley or driveway | 3,400 | 6,000 |
| One car leaving alley or driveway | 2,000 | 4,400 |
| All others | 1,700 | 7,600 |
| Not stated | 3,400 | 6,000 |
| **Motor Vehicle with Pedestrian, At Intersection and Non-Intersection** | | |
| Vehicle going straight | $20,000 | $49,000 |
| Vehicle turning right | 13,600 | 11,200 |
| Vehicle turning left | 17,100 | 11,200 |
| Vehicle backing | 20,600 | 11,200 |
| All others | 14,500 | 11,200 |
| Not stated | 11,200 | 11,200 |
| **Single Vehicle, at Intersection** | | |
| Collision with train | $26,700 | $39,100 |
| Collision with bicycle | 13,100 | 31,900 |
| Injury in vehicle, jacknifed | 5,200 | 2,000 |
| Collision with fixed object in road | 5,500 | 7,000 |
| Overturned in road | 9,200 | 7,500 |
| Left road | 5,200 | 12,300 |

| Type of Accident | RSI Urban | RSI Rural |
|---|---|---|
| **Single Vehicle, Non-Intersection** | | |
| Collision with train | $26,700 | $39,100 |
| Collision with bicycle | 13,100 | 31,900 |
| Injury in vehicle, jacknifed | 5,200 | 2,000 |
| Collision with fixed object in road | 6,300 | 9,200 |
| Overturned in road | 10,000 | 9,400 |
| Left road at curve | 7,600 | 12,400 |
| Left road on straight road | 5,200 | 10,500 |
| **Other One Motor Vehicle, At Intersection and Non-Intersection** | | |
| Fell from moving vehicle | $15,000 | $57,200 |
| Collision with animal | 4,800 | 1,800 |
| Collision with other object | 4,700 | 4,400 |
| All others | 5,200 | 2,000 |
| Not stated | 3,200 | 3,400 |

(Source: Reference No. 9)

The corresponding average RSI values become:

$$\text{Average } RSI_A = \frac{42,500}{10} = \$4,250$$

$$\text{Average } RSI_B = \frac{67,800}{5} = \$13,560$$

Location B would be considered more hazardous than Location A (using the RSI method) despite the fact that twice as many accidents occurred at Location A.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Highway systems of any size
- Junior level engineers on staff (minimum)
- Systemwide accident severity data
- Objectives to reduce accident severities.

This procedure is perhaps more applicable in rural areas, where the percentages of severe accidents is high (relative to those in urban areas).

## RESOURCE REQUIREMENTS

- Manpower - May require considerable manpower for manual methods, including at least one or more junior level engineers to develop listings of hazardous locations based on EPDO number or RSI. Programmer may be necessary for computerized systems.
- Funding - Relatively moderate to high cost.
- Equipment - None. Computer is optional.

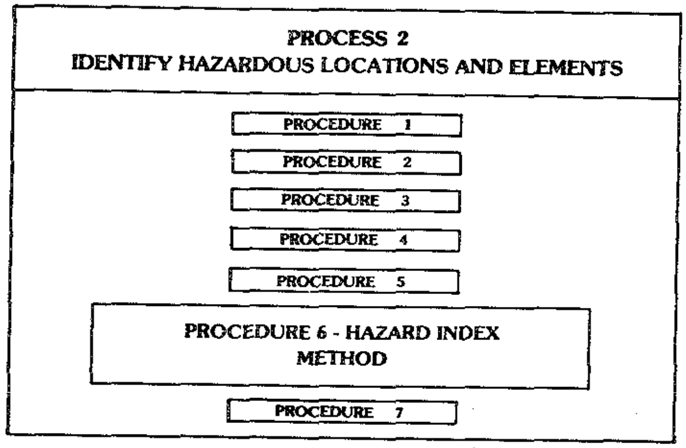
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Accounts for the severity of accidents
- Highly applicable to rural areas, where high percentages of severe accidents occur

### Disadvantages

- The severity of an accident is highly dependent on many factors which are unrelated to the highway location (i.e., age and health of passengers, type of vehicles involved, use or non-use of seat belts, etc.). However, the RSI procedure compensates somewhat for this disadvantage.
- Does not consider locations with a high potential for accidents




## PROCEDURE 6 - HAZARD INDEX METHOD

### DESCRIPTION

The Hazard Index Method employs a formula to develop a rating index for each suspect site. It was developed by Taylor and Thompson under contract with the FHWA to rank spot locations on a common basis [9]. Factors used in the formula are:

- Number of accidents per year
- Accident rate
- Accident severity
- Sight distance
- Volume/capacity ratio
- Traffic conflicts
- Erratic maneuvers
- Driver expectancy
- Information system deficiencies

The raw data value for each factor is converted to an indicator value through the use of a conversion graph. The indicator value is then multiplied by a weighting factor. The weightings are based on a survey of professionals in the traffic safety field. The resulting partial hazard indices (one for each factor) are summed to obtain the hazard index for the locations. Locations are then ranked by magnitude of the hazard index. The tabulated summary of the hazard indices of one location is given in Figure 16.

### PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

Site Number ____________ Date ____________

Type Rural Intersection

| Indicator | Data Value | Indicator Value | | Weight | | Partial H.I.'s |
|---|---|---|---|---|---|---|
| Number of Accidents | 7.67 acc/yr | 59 | x | 0.145 | = | 8.6 |
| Accident Rate | 2.47 acc/MEV | 49 | x | 0.199 | = | 9.8 |
| Accident Severity | $12,850 dollars | 70 | x | 0.169 | = | 11.8 |
| Volume/Capacity Ratio | 0.17 | 22 | x | 0.073 | = | 1.6 |
| Sight Distance Ratio | >2.0 (wt.avg.) | 0 | x | 0.066 | = | 0.0 |
| Traffic Conflict | --- conf/hr.) | -- | x | ~~0.053~~ | = | --- |
| Erratic Maneuvers | --- e.m./hr. | -- | x | ~~0.061~~ | = | --- |
| Driver Expectancy | 2.19 (wt.avg.) | 37 | x | 0.132 | = | 4.9 |
| Info. System Deficiencies | 2.79 (wt.avg.) | 47 | x | 0.102 | = | 4.8 |
| Sums: | | | | 0.886 * | | 41.5 |

$$\text{H.I.} = \frac{\text{Sum of Partial H.I.'s}}{\text{Sum of Applicable Weights}} = \frac{41.5}{0.886} = 47$$

Relative Strength of Evaluation

Sum of Applicable Weights x 100 = 89 %

*Do not include weights for indicators not used at this site.

Figure 16. Hazard Index Method - example.

(Source: Reference No. 9)

- Highway systems of less than 2,500 miles (the collection of required data may be too expensive for large systems with numerous locations to be studied)
- Experienced highway safety engineers, and possibly human factors experts
- Systemwide accident, volume, severity, and hazardous features data available and
- Objectives to reduce accident numbers, rates, severities, and hazardous features

## RESOURCE REQUIREMENTS

- Manpower - Requires considerable manpower. Several experienced highway engineers are required to collect and maintain data and to list hazardous locations based on the hazardousness index computed from these data sources. Human factors experts may also be required. Programmer may be necesssary if a computer is used.
- Funding - Collection and analysis of data can be quite expensive
- Equipment - Computer is optional.

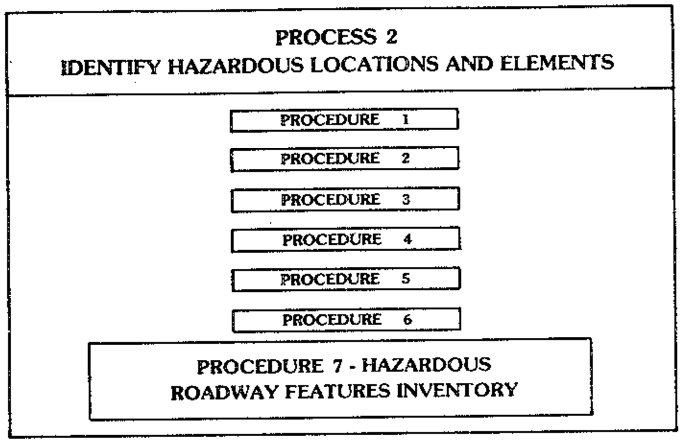
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Comprehensive use of numerous factors related to locational hazards
- Highly adaptable. Factors which do not apply or are not available may be deleted from analysis
- Considers both accident data and variables which indicate a high potential for accidents.

### Disadvantages

- Large amounts of information are necessary to use this procedure properly
- Deletion of too many factors from the analysis reduces its effectiveness
- Requires considerable expertise in highway safety and human factors
- May require data that is not readily available; i.e., additional data may need to be collected




## PROCEDURE 7 - HAZARDOUS ROADWAY FEATURES INVENTORY

### DESCRIPTION

The identification of hazardous roadway features is one method of selecting sites with a potential for high-accident severity or numbers. This procedure is based largely on the comparison of existing roadway features with safety and design standards. Several different programs have been developed for identifying such roadway safety hazards. Many of these types of safety hazards are identified in the AASHTO "Yellow Book" [10].

Examples of such hazardous features include:

- Blunt-end guardrail barrier terminals
- Narrow bridges
- Steep roadside slopes
- Rigid roadside objects
- Narrow lanes and shoulders
- Unprotected bridge overpass structures
- Slippery pavements
- Sharp radii on horizontal curves and ramps
- Hazardous highway-railroad grade crossings

The identification of such hazardous roadway features can be performed in many different ways. For example, information from systemwide highway inventories can be used to select specific hazardous features for further review. Also, some states have hazard report forms which are completed by local police officers when they observe a highway site or condition which they perceive as hazardous. Other agencies utilize routine preventative surveillance of their highways to attempt to locate sites which may be hazardous to the driving public. Another method may be to identify hazardous locations as those where any roadside object accident has occurred which results in at least one fatality [11,12].

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Highway systems of any size
- Experienced highway safety engineers on staff
- Systemwide roadway features data available
- Objectives to reduce hazardous roadway features

## RESOURCE REQUIREMENTS

- Manpower - May require considerable manpower, including several experienced highway safety engineers to interpret and analyze all pertinent data and prepare a listing of hazardous locations based on an inventory of roadway features.
- Funding - Relatively high cost of operation
- Equipment - Little or none required (Computer is recommended)

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Considers locations that are potentially hazardous (even though large numbers of accidents may not have been observed); i.e., considers non-accident data
- Considers locations (e.g., railroad grade crossings, roadside hazards) which have a potential for high-severity accidents

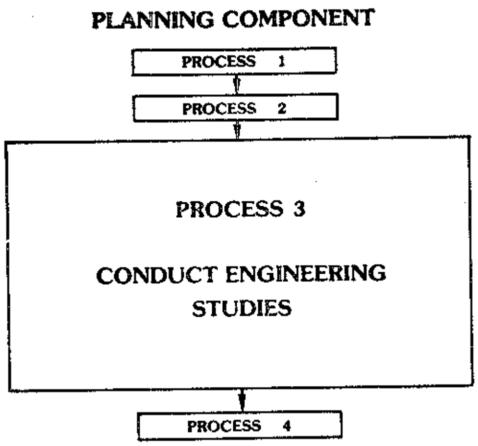
### Disadvantages

- Can require large amounts of data, including data that may not be readily available (additional data collection)
- Requires personnel with experience in highway safety, particularly in the analysis of hazardous roadway features
- Improvement expenditures must be justified on some basis other than reduction in accident experience

CHAPTER VII

# PROCESS 3

# CONDUCT ENGINEERING STUDIES




## PURPOSE

The purpose of this process is to collect and analyze data at identified hazardous locations, and then to select appropriate safety improvement projects.

## DESCRIPTION

This process is conducted after a listing of hazardous locations and elements is developed (from Process 2). The output of this process will be a list of specific safety improvement projects for which implementation is theoretically justified. Those for which actual funding is recommended will be determined through in Process 4 -- "Establish Project Priorities."

This process includes the following subprocesses:

Subprocess 1 - Collect and Analyze Data
Subprocess 2 - Develop Candidate Countermeasures
Subprocess 3 - Develop Projects

A 4-day training course entitled "Highway Safety Engineering Studies" is currently being developed by FHWA, which provides a detailed description of all activities within Process 3 [1].

MANAGERIAL CONCERNS

- Which procedures are most applicable for the agency?
- Are adequate resources (i.e, manpower, equipment and funding) available to satisfy the resource requirements of the procedures?
- What types of input data are needed?
- Is the available data sufficient or should additional data be collected?
- Are there any time constraints involved?

PROCESS INPUTS AND OUTPUTS

Management Input

- A knowledge of highway safety design standards
- A knowledge of warrants for traffic control devices
- A basic understanding of engineering studies
- A basic understanding of available safety improvements which are effective in reducing accidents
- A basic understanding of economic evaluation methodologies

Resource and Equipment Input

- Manpower to collect and analyze necessary data at each hazardous location
- Funding
- Computer capabilities (optional)

Data or Informational Input

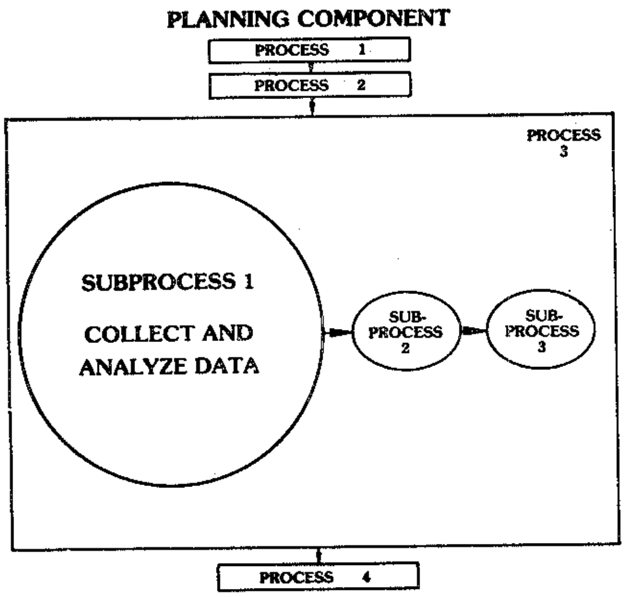
- A listing of hazardous locations (from Process 2 - "Identify Hazardous Locations and Elements")

Output

- A listing of safety improvement projects for each site which should be priority ranked before implementation.

# PROCESS 3, SUBPROCESS 1

# COLLECT AND ANALYZE DATA AT HAZARDOUS LOCATIONS




## PURPOSE

The purpose of this subprocess is to perform specific studies which involve the collection and analysis of all types of data required as input for Process 3, Subprocess 2 - "Develop Candidate Countermeasures." This subprocess should follow the completion of Process 2 - "Identify Hazardous Locations and Elements."

## DESCRIPTION

After the hazardous locations and elements have been identified, it is necessary to collect and analyze all pertinent information required to develop countermeasures for each location. There are numerous procedures, or studies, which can be used to obtain and analyze the necessary information. These studies may be classified into four general categories [1]:

Procedures 1-5 - Accident-Based Studies
Procedures 6-14 - Traffic Operations-Based Studies
Procedures 15-20 - Environmental-Based Studies
Procedures 21-24 - Special Studies

A total of 24 procedures (studies) have been identified within these categories, including five accident-based studies, nine traffic operations-based studies, six environmental-based studies, and four special studies. These 24 procedures are as follows:

## ACCIDENT-BASED PROCEDURES (STUDIES)

Procedure 1 - Accident Summary by Type
Procedure 2 - Accident Summary by Severity
Procedure 3 - Accident Summary by Contributing Circumstances
Procedure 4 - Accident Summary by Environmental Conditions
Procedure 5 - Accident Summary by Time of Day

## TRAFFIC OPERATIONS-BASED PROCEDURES (STUDIES)

Procedure 6 - Safety Performance Studies
Procedure 7 - Volume Studies
Procedure 8 - Spot Speed Studies
Procedure 9 - Delay and Travel Time Studies
Procedure 10 - Roadway and Intersection Capacity Studies
Procedure 11 - Traffic Conflict Studies
Procedure 12 - Gap Studies
Procedure 13 - Traffic Lane Occupancy Studies
Procedure 14 - Queue Length Studies

## ENVIRONMENTAL-BASED PROCEDURES (STUDIES)

Procedure 15 - Roadway Inventory Studies
Procedure 16 - Sight Distance Studies
Procedure 17 - Roadway Serviceability Studies
Procedure 18 - Skid Resistance Studies
Procedure 19 - Highway Lighting Studies
Procedure 20 - Weather-Related Studies

## SPECIAL PROCEDURES (STUDIES)

Procedure 21 - School Crossing Studies
Procedure 22 - Railroad Crossing Studies
Procedure 23 - Traffic Control Device Studies
Procedure 24 - Bicycle and Pedestrian Studies

The proper selection and use of these studies will provide the information needed to determine the specific safety deficiencies at each location. Countermeasures can then be developed to eliminate or alleviate the hazardous condition.

## RANGE OF COMPLEXITY AMONG PROCEDURES

The procedures within this process cover a wide range of complexity. The procedures include simple studies requiring very little training (e.g., traffic volume and spot speed studies), as well as those which require considerable experience and training, (e.g, traffic conflict studies). The range of complexity of some procedures, particularly the accident-based procedures, becomes even more varied with the application of either manual or computer techniques.

## MANAGERIAL CONCERNS

- Are adequate resources (manpower, funding, equipment) available to satisfy the resource requirements of these procedures?
- What types of input data are needed?
- Is this data sufficient or should additional data be collected?
- Are any time constraints involved?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- A knowledge of highway safety design standards
- A knowledge of warrants for traffic control devices
- A basic understanding of engineering studies

### Resource and Equipment Input

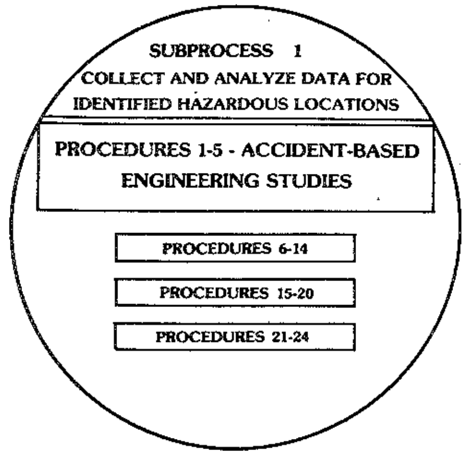
- Manpower
- Funding
- Computer capabilities (optional)

### Data or Informational Input

- A listing of hazardous locations (from Process 2 - "Identify Hazardous Locations and Elements")

### Output

- The results of analyzed data from appropriate engineering studies for use in countermeasure development




## PROCEDURES 1-5 - ACCIDENT-BASED STUDIES

### DESCRIPTION

Traffic accidents provide the major indication of safety problems at a location. Accident-based engineering studies are utilized to identify the safety deficiencies of the location. The five accident-based studies are [1]:

Procedure 1 - Accident Summary by Type
Procedure 2 - Accident Summary by Severity
Procedure 3 - Accident Summary by Contributing Circumstances
Procedure 4 - Accident Summary by Environmental Conditions
Procedure 5 - Accident Summary by Time of Day

Accident-based studies involve the development of statistical summaries of the accident data by various characteristics (Table 6) to detect abnormal accident trends. The accident data required for these summaries may be obtained manually from hard copy accident reports or by computer techniques from computerized accident files. Safety deficiencies are then identified based on a comparison of the frequency of occurrence of a specific characteristic to a "standard" frequency. Overrepresentations are identified by a disproportionately high percentage of a certain accident characteristic when compared to similar locations. An adequate sample of data at comparable sites is necessary to identify an accurate overrepresentation of accident characteristics.

The statistical summaries of accident data may be developed either manually or by computer techniques, as shown in Table 7. Several statistical packages are available for computer application, including the Statistical Package for the Social Sciences (SPSS), Data Analysis and Reporting Techniques (DART), Michigan Dimensional Analysis System (MIDAS), and

Table 6. Typical accident characteristic categories.

| Description | Categories |
|---|---|
| Summary by Type | 1. Left-turn, head-on<br>2. Right-angle<br>3. Rear-end<br>4. Sideswipe<br>5. Pedestrian-related<br>6. Run-off-road<br>7. Fixed object<br>8. Head-on<br>9. Parked vehicle<br>10. Other |
| Summary by Severity | 1. Fatal<br>2. Personal Injury<br>- incapacitating<br>- nonincapacitating<br>- possible injury<br>3. Property Damage |
| Summary by Contributing Circumstances | 1. Driving under the influence of alcohol or drugs<br>2. Reckless or careless driving<br>3. Ill, fatigued or inattention<br>4. Failure to comply with license restrictions<br>5. Obscurred vision<br>6. Defective equipment tributing)<br>7. Lost control due to shifting load, wind, or vacuum |
| Summary by Environmental Conditions | 1. Weather (clear, cloudy, rain, fog, snow)<br>2. Ambient light (light, dark, dawn, dusk, street lights)<br>3. Roadway surface (dry wet, snowy, icy) |
| Summary by Time of Day | 1. 12:00 midnight - 1:00 A.M.<br>2. 1:00 A.M. - 2:00 A.M.<br>3. 2:00 A.M. - 3:00 A.M.<br>4. 3:00 A.M. - 4:00 A.M.<br>.<br>.<br>.<br>24. 11:00 P.M. - 12:00 Midnight |

Table 7. Computerized accident summary (SPSS) - example.

VAR011 TWO VEHICLE ACCIDENT CODE

| CATEGORY LABEL | CODE | ABSOLUTE FREQ | RELATIVE FREQ (PCT) | ADJUSTED FREQ (PCT) | CUM FREQ (PCT) |
|---|---|---|---|---|---|
| HEAD-ON | 1. | 2 | 3.0 | 3.0 | 3.0 |
| REAR-END | 2. | 20 | 29.9 | 29.9 | 32.8 |
| SIDESWIPE-MEETING | 3. | 3 | 4.5 | 4.5 | 37.3 |
| SIDESWIPE-PASSING | 4. | 1 | 1.5 | 1.5 | 38.8 |
| ANGLE | 5. | 24 | 35.8 | 35.8 | 74.6 |
| OPP LEFT TURN | 7. | 15 | 22.4 | 22.4 | 97.0 |
| NOT STATED | 8. | 2 | 3.0 | 3.0 | 100.0 |
| | TOTAL | 67 | 100.0 | 100.0 | |

Table 8. Computerized cross tabulation (SPSS) - example.

C R O S S T A B U L A T I O N O F
VAR009 ACCIDENT SEVERITY BY VAR011 TWO VEHICLE ACCIDENT COD

| VAR009 | COUNT / ROW PCT / COL PCT / TOT PCT | HEAD-ON 1. | REAR-END 2. | SIDESWIP E-MEETIN 3. | SIDESWIP E-PASSIN 4. | ANGLE 5. | OPP LEFT TURN 7. | NOT STATED 8. | ROW TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| 2. PERSONAL INJURY | COUNT | 1 | 5 | 1 | 0 | 11 | 8 | 1 | 27 |
| | ROW PCT | 3.7 | 18.5 | 3.7 | 0.0 | 40.7 | 29.6 | 3.7 | 40.3 |
| | COL PCT | 50.0 | 25.0 | 33.3 | 0.0 | 45.8 | 53.3 | 50.0 | |
| | TOT PCT | 1.5 | 7.5 | 1.5 | 0.0 | 16.4 | 11.9 | 1.5 | |
| 3. PROPERTY DAMAGE | COUNT | 1 | 15 | 2 | 1 | 13 | 7 | 1 | 40 |
| | ROW PCT | 2.5 | 37.5 | 5.0 | 2.5 | 32.5 | 17.5 | 2.5 | 59.7 |
| | COL PCT | 50.0 | 75.0 | 66.7 | 100.0 | 54.2 | 46.7 | 50.0 | |
| | TOT PCT | 1.5 | 22.4 | 3.0 | 1.5 | 19.4 | 10.4 | 1.5 | |
| COLUMN TOTAL | | 2 | 20 | 3 | 1 | 24 | 15 | 2 | 67 |
| | | 3.0 | 29.9 | 4.5 | 1.5 | 35.8 | 22.4 | 3.0 | 100.0 |

and Organized Set of Integrated Routines for the Investigation of Social Science Data (OSIRIS IV).

The accident procedures may be combined to provide more detailed analyses. Cross-tabulations are often quite useful for representing statistical analysis of two or more variables. An example of a cross-tabulation from computer application (SPSS) is given in Table 8. Collision diagrams are also used extensively as a graphic representation of the accident summaries and may include all of the information covered by the five accident-based procedures. In addition, these schematic drawings provide locational information that is not provided by statistical summaries. Therefore, collision diagrams often yield more effective information to the engineer than do statistical summaries.

The following items are essential to the development of any collision diagram [2]:

1. All important elements of each accident should be noted, such as:

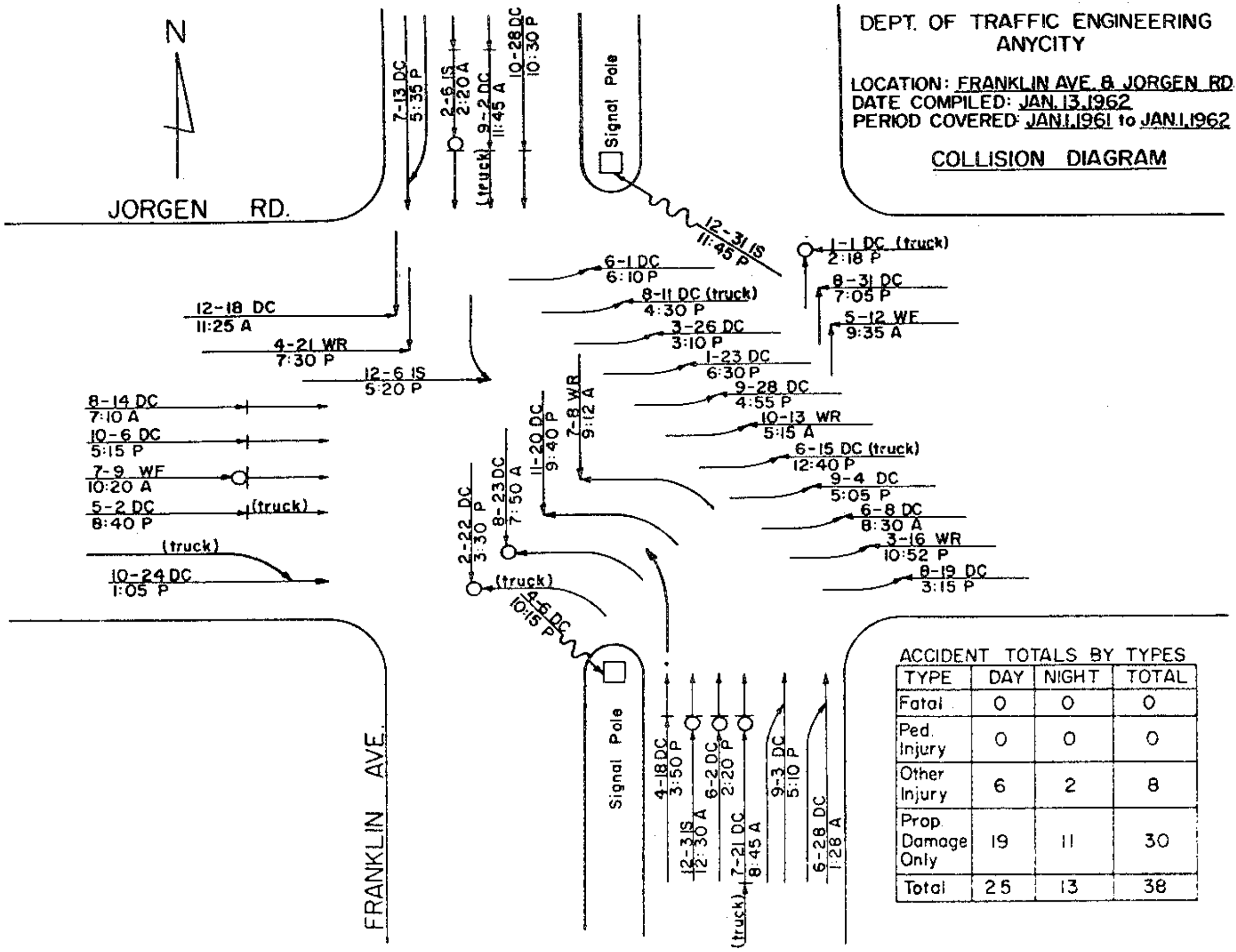
   - The direction of travel of involved vehicles and pedestrians prior to impact (collision)
   - Driver and pedestrian intent (i.e., going straight, making left-turn, stopping, etc.) prior to impact
   - Date, day of week, time of day
   - Ambient light conditions (daylight, dawn or dusk, dark with street lights, dark without street lights)
   - Adverse weather conditions (rain, snow, fog, etc.)
   - Adverse pavment conditions (wet, icy, etc.)
   - Unusual operational conditions (control devices not operating properly, construction area, etc.)
   - Accident severity (fatal, personal injury, property damage only)

2. Standard symbols should be used to indicate driver or pedestrian intent, direction of travel, accident severity, fixed objects, etc.

3. Non-involved vehicles or pedestrians (no physical contact) contributing to individual accidents may be included on the diagram. However, this may not be applicable in many cases due to the inconsistencies in the level of reportings of such items.

4. For intersections, all intersection-related accidents should be indicated. Intersection-related accidents are all accidents in which the physical characteristics or operating conditions of the intersection contribute to the accident. These include many of the accidents on each approach to the intersection within several hundred feet.

A typical collision diagram is given in Figure 17.




ACCIDENT TOTALS BY TYPES

| TYPE | DAY | NIGHT | TOTAL |
|---|---|---|---|
| Fatal | 0 | 0 | 0 |
| Ped. Injury | 0 | 0 | 0 |
| Other Injury | 6 | 2 | 8 |
| Prop. Damage Only | 19 | 11 | 30 |
| Total | 25 | 13 | 38 |

LEGEND

Path of moving motor vehicle ..
Pedestrian path ..............
Fatal ........................
Non-fatal ....................
Rear-end collision ...........
Parked vehicle ...............
Fixed object .................
Overturned ...................
Out of control ...............
Sideswipe ....................
Non-involved vehicle .........

Time : A=AM P=PM
Pavement : D=Dry I=Icy W=Wet
Weather : C=Clear F=Fog R=Rain
SL=Sleet S=Snow

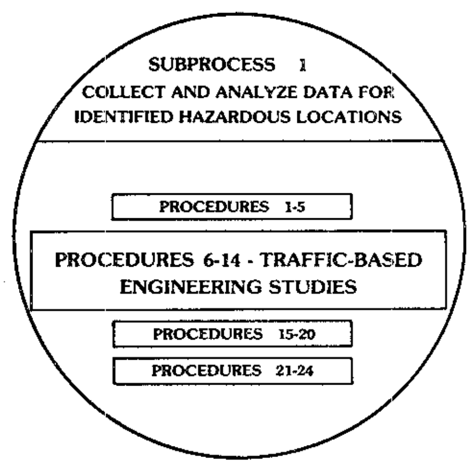
Figure 17. Typical collision diagram.

The use of computerized collision diagrams has been developed in recent years [3] for quick and easy production of such information. Accident types are plotted on the proper intersection legs and may be color coded by severity. Collision diagrams may be quickly produced in any size, depending on the need.

After a particular category of an accident characteristic has been identified as predominant, a list of possible causes or safety deficiencies can be developed. For example, at a signalized intersection, left-turn, head-on collisions comprised 37 percent of all accidents, compared to a citywide average of 20 percent for similar intersections. This overrepresentation of left-turn, head-on accidents may have as possible causes [4]:

- Restricted sight distance due to the presence of left-turning traffic on the opposite approach, and improper channelization and geometrics
- Too short amber phase
- Absence of special left-turning phase when needed
- Excessive speed on approaches

Further analysis might be necessary to determine which of the possible causes would be most probable. After the most probable cause has been identified, a list of specific countermeasures can be developed.




## PROCEDURES 6-14 - TRAFFIC OPERATIONS-BASED STUDIES

### DESCRIPTION

Traffic operations-based studies at identified hazardous locations can provide essential information to assist in the selection of the most appropriate safety improvements at each location. The nine traffic operations-based studies are:

Procedure 6 - Safety Performance Studies
Procedure 7 - Volume Studies
Procedure 8 - Spot Speed Studies
Procedure 9 - Travel Time and Delay Studies
Procedure 10 - Roadway and Intersection Capacity Studies
Procedure 11 - Traffic Conflict Studies
Procedure 12 - Gap Studies
Procedure 13 - Traffic Lane Occupancy Studies
Procedure 14 - Queue Length Studies

The need for any of the above mentioned studies is determined from an analysis of the list of existing and potential safety deficiencies which are identified through the accident-based procedures. By identifying the traffic stream characteristics, a more specific list of safety problem(s) can be identified and a more reliable selection of candidate countermeasures may be obtained. The following is a brief description of each of the traffic operations-based studies.

### Safety Performance Studies

A safety performance study is an organized program of field observation and inspection of highway facilities and traffic to detect deficiencies in the operational and environmental conditions at a location. This study provides a review of a hazardous location or situation under field conditions and serves to verify or supplement the findings of the accident-based procedures. Checklists [5] and lists of questions [6] have been developed for the purposes of performing these studies. An example question list is given in Table 9.

### Volume Studies

Traffic volume studies are conducted to determine the number and movement of vehicles and/or pedestrians within, through, or at selected points in an area. Volume data are used as basic input in all operations-based procedures. Its use is as a basic study procedure describing the exposure (vehicular or pedestrian) at each hazardous location.

Volume counts may include peak hour counts, 24-hour counts, continuous long-term counts, or short-term counts (5 minutes, 15 minutes, etc.). Volume counts may include only total vehicle movements or may specify turning movements (at intersections or driveways). Vehicle classification counts and pedestrian counts may also be performed within the scope of volume studies.

### Spot Speed Studies

Spot speed studies are used to obtain an indication of the speed of traffic at one point on a roadway. They serve to estimate the speed distribution of the traffic stream during the observation period. Spot speed

Table 9. Typical question list for field observations.

1. Are the accidents caused by physical conditions of the road or adjacent property. Can the conditions be eliminated or corrected?

2. Is a blind corner responsible? Can it be eliminated? If not, can adequate measures be taken to warn the motorists?

3. Are the existing signs, signals, and pavement markings doing the job for which they were intended? Is it possible they are contributing to accidents rather than preventing them?

4. Is traffic properly channelized to minimize the occurrence of accidents?

5. Would accidents be prevented by prohibiting any single traffic movement, such as a minor left-turn movement?

6. Can part of the traffic be diverted to other thoroughfares where the accident potentials are not as great?

7. Are night accidents far out of proportion to daytime accidents (based on traffic volume) indicating a need for special nighttime protection, such as street lighting, signal control or reflectorized signs or markings?

8. Do conditions show that additional traffic laws or selective enforcement are required?

9. Is there a need for supplemental studies of traffic movement, such as driver observance of existing control devices, or speed studies of vehicles approaching the accident location?

10. Is parking in the area contributing to accidents? If so, are reductions in the width of approach lanes, or sight obstructions (caused by parking), causing the accidents?

11. Are there adequate advance warning signs of route changes so that the proper lanes may be chosen by approaching motorists well in advance of the area, thus minimizing the need for lane changing near the accident location.

(Source: Reference No. 6)

data are usually necessary when accident summary information indicates safety problems that may be caused by high speeds or unusual speed distributions. Spot speed studies may also be conducted upon completion of the safety performance studies if field observations indicate a possible vehicle speed problem.

### Travel Time and Delay Studies

Travel time and delay studies are used to obtain data on the amount of time it takes to traverse a specified section of roadway and the amount, cause, location, duration, and frequency of delays. Travel time and delay characteristics are indicators of the level of service that is operating along a facility and can be used as a relative measure of the efficiency of the traffic. Information from these studies can also be used to identify problem locations where safety improvements may be required to increase mobility and provide improved safety conditions.

Travel time and delay studies are useful for obtaining information on locations where accident patterns relating to congestion-type accidents exist; i.e., a significant number of rear-end, right-angle, or left-turn accidents. Intersection delays may be handled in a fashion similar to the travel time and delay studies.

### Roadway and Intersection Capacity Studies

Highway capacity studies are conducted to measure the ability (supply) of a highway facility to accomodate or service the existing or projected traffic volumes (demand). Capacity is defined as the maximum number of vehicles that can pass over a section of a lane or roadway (or through an intersection), during a given time period (one hour unless otherwise specified), under prevailing highway and traffic conditions. The purpose of conducting a capacity study for traffic engineering safety projects is to provide a measure of the adequacy and quality of service being provided by the facility. Highway capacity studies are useful for obtaining information on locations where accident patterns relating to congestion-type accidents exist.

### Traffic Conflict Studies

Traffic conflict studies can assist in the diagnosis of safety and operational problems at a highway location, and in the evaluation of the effectiveness of improvements at a location. These studies are believed (by many safety engineers) to be useful in determining the accident potential at a site. Defined relationships between conflicts and accidents, however, have not yet been clearly established. Traffic conflict studies can be a supplement to routine field inspections of high-accident locations, or they can be conducted at suspected hazardous sites.

A traffic conflict occurs when a driver takes evasive action, such as braking or weaving, to avoid a collision. Some conflict and event types include weave conflict, abrupt stops, slow for right-turn conflict, opposing left-turn conflict, pedestrian conflict, etc.

Conflicts may be counted based on type and severity. Erratic maneuvers, such as turns from wrong lane, run-off-road, etc., may also be counted during the conflict study. The Traffic Conflict Technique (TCT) was originally developed by the General Motors Laboratories in 1967 as a systematic method of observing and measuring accident potential at intersections [7,8]. Since then, it has been modified and used by various U.S. highway agencies, particularly in the States of Ohio, Virginia, Kentucky, and Washington [9,10,11]. A modified traffic conflicts technique was recently developed in an NCHRP study by Midwest Research Institute [12].

## Gap Studies

Gap studies measure the time headway or gap between vehicles along a highway section (or at a point), and to analyze the gap acceptance characteristics where a minor or alternate traffic stream intersects a major traffic stream. The need for gap analysis in highway safety studies is determined by the locational characteristics and the accident (or conflict) patterns occurring at the study location.

## Traffic Lane Occupancy Studies

A traffic lane occupancy study can provide a measure of the traffic performance of a highway facility as a function of vehicle lengths, volumes and speeds. The occupancy factor is related to density and measures the percent of time a point on a roadway is occupied by a vehicle. Lane occupancy is defined as:

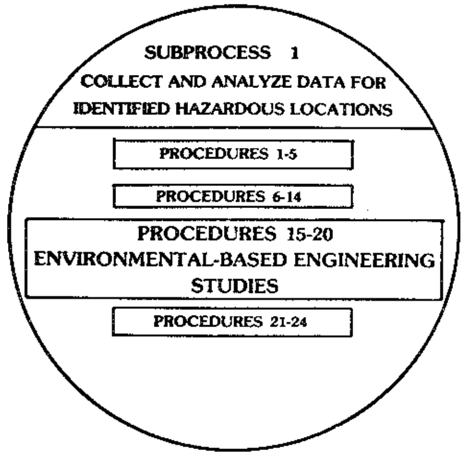
$$\text{Lane Occupancy} = \frac{\text{Time vehicles are present at a point on a roadway}}{\text{Total specified time period}}$$

Based on an established relationship between lane occupancy and traffic volume, the occupancy at various intervals can be determined. Lane occupancy studies are useful for obtaining information on locations where congestion-type accident patterns exist.

## Queue Length Studies

Queue length studies identify the number of vehicles that are stopped in a traffic lane behind the stop line at an intersection. They can also be used to determine the vehicular back-up at other locations, such as lane drop sections, railroad crossings, freeway incident locations, and other bottleneck situations. However, the primary purpose of queue length studies is to measure the performance of an intersection.

Queue lengths are usually observed at the beginning of the green phase, and at the end of the amber phase for signalized intersections. A comparison of the queue lengths at these two distinct time points is used to assess the level of traffic flow as a measure of the "expected" delay to the vehicles. Queue length studies are useful in acquiring information for locations where congestion-related accidents (particularly rear-end accidents) occur frequently.




## PROCEDURES 15-20 - ENVIRONMENTAL-BASED STUDIES

### DESCRIPTION

Environmental-based engineering studies include the collection and analysis of all information related to the physical features of the roadway for specific spots, sections, and elements. The six environmental-based procedures are:

Procedure 15 - Roadway Inventory Studies
Procedure 16 - Sight Distance Studies
Procedure 17 - Roadway Serviceability Studies
Procedure 18 - Skid Resistance Studies
Procedure 19 - Highway Lighting Studies
Procedure 20 - Weather-Related Studies

An analysis of the accident data will provide hints as to which environmental studies should be conducted. Another consideration involves the types of highway features to be inventoried and analyzed. It would be unnecessary and virtually impossible to collect all highway information for all identified hazardous locations. Therefore, it is important to determine the data items needed for each location. The following is a brief description of each of the environmental-based procedures.

### Roadway Inventory Studies

Roadway inventory studies are used to obtain a survey of the physical roadway environment at a location. Included are such items as:

- Roadway characteristics
- Roadside characteristics
- Geometrics
- Street names
- Functional classification
- Parking conditions
- Corner radii
- Sidewalk locations
- Traffic requlations
- Traffic control devices
- Speed limits
- Visual obstructions
- Driveway locations
- Road surface irregularities
- All pavement markings

These information items are usually included in the condition diagram, which provides a scaled, pictorial representation of the area, as shown in Figure 18.

It is recommended that roadway inventory studies be conducted for each specific location under analysis. These studies are not to be confused with the safety performance studies. Safety performance studies are used to review specific roadway items based on their effect on the safety and operations of a study location. Roadway inventory studies, on the other hand, are used to obtain a direct measurement of the roadway features and produce a record of the location environment.

## Sight Distance Studies

Sight distance studies are conducted to review the sight distance characteristics at or along a roadway facility to obtain an assessment of the adequacy of sight distance conditions at the location. The purpose of these studies is to determine if sight distance conditions are a causative factor in accidents at a defined hazardous location. Sight distance studies are useful for:

- Reviewing "NO PASSING" zones
- Determining traffic control needs at an intersection
- Identifying sight obstructions
- Accident review

## Roadway Serviceability Studies

Roadway serviceability studies identify the properties of the roadway pavement surface and are typically used when a field review of the study site indicates a highly irregular pavement surface, i.e., potholes, bumps, etc., which may have an effect on safety at the site. Another indication that a roadway serviceability study may be necessary is the occurrence of a pattern of traffic accidents in which "vehicle out of control" or "poor pavement conditions" were noted as causes or contributing circumstances.

## Skid Resistance Studies

Skid resistance studies are conducted to measure the traction properties between the vehicle tires and the pavement surface. These studies are useful in identifying any excessive "slipperiness" of the pavement surface at a site.

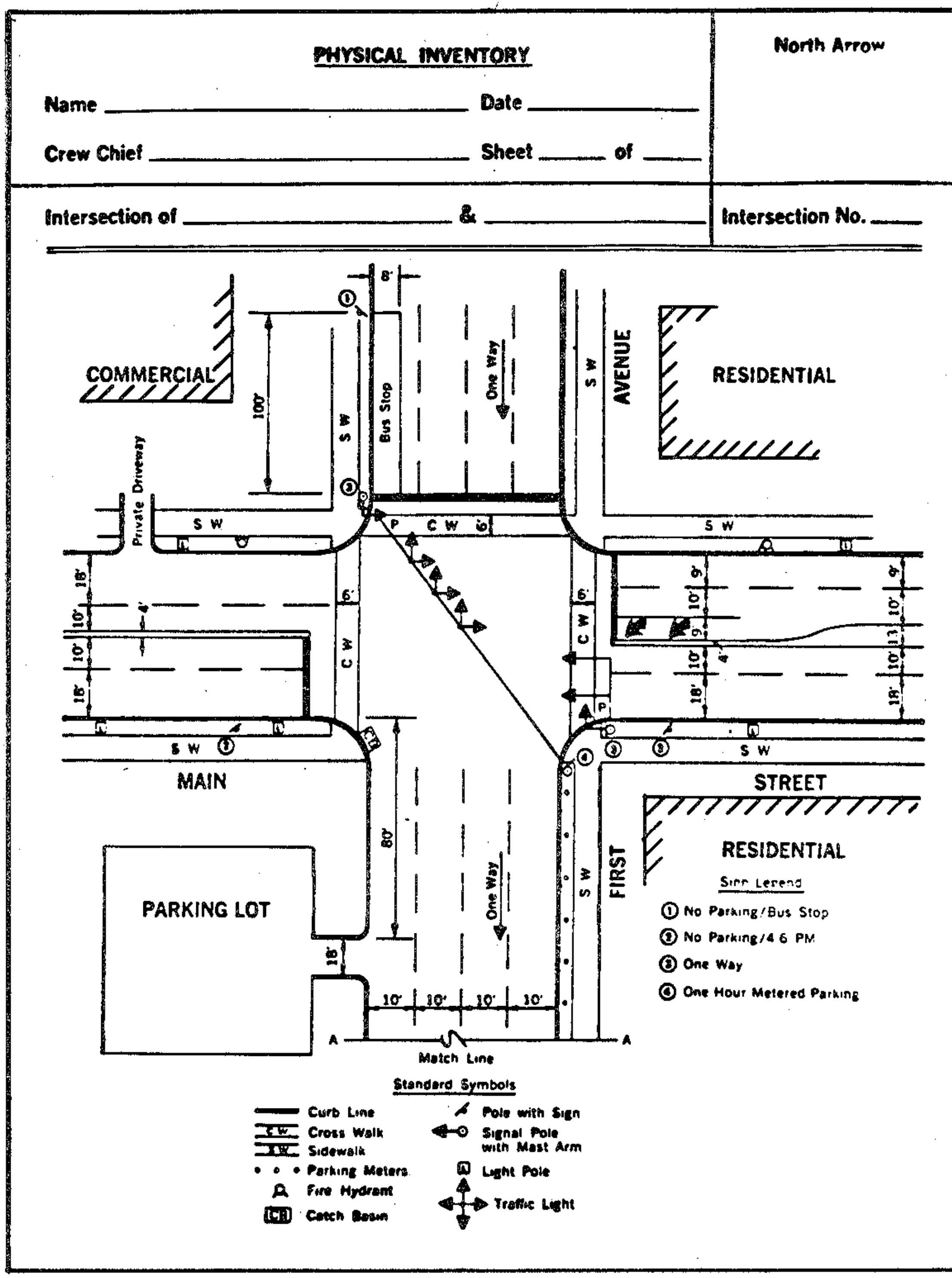



Figure 18. Typical condition diagram.

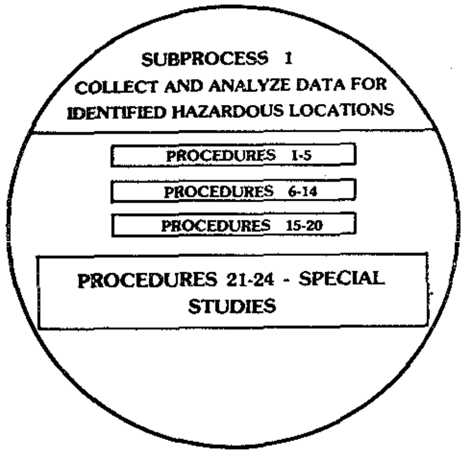
The need for performing skid resistance studies is dictated by the occurrence of a pattern of accidents under "wet-weather" or "wet pavement" conditions. Skid tests are conducted based on ASTM (American Society of Testing Materials) standards which develops skid numbers. These measured skid numbers are compared to areawide averages or standards. Measured values lower than the standard indicate inadequate skid resistance.

## Highway Lighting Studies

Highway lighting studies are used to assess the adequacy of existing lighting facilities or the need for new, additional, or improved lighting facilities. These studies are necessary where a high nighttime accident rate (percentage) occurs or a possible nighttime accident problem is observed in the field review. Existing lighting conditions are compared to design standards to determine if lighting facilities should be installed or improved. Design standards are set forth in the Roadway Lighting Handbook (U.S. Department of Transportation, Federal Highway Administration, December, 1979) [13].

## Weather-Related Studies

Weather-related studies are used to determine the existing or potential hazardousness of a location under certain weather-related conditions, such as fog or ice. Although these conditions may have an impact on a site for only a limited period of time, appropriate countermeasures can still be developed to reduce the safety deficiency.




## PROCEDURES 21-24 - SPECIAL PROCEDURES

### DESCRIPTION

There are several engineering studies which may be required in special situations and are not classified as either accident-based, traffic operations-based, or environmental-based. These studies are:

Procedure 21 - School Crossing Studies
Procedure 22 - Railroad Crossing Studies
Procedure 23 - Traffic Control Device Studies
Procedure 24 - Bicycle and Pedestrian Studies

A brief description of each of these special procedures is given in the following.

### School Crossing Studies

The purpose of these studies is to provide optimal safety conditions for school-age pedestrians within the roadway environment in and around school areas. These studies must not only evaluate the relative hazard at the site based on the physical and operational conditions, but must also account for the student's level of understanding of the situation. School crossing pedestrian accidents are relatively rare events. Available pedestrian accident data at such locations are usually non-existent or insufficient for most study purposes. Other forms of data need to be collected to facilitate the assessment of school crossing locations. This data may include pedestrian volumes, pedestrian delay, roadway width, types of traffic control devices, etc. [14].

Railroad Crossing Studies

Railroad crossing studies are used to determine the hazardousness of an at-grade crossing situation. This hazardousness can be determined through the collection and analysis of inventory and accident data at each crossing location. The Railroad Crossing Inventory Form, as recommended by the U.S. DOT is given in Table 10 [15]. All signs, pavement markings and signals must conform to the MUTCD. Hazard indices are often determined, as part of the analysis, through numerical methods. Recently, several hazard indicies have been developed and tested and evaluated in a study conducted by the Transportation Systems Center, U.S. DOT [16].

Railroad crossing studies may be necessitated through accident experience, the occurrence of a recent fatal accident, citizen complaints, or continous monitoring.

Traffic Control Device Studies

Traffic control device studies are used to determine the effectiveness of existing traffic control devices. Included under this classification of studies are inventories, signal warrant studies, stop-yield sign studies, and law observance studies. The inventories are conducted to review existing signs, signals, and pavement markings, and evaluate their quality, standardization, and application. The other three studies are conducted to evaluate the application and/or compliance of the various traffic control devices.

Bicycle and Pedestrian Studies

Bicycle and pedestrian studies are conducted to evaluate the safety and operational characteristics of bicycle- and pedestrian-related activities. Bicycle studies may include the following data items:

- Capacity of bicycle facility
- Bicycle speeds
- Bicycle-related accidents
- Bicycle volumes
- Sight distances
- Use and compliance of traffic control devices

Pedestrian studies may include the following data items:

- Pedestrian volumes
- Pedestrian delay times at crossings
- Pedestrian-related conflicts
- Pedestrian use and compliance of traffic control devices
- Behavioral information
- Pedestrian-related accidents

The decision to conduct these studies may develop from accident experience, citizen complaints, or field reviews.

Table 10. USDOT - AAR crossing inventory form.

OMB-004-R4039

# U.S. DOT — AAR CROSSING INVENTORY FORM

A. INITIATING AGENCY
☐ RAILROAD ☐ STATE

B. CROSSING NUMBER

C. REASON FOR UPDATE:
☐ CHANGES IN EXISTING CROSSING DATA
☐ NEW CROSSING
☐ CLOSED CROSSING

D. EFFECTIVE DATE
M D Y

## Part I Location and Classification of All Crossings (Must Be Completed)

1. Railroad Operating Company
2. Railroad Division or Region
3. Railroad Subdivision or District
4. State
5. County
6. County Map. Ref. No.
7. City
8. Nearest City
9. Highway Type and No.
10. Street or Road Name
11. RR I. D. No.
12. Nearest RR Timetable Station
13. Branch or Line Name
14. Railroad Mile Post

DO NOT WRITE IN THIS SPACE
State County
City Nearest City
RR Code Timetable Station

15. Pedestrian Crossing
☐ 1. at grade
☐ 2. RR under
☐ 3. RR over

16. Private Vehicle Crossing
A. ☐ 1. Farm ☐ 2. Residential ☐ 3. Recreational ☐ 4. Industrial
B. ☐ 5. at grade ☐ 6. RR under ☐ 7. RR over
C. ☐ 8. signs-specify ☐ 9. signals-specify ☐ 0. none

17. Public Vehicle Crossing
☐ 1. at grade
☐ 2. RR under
☐ 3. RR over

COMPLETE REMAINDER OF FORM ONLY FOR PUBLIC VEHICLE CROSSINGS AT GRADE

## Part II Detailed Information for Public Vehicular at Grade Crossing

1A. Typical Number of Daily Train Movements

| Daylight (6 AM to 6 PM) | | Night (6 PM to 6 AM) | |
|---|---|---|---|
| thru trains | switching | thru trains | switching |
| 1 | 2 | 3 | 4 |

1B. Check if Less Than One Movement Per Day ☐ 5

2. Speed of Train at Crossing
A. Maximum time table speed 1
B. Typical Speed Range Over Crossing from 2 to 3 mph

3. Type and Number of Tracks
main 1 other 2 If other specify 3

4. Does Another RR Operate a Separate Track at Crossing?
☐ Yes 1☐ No Specify: RR 2

5. Does Another RR Operate Over Your Track at Crossing?
☐ Yes 1☐ No Specify: RR 2

6. Type of Warning Device at Crossing

A. Signs

| Crossbucks | | Standard Highway Stop Sign | Other Stop Signs | Other Signs: Specify |
|---|---|---|---|---|
| reflectorized | non-reflectorized | | | |
| 01 Number | 02 Number | 03 Number | 04 Number | 05 Number 06; 07 Number 08 |

B. Train Activated Devices

| Gates | | Cantilevered Flashing Lights | | Mast Mounted Flashing Lights | Other Flashing Lights | Specify | Highway Traffic Signals | Wigwags | Bells |
|---|---|---|---|---|---|---|---|---|---|
| red & white reflectorized | other colored | over traffic lane | not over traffic lane | | | | | | |
| 09 Number | 10 Number | 11 Number | 12 Number | 13 Number | 14 Number | 15 | 16 Number | 17 Number | 18 Number |

C. Specify Special Warning Device not Train Activated 19

D. No Signs or Signals ☐ 20

7. Is Commercial Power Available? ☐ Yes ☐ No

8. Does Crossing Signal Provide Speed Selection for Trains? ☐ Yes ☐ No ☐ N/A

9. Method of Signalling for Train Operation: Is Track Equipped with Signals? ☐ Yes ☐ No

## Part III Physical Data

1. Type of Development ☐ 1. Open Sp. ☐ 2. Res ☐ 3. Comm. ☐ 4. Ind. ☐ 5. Inst.
2. Smallest Crossing Angle ☐ 0°-29° ☐ 30°-59° ☐ 60°-90°
3. Number of Traffic Lanes Crossing Railroad Number
4. Are Truck Pullout Lanes Present? ☐ Yes ☐ No
5. Is Highway Paved ☐ Yes ☐ No
6. Pavement Markings ☐ Stoplines ☐ RR Xing Sym. ☐ None
7. Are RR Advance Warning Signs Present? ☐ Yes ☐ No
8. Crossing Surface ☐ 1. Sec. Timber ☐ 2. Full Wd. Plank ☐ 3. Asphalt ☐ 4. Concrete Slab ☐ 5. Concrete Pave. ☐ 6. Rubber ☐ 7. Metal Sections ☐ 8. Other Metal ☐ 9. Unconsolidated ☐ 0. Other Specify
9. Does Track Run Down A Street? ☐ Yes ☐ No
10. Nearby Intersecting Highway? ☐ Yes ☐ No

## Part IV Highway Department Information

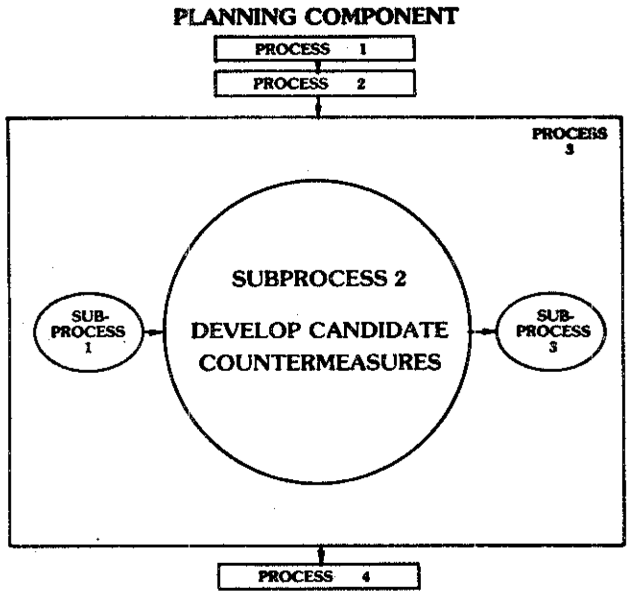
1. Highway System
2. Is Crossing on State Highway System? ☐ Yes ☐ No.
3. Functional Classification of Road over Crossing
4. Estimate AADT
5. Estimate Percent Trucks

I. D. Number

(Source: Reference No. 15)

# PROCESS 3, SUBPROCESS 2

# DEVELOP CANDIDATE COUNTERMEASURES




## PURPOSE

The purpose of this subprocess is to develop candidate countermeasures for the identified hazardous locations. Specific candidate countermeasures should be developed on the basis of the known deficiencies of the location. This subprocess should be carried out upon completion of Process 3, Subprocess 1, "Collect and Analyze Data".

## DESCRIPTION

This subprocess consists of the following three procedures:

Procedure 1 - Accident Pattern Tables
Procedure 2 - Fault Tree Analysis
Procedure 3 - Multi-Disciplinary Investigation Team

For each of these procedures, candidate accident countermeasures should be selected carefully based on a knowledge of the effectiveness of similar improvements in the past. Results of past project and program evaluations (Evaluation Component) are very important inputs to this subprocess. If a past improvement type has been found to result in favorable safety benefits at similar locations (and traffic conditions), then such improvements would likely be considered as candidate improvements. Several candidate improvements can be proposed for the same location, since they can all be included in the analyses in the next subprocess (based on expected accident benefits and project costs).

The following should be identified in the development of candidate countermeasures [1]:

- All practical improvements, from the "do nothing" alternative to ultimate alternatives, should be identified and considered such that no feasible alternative is overlooked
- All practical combinations of improvements should be identified
- The potential effect of each alternative improvement should be defined

The identification of all candidate improvements (and their expected effects on accidents) will serve as input to Process 3, Subprocess 3, "Develop Projects".

## RANGE OF COMPLEXITY AMONG PROCEDURES

The degree of complexity of the procedures in this subprocess depends on the amount of information available and the actual location under study. For example, a location with 80 percent wet-weather accidents and poor pavement skid properties should lead directly to a recommendation that a non-skid pavement overlay be included in the list of candidate countermeasures. On the other hand, a high-volume, multi-legged intersection may be a very complex problem and require extensive analyses to determine the most appropriate combination of accident countermeasures.

## MANAGERIAL CONCERNS

- How complex is the safety problem at the location?
- What is the objective of the agency's HSIP in terms of reducing accidents, severity, etc.?
- Are the available manpower and operating funds sufficient to perform these procedures?
- Are the problems being identified correctly?
- Is more information needed?
- Are there any peculiarities at the location that may cause improvements to produce non-typical results?
- Are proposed countermeasures consistent with the budgetary constraints?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- A basic understanding of the available safety improvements which are effective in reducing accidents

Resource and Equipment Input

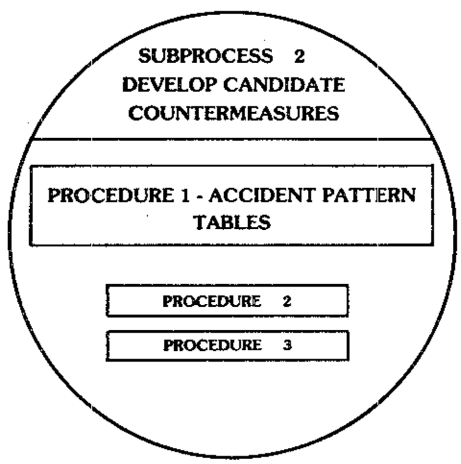
- Manpower for selection of candidate countermeasures
- Funding

Data or Informational Input

- A file of data from engineering studies for further analysis of hazardous locations (from Process 1, Subprocess 1, "Collect and Analyze Data")
- Evaluation information regarding previous countermeasures of the same type (from Evaluation Component or previous studies reported in the literature)

Output

- A listing of candidate accident countermeasures for each identified hazardous location and element




PROCEDURE 1 - ACCIDENT PATTERN TABLES

DESCRIPTION

Based on accident patterns and location types, tables have been developed to suggest possible accident countermeasures which are likely to be most effective in accident reduction. These accident pattern tables are used primarily as an aid in the selection of candidate countermeasures. Countermeasure should not be selected without consideration of supporting data, such as traffic volumes and field observations [1]. Accident pattern tables are developed on the assumptions that [2]:

- Patterns of accident types are associated with probable causes of accidents
- The need for specific improvements can be inferred from analysis of

probable causes of accidents

An example of an accident pattern table is shown in Table 11.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Agencies with traffic or safety engineers having highway safety experience
- Locations with relatively obvious safety problems for which the selection of appropriate countermeasures can be made with little difficulty
- Agencies with the objective of reducing the number of accidents at specific locations

## PROCEDURE REQUIREMENTS

- Manpower - At least one or more traffic or safety engineers. Experts in such areas as highway safety, human factors, police, etc., will also be helpful.
- Funding - Funding requirements will range from very little time or money to relatively large amounts of time and money, depending on the number of sites to be studied and the complexity of the analyses.

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Provides a method which is inexpensive and easy to use

### Disadvantages

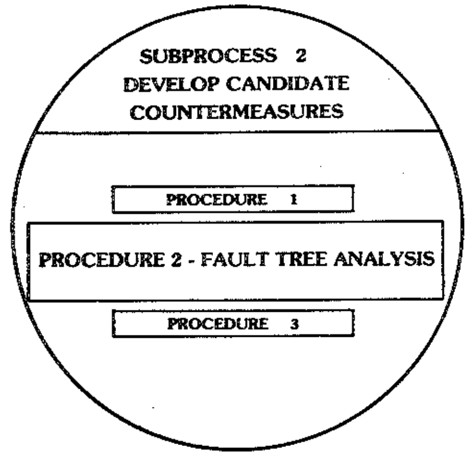
- Not complete or conclusive
- Not applicable to locations with complex safety problems

Table 11. Sample accident pattern table.

| ACCIDENT PATTERN | PROBABLE CAUSE | GENERAL COUNTERMEASURE |
|---|---|---|
| Right-angle collisions at unsignalized intersections | Restricted sight distance | Remove sight obstructions<br>Restrict parking near corners<br>Install stop signs (see MUTCD)<br>Install warning signs (see MUTCD)<br>Install/improve street lighting<br>Reduce speed limit on approaches*<br>Install signals (see MUTCD)<br>Install yield signs (see MUTCD)<br>Channelize intersection |
| | Large total intersection volume | Install signals (see MUTCD)<br>Reroute through traffic |
| | High approach speed | Reduce speed limit on approaches*<br>Install rumble strips |
| Right-angle collisions at signalized intersections<br><br>(Continued) | Poor visibility of signals<br><br>(Continued) | Install advanced warning devices (see MUTCD)<br>Install 12-in. signal lenses (see MUTCD)<br>Install overhead signals<br>Install visors<br>Install back plates |

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

(Source: Reference No. 9)




## PROCEDURE 2 - FAULT TREE ANALYSIS

### DESCRIPTION

This analysis utilizes logic in an attempt to trace all events and combinations of events which may result in an accident. The events are analyzed in a reverse sequence, beginning with the collision and working backwards until all relevant events are covered. Probabilities may be assigned to the likelihood of the occurrence of each event.

Fault trees are similar to the decision and probability trees used in business and management [4,5,6], except that the sequence of events is analyzed in a reverse direction. Fault tree analysis is based on the assumption that [2]:

- The cause and effect relationships of accidents follow a logical flow that can be documented.
- A probability may be assigned to each event in the logical flow of accident causation.

The identification of the possible causes of an accident can then serve to indicate the most appropriate countermeasures.

The steps to follow in developing fault trees are [2]:

1. Identify the final occurrence or consequent event (i.e., the collision).
2. Identify all possible events immediately preceding the collision.
3. Determine the events as dependent or independent of other events.
4. Analyze each event, determining which require further development of cause (non-basic events) and which do not (basic events).

5. Identify and analyze all possible events preceding all non-basic events until all basic events are covered.
6. (Optional) Assign probabilities to each basic event.
7. (Optional) Calculate the probabilities of subsequent events, adding the probabilities of events leading directly to an "OR" gate and multiplying the probabilities of events leading directly to an "AND" gate.
8. (Optional) Determine the influence of candidate countermeasures by reducing the probabilities of events affected by the countermeasure and recalculating subsequent events.

Steps 6, 7, and 8 are optional based on the availability of estimated probabilities for basic events. An example fault tree is given in Figure 19.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Agencies with a very knowledgeable safety engineer on staff
- Locations with very complex highway safety problems
- Agencies with HSIP objectives to reduce accident frequencies
- Highly unusual accidents or situations.

## RESOURCE REQUIREMENTS

- Manpower - At least one or more traffic or safety engineers. Experts in such areas as highway safety, human factors, police, etc., may also be needed.
- Funding - Relatively moderate to large amounts of time and funding required.

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Includes behavioral factors affecting accident experience.
- Effective for analyzing specific accidents, such as fatal accidents.

### Disadvantages

- Difficulty in determining probabilities of occurrence for the critical events.
- The occurrence and sequence of events used in the analysis must be based on engineering judgement rather than on more objective sources.
- Usually requires considerable amounts of manpower, time, and funding to provide meaningful results.

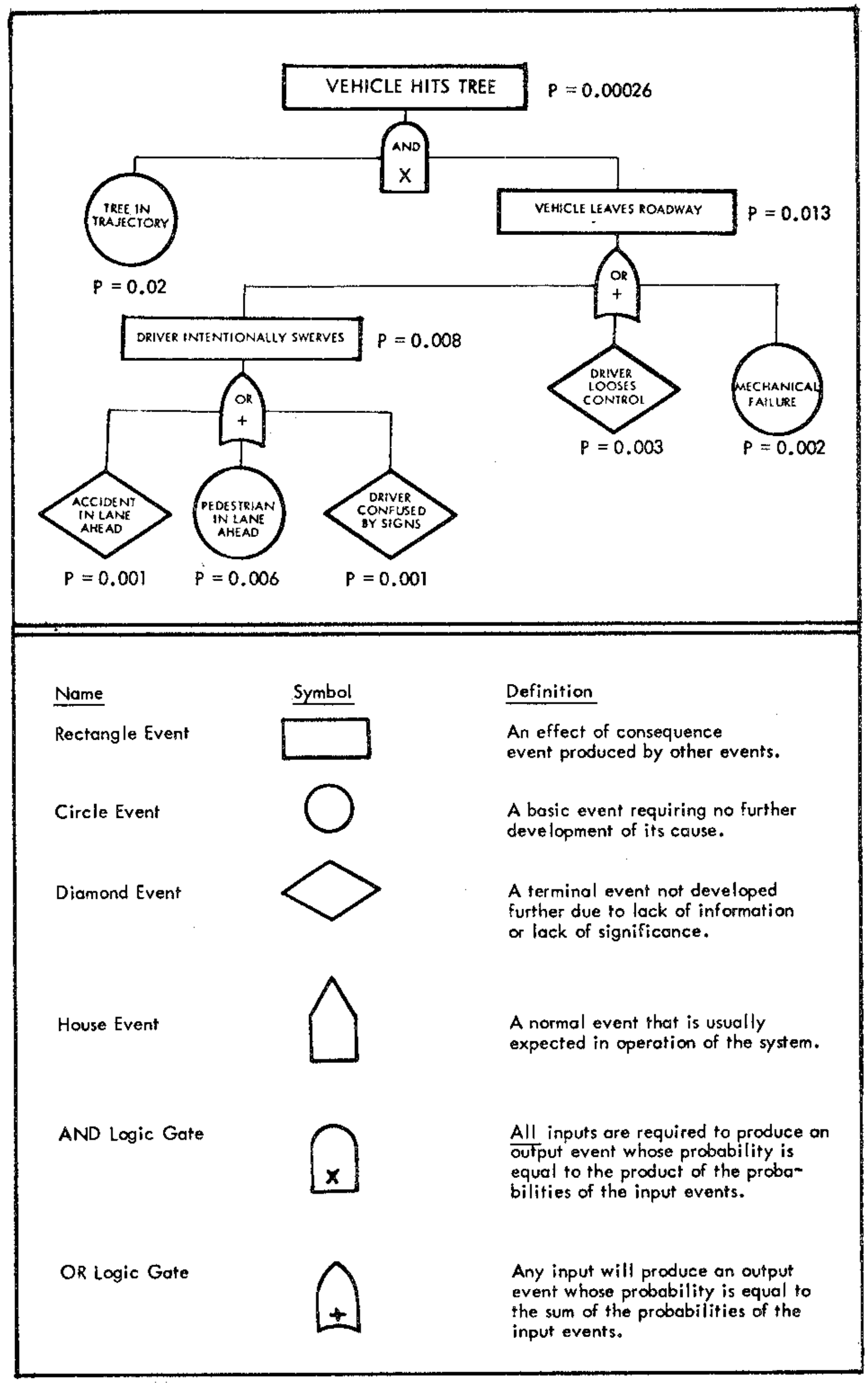
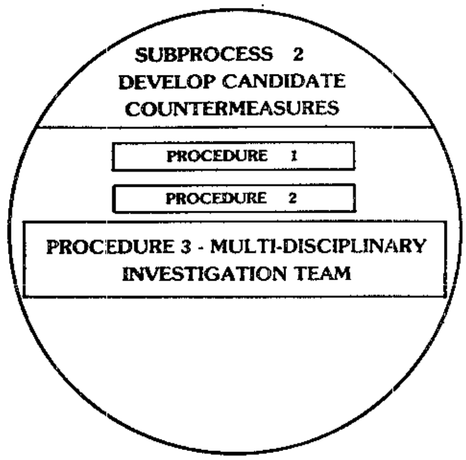



Figure 19. Sample fault tree.

(Source: Reference No. 2)




## PROCEDURE 3 - MULTI-DISCIPLINARY INVESTIGATION TEAM

### DESCRIPTION

The multi-disciplinary investigation team approach to the development of candidate countermeasures for hazardous locations is based on the belief that accidents rarely occur because of any single causal factor. These factors are usually interactive and it may be desirable to analyze these factors from not only the highway or traffic engineering standpoint, but from others as well. The multi-disciplinary investigation team attempts to do this by assembling a team of individuals from a variety of disciplines to analyze and form a consensus opinion on the causal factors and methods of correcting hazardous locations [7].

In addition to highway and traffic engineers, the multi-disciplinary team may also include:

- Human factors experts (psychologists, sociologists, etc.)
- Law enforcement officers
- Automotive engineers (mechanical engineers)
- Physicians
- Lay persons

Three criteria must be met for an effective multidisciplinary investigation team [7]:

1. The team should be small enough to be manageable and easily organized, yet large enough to incorporate all desired disciplines.
2. The professional disciplines should cover the areas of roadway, driver, and vehicle aspects of highway safety to obtain a comprehensive analysis of the location.

3. There should be a variation in the degree of familiarity with the location.

In addition, it is recommended that the investigations be conducted individually by each team member, with the results combined later to form the consensus opinion [7].

The investigation team does not restrict its analysis and countermeasure development solely to the use of traffic data and accident reports and summaries. The team conducts extensive, in-depth analyses of all causal factors which may have led up to an accident. A typical investigation of a high-accident intersection would follow these steps:

1. Conduct a briefing session of team members, with the team leader supplying all pertinent data on the location (volume data, collision diagrams, condition diagrams).
2. Conduct individual site investigations, driving each approach to the intersection, noting sight distances, signs, markings, obstructions, etc.
3. Determine the predominant accident types, causal factors, and possible countermeasures.
4. Submit individual reports to the team leader, documenting all findings of the investigation.
5. Conduct a meeting of all team members to form a consensus opinion on the predominant accident types, causal factors, and possible countermeasures for the location.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Agencies with a team of experts available from a variety of backgrounds, including a highway safety engineer, psychologist or human factors expert, police officer, etc.
- Locations with very complex safety problems

## RESOURCE REQUIREMENTS

- Manpower - A team of experts from a variety of disciplines is required, including highway and traffic engineers, human factors experts, and law enforcement officers.
- Funding - Requires relatively large amounts of time and money.

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

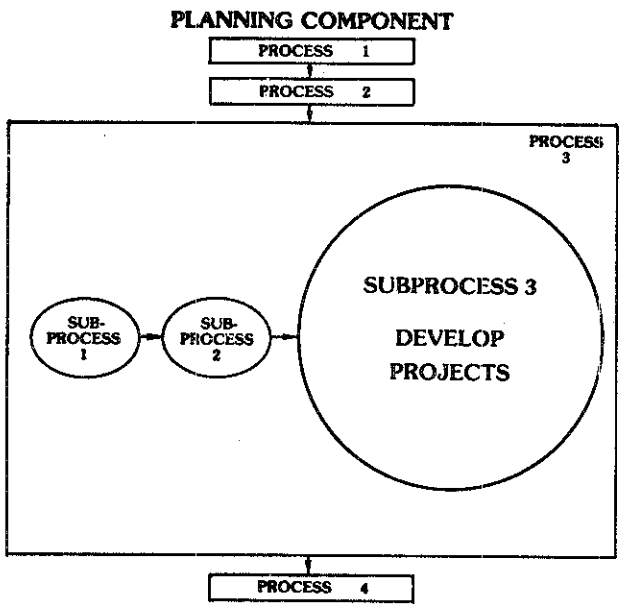
- Attempts to view hazardous locations from the standpoint of human factors, law enforcement, etc., as well as from the highway and traffic engineering standpoint.
- Provides extensive, detailed, in-depth analyses.

### Disadvantages

- Requires large amounts of time, effort, and funding.

# PROCESS 3, SUBPROCESS 3

# DEVELOP PROJECTS




## PURPOSE

The purpose of this subprocess is to determine the most desirable improvement alternatives at a location, using estimates of expected project costs and accident benefits for each alternative. This subprocess should be carried out directly after the development of candidate countermeasures (Process 3, Subprocess 2 - "Develop Candidate Countermeasures").

## DESCRIPTION

This subprocess can be accomplished through the use of one or more of the following procedures:

Procedure 1 - Cost-Effectiveness Method
Procedure 2 - Benefit-To-Cost Ratio Method
Procedure 3 - Rate-Of-Return Method
Procedure 4 - Time-Of-Return Method
Procedure 5 - Net Benefit Method

These procedures involve the economic evaluation of improvement alternatives to develop effective improvement projects from the candidate alternatives. All of these methods allow consideration of the economic feasibility of projects at a particular location.

While some highway agencies may evaluate candidate countermeasures based on "engineering judgment" or "intuition", economic evaluation methods are preferred. This is because "intuition" is likely to be incorrect or based on the way things have been done in the past, without regard to current state-of-the-art knowledge. Economic analyses may provide results based on a common unit (dollars) for both benefits and costs, and provide objective information from which to make important project selections. All benefits and costs for a highway improvement project need not necessarily be expressed in dollar terms. However, generally accepted procedures have been developed for the quantifications of the major factors included in most safety projects. Consideration of non-quantifiable factors must be included in arriving at final project implementation decisions.

Input into all five of the economic analysis procedures consists of some form of accident benefits and project costs. Benefits are generally assumed to include benefits to the road user, such as accident savings. Costs are generally understood to include costs to the highway agency, such as construction costs and maintenance costs.

Factors which affect the calculation of accident benefits include:

- Accident costs
- Interest rates
- Project service life
- Accident reduction factors
- Traffic growth rates

Much care should be taken in establishing values for these items, since they will have considerable impacts on the determination of the recommended alternative improvements. A discussion of these items is given below.

Accident Costs

The selection of accident cost values is of major importance in computing the expected accident benefits for the economic analyses. The two most commonly used sources of accident costs are:

- National Safety Council (NSC)
- National Highway Traffic Safety Administration (NHTSA)

NSC costs include wage losses, medical expenses, insurance administrative costs, and property damage. NHTSA includes the calculable costs associated with each fatality and injury plus the cost to society (i.e. consumption losses of individuals and society at large caused by losses in production and the inability to produce). Recent accident cost values for the two methods are shown in Table 12 [1,2].

Table 12
Sample Accident Costs

| Source/Accident Severity | | Cost Per Fatality, Injury Or PDO Accident |
|---|---|---|
| NSC(1980)/ | Fatal | $170,000 |
| | Nonfatal disabling injury | 6,700 |
| | Property damage (including minor injuries) | 980 |
| | | Cost Per Involvement |
| NHTSA(1975)/ | Fatality | $287,175 |
| | Critical injury | 192,240 |
| | Severe injury - life threatening | 86,955 |
| | Severe injury - not life threatening | 8,085 |
| | Moderate injury | 4,350 |
| | Minor injury | 2,190 |
| | Average injury | 3,185 |
| | Property damage only | 520 |

## Interest Rates

It is necessary to adopt an interest rate in all of the procedures except the rate-of-return method. For the other methods, the selection of an interest rate may have a significant effect on the economic evaluation of alternative improvements. The selection of an inappropriate interest rate could easily result in inappropriate project costs and benefits. In a time of rapidly fluctuating interest rates, it is imperative that a sensitivity analysis be conducted to assess the effects of project feasibility.

## Project Service Life

The service life of an improvement should be taken as equal to the time period that the improvement can reasonably be expected to affect accident rates [3]. Both costs and benefits should be calculated for this time period. Therefore, the expected service life should reflect the time period and is not necessarily the physical life of the improvement. The selected service life can have a profound effect on the economic evaluation of improvement alternatives.

## Accident Reduction Factors

Accident reduction factors (AR factors) are numerical estimates of the percent reduction in particular types of accidents which may be expected from a particular roadway improvement. Such AR factors should be generated as a result of evaluations from similar projects and programs. Many states generate their own tables of accident reduction factors based on formal project evaluations and then update those factors as additional evaluation results become available. An example of an accident reduction factor would be a 25% reduction expected in opposing left-turn accidents due to the installation of a separate left-turn signal phase. Various lists of accident reduction factors may be found in published and unpublished documents. One recent publication by the Federal Highway Administration entitled "Accident Reduction Factors" provides estimates of potential accident reductions for a wide range of highway safety improvements based on available published and unpublished literature [4].

Traffic Growth Rates

In addition to the above mentioned items, traffic growth rates may also warrant consideration. If a significant growth in traffic is anticipated, it may have a substantial effect on project service lives, maintenance costs and the subsequent accident reductions associated with the improvement.

Besides factors related to accident benefits, several factors must also be considered in the computation of project costs. These factors include:

- Initial project costs
- Salvage value
- Maintenance costs

A brief discussion of these items is provided below.

Project Costs

The initial cost and maintenance costs of projects are of major concern in economic analyses. Care should be taken to consider high-cost as well as low-cost improvements. The selection of only low-cost improvements does not necessarily provide the most appropriate improvements. The costs used should be obtained from the most recent sources available and should reflect the costs that are most applicable to the immediate geographic area of the agency.

Salvage Value

The salvage value is defined as the dollar value of a project at the end of its service life and is therefore dependent on the service life of the project. For highway safety projects, salvage values are generally very small, particularly for those with relatively long service lives. Since this value is usually quite small, the difference in the economic analysis, whether a salvage value is used or not, is often insignificant. Therefore, a salvage value of zero is considered appropriate for most highway safety improvement projects [5].

### Maintenance Costs

The change in expected maintenance cost due to a highway improvement is also a cost consideration that should be included in an economic analysis, in many cases. For example, assume that a traffic signal is proposed for an intersection which is currently controlled by stop signs on the minor street approaches. There would be an expected increase in maintenance costs at the location (due to servicing signal malfunctions, replacing signal bulbs, etc.) compared to the small cost of maintaining the two stop signs. Some types of improvements involve little or no consideration to changes in maintenance costs (i.e., removal of trees along a highway section).

## RANGE OF COMPLEXITY AMONG PROCEDURES

All the procedures in this subprocess are moderately complex and can be applied using either manual or computer calculations.

## MANAGERIAL CONCERNS

- Are available resources (manpower, funds, equipment) sufficient to satisfy the resource requirements of the procedure(s) selected?
- Is a computer facility available to perform these procedures?
- What are the most appropriate accident costs, interest rates, service lives, etc., for the improvement?
- Have all appropriate candidate countermeasures been identified?
- Does the agency wish to assign dollar values to human life?

## SUBPROCESS INPUTS AND OUTPUTS

### Management Input

- A knowledge of the economic evaluation methods which can be used for project development

### Resource and Equipment Input

- Manpower for developing projects
- Computer capabilities (Optional)
- Funding

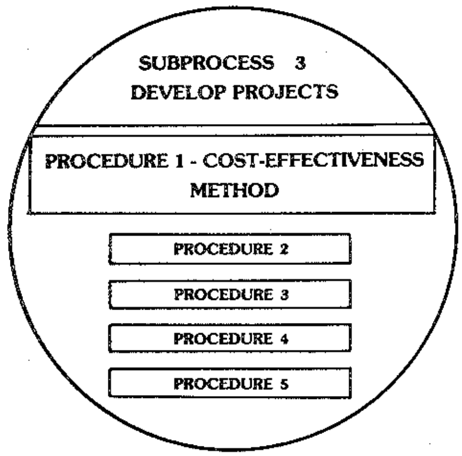
### Data or Informational Input

- A listing of candidate accident countermeasures at each hazardous spot location, section, and element (from Process 3, Subprocess 2 - "Develop Candidate Countermeasures")
- Project costs for each improvement alternative
- Reductions in various accident types which are expected after improvements, with factors to convert these reductions to dollar values.

- Relevant information to perform the economic analyses including (1) initial project capital cost, (2) project life, (3) project salvage value, (4) interest rates, (5) future maintenance costs, (6) traffic growth rates, etc.

Output

- A list of the most appropriate countermeasures for implementation at each identified hazardous location.




PROCEDURE 1 - COST-EFFECTIVENESS METHOD

DESCRIPTION

This procedure is based upon the computation of a cost for the achievement of a given unit of effect (a given reduction in accidents). Some researchers have considered it analogous to the benefit-to-cost ratio technique, in that it attempts to compute an average cost per unit of benefit, and the project with the least cost to attain a given level of benefit is generally considered the most cost-effective. The prime difference between the two methods is that accident savings are not converted to an equivalent dollar value with the cost-effectiveness analysis.

The following steps should be performed for the cost-effectiveness technique [6]:

1. Determine the initial cost of design, construction, right-of-way, and other costs associated with project implementation.
2. Determine the annual operating and maintenance costs for the project.
3. Select units of effectiveness to be used in the analysis. The desired units of effectiveness may be:

- Number of total accidents prevented,
- Number of accidents by type prevented,
- Number of fatalities or fatal accidents prevented,
- Number of personal injuries or personal injury accidents prevented, and/or
- Number of EPDO accidents prevented.

4. Determine the annual benefit for the project in the selected units of effectiveness (i.e., total number of accidents prevented).
5. Estimate the service life.
6. Estimate the net salvage value.
7. Assume an interest rate.
8. Calculate the equivalent uniform annual costs (EUAC) or present worth of costs (PWOC).
9. Calculate the average annual benefit, B, in the desired units of effectiveness.
10. Calculate the cost-effectiveness (C-E) value using one of the following equations:

- C-E = EUAC/B

or

- C-E = PWOC $(CRF_n^i)$/B

Where

$CRF_n^i$ = Capital recovery factor for n years at interest rate i.

A sample C-E worksheet is given in Figure 20.

## PROCEDURE APPLICABILITY

This procedure is generally applicable to agencies which do not wish to directly assign dollar values to human injuries and fatalities.

## RESOURCE REQUIREMENTS

- Manpower - Requires minimal manpower. Technicians or junior engineers can perform analysis.
- Funding - Relatively low cost.
- Equipment - None required. Computer is optional.

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Does not require assigning a dollar value to losses from injuries or fatalities.
- Considers the optimization of benefits on a systemwide basis.

Evaluation No:

Project No:

Date/Evaluator:

1. Initial Implementation Cost, I: $________

2. Annual Operating and Maintenance Costs Before Project Implementation: $________

3. Annual Operating and Maintenance Costs After Project Implementation: $________

4. Net Annual Operating and Maintenance Costs, K (3-2): $________

5. Annual Safety Benefits in Number of Accidents Prevented, $\overline{B}$: ________

| Accident Type | Actual | − Expected | = Annual Benefit |
|---|---|---|---|
| | | | |
| Total | ______ | ______ | ______ |
| | | = | ______ |

6. Service Life, n: ______ yrs.

7. Salvage Value, T: $______

8. Interest Rate: ______ % = 0.______

9. EUAC Calculation:

$CR_n^i$ = ________

$SF_n^i$ = ________

$EUAC = I\ (CR_n^i) + K - T\ (SF_n^i)$

=

10. Annual Benefit:

$\overline{B}$ (from 5) =

11. $C\text{-}E = EUAC/\overline{B}$ =

12. PWOC Calculation:

$PW_n^i$ = ________

$SPW_n^i$ = ________

$PWOC = I + K\ (SPW_n^i) - T\ (PW_n^i)$

13. Annual Benefit

n (from 6) = yrs.

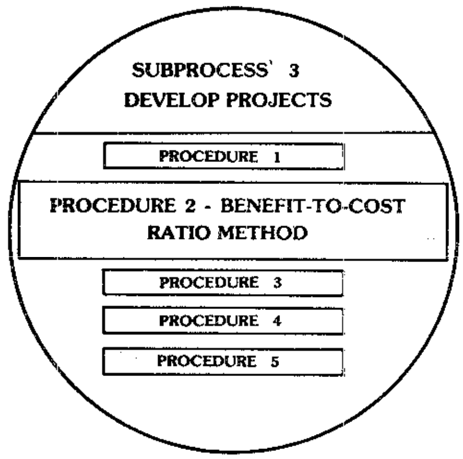
$\overline{B}$ (from 5) = accidents prevented per year

14. $C\text{-}E = PWOC\ (CR_n^i)/\overline{B}$

Figure 20. Sample Cost-Effectiveness analysis worksheet

Disadvantages

- Results are often difficult to interpret in terms of when an improvement is justified.




## PROCEDURE 2 - BENEFIT-TO-COST (B/C) RATIO METHOD

### DESCRIPTION

The Benefit/Cost ratio is the monetary accident savings divided by the improvement cost. Using this method, costs and benefits may be expressed as either an equivalent annual or present worth value of the project. Any project with a benefit-to-cost (B/C) ratio greater than 1.0 can be considered economically sound.

It is commonly the practice of many state and local agencies to rank projects on the basis of their respective B/C ratio to select the most viable project. However, it is argued by some economists that this approach is inappropriate for selecting projects, because of the added costs of each more sophisticated project. They suggest the use of an incremental benefit-to-cost ratio analysis to select the best project. This technique is discussed in the next section.

The B/C technique requires the following steps [6]:

1. Determine the initial cost of implementation of the safety improvement being studied.
2. Determine the net annual operating and maintenance costs.
3. Determine the annual safety benefits derived from the project.
4. Assign a dollar value to each safety benefit unit (NSC, NHTSA or states own costs).

5. Estimate the service life of the project based on patterns of historic depreciation of similar types of projects or facilities.
6. Estimate the salvage value of the project or improvement after its primary service life has ended.
7. Determine the interest rate by taking into account the time value of money.
8. Calculate the B/C ratio using equivalent uniform annual costs (EUAC) and equivalent uniform annual benefits (EUAB).
9. Calculate the B/C ratio using present worth of costs (PWOC) and present worth of benefits (PWOB)

A sample worksheet for the B/C analysis is given in Figure 21.

## PROCEDURE APPLICABILITY

This procedure is generally applicable to:

- Highway systems of all sizes
- Agencies which have no objection to placing a dollar value on losses due to human injuries or fatalities

The benefit-to-cost method may be applied using either manual or computer techniques.

## RESOURCE REQUIREMENTS

- Manpower - Personnel should include engineers experienced in highway safety and/or economic analysis.
- Funding - Relatively low cost
- Equipment - None required. Computer is optional.

## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Provides a straight-forward, familiar method for performing economic evaluations
- Useful for situations where accident severity is an important measure of effectiveness

### Disadvantages

- Results are often affected considerably by the accident cost values (NSC, NHTSA, states' cost) selected, particularly when fatal accidents are being considered.
- Relies on the placement of a dollar value on a human losses.
- Relies on an assumed interest rate.

Evaluation No:

Project No:

Date/Evaluator:

1. Initial Implementation Cost, I: $__________

2. Annual Operating and Maintenance Costs Before Project Implementation: $__________

3. Annual Operating and Maintenance Cost After Project Implementation: $__________

4. Net Annual Operating and Maintenance Costs, $\bar{K}$ (3-2): $__________

5. Annual Safety Benefits in Number of Accidents Prevented:

| Severity | Actual | - Expected | = Annual Benefit |
|---|---|---|---|
| a) Fatal Accidents (Fatalities) | | | |
| b) Injury Accidents (Injuries) | | | |
| c) PDO Accidents (Involvement) | | | |

6. Accident Cost Values (Source__________):

| Severity | Cost |
|---|---|
| a) Fatal Accident (Fatality) | $ |
| b) Injury Accident (Injury) | $ |
| c) PDO Accident (Involvement) | $ |

7. Annual Safety Benefits in Dollars Saved, $\bar{B}$:

5a) x 6a) =

5b) x 6b) =

5c) x 6c) =

Total = $

8. Services life, n: __________yrs

9. Salvage Value, T: $__________

10. Interest Rate, i: ______% = 0.______

11. EUAC Calculation:

$CR_n^i$ = ________

$SF_n^i$ = ________

$EUAC = I\ (CR_n^i) + K - T\ (SF_n^i)$

12. EUAB Calculation:

$EUAB = \bar{B}$

=

13. B/C = EUAB/EUAC =

14. PWOC Calculation:

$PW_n^i$ =

$SPW_n^i$ =

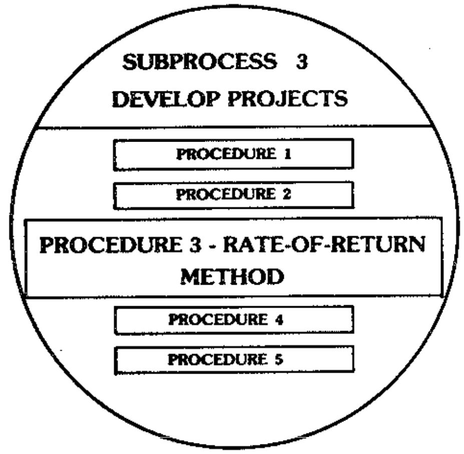
$PWOC = I + K\ (SPW_n^i) - T\ (PW_n^i)$

15. PWOB Calculation:

$PWOB = \bar{B}(SPW_n^i)$

16. B/C = PWOB/PWOC =

Figure 21. Sample Benefit-to-Cost analysis worksheet




## PROCEDURE 3 - RATE-OF-RETURN METHOD

### DESCRIPTION

This technique is based upon the computation of the rate of return on an investment. The calculated interest rate is considered as the "yield" of the investment. When a number of alternatives are considered for possible implementation, the project with the highest yield is considered to be the most desirable, subject to its meeting a minimum value (minimum attractive rate of return).

There are two assumptions upon which this method is based [5]:

- The relative merit of an improvement is measured by the interest rate that sets its benefits equal to zero.
- The costs and benefits remain constant each year.

The rate of return is calculated from the following equations (which are set equal to zero) [5]:

$$I = (B-K)SPW_n^i - T(PW_n^i) \quad \ldots \ldots \ldots \ldots \ldots \quad (A)$$

or

$$\frac{B-K}{I} = CR_n^i \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \quad (B)$$

Where, i = rate of return
B = annual benefit
K = annual cost

$SPW_n^i$ = Series present worth factor for n years at interest rate i

T = terminal value

$PW_n^i$ = Present worth factor for nth year at interest rate i

I = Initial cost

$CR_n^i$ = Capital recovery factor for n years at interest rate i

Equation (B) is used for improvements with no terminal value or a perpetual service life. Both equations must be used on a "trial and error" basis. A mathematical algorithm may be formulated for either manual or computer techniques, with the objective of "converging" to the required solution when specific "bounds" of the solution are defined in order to minimize the searching effort.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Medium-size highway systems (100 to 10,000 miles)
- Agencies with no objection to assigning dollar values to human lives
- Agencies which desire to compare projects based on their rate of return on their investment

The rate-of-return method may be applied using either manual or computer techniques. Computer techniques are recommended.

## RESOURCE REQUIREMENTS

- Manpower - May require considerable manpower for manual techniques. One or more engineers experienced in economic analysis are necessary for either manual or computer application.
- Funding - Moderate cost.
- Equipment - Computer is desirable.

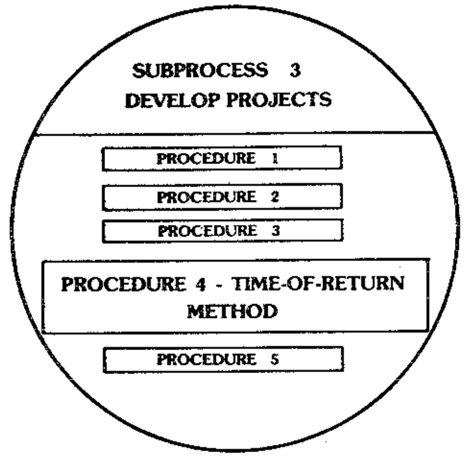
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Does not rely on an assumed interest rate
- Considers the optimization of benefits on a systemwide basis

### Disadvantages

- Must be performed on an iterative, i.e., "trial and error" basis. This can be very time consuming, particularly for manual methods.
- Somewhat difficult to interpret




## PROCEDURE 4 - TIME-OF-RETURN METHOD

### DESCRIPTION

In the Time-of-Return (TOR) method, expected accident reductions are forecast using data from previous before-and-after accident studies as with the other economic methods. A TOR value is computed by dividing the estimated cost of the project by the computed annual benefit. Interest rates, annual maintenance costs, service lives of all projects, and salvage values are not considered in this anlaysis. Projects with the lowest TOR values are considered to be the best. An example of a completed worksheet for an intersection improvement is given in Figure 22 using the TOR method. Details of the accident information by type and expected percent reduction are given on the form. One analysis sheet should be completed for each improvement alternative.

The following steps should be carried out in this procedure:

1. Determine the accident types to be affected by the improvement(s).
2. Estimate the reduction in each accident type.
3. Estimate the change in traffic volume (growth) due to the improvement(s).
4. Determine the total cost of the improvement(s).
5. Determine the total benefit based on the number of years of data analyzed.
6. Compute the annual benefit.
7. Compute the time-of-return.

Location____________ City/Twp.____________ County________

The method of evaluating accident costs, used below, is given on page 67 of Roy Jorgensen's report of Highway Safety Improvement Criteria, 1966 edition.

In the following analysis the costs provided by the National Safety Council are: 1977 values

Death – $135,000

Nonfatal Injury – $5,500

Property Damage Accident – $800

$$B = \frac{ADT_a}{ADT_b} \times (Q\,R_1 + 800\,R_2)$$

where

B = benefit in dollars

$ADT_a$ = Average traffic volume after the improvement 79,200

$ADT_b$ = Average traffic volume before the improvement 72,000

$R_1$ = Reduction in fatalities and injuries combined 13

$R_2$ = Reduction in property damage accidents 12

Q = 5500 if no fatal accidents occurred, and

$$Q = \frac{135{,}000 + (I/F \times 5{,}500)}{1 + I/F} = 7{,}001 \text{ if at least 1 fatality occurred.}$$

where

I/F = Ratio of injuries to fatalities that occurred statewide during the year 1977

$$= \frac{166{,}389}{1{,}950} = 85.3$$

Time of Return (T.O.R.) based on 2 years of data.

2 yrs. B= 1.1 [(5500 ~~XXXXXX~~) 13 + (800) 12 ]

2 yrs. B= 1.1 [( 71,500 ) + ( 9600 )] = 89,210

Annual B= 44,605 dollars

C= Total cost of project

$$T.O.R. = \frac{C}{B} = \frac{42{,}580}{44{,}605} = 0.96 \text{ years} = 11.5 \text{ Months}$$

Location ____________

City/Twp. ____________ County ____________

Control Section ____________ SII # ____________

Type of Improvement Pavement Overlay, Pavement Markings, Upgrading Signals, Driveway Signing, Driveway Reconstruction.

| PERIOD | ACCIDENT TYPES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Driveway Related A | | Rear End B | | Opposing Left-Turn | | | | | |
| 1977 | 7 | 3 pd / Injd 4 | 22 | 15 pd / Injd 7 | 13 | 7 pd / Injd 6 | | pd / Injd | | Injd |
| 1978 | 9 | 6 / 3 | 19 | 10 / 9 | 12 | 6 / 6 | | | | |
| | | | | | | | | | | |
| TOTALS | 16 | 9 / 7 | 41 | 25 / 16 | 25 | 13 / 12 | | | | |

| Estimated Accident Reduction | 50% Red. | | 15 % Red. | | 25 % Red. | | % Red. | | % Red. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 5 / 3(5) | 6 | 4 / 2(3) | 6 | 3 / 3(5) | | | | |

Remarks

A- Includes only those accidents at driveways where improvements are proposed. Includes left-turns out of driveways, and rear-ends, sideswipes, and angles caused by right turns into or out of the driveways.

B- Includes only those accidents on the approaches (not driveway-related)

Estimated Project Cost $42,580

Anticipated Annual Benefit $44,605

Project Amortization (T.O.R.) 0.96 years

Figure 22. Sample Time of Return worksheet

## PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Small to medium-sized highway systems (up to 2500 miles) - agencies with large highway systems often need to consider a wider range of projects than smaller agencies, and should use a more sophisticated method.
- Agencies with no objection to the placement of dollar values on losses from injuries and fatalities.
- Agencies desiring to compare projects based on the time in which project will pay for themselves in terms of accident savings.

## RESOURCE REQUIREMENTS

- Manpower - Requires a minimum of manpower. However, one or more engineers with experience in highway safety and economic analyses should be on staff.
- Funding - Relatively low cost.
- Equipment - None required. Computer is optional.

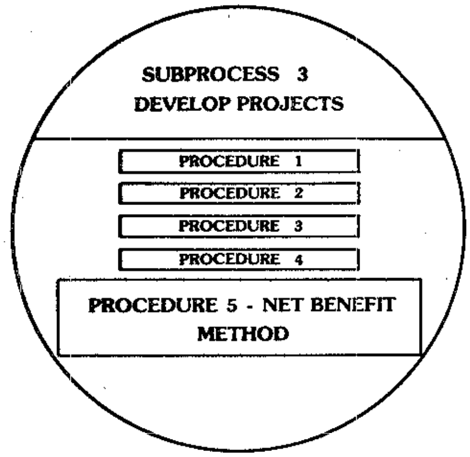
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Results directly in the amount of time required for a given improvement or set of improvements to pay for itself.
- Can consider the optimization of benefits on a systemwide basis.

### Disadvantages

- A time measure is often misleading or difficult to interpret. For example, a time of return of 5 years may be considered very good for a highway reconstruction project which has a 20-year service life but not desirable for a pavement striping project with a service life of less than two years.
- Does not normally account for interest rates, annual maintenance costs, service lives of all projects, or salvage values.




## PROCEDURE 5 - NET BENEFIT METHOD

### DESCRIPTION

This procedure is based on the premise that the relative merit of an improvement is measured by its net annual benefit[4]. The net annual benefit of an improvement is defined as:

Net Annual Benefit = (EUAB)-(EUAC)

Where:

EUAB = Equivalent Uniform Annual Benefit
EUAC = Equivalent Uniform Annual Cost

A positive value for Net Annual Benefit indicates a feasible improvement and the improvement or set of improvements with the largest positive Net Annual Benefit is considered to be the best alternative.

The following steps should be used to compute the Net Annual Benefit [3]:

1. Estimate the initial cost, annual cost, terminal value, and service life of each improvement.
2. Estimate the benefits (in dollars) for each improvement.
3. Select an interest rate.
4. Compute the Equivalent Uniform Annual Benefit, EUAB.
5. Compute the Equivalent Uniform Annual Cost, EUAC.
6. Calculate the Net Annual Benefit of each improvement.

This method is used to select improvements that will insure maximum total benefits at each location. As an example, suppose a location is being considered for improvement. The four alternative improvements for this site are given in Table 13 along with their corresponding B/C ratios and net benefit values.

Table 13. Comparison of Net Benefit Method to B/C Ratio

| Alternative | B/C | Net Benefit |
|---|---|---|
| 1. Sign and Stripe | 12.0 | 10,000 |
| 2. Pavement Overlay | 7.0 | 20,000 |
| 3. Overlay, Sign and Stripe | 5.0 | 25,000 |
| 4. Reconstruction | 2.0 | 200,000 |

Using the Benefit/Cost Ratio methods, Alternative 1, would be selected, while the Net Benefit method would result in the selection of Alternative 4. The Benefit-to-Cost Ratio will usually allow for the selection of mostly low-cost alternative improvements which may enhance project selection on a systemwide basis when safety budgets are limited. However, these improvements may not offer the optimum benefits for each individual location. The Net Benefit method results in the selection of improvement alternatives that generally offer the greatest safety benefits at each location. However, these alternatives are often high-cost improvements which have serious implications on the number of projects which may be undertaken on the whole system.

An agency should, therefore, be aware of both the expected net benefits and the benefit-to-cost ratio (or cost-effectiveness, rate-of-return, etc.) for each project under consideration. A combination of two or more economic methods may also be desirable.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for:

- Highway systems of all sizes
- Agencies with no objection to assigning dollar values to human lives
- Agencies whose primary objective is to insure selection of the most appropriate projects on a location by location basis

## RESOURCE REQUIREMENTS

- Manpower - Requires very little manpower. However, one or more engineers with experience in highway safety and economic analysis are necessary.
- Funding - Relatively low cost.
- Equipment - None Required. Computer is optional.

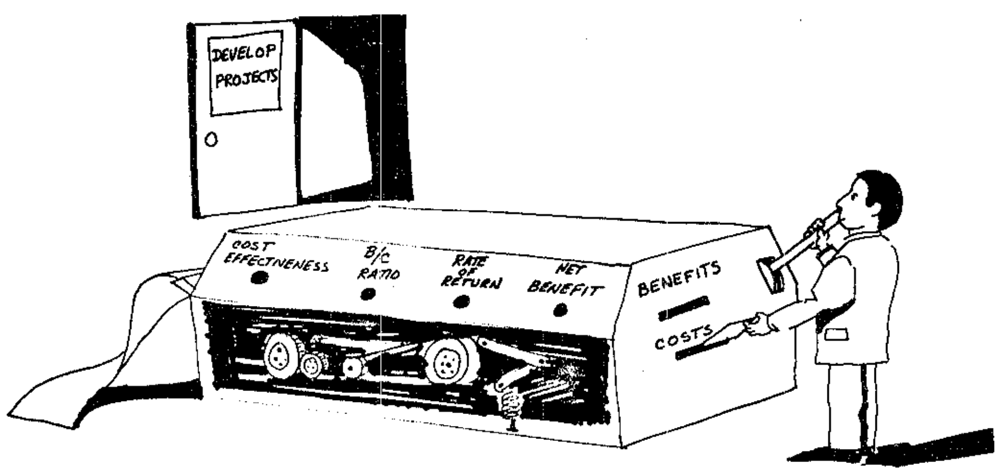
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Relative ease of calculation
- Applicable when the selection of one alternative precludes the selection of another alternative at the same time
- Can consider the optimization of benefits for each individual location

Disadvantages

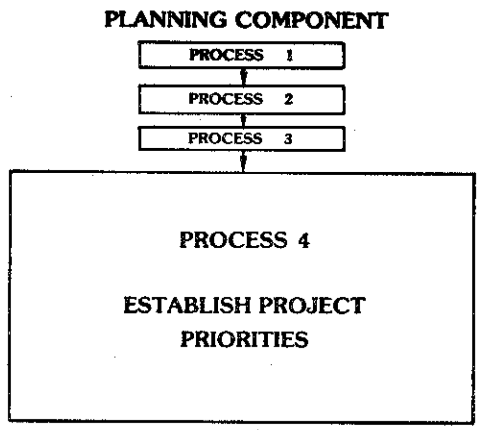
- Requires the placement of a dollar value on losses from injuries and fatalities.
- Often places a low priority on low cost projects compared to higher cost projects.



CHAPTER VIII

# PROCESS 4

# ESTABLISH PROJECT PRIORITIES




## PURPOSE

The purpose of this process is to establish a priority list of the countermeasures developed in Process 3, Subprocess 3 ("Develop Projects"). This process should result in the selection of improvements which will result in the optimal safety benefits per dollar spent.

## DESCRIPTION

This process includes the following procedures:

Procedure 1 - Project Development Ranking
Procedure 2 - Incremental Benefit-to-Cost Ratio
Procedure 3 - Dynamic Programming
Procedure 4 - Integer Programming

After countermeasures are developed for each hazardous location, the next step is to establish priorities for implementing these projects. Priorities should be based on many considerations such as available funding levels, project costs, and accident benefits for each countermeasure. This process should be used to select the final list of countermeasures to be completed at each location under available funding.

In most cases, there will not be enough money available to complete all needed improvements. Therefore, many improvements may not be implemented and a careful analysis is needed to select improvements which will result in optimal safety benefits per dollar spent.

Care should be exercised not to select only very low-cost improvements. These improvements might show very high benefits per dollar spent, but such low-cost improvements often do not provide for the reduction in large numbers and severities of accidents over periods of several years. The engineer should ensure that many of the most hazardous locations are properly corrected if possible, to help insure that long-term safety benefits will be provided to the public.

## RANGE OF COMPLEXITY AMONG PROCEDURES

A wide range of complexities is involved among the various procedures. Project development ranking is very simple to use and can be done manually, while the other three procedures are more complex, with the dynamic and integer programming methods usually requiring the use of a computer.

## MANAGERIAL CONCERNS

- What are the magnitudes and types of funds that are available for project implementation?
- Are computer facilities available for this process?

## PROCESS INPUTS AND OUTPUTS

### Management Input

- An understanding of the available procedures for establishing priorities

### Resource and Equipment Input

- Manpower - Programmers for using computerized methods
- Funding - Funds for computer rental, maintaining qualified personnel, etc.
- Equipment - Computer capabilities (Required for Procedures 3 and 4, and optional for Procedures 1 and 2)

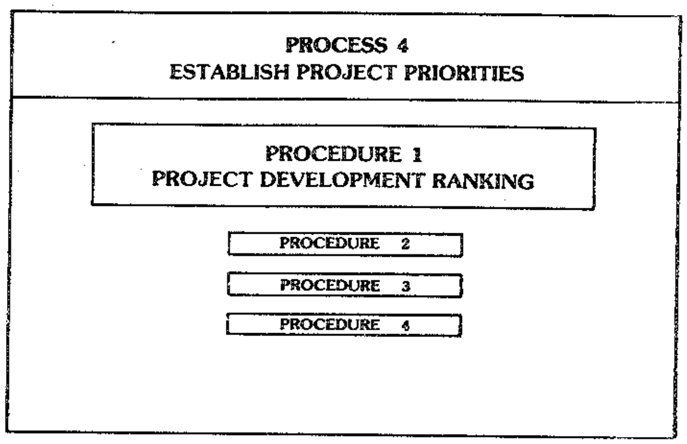
### Data or Informational Input

- A listing of countermeasures (possibly short-range and long-range) which should be implemented for each hazardous location (from Process 3, Subprocess 3 - "Develop Projects")
- The estimated construction costs of projects
- The estimated changes in annual maintenance costs for each project

- The accident benefits to be derived from each project alternative
- The economic indicator (B/C ratio, rate of return, etc.) for each project alternative.

Output

- A recommended list of safety improvement projects to be implemented at specific locations based on available or expected funding levels.




PROCEDURE 1 - PROJECT DEVELOPMENT RANKING

DESCRIPTION

This procedure is a priority ranking based on the output from Subprocess 3 of Process 3 - "Develop Projects." For example, assume that the net benefit procedure is used to develop projects for each hazardous location. The locations can be ranked in priority order based on the net benefit. Then, projects can be selected from the priority listing until available funds are depleted. Similar rankings could also be made using cost-effectiveness, rate-of-return, or other economic measures.

PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- At least technician level personnel and junior level engineers
- Desire for final selection of projects based on project ranking
- No access to more sophisticated methods (i.e., dynamic programming) for establishing project priorities.

RESOURCE REQUIREMENTS

- Manpower - Requires minimal manpower. Technicians and engineers to rank projects based on output from Process 3, Subprocess 3 - "Develop Projects."
- Funding - Very low cost
- Equipment - None. Computer is optional

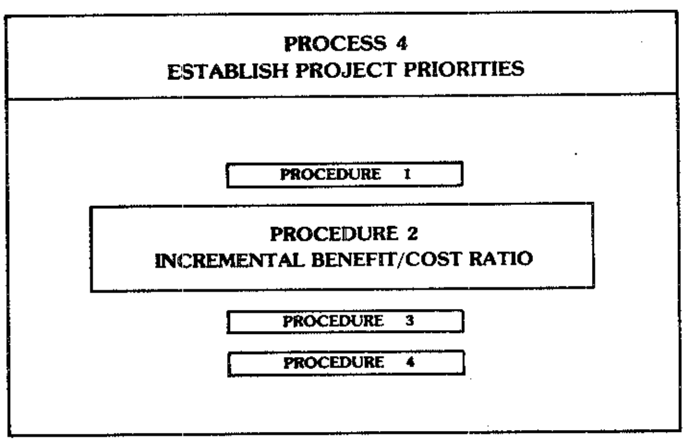
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Provides a simple, easy to use method of establishing priorities for implementing safety projects.
- Does not require computer facilities.

Disadvantages

- Not effective for establishing priorities for a list of projects with numerous alternatives at each location
- Is not particularly adaptable to revisions in the priority listing




PROCEDURE 2 - INCREMENTAL BENEFIT-TO-COST RATIO METHOD

DESCRIPTION

This method can be used to select projects based on whether extra increments of expenditure are justified for a particular location. It can also be used to simultaneously determine the optimal level of expenditure at multiple locations each having more than one possible alternative. The method assumes that the relative merit of a project is measured by its increased benefits (compared to the next lower-priced alternative) divided by its increase in cost (compared to the next lower-priced alternative).

This may be stated: $IB/C_{ij} = \frac{B_i - B_j}{C_i - C_j}$

Where: $IB/C_{ij}$ = Incremental B/C ratio between projects i and j
$B_i, B_j$ = The benefits derived from projects i and j
$C_i, C_j$ = The costs associated with projects i and j

The basic input required for using the incremental benefit-to-cost ratio is similar to that of the simple B/C ratio method.

The steps for using the incremental benefit-to-cost ratio method are [1]:

1. Determine the benefits, costs and the benefit-to-cost ratio for each improvement.
2. List the improvements with a B/C ratio greater than one in order of increasing cost.
3. Calculate the incremental B/C ratio of the second lowest-cost improvement compared to the first.
4. Continue, in order of increasing costs, to calculate the incremental B/C ratio for each improvement compared to the next lower cost improvement.
5. Stop when the incremental B/C ratio is less than 1.0.

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- At least one engineer experienced in highway safety and economic analysis
- Computer capabilities, particularly for a large number of projects under consideration
- Desire to select projects based on the additional benefits which can be gained for a given incremental cost increase

## RESOURCE REQUIREMENTS

- Manpower - Technicians and engineers to develop a priority listing of improvements based on incremental benefit-to-cost ratios. Programmer may be necessary for computerized analyses.
- Funding - May require money for computer program development and application
- Equipment - Computer is highly recommended.

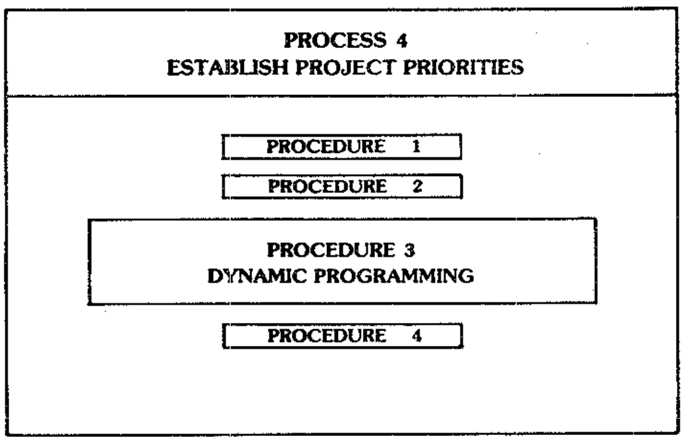
## PROCEDURE ADVANTAGES AND DISADVANTAGES

### Advantages

- Reduces the impact of very low cost projects
- Enhances consideration of additional improvements which are justified based on their expected additional benefits

### Disadvantages

- Manual calculations may require considerable time and manpower
- Can be quite complex to use, particularly without the aid of a computer




## PROCEDURE 3 - DYNAMIC PROGRAMMING

### DESCRIPTION

Dynamic programming is an optimization technique which transforms a multistage decision problem into a series of one-stage decision problems. The term Dynamic Programming was first used by Bellman [1] to represent the mathematical theory of a multi-stage decision process. It is used to allocate money to obtain the maximum possible benefits under a fixed budget. The three possible levels of dynamic programming are [2]:

- Single-stage (used to evaluate a single project with several alternatives)
- Multi-stage (involves selection among several projects with several alternatives each)
- Multi-stage with a time factor (used where several alternatives are considered and various time periods are involved)

Basic input into the dynamic programming model consist of:

- Initial costs, operating costs and maintenance costs for each project alternative
- Accident benefits for each project alternative
- Budget available for improvements

To illustrate dynamic programming, an example of eight projects is shown in Table 14. The cost estimates and expected benefits are given for each project, ordered by benefit-to-cost ratio. Assume a budget of $400,000, and using the benefit-to-cost analysis, Projects A,B,C,D, and E would be selected in that order. The cost of these five projects totals $250,000, which leaves $150,000 yet to be spent. Since Project F costs $200,000, it is skipped and Project G is selected. The $400,000 spent by this method yields total benefits of $4,440,000.

Using dynamic programming, Projects A,B, and C are also chosen. These projects total $200,000, leaving $200,000 to spend. Considering all possibilities, it can be seen that by choosing Project F instead of D,E, and G, greater benefits can be obtained from the remaining $200,000. Therefore, using dynamic programming, the projects selected are A,B,C, and F. The total benefit then is $4,900,000, which is $460,000 more than would result from selection of projects by the benefit-to-cost method.

In some instances, the same projects will be selected whether dynamic programming or some other method is used. Depending on the number of projects under consideration, the use of dynamic programming may result in the selection of projects which yield greater benefits than other procedures. In the above example, the optimal selection of projects was fairly obvious without using a computer. However, many more projects usually are involved than shown in this example, and the manual selection of the optimum listing of projects becomes infeasible. Analysis with the aid of a computer is then necessary. The dynamic programming concept has already been applied to highway safety programs in Kentucky and Alabama, and is expected to also be utilized in other states in the near future [2,3].

## PROCEDURE APPLICABILITY

This procedure is generally applicable for agencies with:

- Experienced safety engineers and computer programmers on staff
- Available computer facilities
- A need to obtain quick revisions of project listings for any modifications (budgets, cost revisions, etc.)
- A desire to select the optimal listing of projects for any given budget by considering all combinations of projects

Table 14. Dynamic programming vs. B/C ratio example

| Project | Benefit | Cost | Benefit/Cost Ratio |
|---|---|---|---|
| A | $ 800,000 | $ 20,000 | 40 |
| B | 1,600,000 | 80,000 | 20 |
| C | 1,300,000 | 100,000 | 13 |
| D | 200,000 | 20,000 | 10 |
| E | 240,000 | 30,000 | 8 |
| F | 1,200,000 | 200,000 | 6 |
| G | 300,000 | 150,000 | 2 |
| H | 80,000 | 80,000 | 1 |

| Method | Budget | Projects Selected | Total Benefits |
|---|---|---|---|
| Benefit/Cost | $400,000 | A,B,C,D,E,G | $4,440,000 |
| Dynamic Programming | 400,000 | A,B,C,F | 4,900,000 |

RESOURCE REQUIREMENTS

- Manpower - Technicians and engineers to develop the dynamic programming model for the system. Programmer to implement the model on computer
- Funding - Requires funds for application of computer program
- Equipment - Computer capabilities

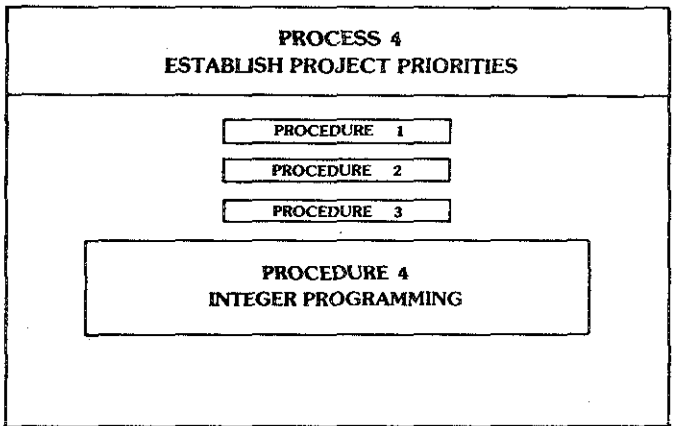
PROCEDURE ADVANTAGES AND DISADVANTAGES

Advantages

- Responsive to changes in budget, inflation rates, cost of materials, etc.
- Useful in the analysis of several different alternatives
- Allows for the selection of an optimal plan, and therefore guarantees the best economic investment (within practical limits)

Disadvantages

- Complex, requiring computer capabilities




PROCEDURE 4 - INTEGER PROGRAMMING

DESCRIPTION

Programming problems in general deal with the use or allocation of scarce resources in a manner such that costs are minimized or profits are maximized. An Integer Programming problem is characterized by the following conditions [4]:

- The relationship between the dependent variable and independent variables is linear and is referred to as the objective function

- All decision variables of the problem are non-negative
- Some or all of the decision variables are restricted to integer values
- The decision variables are subject to various constraints which can be expressed as a set of linear equations or inequalities.

In short, an integer programming problem is a linear programming problem in which some or all of the decision variables are restricted to integer values.

Integer programming is a valuable operations research tool and has potential in highway system applications. Considerable theoretical research has been conducted in the past, but limited progress has been made in the computation of large-scale integer programs for highway safety use. The solution of the integer programming problem usually requires the use of a computer, particularly for large-scale problems. The standard form of the integer programming problem is [4]:

$$\text{Maximize } X_0 = \sum_{j=1}^{n} c_j X_j$$

$$\text{Subject to} \quad \sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad i = 1,2,\ldots,m$$

$$\text{Integer } X_j \geq 0 \qquad j = 1,2,\ldots,n$$

Where:

$X_0$ = Benefits resulting from lives saved or costs reduced

$X_j$ = Decision variables

$C_j$ = Cost coefficient ($ per unit of variable X)

$a_{ij}$ = Structural coefficients

$b_i$ = Resource constraints (i.e. the amount of money, time or equipment available

In the standard form shown above, the objective is to maximize the profit ($X_0$) which is a linear combination of a number of decision variables ($X_j$). The objective function is subject to the following conditions:

- There is a limited amount of resources available ($b_i$)
- The decision variable (project alternative $X_j$) must be 0 (not selected) or a positive integer (totally selected)

PROCEDURE APPLICABILITY

- Experienced safety engineers and computer programmers who are knowledgeble in the use of linear programming
- Computer facilities available
- A need to obtain quick revisions of project listings for any modifications
- A desire to select the optimal listing of projects for any given budget by considering all possible combinations of projects

RESOURCE REQUIREMENTS

- Manpower - Engineers to formulate the integer programming problem. Programmer to implement the formulation on the computer system.
- Equipment - computer facilities
- Funding - Money to develop and/or apply the computer program

PROCEDURE ADVANTAGES AND DISADVANTAGES

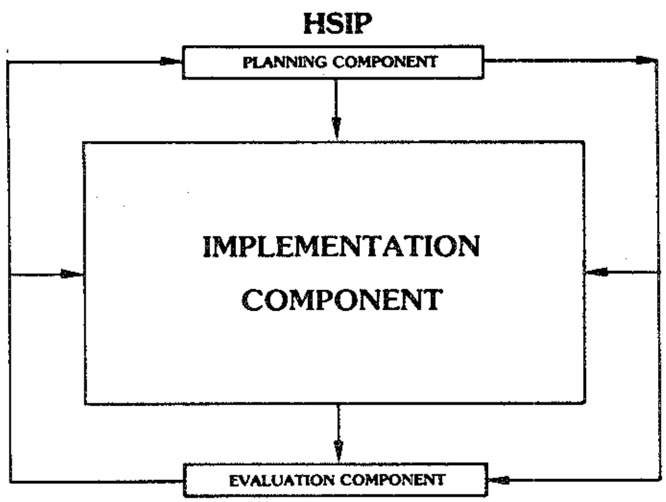
Advantages

- Accounts for the various restraints upon the independent factors, i.e., budget restraints, material costs, etc.
- Has capabilities for quick updates and revisions of prioritized listing
- Will result in the optimal selection of projects (within limits)

Disadvantages

- Complex - requires computer solution techniques and personnel with experience in solving linear programming problems
- Limited progress has been made in the solution of large-scale highway safety problems using linear programming

# IMPLEMENTATION COMPONENT




## PURPOSE

The purpose of the Implementation Component is to design, schedule, construct, and make necessary final adjustments to the highway safety improvements which were selected in the Planning Component.

## DESCRIPTION

The Implementation Component consists of one process, according to FHPM 8-2-3, which is designated as Process 1 - "Schedule and Implement Safety Improvement Projects." The Implementation Component is situated between the Planning and Evaluation components of the HSIP. Projects are selected for implementation in the Planning Component based on the available funds and estimated accident reduction. After projects are implemented, they should be evaluated to determine their effectiveness. Results of the project evaluations can be used to improve the future planning and implementation practices of a highway agency.

## INPUTS AND OUTPUTS

### Managerial Inputs

- Guidance of personnel and/or contractors throughout the construction of projects
- A knowledge and understanding of design standards, construction practices, and scheduling techniques

Resource Input

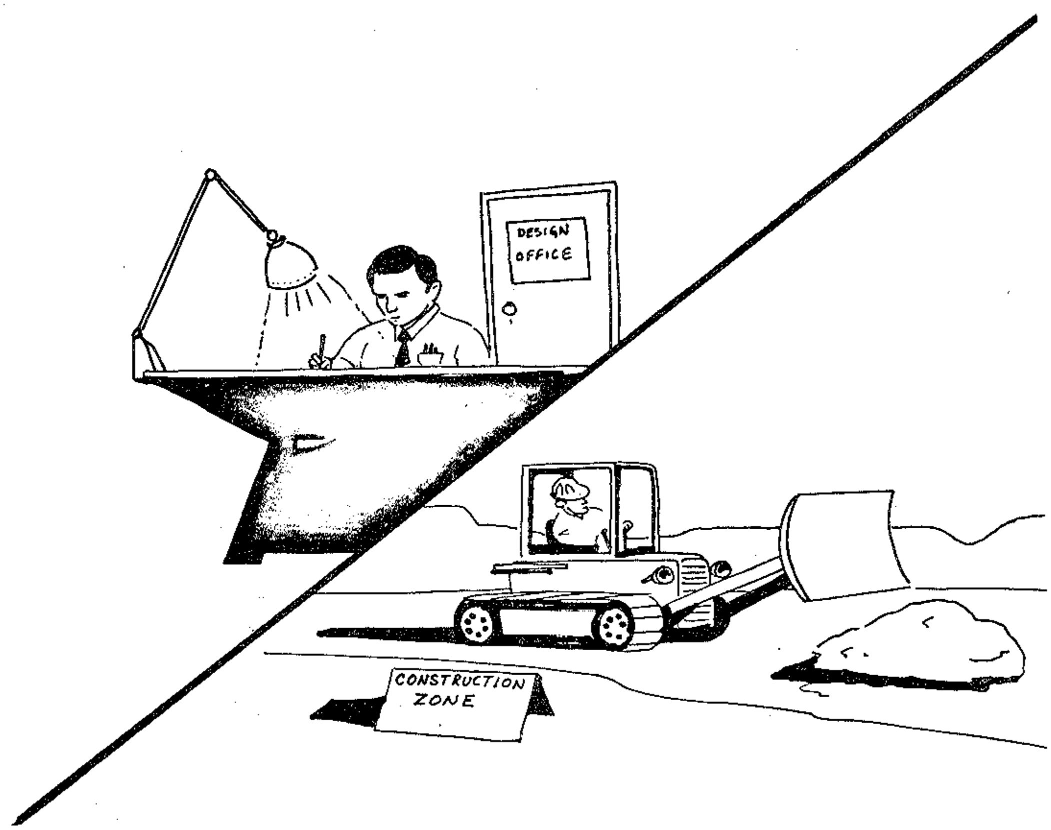
- Funds - Money to complete the improvement projects
- Manpower - Agency or contractor personnel to schedule, design, construct, and review the improvements
- Equipment - Equipment for implementing projects

Data or Informational Input

- A list of projects to implement along with cost information for each

Output

- Implemented highway safety projects



CHAPTER IX

# PROCESS 1

# SCHEDULE AND IMPLEMENT SAFETY IMPROVEMENT PROJECTS

**IMPLEMENTATION COMPONENT**

**PROCESS 1**

**SCHEDULE AND IMPLEMENT SAFETY IMPROVEMENT PROJECTS**

## PURPOSE

The purpose of this process is to conduct the necessary subprocess of project implementation in the most efficient possible manner.

## DESCRIPTION

Safety improvements may be completed by contractors or by agency work forces. Large projects are usually performed by contract, while minor and low-cost projects are usually performed by the agency whenever possible. Some improvements are relatively simple and require little design work such as pavement striping, installation of signs and signals, removal of roadside obstacles, etc. Considerable design and study may be required for such projects as intersection design, grade separation, channelization, and complex signal systems. The extent of the required design work should be defined, and appropriate methods should be identified within the agency or from outside sources for performing the required tasks.

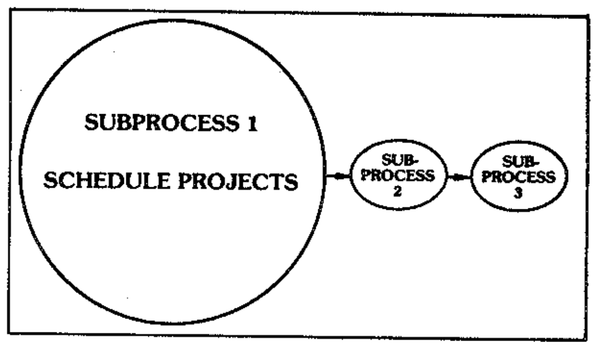
The three subprocesses under this process are:

Subprocess 1 - Schedule Projects
Subprocess 2 - Design and Construct Project
Subprocess 3 - Conduct Operational Review

# PROCESS 1, SUBPROCESS 1

# SCHEDULE PROJECTS

IMPLEMENTATION COMPONENT




PURPOSE

The purpose of this subprocess is to plan and schedule the safety improvement projects to insure the most efficient use of time and resources.

DESCRIPTION

Project scheduling must be undertaken after accident countermeasures are developed and selected. This involves determining when each improvement should be started and completed under real-world constraints. For example, weather conditions are a constraint to paving activities and pavement striping, since temperatures must be high enough to permit proper drying conditions.

Funding availability is another constraint since enough money is seldom available to complete all needed improvements by an agency. Manpower constraints are also important in project scheduling and completion. Existing traffic conditions also pose a major constraint to highway improvements. For example, on high-volume urban streets, major projects involving lane closures are often conducted at night or during off-peak times to prevent massive traffic congestion.

There are five basic steps in project scheduling which include the following [1]:

1. Estimate costs, required time, and other resources for the project's work activities.
2. Determine the time duration of each phase, lead times between each phase, and the priority of each project, arranging the project phases on a time scale so as to efficiently use the funds as they become available.
3. Estimate manpower requirements, summarize them for specific time periods, and project the future manpower situation.
4. Summarize other resources (materials, equipment, facilities) and evaluate appropriate solutions as necessary.
5. Balance the types of construction whenever practical.

To properly schedule a project or a group of projects, several procedures are available. Four of the scheduling procedures currently in use include:

Procedure 1 - Gantt Charts (bar charts)
Procedure 2 - Program Evaluation and Review Technique (PERT)
Procedure 3 - Critical Path Method (CPM)
Procedure 4 - Multiproject Scheduling System (MPSS)

## RANGE OF COMPLEXITY

The degree of complexity of these procedures depends upon the size of the project or the number of activities involved. Projects (or Programs) with a large number of activities with several restraints will require considerable expertise and most likely computer application (for the PERT, CPM, and MPSS techniques).

## MANAGERIAL CONCERNS

- Are accurate estimates available for the manpower, cost and equipment requirements of each project?
- How accurate are the estimated time requirements for each project?
- How will the weather affect the schedule?
- What projects are critical in terms of completion dates?
- Which projects should be completed by agency forces, and which should be let to contract?

## INPUTS AND OUTPUT

### Management Input

- An estimate of the physical, monetary, weather, time, and other constraints which may affect scheduling

Resource and Equipment Input

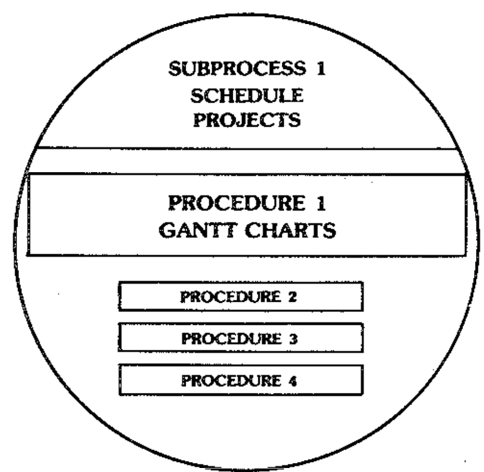
- Project funding
- Manpower to plan the implementation scheduling

Data or Informational Input

- A recommended list of safety improvement projects to be completed at specific locations, based on available funding
- The estimated completion time for each task of each project
- A priority list of projects in order of importance

Output

- A time schedule for implementation of all recommended safety improvement projects




PROCEDURE 1 - GANTT CHARTS

DESCRIPTION

A Gantt Chart (bar chart) provides a visual picture of the project activities with the corresponding time periods for each activity. The format of a Gantt Chart will depend primarily on the nature of other documents used by the highway agency. Some agencies use such manual graphical aids as their sole scheduling device, while others (with greater volumes of work) use computer assisted scheduling techniques. An example of a Gantt Chart is given in Figure 23 [1].

APPLICABILITY

Gantt Charts are generally adaptable to long-range scheduling where projects are classified into three or four major activities.

ROADWAY WIDENING PROJECT - GANTT CHART

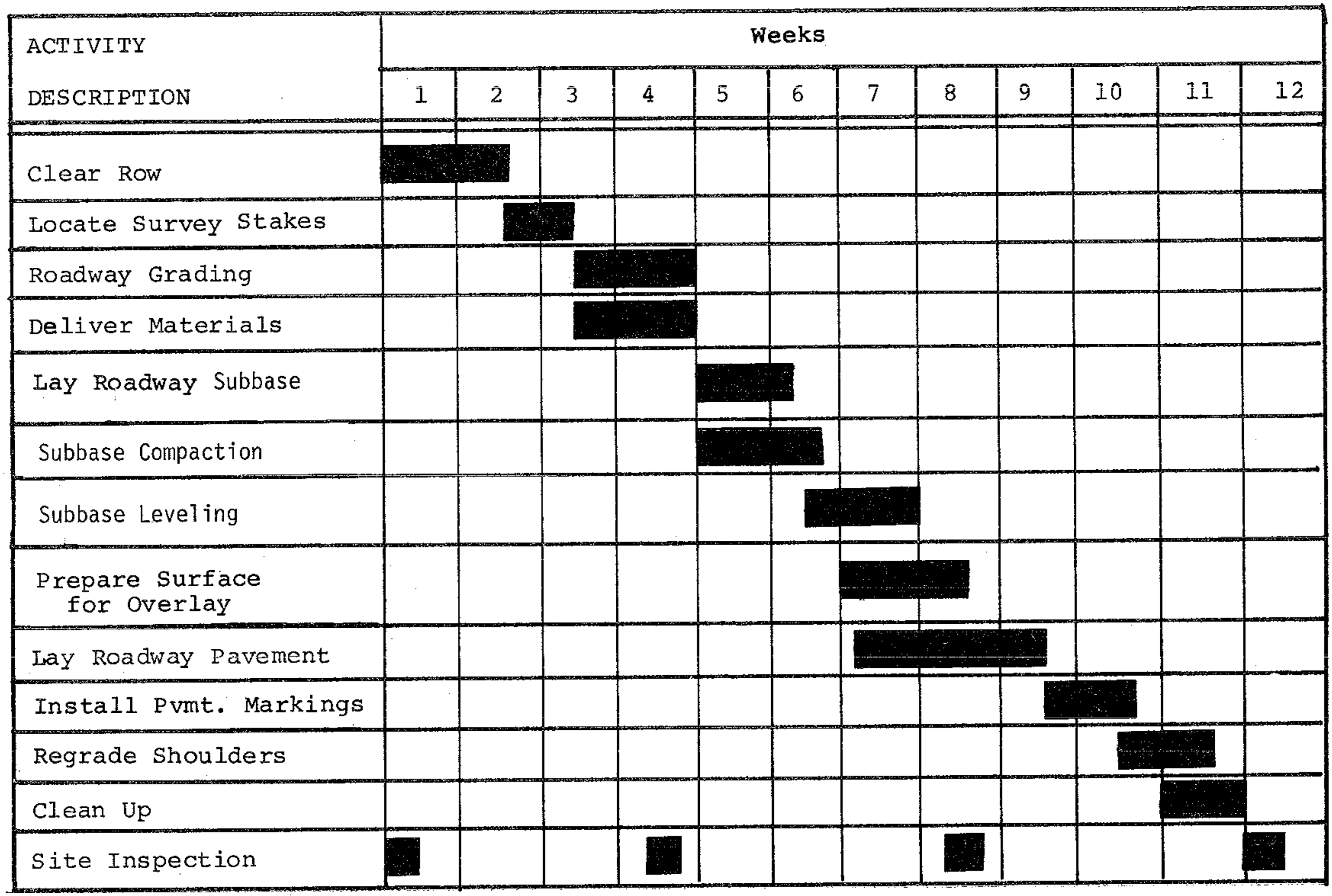



Figure 23. Example of a Gantt Chart.

## RESOURCE REQUIREMENTS

- Requires at least one qualified person to develop the charts.

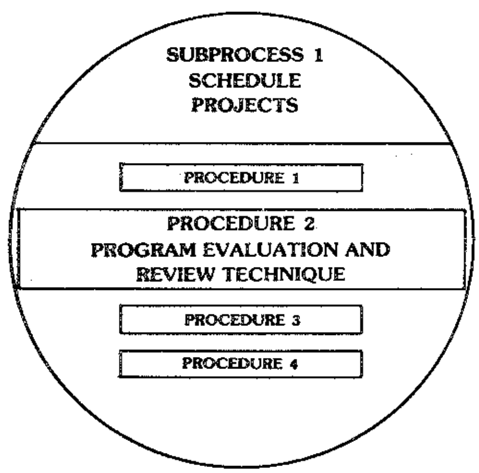
## ADVANTAGES AND DISADVANTAGES

### Advantages

- Can be used in multiproject scheduling
- Easy to prepare and understand
- Can be adapted to detailed schedules

### Disadvantages

- Not practical for complex projects where careful control is needed of critical activities
- Does not show interrelationships between activities
- Does not indicate "critical" activities (or the critical path of activities)




## PROCEDURE 2 - PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT)

## DESCRIPTION

PERT is a network diagrammatic technique used for scheduling and controlling many activities throughout a project. It generally consists of activity blocks which are connected by activity arrows. The activity blocks represent events in the sequence of a logical plan. They indicate work completed to a specific event. The activity arrows contain numbers corresponding to the expected completion time. An example of a PERT chart is given in Figure 24 [1]. For each activity of a project, input includes an estimate of the:

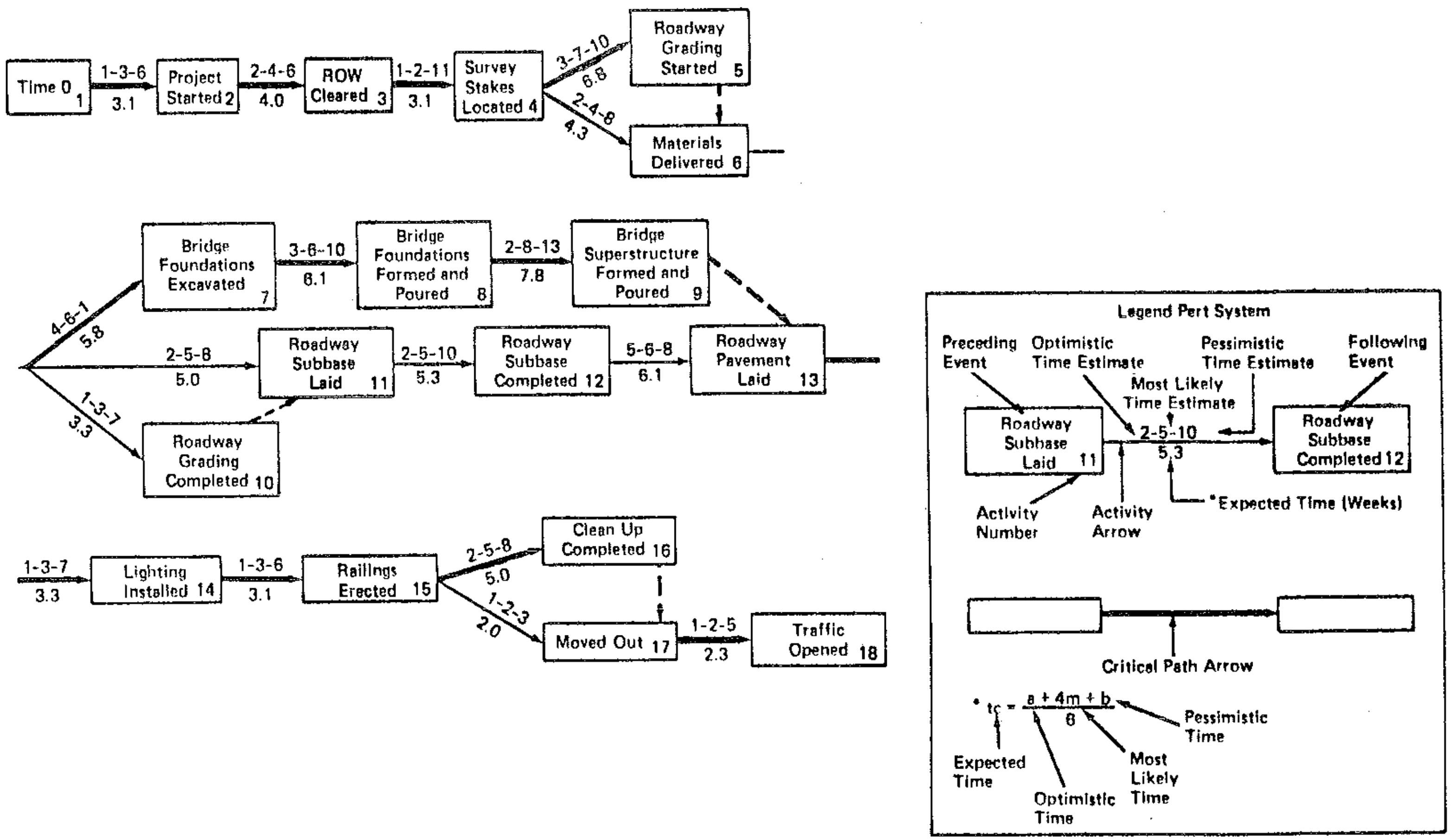



Figure 24. Example of a PERT diagram.

(Source: Reference No. 1)

- Optimistic time estimate
- Most likely time estimate
- Pessimistic time estimate

APPLICABILITY

- Is most applicable for projects where a range of time estimates is preferred for each event

RESOURCE REQUIREMENTS

- A computer program is an optional way to produce PERT charts if desired, particularly for complex projects
- Manual methods require manpower resources

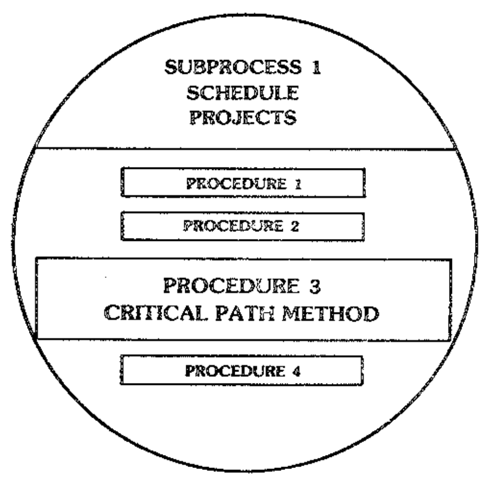
ADVANTAGES AND DISADVANTAGES

Advantages

- Allows for developing schedules in terms of optimistic, most likely, and pessimistic time

Disadvantages

- May be more complex to utilize than other methods




PROCEDURE 3 - CRITICAL PATH METHOD (CPM)

DESCRIPTION

The CPM is also a network diagramming technique. It assumes that time estimates are readily obtainable from past experience and that the network is a progression of activities arranged in logical paths to the ending node. Given a network with times assigned for each task, it is possible to calculate all beginning and ending dates, the slack time available to activities not on the critical path, and the ending date of the entire project. A sample of a CPM chart is given in Figure 25 [1].

With CPM, the emphasis is placed on the completion of activities between nodes in contrast to PERT, which is concerned with reaching the events. The numbers at the nodes can be used to identify the activities taking place between the nodal points. The beginning node of an activity is known as the "i" node, and the end node is called the "j" node. Estimated times for each activity are made by the people responsible for performing the specific activity.

APPLICABILITY

- To most types of highway projects where past experience is available to estimate the duration of activities

RESOURCE REQUIREMENTS

- Manpower - personnel to manually develop CPM diagram, or computer programmer to obtain CPM output on computer
- Equipment - Computer or desk calculator

ADVANTAGES AND DISADVANTAGES

Advantages

- Applicable to most types of highway projects
- Easily applied using the computer
- Works well for very complex projects

Disadvantages

- May not be fully effective to give a clear picture of the effect on the project by intermediate changes or activity revisions
- When and how to apply personal judgement by project managers may not always be clear

Highway and Bridge Project – Critical Path Method (CPM)

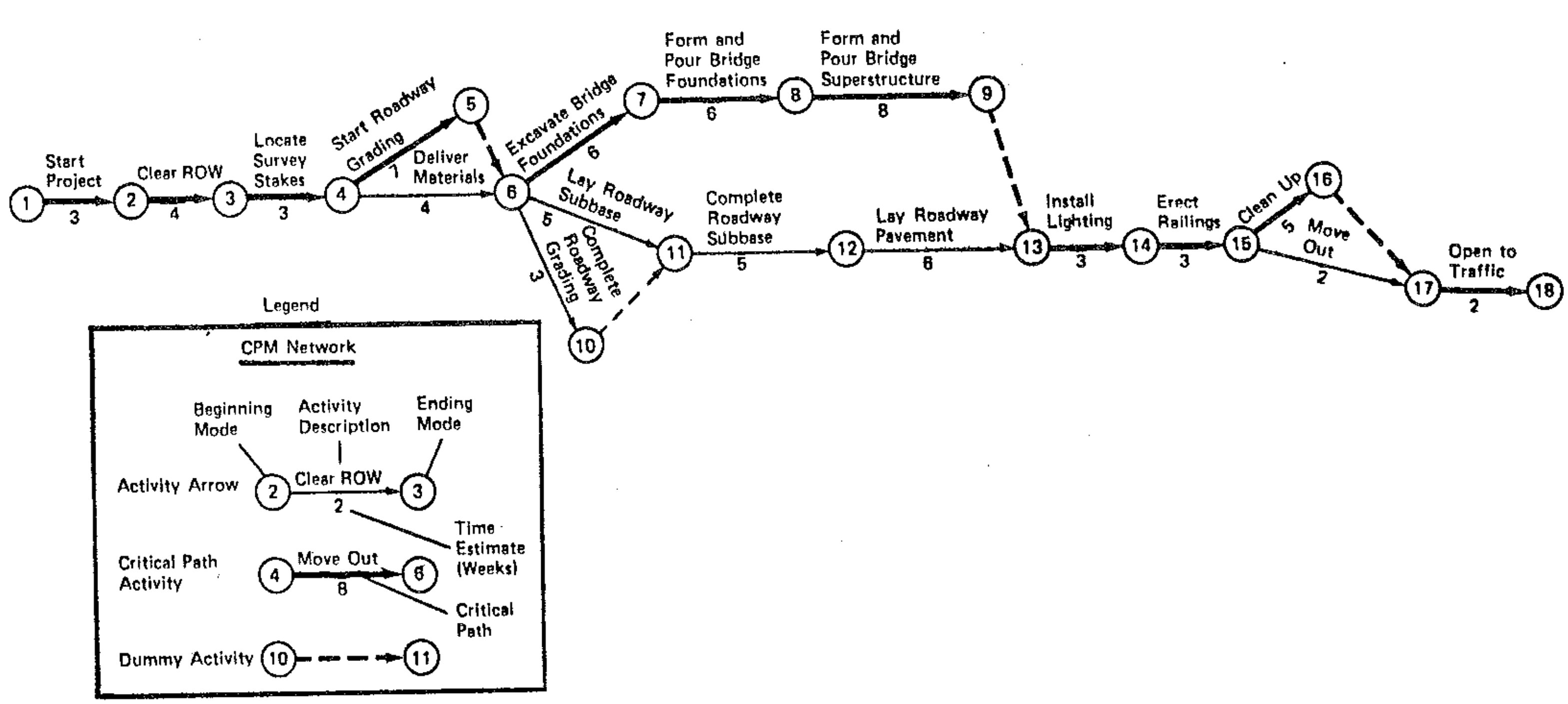
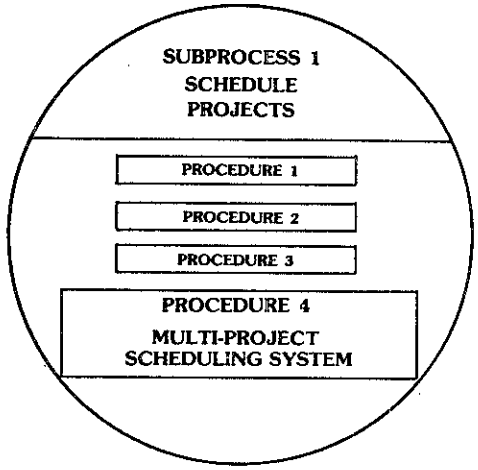



Figure 25. Example of a CPM network

(Source: Reference No. 1)




## PROCEDURE 4 - MULTIPROJECT SCHEDULING SYSTEMS (MPSS)

### DESCRIPTION

Multiproject scheduling provides the necessary information to control a group of projects by a highway agency. MPSS includes resource balancing and is a formal method of scheduling and monitoring the status of highway preconstruction and construction activities. One of the primary purposes of MPSS is to achieve optimum utilization of all available financial and manpower resources. It combines the methodology of CPM and the simplicity of Gantt Charts. It can also handle the problem of a sudden lack of a particular resource (money or manpower) by shifting resources where they are needed the most.

To operate effectively, multiproject scheduling requires the input of planned projects within the next 5 to 10 years. Also, the estimated cost of each project phase must be reasonably matched with expected benefits in the appropriate future time period. As project priorities change, the work program must be updated. Management support is a prerequisite for success of the operation of the system [1].

### APPLICABILITY

- A group of projects within a highway agency
- Individual projects which are complex or consist of numerous activities
- For controlling an agency's total resources over a long period time

### RESOURCE REQUIREMENTS

- Computer facilities and programmers to handle routine monitoring, rescheduling, and revising of multiple projects

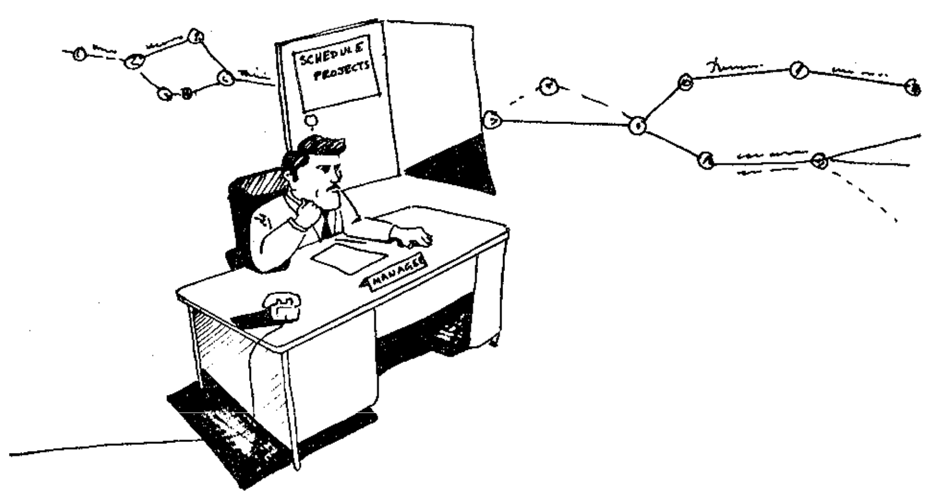
## ADVANTAGES AND DISADVANTAGES

### Advantages

- Allows for the scheduling of resources for a highway agency over a 5 to 10 year period
- Well-suited for scheduling numerous projects
- Allows for detecting future scarcities in certain types of resources, so appropriate management actions can be taken

### Disadvantages

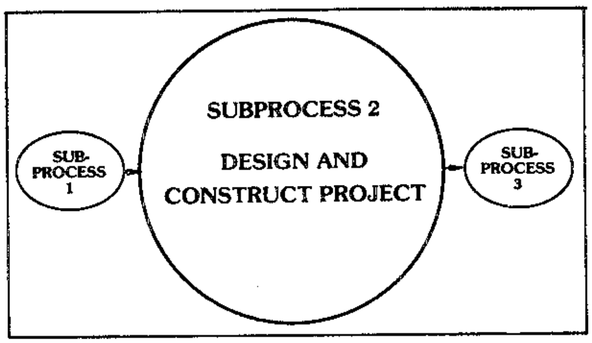
- It is more complex than other scheduling methods
- The use of a computer is needed in most cases
- To operate effectively, it requires a work program which includes all projects to be constructed within the next 5 to 10 years



# PROCESS 1, SUBPROCESS 2

# DESIGN AND CONSTRUCT PROJECTS

IMPLEMENTATION COMPONENT




PURPOSE

The purpose of this subprocess is to design and construct all highway safety projects which were selected in the Planning Component according to the schedule developed in Subprocess 1 (Schedule Projects).

DESCRIPTION

Project design and construction involves performing the selected safety improvement. All improvements should meet current design standards. Some projects will involve major costs for design, such as highway reconstruction projects. Many safety improvement projects, however, require a minimal amount of actual design work. Examples of such projects include:

- Pavement striping projects
- Highway signing
- Traffic signal modification and installation
- Removal of roadside obstacles
- Installation of flashing beacons

The construction of a highway safety project can be carried out by local (city, county, etc.) or state forces, or by private contract. The manpower availability and project costs play an important role in the decision of how a project should be constructed. Project design and construction should be started as soon as possible for most projects, since a delay of a few months could result in considerable cost increases of both labor and materials, particularly for large-scale construction projects. Unnecessary delays in projects could also allow for traffic accidents, injuries and deaths which may have been prevented if the countermeasures were completed in a more timely manner.

## MANAGERIAL CONCERNS

- Does the project design conform to accepted standards and to the Manual on Uniform Traffic Control Devices (MUTCD)?
- Which projects should be completed by agency personnel, and which should be conducted by contract?
- Is sufficient personnel available to properly monitor all projects simultaneously?
- Which projects involve the acquisition of additional right-of-way?
- Which projects will involve Environmental Impact Statements (EIS's) and Public Hearings?
- What is the status of agency supplies and equipment which will be needed to construct some of the projects, which might include:

  - Sign truck
  - Striping machines, paint, glass beads, etc.
  - Graders and other heavy equipment
  - Supply of appropriate signs and posts
  - Traffic signals and electrical equipment
  - Guardrail sections and posts
  - Light poles and luminaries
  - Paving equipment, asphalt, etc.

## INPUT AND OUTPUT

### Management Input

- The guidance of projects through completion

### Resource and Equipment Input

- Equipment for completing improvements
- Materials to be used for completing improvements
- Funding for project design and construction

### Data or Informational Input

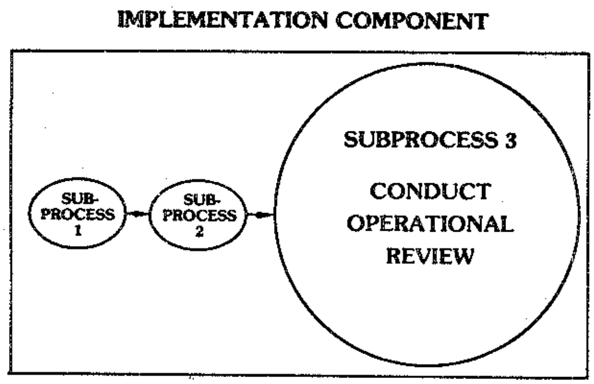
- A time schedule for implementation of all recommended safety improvement projects

### Output

- The completed highway safety improvement projects

# PROCESS 1, SUBPROCESS 3

# CONDUCT OPERATIONAL REVIEW




PURPOSE

The purpose of an operational review is to inspect a location shortly after a safety improvement has been made to determine whether the improvement is working up to expectations. Modifications are then made as required.

DESCRIPTION

An operational review involves the informal observation and possible adjustments in a highway improvement to help insure the smooth and safe flow of vehicles through the location after an improvement is completed. Operational reviews can also be made in stages as a project progresses to help correct possible construction problems at the earliest point in the project.

One example of operational review would be field observations shortly after the installation of a new traffic signal at an intersection. A slight modification in the signal timing may be needed due to excess backup on one particular approach. This may be a result of recent shifts in traffic volumes which were unexpected.

For each highway improvement, the manager must determine what types of considerations to use before conducting an operational review. For example, the following considerations might be used when reviewing two specific improvements:

| Improvement Type | Possible Review Considerations |
|---|---|
| New traffic signal at an intersection | • Is vehicle backup excessive on any approach?<br>• Are many vehicles running the red signal phase?<br>• Can the signal be seen from necessary vantage points?<br>• Does the signal timing handle traffic flow in all directions? |
| Re-design of horizontal curve | • Does water drain properly from curve during rainy conditions?<br>• Do many vehicles run onto shoulder as they negotiate the curve?<br>• Does the new curve conform to design standards within allowable limits? |

While such a list of considerations should be developed before each operational review, there may be other problems detected by the review team during the actual field inspection which should be noted and corrected.

Specific guidelines have been established by FHWA for conducting operational reviews. One FHWA publication in 1973 discusses operational reviews in terms of an organized and continuing program of field observations and inspections of highway facilities and traffic [1]. A later report by FHWA in 1979 updates the guidelines for safety reviews in terms of [2].

- Office review activities
- Field review activities

A report format is recommended which summarizes information for each completed highway project, as given in Figure 26. Individual project reports should reflect observations with respect to standards and policies, as well as the intended final product [2].

It is also recommended that the review team should include the following types of personnel:

- Traffic Engineer from the Central Office DOT
- Design Chief or representative from the appropriate district.
- FHWA Division Safety Program Engineer
- State or division person knowledgeable about the AASHTO Barrier Guide

A representative from the local office of the highway patrol can also provide valuable information with regard to the operational characteristics of the highway facility under review [2].

REPORT FORMAT

Part I - Project History

Project Description:

FAP No.__________________ Facility Type/No. Lanes __________
Route __________________ Posted Speed __________________
Location __________________ Length __________________

Dates:
PS&E Approval __________________
Completed __________________
Opened to Traffic __________________

Widths:
Lanes ____________ Median ____________
Shoulders ____________ Clear Zone ____________

Safety Upgrading Work Completed To Date:

General Statement Describing Terrain __________________

Accident Data:

| | Before | After |
|---|---|---|
| AADT | | |
| Total Accidents (No./Rate) | | |
| Fatal Accidents (No./Rate) | | |
| Injury Accidents (No./Rate) | | |
| Skid Number (Desirable) | | |
| Dates Evaluated | | |

Part II - Project Review

This section should contain review team observations and recommendations, as well as, Division Office and State highway agency response and proposed actions for each major finding covered in the review guidelines.

Figure 26. Recommended Report Format for Operational Review.

(Source: Reference No. 2)

Part III - General Comments

This section should contain any general project-related observations or comments the review team, Division or State, wish to include in the report.

Members of Review Team:

________________________
________________________
________________________
________________________
________________________
________________________
________________________
________________________

Date ____________
State ____________

Figure 26. Recommended Report Format for Operational Review (Continued).

(Source: Reference No. 2)

Specific guidelines for operational reviews have been described by FHWA in terms of ten major categories, or parts, as follows:

- Part A - Accident Data
- Part B - Pavement Surface
- Part C - Traffic Barriers
- Part D - Roadway Discontinuities
- Part E - Bridges
- Part F - Roadside Obstacles
- Part G - Signing
- Part H - Pavement Marking and Delineation
- Part I - Pedestrians and Bicycles
- Part J - Maintenance

The following information is provided which includes many of the important considerations for conducting an operational review as taken from the "Highway Safety Review Guidelines", published by FHWA in 1979 [2].

## GUIDELINES

### Part A - Accident Data

The review team's primary objective in the area of data collection and analysis is to assess how accident reports and experiences are being used by design and traffic engineers, and maintenance personnel to evaluate the performance of highway systems and their appurtenances. The review team should report the following:

- o Describe any advantages or shortcomings of the accident reporting and analysis system. Which roadway classes are included in the data base?

- o Is data available to evaluate the performance of specific types of safety improvements? If so, are evaluations being conducted, and results coordinated with design, traffic, and maintenance personnel to effect change in design and maintenance policy?

- o Is data for a particular project readily retrievable in a useful format -- by number, accident rate, severity, accident type, and location? Have collision diagrams been prepared?

- o Is the accident data used to prioritize high hazard locations? If so, describe the process and estimate the time for corrective action.

Part B - Pavement Surface

The paved portion of any highway facility provides the usable widths of lanes and shoulders, the traction needed for maneuvers on both wet and dry pavements, and the structural stability to accommodate traffic. Full pavement and shoulder widths have been very safety-cost effective in reducing accident rates and should be consistently maintained throughout the roadway cross-section including bridge structures. While roadway elements such as alignment, grade, superelevation, and drainage affect accident frequency, a skid resistance pavement is the key factor providing the traction essential for reducing wet weather accidents. During the office review, the team should report the following:

- Has the State developed a skid resistance inventory for all roads? If so, is this information used to identify locations with a high frequency of wet weather accidents?

- What method(s) does the State use to provide surface texture on asphalt and concrete pavements? How are pavement edge dropoffs avoided on overlay projects? What height of drop-off does the State consider unsafe?

- When resurfacing, does the State carry the skid resistance coarse across bridge decks? If not, are bridge decks retextured? Are pavement design performance records related to skid resistance?

- Does the State permit the use of studded tires? If so, has their use been evaluated with respect to pavement performance and service life? If the State has banned studded tires, have they analyzed their total winter accidents to determine impacts on safety?

- Does the State use rumble strips? If so, to what extent and has their effectiveness been evaluated?

During the field review, the team should report the following:

- Are consistent lane and shoulder widths provided? Is the pavement smooth riding?

- Is the surface texture uniform, or are variations observed on roadway sections, intersections, gore areas, and bridge decks?

- Are pavement edges tapered during resurfacing projects, or do pavement dropoffs (low shoulders) exist?

- o Does the pavement show signs of wear or distress -- bleeding, polishing, rutting, ravelling, pot holes, ponding, etc.?

- o Do maintenance practices such as longitudinal patching cause differential traction?

<u>Part C - Traffic Barriers</u>

To improve highway safety, emphasis has to be placed on the elimination of hazardous roadside conditions. Providing warranted traffic barriers -- guardrail, impact attenuator, New Jersey median barrier -- and upgrading existing barriers is one of the most cost effective methods of eliminating hazardous conditions. For fixed objects and hazards along the roadway, the following rules have generally been applied:

1. Removal is the first alternative considered.

2. If it is not possible to eliminate or relocate, make the hazard yielding or collapsible.

3. Shield the traffic from non-removable or non-breakaway hazards only if the traffic barrier creates less of a hazard than object it is to shield.

Using barriers where needed is only part of the solution: selection of the appropriate system and proper location, installation, and maintenance are also critical to its performance. During the office review, the team should report the following:

- o Has the State adopted AASHTO's "Guide for Selecting, Locating, and Designing Traffic Barriers" (GSLDTB)? If not, which guides or standards are being used, have they been approved by FHWA, and do they reflect current technology with respect to deflection criteria, post spacing, height, end treatments, end post connections, etc.? Identify any significant deviations from the GSLDTB. Does the State's standards include performance criteria?

- o What criteria or priorities are used for selection of sites for barrier treatment? Are the high hazard locations periodically identified, and then field reviewed during the design stage? Is actual accident experience used to identify those hazards which, if protected, yield the highest potential for reducing accident severity?

- What is the State's maintenance policy and practice with respect to priority of timely replacement or damaged barrier systems? Are damaged systems replaced "in-kind" or upgraded? Is cable tension adjusted periodically? Do maintenance personnel report problem locations to design for alternate solutions? Does the State let contracts for maintenance of guardrail?

- What is the State's policy for safety upgrading projects? Are barrier systems raised when resurfacing is required? Is guardrail replacement on upgrading projects limited to terminal sections? Are rail delineators used to improve night visibility, and aid in snow-maintenance operations?

During the field review, the team should report the following:

- Do any unprotected hazards exist? Can they be eliminated, or made yielding? Are traffic barriers warranted, or do they present a more severe hazard? Has sufficient barrier length been provided to satisfactorily shield the hazard from impact? Are all nearby secondary hazards shielded as well?

- Are traffic barriers being installed per plan? Identify any deviations observed -- post spacing, block-outs, height, anchorage, etc.

- Can the barriers perform as intended? Are sufficient deflection space and development length provided to withstand impact? Do adjacent curbs, grades, pavement dropoffs, or snow/ice buildup compromise the effectiveness of the system?

- Are guardrail end sections turned back and buried in cut slopes where possible? Are short gaps left between adjacent sections of rail? Are clear zones behind BCT terminal sections provided?

- Are bridge end post connections susceptible to pocketing or snagging a vehicle? Has bridge rail been upgraded to current standards? Are bridge piers adequately shielded?

- Has maintenance repaired damaged barrier systems in a timely manner especially at critical locations? How long before damaged sections observed will be repaired? Are barrier systems being repaired per original design?

- Does the sequence of construction events permit substandard installation of guardrail? For example, if guardrail is placed before base and pavement, inadequate guardrail height may result.

Part D - Roadway Discontinuities

For the purpose of this review, roadway discontinuities include intersections, interchanges, merge and gore areas, short radius curves, construction zones, and abrupt transitions from new sections of highway to old. These sections must be carefully designed so that the driver, especially the unfamiliar motorist, has time to adjust to reduced standards or changed conditions thereby avoiding "last second" hazardous maneuvers. Appropriate signing and delineation, as well as a skid resistant surface and forgiving roadside, must be provided and maintained in these critical areas. Often times, discontinuities on non-Interstate roadways receive little attention -- even though traffic volumes and posted speeds are similiar to those of Interstate routes. Where these conditions exist and improvements are not economically feasible, the obvious alternative is to post a lower and potentially safer speed, and enforce it. During the office review, the team should report the following:

- o Does design policy emphasize route consistency and uniform treatment of interchanges, intersections, merge and gore areas, clear roadside, etc.?

- o Are accident experience/maintenance records used to identify high hazard roadway discontinuities?

- o What are the factors for determining posted speeds? Is enforcement in construction zones for example, coordinated with the Police?

- o Have formal policies for crossroad construction and maintenance responsibilities been established? Are intersections and grade separations upgraded as part of a safety project?

- o What standards are used for upgrading toll roads?

During the field review, the team should report the following:

- o Are roadway discontinuities designed to current standards? Are adequate signing, delineation, transition length, sight distance, and clear roadside recovery area provided and maintained especially in critical sections?

- o Is design consistency practiced at interchanges, at grade intersections, lane drops, etc.? Are unexpected discontinuities compensated by additional signing, delineation, and clear roadside?

- Comment on the degree of access control and any encroachments. Are railroad crossing, driveways, and at-grade intersections signed appropriately? Are crossroads upgraded to current standards?

- Is the posted speed consistent with existing hazards and roadside geometrics? Is this speed enforced? Does the posted speed reflect bicycle and pedestrian activity?

- Are gores traversable, and free of curbs and other fixed objects? Are signing and delineation adequately maintained? Are advisory ramp speed signs visible and do they provide adequate warning?

- Are smooth transitions to construction zones and to old sections of highway with reduced standards provided? Are traffic control devices adequately maintained?

<u>Part E - Bridges</u>

Bridges pose a significant threat to errant vehicles because of their restricted roadside recovery areas and because some bridge widths are narrower than their approach lanes and shoulders. When it is not economically feasible to widen a narrow structure, adequate signing, striping and approach barriers should be provided and maintained until a more permanent improvement can be made. During the office review, the team should report the following:

- Are accident experience, ADT, and sight distance used to prioritize bridge widening or replacement candidates? What other criteria does the State use for project selection?

- What is the State's policy for narrow bridge treatment when widening is not economically feasible?

- During upgrading projects, are bridge and approach rails upgraded to current standards? Are protruding curbs eliminated? What is the State's median barrier policy to prevent vehicle encroachment between parallel structures (elephant traps)?

- Does the State allow construction projects to terminate at or near a beginning of a bridge? If so, what transition treatment is used?

During the field review, the team should report the following:

- o Is bridge and approach rail installed per-plan? Identify any deviations from current standards. Does the approach rail have the potential to pocket or snag on vehicle impact? Are barrier systems adequately maintained?

- o Are sufficient signing and striping provided and maintained? Are Object/Hazard markers used on all bridges with protruding curbs or less than full width shoulders?

- o Is sufficient median guardrail provided to prevent vehicle encroachment between parallel structures?

- o Are overlays continuous over bridge decks and approach slabs?

Part F - Roadside Obstacles

Roadsides must be negotiable and grading should be such that a recovery area is available to the driver. The recovery area must be clear of fixed objects: those that must remain should be made yielding, or shielded. Desirably, additional clear distances should be obtained where feasible at other critical locations (outside of a tight curve, toe of a steep slope) even though the fixed object may very well be situated outside the minimum clear distance required. During the office review, the team should report the following:

- o Has the State adopted the 30-ft. clear zone as an absolute standard, or is the State's policy sensitive to providing additional clear distance at critical locations and where it can be accommodated? Is the policy flexible enough so that formidable hazards just beyond established clear zone limits are made forgiving?

- o Has the State adopted formal policies concerning the width of clearing for trees and the diameter of small trees that can remain unshielded?

- o Does the State's maintenance policy provide for the removal of large trees close to the travelled way, pruning where sight distance or sign visibility is critical, and for the clearing of seedlings?

- o Does policy provide that rock cuts be shielded with a protective barrier or does State policy permit adequate excavation for a clear recovery area?

- Does the State have uniform standards for the placement of mailboxes? Do the standards include a proximity to travelled way?

- Does the State have permit procedures for driveways? Are driveway sideslopes made traversable?

- Does policy indicate that flat slopes be provided and drainage inlets, ditches, etc. be made traversable? What is the State's policy concerning headwall location and height?

- What is the State's policy on lighting? Is lighting only provided at critical locations such as gore areas or intersections? Do light poles have breakaway qualities?

- Does the State coordinate with the appropriate agencies and formalize policy on the location of utility poles, shielding of railroad crossing signals, etc.?

During the field review, the team should report the following:

- Has a clear/forgiving roadside recovery area been provided? Have all unnecessary roadside obstacles been eliminated? Does the proximity of existing fixed objects -- trees, utility poles, rock outcrops, curbs, mailboxes, headwalls, etc. -- compromise safety effectiveness? Are obstacles that remain delineated?

- Are the formal policies determined in the office review being practiced? Is a lack of clear roadside uniformity evident? Identify any deviations from policy or standards.

- Are drainage grates, ditch slopes, and headwalls traversable? Are existing curbs especially in gore areas necessary for drainage, or can they be eliminated?

- Can rock cut faces in narrow medians, and isolated outcrops or boulders be eliminated? If not, are they shielded? Is pavement edgeline striping adequately maintained adjacent to rock cuts? Are cut areas free of fallen rock?

Since signing constitutes a major portion of roadside obstacles and because of its other safety concerns such as message clarity, it warrants the separate discussion presented in the following section.

## Part G - Signing

Traffic control devices represent the largest group of hardware items placed along our highway systems. They are certainly a necessary part of the design process for safety and effeciency of operations. Signs must not only communicate effectively, but they should be located to present the least possible hazard to the motorist. During the office review, the team should report the following:

- o Has the State adopted the MUTCD? Have they supplemented the MUTCD with State standards? Have these standards been approved by FHWA?
- o What is the State's policy with respect to traffic control devices with breakaway features and their distance from edge of travel lane? What is their interpretation of the clear zone as related to sign supports?
- o Does the State keep records of the safety performance of their sign hardware? Are sign posts overdesigned for sign panel size?
- o Do the plan sheets and signing guides include performance standards and criteria for various sign supports?
- o Do standard plans for breakaway features address proper installation techniques so performance is not sacrificed? Are maintenance forces made aware of the techniques and performance features of the breakaway supports?
- o Evaluate State standards relative to drilling and slotting policy for timber posts. Is maintenance kept informed of this policy?
- o During the widening or upgrading of arterials, does the State also upgrade signing on intersecting crossroads? If not, who does the upgrading and is it monitored by the State?
- o Are dirty signs cleaned as warranted?

During the site review, the team should report the following:

- o Evaluate sign illumination, reflectivity, placement, visibility, adequacy, and maintenance.
- o Do driver cues in the form of signs provide enough advance information for nonlocal drivers to safely negotiate their intended route.

- o Review installations to see if signs are placed outside the recovery zone and are breakaway. Can signs be relocated onto nearby structures or to non-critical areas?

- o Review breakaway sign features for proper installation including panel heights, hinge points, buried slip bases, overheight footings, etc. Are timber posts drilled or notched to meet breakaway criteria?

- o Do signs that are vulnerable to traffic in more than one direction have a multidirectional breakaway feature?

- o Review intersecting crossroads for adequate sight distance and advance warning.

- o Do advisory speed signs on ramps, curves, etc. provide enough advance warning? Are the signs blocked by light poles and other signs etc.? Are they visible at night?

- o Are signs in conformance with the MUTCD with respect to size, height, reflectivity, location etc.?

Part H - Pavement Marking and Delineation

The driver receives visual cues from the pavement and edge of roadway that assist him in the driving task. The fact that over half of the national fatality toll occurs during hours of darknesss points out the need for good roadway delineation. Both day and night reviews are necessary to observe the adequacy of lane and pavement edge delineation. During the office review, the team should report the following:

- o Are the pavement markings and delineation policies in conformance with the MUTCD?

- o What is the State's policy concerning the striping of no passing zones?

- o What is the State's policy concerning unnecessary pavement marking eradication? What is the State's policy concerning maintenance of roadside delineation?

- o What is the State's policy concerning restriping of lane lines, edgelines, and gores? Are night reviews and wear rates considered in developing restriping schedules?

- o What is the State's policy relative to installation of delineators on the Interstate? Are raised pavement markers used?

During the field review the team should report the following:

- o Are pavement markings and delineation appropriate for the particular location or do they cause driver confusion?

- o Are lane lines, edgelines, and delineators adequately maintained and in conformance with the MUTCD?

- o Are sufficient visual cues provided in critical areas such as tight curves, narrow bridges, gores, transitions, etc.?

- o Are pavement markings and delineation effective at night? Have misleading and old markings in construction zones been eradicated?

<u>Part I - Pedestrians and Bicycles</u>

Pedestrian and bicycle safety is a serious national and local problem. Each year about 10,000 pedestrians and 1,100 bicyclists are struck and killed by vehicles. The problem is especially serious in urban areas. Good highway design must accommodate both the pedestrian and bicyclist, and where warranted, provide refuge and separation from vehicular traffic. Care must also be taken to insure that highway features do not prove to be hazardous obstacles to pedestrian traffic. During the office review, the team should report the following:

- o Review the States policy with respect to the accommodation of pedestrians and bicycles on new and upgrading projects. Are pedestrians and bicycles a consideration during design and construction of the project?

- o Are pedestrian accidents analyzed separately? Does the State have warrants for pedestrian accommodations?

- o Is there a statewide policy on sidewalk construction and a requirement to evaluate pedestrian movements in urban areas?

- o Do State laws or policy prohibit or restrict the construction of sidewalks, wheelchair ramps, or bikeway facilities?

- o Is pedestrian accident data readily available and is it being used to establish needs for pedestrian accommodation?

- o Are sidewalks and wheelchair ramps provided in school zones?

During the site review, the review team should report the following:

- o Evaluate projects to see if sidewalks, wheelchair ramps, and bike lanes have been provided in high use areas? Are sidewalks continuous and clear of obstructions? Are curb cuts provided?

- Review grade separations, and access ramps to urban streets to see if there are provisions for pedestrians. Have crosswalk markings been provided?

- Have pedestrian/handicap facilities been provided?

- Are bike lanes signed and striped properly? Observe bike lane treatment at intersections.

Part J - Maintenance

Maintenance personnel must be informed and trained on the safety characteristics and maintenance priorities of various roadway elements. Although all roadway features deserve timely routine maintenance, certain elements require special attention because of their placement, location, design, or volume of traffic. Maintenance personnel must be knowledgeable of how certain designs perform to enhance safety and reduce accident experience and severity. In addition to the maintenance activities previously discussed, the review team should report the following:

- Does the State have a maintenance program that establishes maintenance priorities? Does the State maintain an adequate replacement inventory for replacement of damaged hardware, signs, etc.?

- Are signs, and other traffic control devices maintained adequately at potentially hazardous locations such as narrow bridges, transitions, construction zones, intersections, etc.?

- Have breakaway signs been repaired with the correct replacement parts? Will they operate as orignially intended?

- Do unnecessary signs such as add-on signs compromise breakaway performance?

- Are pavement marking and delineation adequately maintained?

- Do trees, shrubs, etc. obscure traffic signs?

- Have proper adjustments and repairs been made at locations with BCT?

## MANAGERIAL CONCERNS

- Are operational reviews being conducted for all highway safety improvements?
- During the operational reviews, are the investigators aware of the appropriate kinds of considerations?
- Are the operational reviews being performed concurrently with project construction and promptly after an improvement is made to insure that necessary adjustments are made as soon as possible?

## INPUTS AND OUTPUTS

### Management Input

- A knowledge of the intended results of each improvement

### Resource and Equipment Input

- Funding
- Manpower to conduct the Operational Review
- Materials

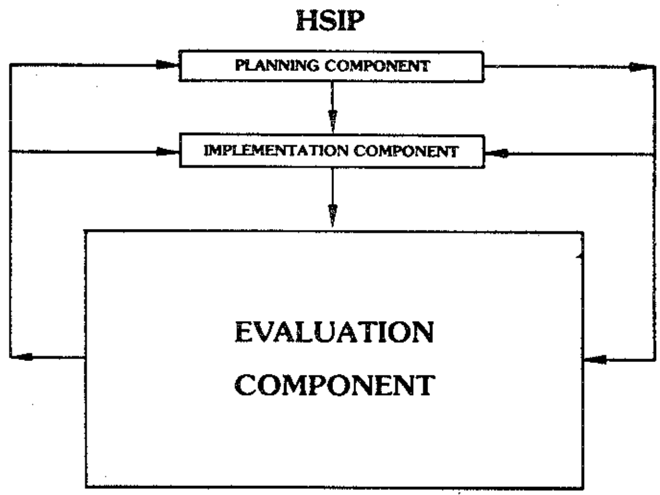
### Data or Informational Input

- The completed highway safety improvement projects (from Subprocess 2 - "Design and Construct Projects")

### Output

- The completed highway safety improvement projects with appropriate operational adjustments

# EVALUATION COMPONENT




PURPOSE

The purpose of the Evaluation Component is to assess the value of ongoing and completed highway safety projects and programs which result from the Planning and Implementation Components.

DESCRIPTION

The Evaluation Component consists of one Process, "Determine the Effect of Highway Safety Improvements" as specified in FHPM 8-2-3, and follows the Implementation Component of the HSIP. The ultimate goal of evaluation is to improve the agency's ability to make future decisions within all components of the HSIP. These decisions can be facilitated by conducting formal evaluations of ongoing and completed highway safety projects and programs. The results of these formal evaluations serve as input to every component of the HSIP.

Evaluation involves obtaining and analyzing quantitative information on the benefits and costs of implemented highway safety improvements. The utilization of estimated benefits and costs reduces the agency's dependence on engineering judgement and helps in selecting future projects with the highest probability for success. This allows for the better allocation of scarce safety funds and minimizes expenditures for projects which are marginal or ineffective.

## INPUTS AND OUTPUTS

### Managerial Inputs

- Guidance of technical personnel in conducting reliable evaluation studies
- A knowledge and understanding of the proper planning and performance of project and program evaluations
- A knowledge and understanding of the reliability of data necessary to conduct the evaluations

### Resource Inputs

- Funds - Money to perform project and program evaluations
- Manpower - Agency personnel to plan and conduct evaluation studies
- Equipment - Standard traffic engineering equipment, including radar meters, volume counters, and tally boards may be needed. Computer facilities may be used to facilitate data analysis.

### Data or Informational Input

- A list of implemented safety improvement projects and programs
- "Before" and "After" accident data (for Accident-Based Evaluations)
- Before and after operational and driver behavior data (for Non-Accident Based Evaluation)

### Work Output

- Evaluated highway safety projects and programs

- Data for future planning and implementation activities.

CHAPTER X

# PROCESS 1

# DETERMINE THE EFFECT OF HIGHWAY SAFETY IMPROVEMENTS

**EVALUATION COMPONENT**

**PROCESS 1**

**DETERMINE THE EFFECT OF HIGHWAY SAFETY IMPROVEMENTS**

## PURPOSE

The purpose of this process is to perform the appropriate evaluations (subprocesses) needed to assess the value of implemented highway safety improvement projects and programs.

## DESCRIPTION

There are two types of evaluation which may be conducted in the HSIP: Effectiveness Evaluation and Administrative Evaluation. Either type of evaluation may be performed for safety projects or programs. A project is one or more corrective measure that has been implemented at a location to correct a hazardous or potentially hazardous condition. A program is broader in scope and may consist of many projects or project groups implemented throughout an area to correct a common highway safety problem. Effectiveness Evaluation consists of:

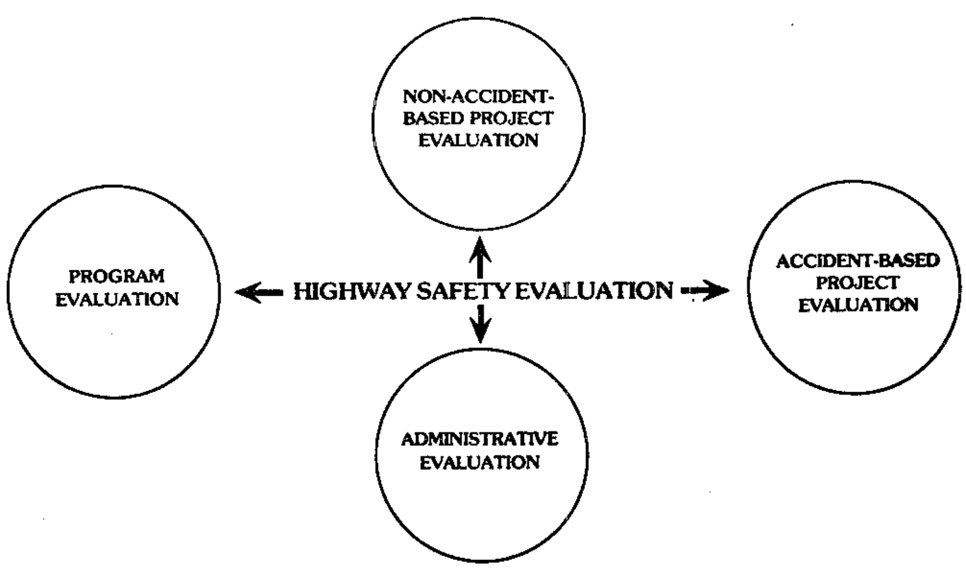
. Accident-Based Project Evaluation
. Non-Accident-Based Project Evaluation
. Program Evaluation

Accident-Based Project Evaluation measures the effectiveness of an improvement project by observed changes in the number, rate, and severity of traffic accidents resulting from project implementation. Non-Accident-Based Project Evaluation measures the intermediate effectiveness of a completed improvement project by observed changes in non-accident safety measures. Program Effectiveness measures the effectiveness of an improvement program by observed changes in accident number, rate, and severity resulting from program implementation.

Administrative Evaluation is used to supplement the Effectiveness Evaluation. It provides guidelines for determining the amounts of manpower, time, money, and material used, the differences between planned and actual resource expenditures and the productivity of implementing highway safety projects and programs.

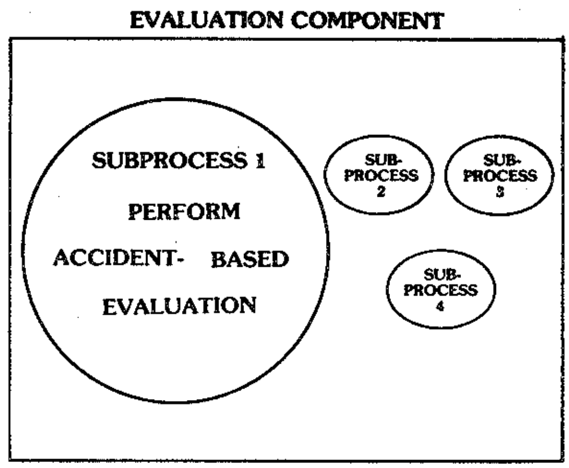
The four subprocess included under this process are:

Subprocess 1 - Perform Non-Accident-Based Project Evaluation
Subprocess 2 - Perform Accident-Based Project Evaluation
Subprocess 3 - Perform Program Evaluation
Subprocess 4 - Perform Administrative Evaluation



# PROCESS 1, SUBPROCESS 1

# PERFORM ACCIDENT-BASED EVALUATION




## Purpose

The objective of Accident-Based Project Evaluation is to assess the value of a completed highway safety project.

## Description

Accident-Based Project Evaluation consists of the following seven functions:

FUNCTION A - Develop Evaluation Plan
FUNCTION B - Collect and Reduce Data
FUNCTION C - Compare Measures of Effectiveness (MOE's)
FUNCTION D - Perform Statistical Tests
FUNCTION E - Perform Economic Analysis
FUNCTION F - Prepare Evaluation Documentation
FUNCTION G - Develop and Update Effectiveness Data Base

## FUNCTION A - Develop Evaluation Plan

The plan addresses such issues as the selection of:

- Projects for evaluation

- Project purposes
- Evaluation objectives and measures of effectiveness (MOE's)
- Experimental plans
- Data requirements

## Project Selection

The following factors should be considered when selecting projects for evaluation:

- Evaluation should be performed for those types of projects which have the highest probability of being implemented in the future.
- Accident-Based Evaluation requires collection of accident data for two- to three-year periods before and after project implementation. Monthly and seasonal variations can bias the traffic and accident characteristics of a project site if the study period is less than 2 years.
- The availability, completeness, and accuracy of accident and traffic exposure data is essential for conducting an effectiveness evaluation.
- During project selection, projects should be chosen where there are a sufficiently large number of accidents to allow statistical analysis.
- The purpose of the project should also be clearly recognized when conducting any effectiveness evaluation.

When the before number of accidents is too small to allow the project to be evaluated using Accident-Based Evaluation, the project may be combined with other similar projects to increase the size of the before accident frequency. Highway safety project files for projects implemented within the last five years should be reviewed. After grouping all highway safety projects into similar categories, the evaluator has <u>three</u> options:

- <u>Individual Project Evaluation</u> - Evaluate a project of particular interest or randomly select a single project.
- <u>Aggregate Project Evaluation</u> - When the accident sample sizes are too small for individual project evaluations, aggregate projects: where the number of projects is large enough to permit an evaluation of the entire category, representative projects can be selected using a statistical sampling technique. The selected projects can then be aggregated and/or evaluated as a single project.
- <u>Program Development For Evaluation</u> - Select completed projects to form a program for evaluation.

## Project Purpose

The <u>purpose</u> of a project is defined as the reason that the countermeasure(s) was selected for implementation. The most common project purposes are:

- To reduce traffic accidents
- To reduce the severity of traffic accidents
- To reduce hazard potential
- To improve traffic performance (secondary purpose)

Figure 27 illustrates a format for listing project purposes.

Objectives

Five fundamental evaluation objectives should be selected for every evaluation study. These objectives are to determine the effect of the project on:

- Total accidents
- Fatal accidents
- Personal Injury Accidents
- Property Damage Accidents
- Additional specific objectives related to the purpose of the project

MOE's

Measures of Effectiveness (MOE's) should be stated for each objective to provide quantifiable units of measurements. MOE's may be expressed in terms of frequency, rates, proportions, or ratios. If traffic volume or exposure data are available for the project site, the evaluator may select a rate-related MOE for each objective. Exposure units are expressed in terms of either the number of vehicles or the number of vehicle-miles of travel, depending on the type of project. The objectives, along with the MOE's of the evaluation, should be recorded as shown in Figure 28, and included in an evaluation study file.

Experimental Plan

The experimental plan should be the strongest possible experimental design that is consistent with the nature of the project and the availability of data. Four plans have been selected for use in evaluating highway safety projects:

- Before and After Study With Control Sites
- Before and After Study
- Comparative Parallel Study
- Before, During and After Study

A description of each of these experimental plans follows:

A. Before-After Study With Control Sites

This plan compares the percent change in the MOE at the project site (test site) with the percent change in the MOE at similar sites without the improvement (control sites) for the same before and after time periods.

Page ____ of ____

## PROJECT PURPOSE LISTING

**Evaluation No.** A-1

**Date/Evaluator** 2/23/77/DDP **Checked by** 2/28/77/HES

**Project No.** P-1

**Project Description and Location(s)** Replace four-way stop sign with two-phased fixed time controller at Broadway and 7th Streets

**Countermeasure(s)/Codes** Traffic Signal Installation (FHWA Code 11)

| Project Purpose | Justification |
|---|---|
| 1. To Reduce Right Angle Accidents. | 1. High incidence (32 for 3 years) |
| | of right angle type accidents |
| | during pre-project period. |
| | |
| 2. To Reduce Accident Severity. | 2. Severity of accidents was great |
| | (F and I = 50%) due to high |
| | approach speeds. |
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Figure 27. Sample project purpose listing.

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## OBJECTIVE AND MOE LISTING

Evaluation No. A-1

Date/Evaluator 2/23/77/DDP Checked by 2/28/77/HES

| Evaluation Objective | Measure of Effectiveness (MOE) |
|---|---|
| Determine the effect of the project on: (fundamental) | Percent change in: (check one) Rate X or Frequency ____ (fundamental) |
| 1. Total Accidents | 1. Total Accidents/ MV |
| 2. Fatal Accidents | 2. Fatal Accidents/ MV |
| 3. Injury Accidents | 3. Injury Accidents/ MV |
| 4. PDO Accidents | 4. PDO Accidents/ MV |
| (project purpose) | (project purpose) |
| 5. Sideswipe Accident | 5. Sideswipe Accident/MV |
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Figure 28. Sample objectives and MOE listing.

This study is considered a strong plan for highway safety project evaluation when "good" control sites can be identified. The use of control sites allows the evaluator to control for the influence of other variables on the study results. A schematic drawing describing the Before-After Study With Control Sites is shown in Figures 29 and 30.

B. Before-After Study

This plan is commonly used in the evaluation of highway safety projects, if control sites are not available. This approach is based on data collected at two points in time; before and after project implementation (see Figures 31 and 32). This plan is considered to be a rather weak design. However, in certain cases the shortcomings of the design may be minimized.

C. Comparative Parallel Study

This plan is similar to Before-After Study With Control Sites with the the exception that MOE's are not required prior to project implementation; i.e., the evaluation period specified is after project implementation. This plan is less desirable than Before-After Study With Control Sites and in some cases, less desirable than Before-After Study (see Figure 33).

D. Before, During and After Study

This is similar to the Before-After Study with the modification that measurements are taken at three points in time. This plan is applicable for temporary projects which are to be discontinued or eliminated after a period of time (see Figure 34).

Experimental plans should be selected on the basis of their ability to maximize internal validity and be applied under prevailing practical limitations. The flow diagram shown in Figure 35 illustrates the experimental plan selection process when practical limitations are to be considered.

The selection of the experimental plan aids in the identification and collection of data and guides the evaluator to the appropriate data analysis and comparison activities.

Data Requirements

Evaluation data needs depend on the following criteria:

- Objectives and MOE's of the evaluation
- Anticipated impacts from the environment surrounding the project site
- Project costs, including implementation, operation, and maintenance costs
- Anticipated impacts (other than the objectives) on the environment resulting from the project

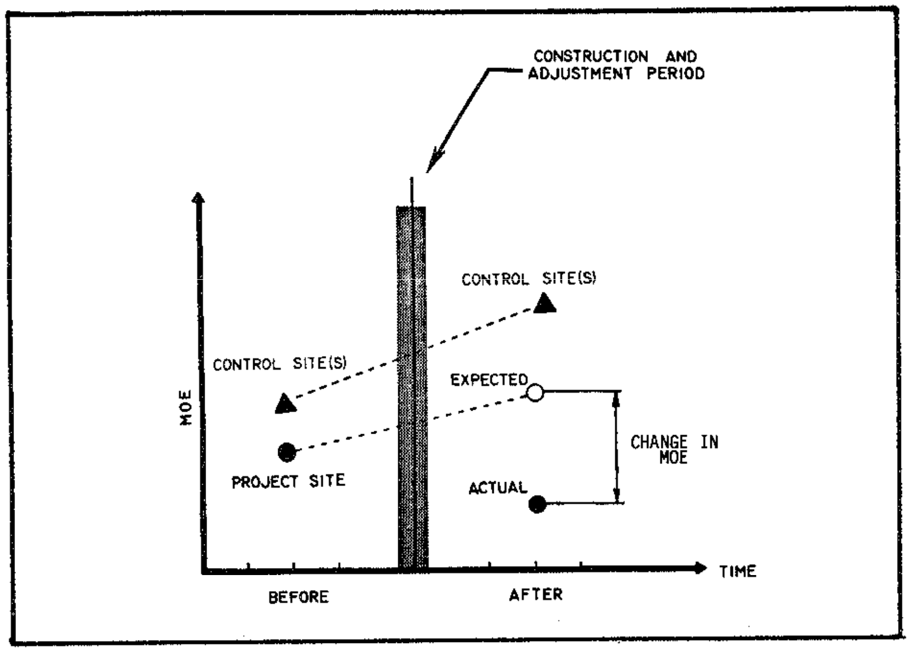



Figure 29. Before and after study with control sites.

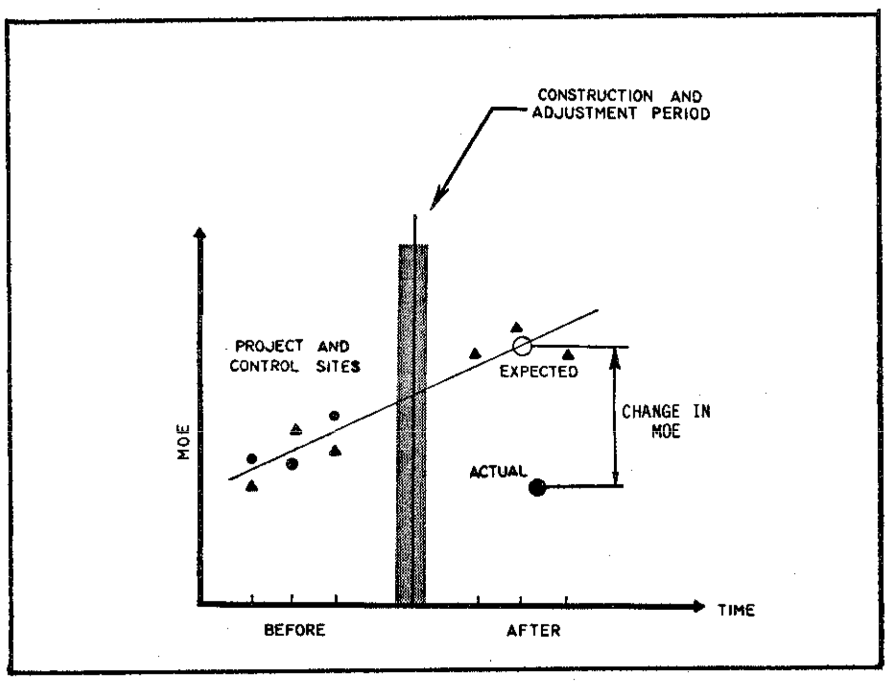



Figure 30. Before and after study with control sites (trend analysis).

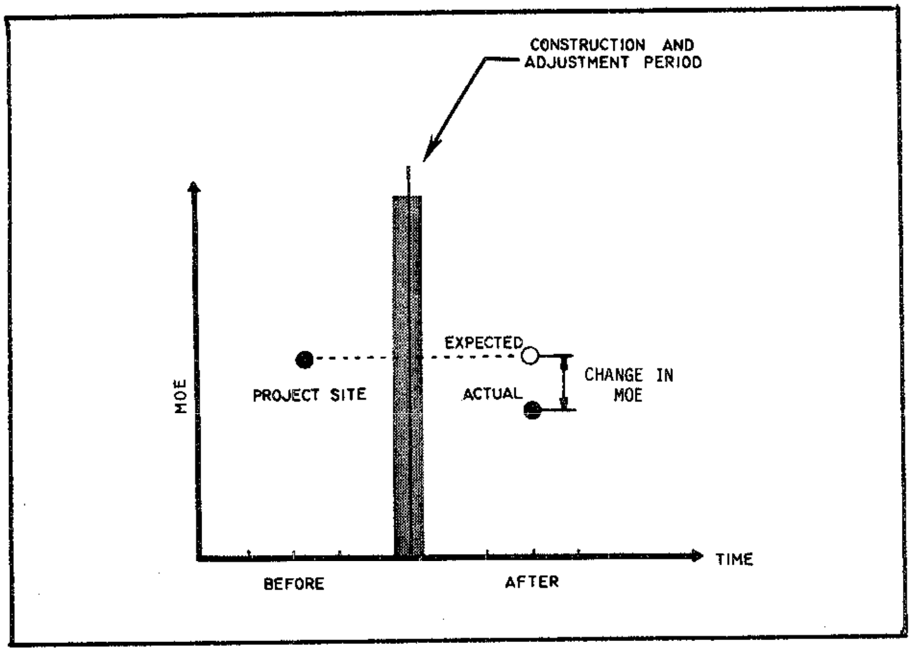



Figure 31. Before and after study.

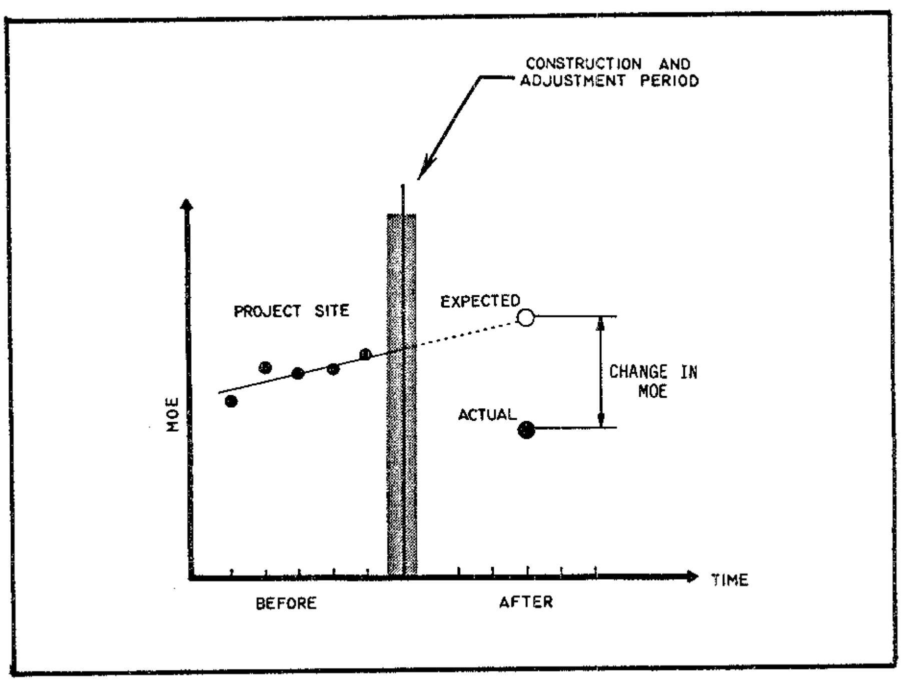



Figure 32. Before and after study (trend analysis).

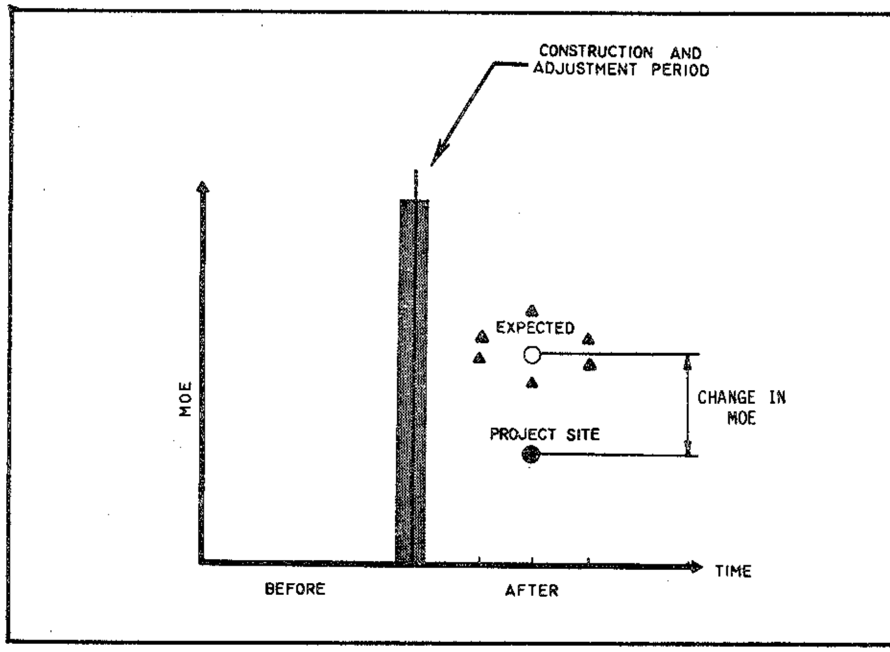



Figure 33. Comparative parallel study.

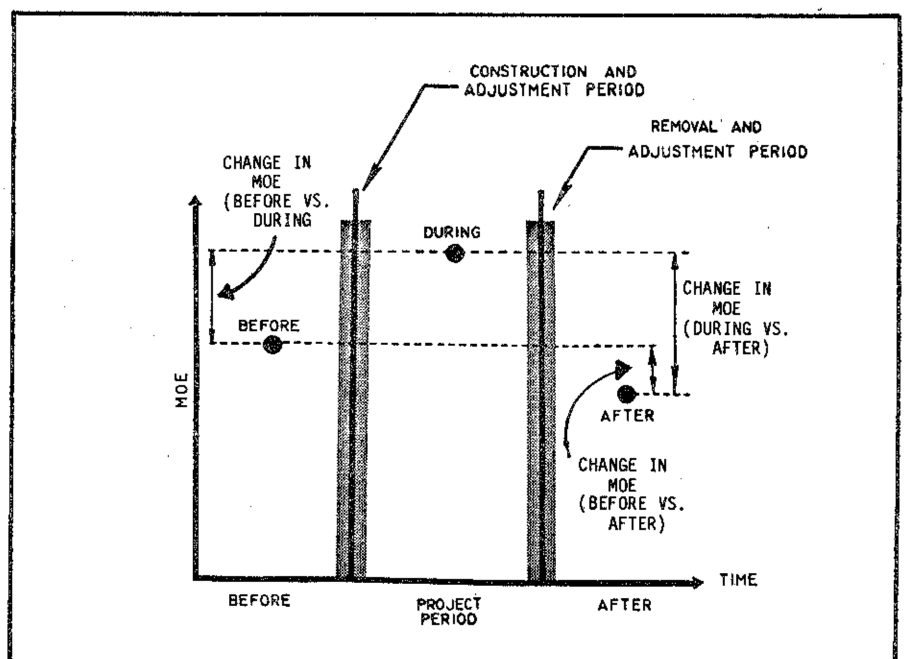
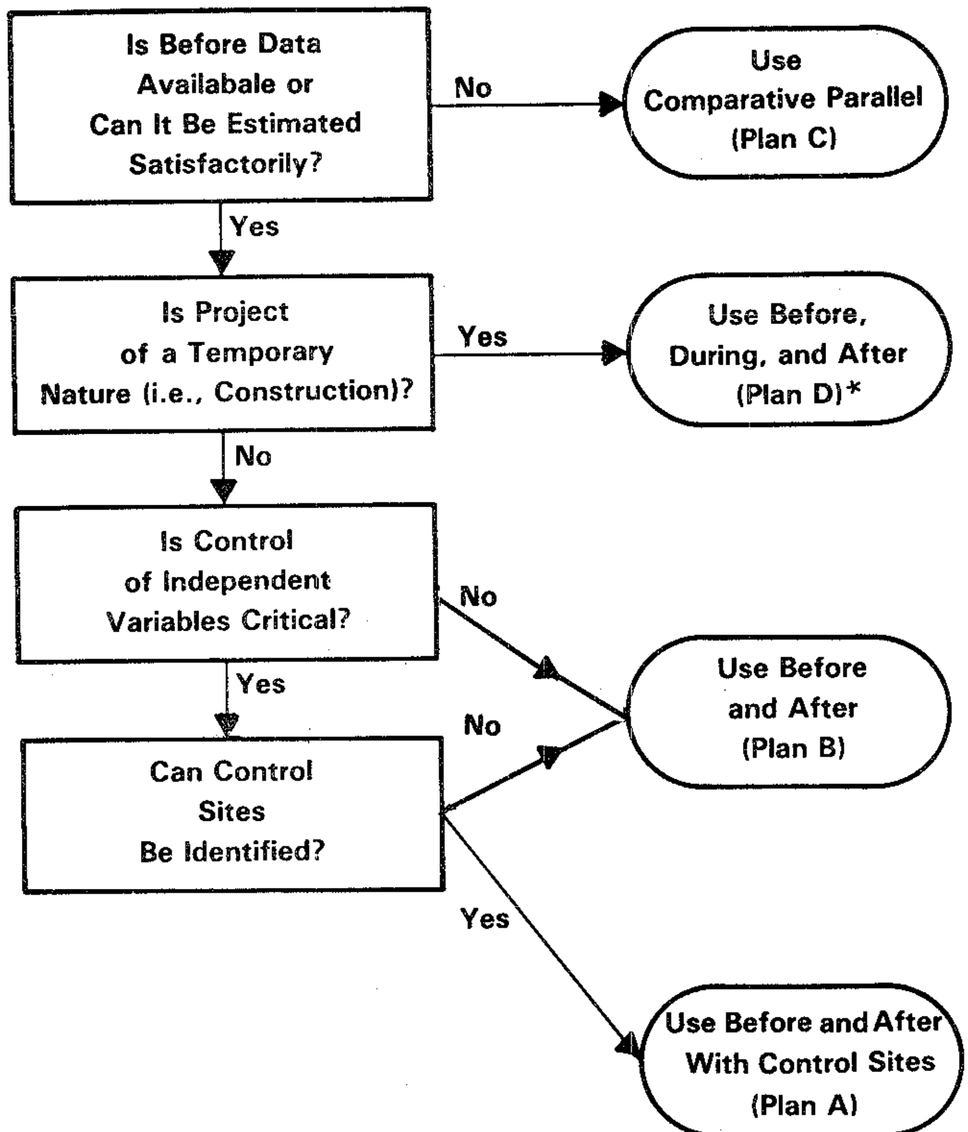



Figure 34. Before, during and after study.




* Combine with Plan A if control sites
are desirable and available.

Figure 35. Experimental plan selection.

Depending on the plan used, data sets must be collected at various locations and points in time. The number of data sets required for the selected experimental plan should be estimated for the purpose of developing a detailed data collection scheme. Another consideration in establishing the magnitude of data needs is related to sample size requirements.

The experimental plans outlined above are based on the assumption that the number of accidents used in the analysis accurately reflects the number of accidents for the entire before or after analysis period. Previous studies have indicated that a three-year accident history is a sufficient approximation to the long term average for safety analysis. It is recommended that a three-year before and a three-year after period be selected for a final Accident-Based Project Evaluation.

There are two factors to consider when selecting the length of the analysis period.

- Periods should be selected for which there is no significant change in geometric, traffic or traffic control conditions at the site (except for the countermeasures) during the entire before and after study

- It is desirable to evaluate the effectiveness of a project as soon as possible to determine whether additional countermeasures are warranted at the site.

FUNCTION B - Collect and Reduce Data

The evaluator should collect all data necessary for an evaluation study, including:

- Data necessary for selection of control sites
- Before data (accident, volume, and other)
- Data during implementation period
- Accident and other data after project completion

The control sites should exhibit accident patterns similar to those of the project site. Since the accident frequency and severity can be similar at two or more different sites due to chance, variables such as horizontal and vertical alignment, number of lanes, traffic volume, etc., should be similar. In addition to these considerations, the evaluator should identify key variables which must be controlled in the evaluation. A rather critical factor to consider in the data collection process is the delineation of boundaries for the project site (and control site(s) if applicable). All before data must be collected and reduced to a usable form for subsequent analysis. After the project countermeasures have been implemented, the evaluator must establish a data base of the impacted conditions after traffic has adjusted to the changed conditions.

## FUNCTION C - Compare MOE's

This function involves determining the effect of the project on the selected MOE's.

MOE data summary tables should be developed using the data compiled in FUNCTION B. The MOE Data Comparison Worksheet shown in Figure 36 may be used to tabulate accident and exposure data used in developing the MOE's. Figures 37 to 40 illustrate the sample formats to be used for tabulating MOE's for different experimental plans. The evaluator should calculate the expected values and percent changes of the MOE's and record them on the worksheet.

## FUNCTION D - Perform Statistical Tests

The evaluator must test the statistical significance of the effectiveness of the safety project to better understand whether the changes (if any) observed in the MOE are attributable to the safety project or due to some other factors unrelated to the project. To perform statistical tests, a test statistic and a confidence level must be selected. The choice of a confidence level should depend on project costs, i.e., a confidence level of 95% or more should be used for large, expensive projects.

The Poisson Test is appropriate for project evaluation to determine whether a significant change in the MOE's has occurred. Poisson curves are given in Figure 41 for use in determining whether a change in accident experience is statistically significant.

## FUNCTION E - Perform Economic Analysis

Economic analysis provides an additional perspective of the effectiveness of the completed safety project. The following methods are appropriate for use in the evaluation of completed highway safety projects.

- Benefit/Cost Ratio Method - The ratio of the benefits accrued from accident and/or severity reduction to costs needed to implement the countermeasures.

- Cost Effectiveness Method - The cost to the agency of preventing a single accident or accident type.

## FUNCTION F - Prepare Evaluation Documentation

The evaluator now must draw conclusions regarding the overall effectiveness and worth of the project and review the appropriateness of all activities of the evaluation study which lead to the final conclusions. The evaluation activities and results should be thoroughly discussed and documented in the study report. The documentation should include a concise and comprehensive coverage of all evaluation study activities and results, and should follow a standardized format.

Page ____ of ____

## MOE DATA COMPARISON WORKSHEET

**Evaluation No.** ______________________

**Date/Evaluator** ______________________ **Checked by** ____________

**Experimental Plan** ______________________________________

| | Control | | Project | | Expected After Rate __ or Freq.__ | Percent Reduction (%) |
|---|---|---|---|---|---|---|
| | Before | After | Before | After | | |
| **MOE Data Summary** | ($B_{CF}$) | ($A_{CF}$) | ($B_{PF}$) | ($A_{PF}$) | | |
| Accidents: | | | | | | |
| (Fundamental) | | | | | | |
| | | | | | | |
| Total Accidents | | | | | | |
| Fatal Accidents | | | | | | |
| Injury Accidents | | | | | | |
| PDO Accidents | | | | | | |
| (Project Purpose) | | | | | | |
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| Exposure | | | | | | |
| units:___V, or___VM | | | | | | |
| **MOE Comparison** Rate ____ or Frequency ____ | $B_C$ _ | $A_C$ _ | $B_P$ _ | $A_P$ _ | E_ | (%) |
| Total Accidents/ | | | | | | |
| Fatal Accidents/ | | | | | | |
| Injury Accidents/ | | | | | | |
| PDO Accidents/ | | | | | | |
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Figure 36. MOE data comparison worksheet.

## MOE DATA COMPARISON WORKSHEET

**Evaluation No.** ______________________

**Date/Evaluator** ______________________ **Checked by** ____________

**Experimental Plan** ______________________________________________

| | Control | | Project | | Expected After Rate ___ or Freq. ___ | Percent Reduction (%) |
|---|---|---|---|---|---|---|
| | Before | After | Before | After | | |
| MOE Data Summary | ($B_{CF}$) | ($A_{CF}$) | ($B_{PF}$) | ($A_{PF}$) | | |
| Accidents: | | | | | | |

Figure 37. Illustration of MOE data comparison worksheet for before and after control sites study plan.

## MOE DATA COMPARISON WORKSHEET

**Evaluation No.** ______________________

**Date/Evaluator** ______________________ **Checked by** ____________

**Experimental Plan** ______________________________________________

| | ~~Control~~ | | Project | | Expected After Rate ___ or Freq. ___ | Percent Reduction (%) |
|---|---|---|---|---|---|---|
| | ~~Before~~ | ~~After~~ | Before | After | | |
| MOE Data Summary | ~~($B_{CF}$)~~ | ~~($A_{CF}$)~~ | ($B_{PF}$) | ($A_{PF}$) | | |
| Accidents: | | | | | | |

Figure 38. Illustration of MOE data comparison worksheet for before and after study plan.

**MOE DATA COMPARISON WORKSHEET**

**Evaluation No.** ____________________

**Date/Evaluator** ____________________ **Checked by** __________

**Experimental Plan** ______________________________

| | Control | | Project | | Expected After Rate __ or Freq. __ | Percent Reduction (%) |
|---|---|---|---|---|---|---|
| | ~~Before~~ | After | ~~Before~~ | After | | |
| **MOE Data Summary** | ~~($B_{CF}$)~~ | ($A_{CF}$) | ~~($B_{PF}$)~~ | ($A_{PF}$) | | |
| Accidents: | | | | | | |

Figure 39. Illustration of MOE data comparison worksheet for comparative parallel study plan.

**MOE DATA COMPARISON WORKSHEET**

**Evaluation No.** ____________________

**Date/Evaluator** ____________________ **Checked by** __________

**Experimental Plan** ______________________________

Project During ($D_{PF}$)

| | ~~Control~~ | | Project | | Expected After Rate __ or Freq. __ | Percent Reduction (%) |
|---|---|---|---|---|---|---|
| | ~~Before~~ | ~~After~~ | Before | After | | |
| **MOE Data Summary** | ~~($B_{CF}$)~~ | ~~($A_{CF}$)~~ | ($B_{PF}$) | ($A_{PF}$) | | |
| Accidents: | | | | | | |

Figure 40. Illustration of MOE data comparison worksheet for before, during and after study plan.

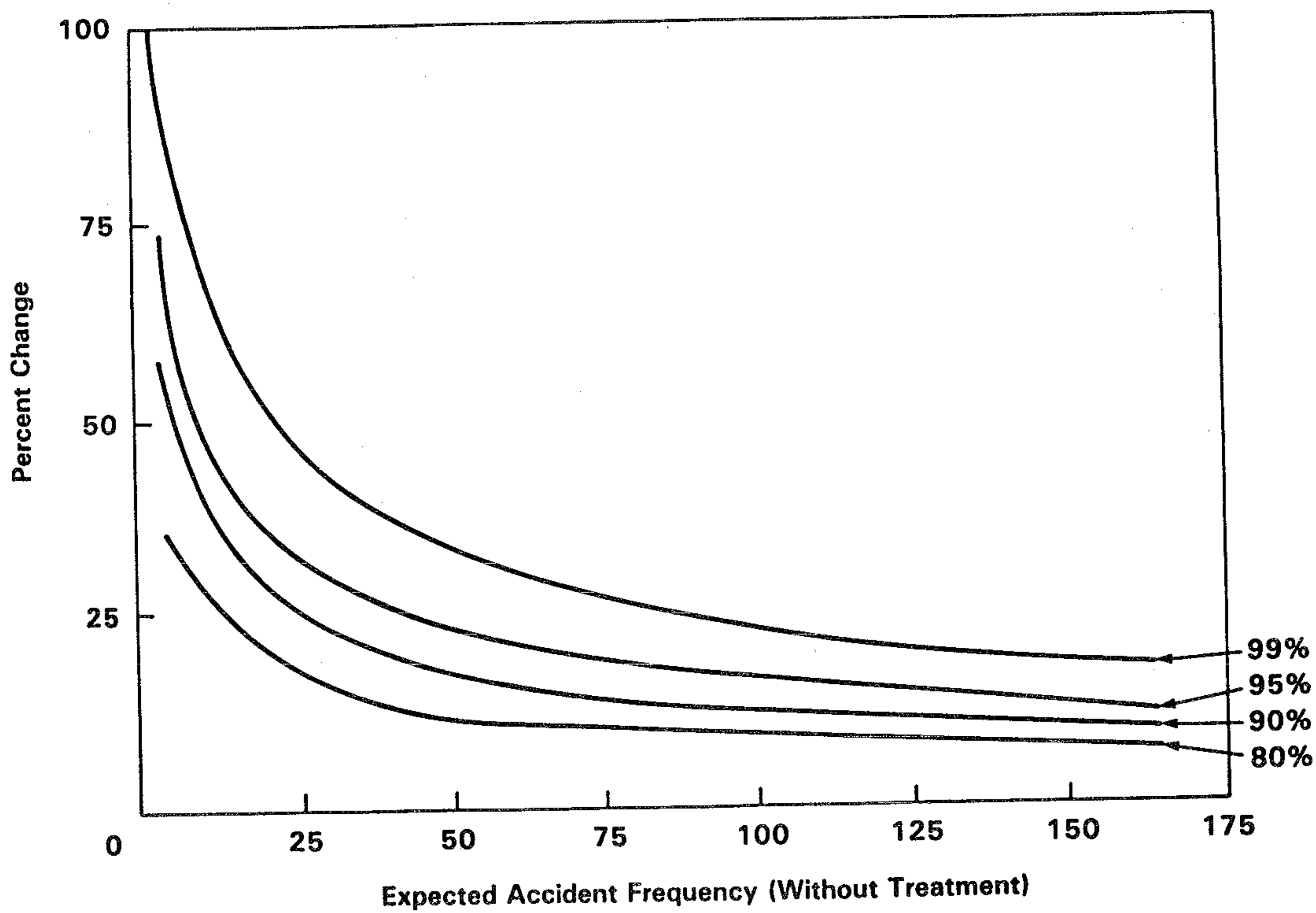



Figure 41. Poisson curves.

## FUNCTION G - Develop and Update Effectiveness of Data Base

An effectiveness data base is an accumulation of sound project evaluation results which are directly usable as input to project selection (Process 3, Subprocess 2) and project development (Process 3, Subprocess 3) within the Planning Component. The data base should contain information on the accident reducing capabilities of a project in terms of average accident rate reduction. This information is a requirement for use in economic analysis of proposed projects. The data base must be continually updated with new effectiveness evaluation information as it becomes available.

### MANAGERIAL CONCERNS

- What projects should be selected for effectiveness evaluation?
- What is the manpower required for the evaluation?
- Are adequate funds available?

### INPUTS AND OUTPUTS

#### Management Input

- A knowledge and understanding of Accident-Based Project Evaluation techniques

#### Resource and Equipment Input

- Manpower
- Funding

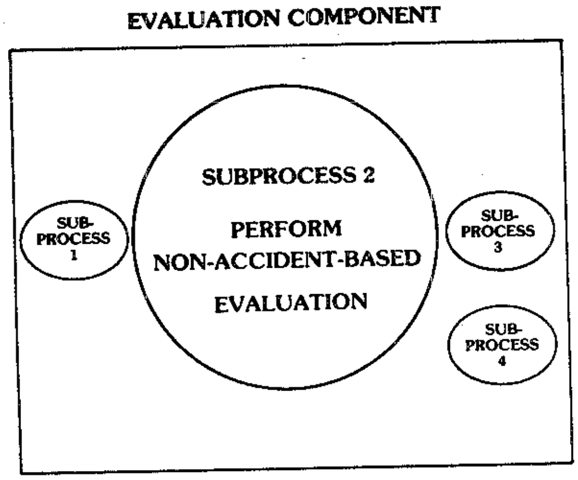
#### Data or Information Input

- Total project cost
- For the analysis period:
  - Numbers of years of accident data
  - Total number of accidents
  - Number of fatal accidents and fatalities
  - Number of injury accidents and injuries
  - Number of PDO accidents and involvements
  - Number of vehicles for spot or intersection locations, and vehicle-miles of travel for roadway section locations.
- Maintenance files, photologs or historic project files or field reconnaissance for conducting inventory of existing roadway and environmental features.

#### Output

- MOE data summary tables which explain the effect of the project on the change of selected MOE's and their statistical significance.
- An assessment of the cost-effectiveness of the project
- Updated data base

# PROCESS 1, SUBPROCESS 2
# PERFORM NON-ACCIDENT-BASED EVALUATION




PURPOSE

The objective of the Non-Accident-Based Evaluation is to provide guidelines for determining the intermediate effectiveness of a completed highway safety project based on changes in non-accident MOE's.

DESCRIPTION

Non-Accident-Based Evaluation refers to the method of evaluation using non-accident measures expressed in terms other than the rate or frequency of accidents or accident severities. Examples of non-accident measures are:

- Traffic conflicts
- Auto-Pedestrian conflicts
- Vehicle speeds
- Traffic control violations
- Erratic vehicle maneuvers
- Other

Non-accident measures are used in much the same way as accident measures in Accident-Based Project Evaluation.

Although the use of Non-Accident-Based Project Evaluation is suggested as a means of evaluating intermediate project effectiveness, it is not intended for use in place of ultimate safety measures (accident and accident severity reductions) due to the lack of a proven relationship between accident and non-accident measures.

The following two basic differences exist between Accident- and Non-Accident-Based Evaluation.

1. When conducting a Non-Accident-Based Project Evaluation, an evaluator addresses the chain of events which leads to observed or potential accident experience, rather than addressing the purpose of the project in terms of how it will affect accident experience at the project site (as related to Accident-Based Project Evaluation).

   The chain of events addresses:

   - Major Causal Factors
   - Major Contributory Factors
   - Safety Problems

2. Evaluation Timing - This subprocess requires that the evaluation plan be developed during the Planning Component of the HSIP (before project implementation) so that before evaluation data can be obtained.

As in Accident-Based Project Evaluation there are seven functions in Non-Accident-Based Project Evaluation, each containing a series of steps which lead an evaluator through the activities and decision-making activities of a properly designed evaluation study.

The seven functions which comprise Non-Accident-Based Evaluation are:

FUNCTION A - Develop Evaluation Plan
FUNCTION B - Collect and Reduce Non-Accident Data
FUNCTION C - Compare Non-Accident Measures of Effectiveness (MOE's)
FUNCTION D - Perform Statistical Tests
FUNCTION E - Prepare Economic Analysis
FUNCTION F - Prepare Evaluation Documentation
FUNCTION G - Develop and Update Effectiveness Data Base.

Projects which are well-suited to Non-Accident-Based Evaluation include:

- Projects implemented to reduce accident potential
- Projects involving staged countermeasure implementation

Non-Accident-Based Evaluation can be used to provide information on:

- Project impact on traffic performance
- Project effectiveness, when a quick indication is desired
- The presence of factors which affect "after" accident experience
- The relationship between accident and non-accident measures

FUNCTION A - Develop Evaluation Plan

As in Accident-Based Project Evaluation, five steps are required in this function:

- Select projects for evaluation
- Determine project purpose
- Select intermediate evaluation objectives and MOE's
- Select experimental plan
- Determine data requirements

Intermediate evaluation objectives and MOE's are expressed in terms of non-accident measures.

Four experimental plans, described in Accident-Based Project Evaluation (Subprocess 1), are appropriate for use in this subprocess:

- Before and after study with randomized control sites
- Before and after study
- Comparative parallel study
- Before, during and after study

Data requirements for obtaining non-accident measures are developed from traffic engineering studies. Information on these studies are contained in many traffic engineering texts and references, such as:

- Highway Safety Engineering Studies (FHWA training course)
- Traffic Engineering, Theory and Practice (by Louis J. Pignataro)
- Manual of Traffic Engineering Studies (Institute of Transportation Engineers)
- Traffic and Transportation Engineering Handbook (Institute of Transportation Engineers)

Examples of traffic engineering studies which can be performed to obtain non-accident measures include:

- Spot speed studies
- Travel time and delay studies
- Intersection delay studies
- Traffic conflict studies

Sample size requirements for these and other studies are calculated using sampling techniques which yield the required minimum sample size at a specified level of confidence.

FUNCTION B - Collect and Reduce Data

Non-Accident-Based Project Evaluation requires relatively more field data collection than Accident-Based Project Evaluation. This is due to the various engineering studies that must be performed to obtain non-accident measures.

The steps involved in this function are:

- Select control sites (if applicable)
- Collect and reduce non-accident data
- Collect and reduce project cost data

FUNCTION C - Compare Non-Accident MOE's

The methods for computing changes in accident-based MOE's, described in FUNCTION C of Accident-Based Project Evaluation, are appropriate for use in this subprocess.

Non-Accident MOE data can be summarized in prepared tables (MOE Data Comparison Worksheets) similar to those for Accident-Based Project Evaluation. These tables can be modified to simplify calculations of percent changes in non-accident MOE's for a given experimental study plan.

As in Accident-Based Project Evaluation, the percent change in nonaccident MOE's involve two computations:

- Compute the expected values of the non-accident MOE's if the project had not been implemented.
- Compute the percent change between the expected and after non-accident MOE's.

The methods for determining the expected values may differ for each experimental plan.

FUNCTION D - Perform Tests of Significance

In this function, statistical tests are selected and performed to determine the effectiveness of the non-accident MOE's, as described for accident-based procedures.

Several test statistics are appropriate for use in Non-Accident-Based Project Evaluation, including:

Chi-Square Test

This technique is used to test whether two discrete variables are independent of each other. The variables may be nominal or ordinal. All experimental plans are appropriate for testing by Chi-Square.

t-Test

The t-Test is used to test the statistical significance of differences in the mean values of two sets of MOE's when the data are continuous and an assumption of normality in the data can be made. There are two types of t-Test:

- Paired t-Test - compared at same location, i.e., Before and After
- Student's t-Test - compared at different locations, i.e., Project and Control

Z-Test of Proportion

This test is applicable for continous data which are expressed as proportions. The analysis question addressed by this test is whether the proportion of occurrences in one group is significantly different from the proportion in a second group.

F-Test

This test is applicable for testing the significance of differences in the variance of two populations.

Results of these statistical tests give an indication of whether changes in MOE's are attributable to chance or are consequences of external factors (the project).

FUNCTION E - Perform Economic Analysis

An economic analysis is conducted in order to obtain information on whether a project is justified in terms of dollars spent. Only one type of economic analysis method (Cost-Effectiveness technique) is recommended for this subprocess. Results of the Cost-Effectiveness technique indicate the approximate agency cost for each single non-accident measure eliminated. For example, a cost-effectiveness analysis may yield an agency cost of $30.00 for every MPH reduced for vehicles approaching a warning beacon in advance of a railroad crossing.

FUNCTION F - Evaluation Documentation

This function involves organizing and reviewing all non-accident evaluation activities. Evaluation decisions, assumptions and procedures are reviewed to determine their appropriateness. From this review, a decision on the reliability of evaluation results can be made.

All evaluation results (changes in non-accident MOE's) that are determined to be reliable (changes in MOE's which were affected by the project only) are entered into an intermediate Effectiveness Data Base (see FUNCTION G). A product of this function is a final evaluation report. This report is a concise description of the non-accident evaluation activities.

In the documentation, it may be necessary to include information relative to the non-accident measures utilized, to insure the proper interpretation of the evaluation results.

## FUNCTION G - Develop and Update Intermediate Effectiveness Data Base

Changes in non-accident MOE's which were found to be reliable (per evaluation review, see FUNCTION F), are entered into a table format. The format consists of various project types and their associated changes in the percent non-accident MOE. Percent reductions entered into this table are not restricted to the positive effects of a project (i.e., decreases in non-accident MOE's), but include negative effects (i.e., increases in non-accident MOE's).

The Intermediate Effectiveness Data Base has two primary uses:

- It provides feedback information useful in planning and implementing future projects for which Non-Accident-Based Evaluation may be performed.
- It provides information on the relationship between accident and non-accident measures when Accident-Based Project Evaluation are performed after sufficient accident data are available.

## MANAGERIAL CONCERNS

- What projects should be selected for Non-Accident-Based Project Evaluation?
- What are the manpower requirements?
- What is the degree of sophistication of engineering studies needed for the evaluation?
- What degree of manpower expertise or training is required?
- Are adequate funds available?

## INPUTS AND OUPUTS

### Management Input

- A knowledge and understanding of Non-Accident-Based Project Evaluation

### Resource and Equipment Input

- Manpower

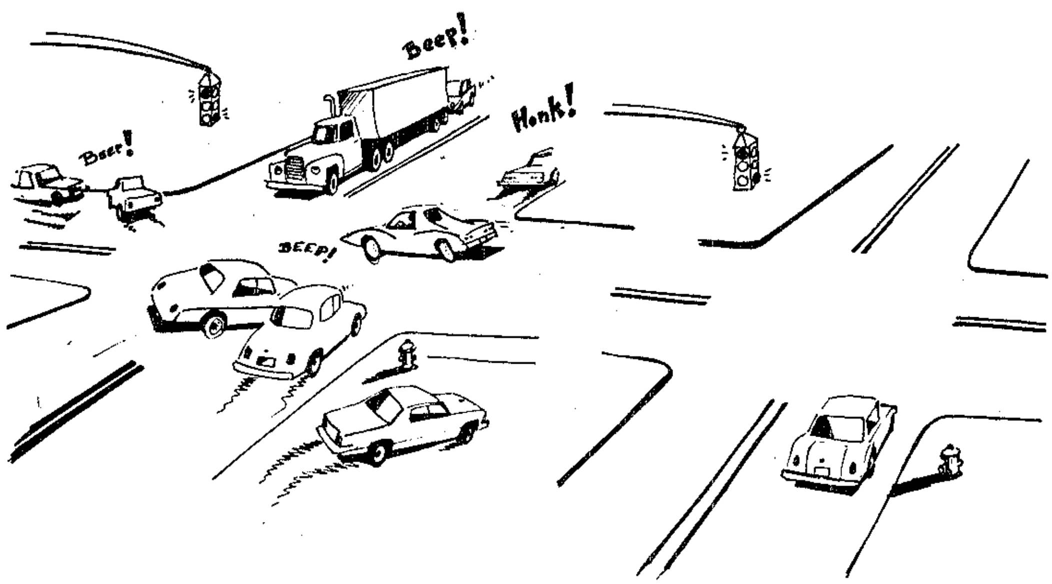
- Funding
- Equipment required for engineering studies

Data or Information Input

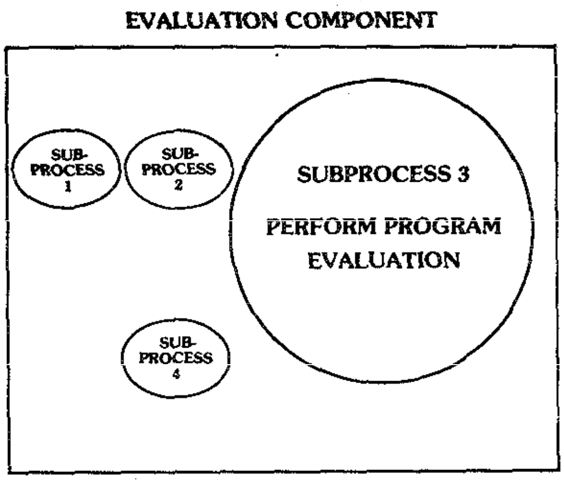
- Total cost
- For the analysis period(s):
  - Size of non-accident measure sample
  - Types of non-accident measures to be evaluated

Output

- Percent change in non-accident MOE's
- Economic assessment of project
- Intermediate effectiveness data base
- Final report



# PROCESS 1, SUBPROCESS 3
# PERFORM PROGRAM EVALUATION




PURPOSE

The purpose of this subprocess is to provide guidelines for assessing the value of a completed or ongoing highway safety program.

DESCRIPTION

The program evaluation subprocess also consists of seven functions. Each function contains a series of systematic steps which lead the evaluator through the activities and decision-making processes of a properly designed evaluation study. The seven functions are:

FUNCTION A - Develop Evaluation Plan
FUNCTION B - Collect and Reduce Data
FUNCTION C - Compare Measures of Effectiveness (MOE's)
FUNCTION D - Perform Tests of Significance
FUNCTION E - Perform Economic Analysis
FUNCTION F - Prepare Evaluation Documentation
FUNCTION G - Develop and Update Effectiveness Data Base

## FUNCTION A - Develop Evaluation Plan

During plan development, the evaluator is required to think through the entire evaluation process and establish a plan to be followed during the actual evaluation. Prior planning in advance of program implementation makes it possible to select and utilize a more reliable experimental plan. Also, data collection activities may be planned in advance of actual data collection.

### Program Goal

The first activity in program evaluation is to determine the highway safety goal to be evaluated. The goal must be stated in a brief but concise statement in accordance with the following criteria:

- The program scope
- The objective of program activities
- The location type
- The geographic program area

If the stated program goal includes several types of projects implemented at different locations, it is advisable to stratify the projects into program subsets with similar project and location characteristics.

A fundamental step in effectiveness evaluation is the formal selection of evaluation objectives and MOE's (Measures of Effectiveness).

### Objective

An evaluation objective is a brief statement describing the desired outcome of the evaluation study. Regardless of the safety goals of the program, four fundamental evaluation objectives should be selected for every program. These objectives are to determine the effect of the program on:

- Total accidents
- Fatal accidents
- Personnel injury accidents
- Property damage accidents
- Other objectives related to the goals of the program

One or more MOE's must be assigned to each evaluation objective to transform the objective into a measurable unit which provides evidence of the effectiveness of the program. These measures may be related to:

- Accident frequency
- Severity
- Rate
- Proportion or percentage

The evaluation objectives and their related MOE's should be recorded in an objective and MOE listing (mentioned previously in Accident-Based Project Evaluation). MOE's should also be assigned to economic evaluation objectives.

Experimental Plan

The evaluator must select the experimental plan for comparing the MOE's selected for each program subset. There are several factors which may threaten the validity of the evaluation study and must be recognized and overcome, including:

- Changes due to factors other than the program.
- Changes in the values of the MOE's over time. Decreases in accident rate may be a result of the program or it may be that the decrease is an extension of a long-term decreasing trend in total accident rates at the program sites.
- Regression to the mean - a tendency of a response variable such as accidents to fluctuate about the true mean value.
- Random data fluctuation.

(These factors should also be considered when selecting experimental plans in Accident- and Non-Accident-Based Project Evaluation.)

The threats to the validity of the evaluation study can be minimized through the use of experimental plans which utilize control sites. The following experimental plans are variations of the four plans mentioned previously in Accident- and Non-Accident-Based Project Evaluation.

Data Needs

Evaluation data needs must reflect the evaluation MOE's and the type of experimental plan selected for the evaluation. If one of the evaluation objectives is to determine the economic aspects of the program, cost data must be collected. The data needs for each subset are recorded in the appropriate form (Figure 42). The next step consists of organizing the decisions made in the development plan and the rationale for these decisions along with the listing of objectives, MOE's, selected experimental plans and data needs.

FUNCTION B - Collect and Reduce Data

This function involves the collection and reduction of the data required for a project evaluation. Accident and volume data are used most often as the evaluation criterion on which program effectiveness and control group selection is based. Inconsistent, biased, erroneous or incomplete accident report information present a significant problem to the evaluator. Again, the exposure data must be taken during the same period

## DATA REQUIREMENTS LISTING

Evaluation No. A-1

Date/Evaluator 2/23/77/DDP Checked by 2/28/77/HES

Experimental Plan Before and After

| Data Needs | Magnitude (Number of Sites, Time Period, Dates) |
|---|---|
| 1. Total Accidents Stratified by Severity | 1. 3 years before (5/73 to 5/76) and after (5/77 to 5/80) project implementation for five sites. |
| 2. Run-off-Road accidents stratified by lighting condition (night vs. day) | 2. 3 years before (5/73 to 5/76) and after (5/77 to 5/80) project implementation for five sites. |
| 3. Average annual daily traffic | 3. For each year (5/73 thru 5/80) of the analysis for five sites. |

Figure 42. Data requirements listing.

that the accident data are required. The use of existing volume data creates a problem in defining accident rates for such MOE's as wet-weather accident rates and night or day accident rates.

The evaluator may be faced with either selecting control groups for a completed program or randomly assigning program treatments to a portion of a group of sites which warrant improvements.

The first activity in control site selection is to collect data related to key variables at all program sites and candidate control sites. Data should be reviewed and control sites which are not comparable with the program group should be eliminated. Next, the evaluator should obtain and critically review accident and exposure data for control sites and program sites and eliminate the control sites which are not comparable with the program group MOE's. The remaining control sites constitute the control group for the evaluation. The evaluator should select a random sampling technique to select control sites. Accident and exposure data should then be used to develop the MOE's for the evaluation study.

FUNCTION C - Compare MOE's

This function involves preparation of the MOE summary tables and calculation of percent changes in the MOE's. MOE data for each program subset should be tabulated on the appropriate summary table (shown previously in Accident-Based Project Evaluation) using accident and exposure data collected and recorded for individual projects in each subset in FUNCTION B. MOE's for the before and after periods for the program and control groups are computed for each program subset. Next, the expected value of the MOE is determined and compared with the annual MOE value and a percent difference is calculated for each program subset.

FUNCTION D - Perform Tests of Significance

The evaluator should review the selected evaluation objectives, MOE's and experimental plan and determine the types of data to be evaluated. The next step involves listing the hypothesis to be statistically tested for each evaluation objective and select the appropriate statistical test based on objectives, the MOE's, experimental plan, and types of statements listed. The following are the various statistical techniques that may be appropriate for program evaluation:

- Poisson Test
- Chi-Square Test
- t-Test
- Z-Test
- F-Test

## FUNCTION E - Perform Economic Analysis

The evaluator should determine the need for economic analysis by assessing whether statistically significant changes occurred in the MOE's. The economic analysis technique should be selected on the basis of the acceptability of assigning dollar values to accident outcomes, availability of cost data and type of MOE. The next step is to perform the economic analysis using a Benefit/Cost technique or Cost-Effectiveness technique as applicable.

## FUNCTION F - Prepare Evaluation Documentation

The evaluator must organize the results of FUNCTIONS C, D & E for each subset and examine the effectiveness of the program in the following way:

- From FUNCTION C, identify whether each subset reduced the safety deficiencies for which it was intended
- From FUNCTION D, identify whether each subset resulted in a statistically significant change in the MOE's
- From FUNCTION E, identify whether each subset resulted in benefits which are considered acceptable when compared to program costs.

The evaluator should next determine the effectiveness of each subset and appropriateness of all evaluation activities, and the activities associated with planning and implementation. Any observed deficiencies should be corrected, if possible, and any non-correctable problems encountered should be recorded. The next step is to identify evaluation results for incorporation into the effectiveness data base, and to write, review and distribute the final evaluation study report.

## FUNCTION G - Develop and Update Effectiveness Data Base

A data base of accident reduction factors should be developed for projects to provide planning personnel with a useful tool for improving their ability to estimate expected benefits for projects and programs. Evaluation data for individual projects within a program or program subset are required as input to the data base in the form of accident reduction factors and associated expected ranges.

## MANAGERIAL CONCERNS

- What number of persons are available for conducting evaluations?
- What are the problems with accident data availability?
- What should be the timing for evaluation plan development; pre-implementation or post-implementation?

## INPUTS AND OUTPUTS

### Managerial Inputs

- A knowledge and understanding of program evaluation techniques.

Resource and Equipment Input

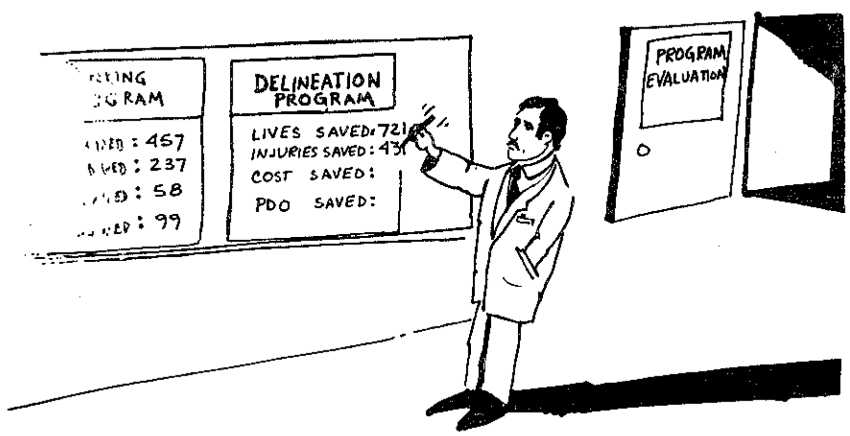
- Manpower
- Time
- Funding

Data or Information Input

- Data collected for the selection of control groups
- Exposure data conducted for control sites and program sites
- Cost data from project files

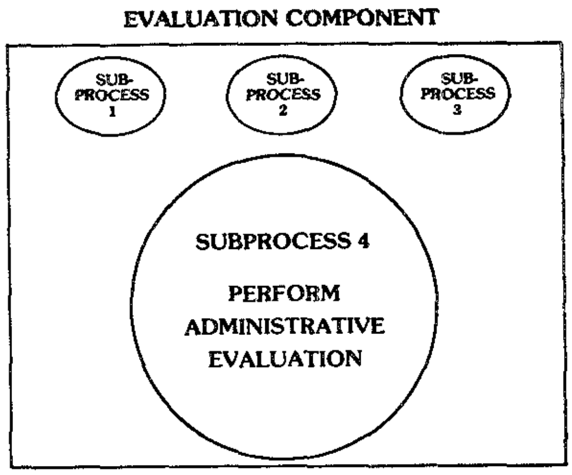
Output

- Effectiveness of program
- "Data Summary Tables" for each program subset. Percent change in the MOE's for each program subset can be calculated from the tables.
- Effectiveness Data Base



# PROCESS 1, SUBPROCESS 4

# PERFORM ADMINISTRATIVE EVALUATION




PURPOSE

The purpose of this subprocess is to assess implementation activities and to produce feedback information to all HSIP components. This type of evaluation is a fundamental part of the Evaluation Component of the HSIP. It is a supplement to but not a substitute for an Effectiveness Evaluation.

DISCUSSION

Administrative Evaluation is the assessment of project or program implementation activities exploring three basic issues:

- Actual resource expenditures
- Planned versus actual resource requirements
- Productivity of implementation activities

In the Evaluation Component, Administrative Evaluation provides cost information for economic analyses which accompany Effectivenss Evaluation. Administrative Evaluation also insures that the Effectiveness Evaluation is being performed on the project or program as it was actually implemented and not as it was planned.

Administrative Evaluation is recommended for all projects and programs. Also, Administrative Evaluation is recommended to be conducted during project/program implementation. Administrative Evaluation may be performed at various levels of detail, depending on the amount and type of information desired. High-cost projects or programs which involve a number of implementation activities may warrant a detailed level of evaluation. The least detailed level involves evaluating implementation scheduling, design, construction and operational review, without regard to specific activities. The Administrative Evaluation subprocess consists of eight steps:

1. Select evaluation subjects
2. Review project (program) details
3. Identify administrative issues
4. Obtain available data sources
5. Prepare administrative data summary tables
6. Evaluate administrative issues
7. Prepare and distribute the evaluation report
8. Develop and update data base

STEP #1 - Select Evaluation Subjects

This step involves selecting completed or future projects and programs for evaluation.

STEP #2 - Review Project (Program) Details

The purpose of the review and information gathering process is to obtain necessary input to prepare a written description of the project or projects to be evaluated. The description of the project(s) should be concise and convey a clear description of the retrieval of the Administrative Evaluation results data for similar types of projects.

STEP #3 - Identify Administrative Issues

This step presents guidelines for determining the administrative issues to be evaluated. In this step, the evaluator must specify the manpower categories, the activities, the milestones, and the material to be evaluated in each implementation element. The level of detail may vary for each implementation element. When the level of administrative evaluation detail has been established, a form such as that shown in Figure 43 should be used to record specific implementation issues to be evaluated. The following guidelines may be helpful when completing the form.

- Manpower categories should reflect only the major types of manpower involvement required to perform the activities within each implementation element
- Only major activities should be listed
- As a minimum, time scheduling includes the start date, end date, and duration of each implementation element

ADMINISTRATIVE ISSUES LISTING

| Administrative Issues | Implementation Elements | | | |
|---|---|---|---|---|
| | SCHEDULING | DESIGN | CONSTRUCTION | REVIEW |
| MANPOWER CATEGORY<br><br>List categories for which information is desired on the level of effort expended. | | | | |
| ACTIVITIES<br><br>List activities for which information is desired on the total cost of achieving the activity. | | | | |
| TIME SCHEDULE<br><br>List the major milestones for which information is desired on the start and completion dates. | | | | |
| MATERIALS<br><br>List material items for which information is desired on cost and quantity. | | | | |
| PRODUCTIVITY<br><br>List productivity measures to be evaluated. | | | | |
| OTHER<br><br>List other specific administrative issues to be evaluated. | | | | |

Figure 43. Administrative issues listing.

- Construction materials should include the specific materials being placed in the field, i.e., guardrails, signs and supports, etc.

The following questions are recommended as the minimum which need to be answered for each implementation element.

A. Actual Resource Expenditures

- For each major manpower category, what was the actual level of effort (number of days, hours, etc.) expended?
- What was the actual cost for performing major activities within the implementation element?
- What was the actual start date, end date, and duration of each element and its major activities?

B. Actual Versus Planned Resource Requirements

- How did the planned manpower categories (job classifications) compare with actual categories?
- How did the planned levels of effort for each manpower category compare with the actual level of effort?
- How did the estimated cost compare with the actual costs?
- How did the scheduled start date, end date, and duration compare with actual events and durations?
- What was the productivity of output produced per unit of manpower expended?
- What was the productivity of output produced per unit of cost incurred?
- What was the productivity of output produced per unit of time expended?

When developing the administrative questions, the evaluator should coordinate with those individuals who are most likely to use the results of the evaluation.

STEP #4 - Obtain Available Data

Data on planned implementation resource expenditures and actual resource expenditures may be obtained from several sources including the ones detailed under "Data or Informational Input". The data sources should be thoroughly reviewed and, if required, additional data and information sources must be identified to meet the evaluation needs.

STEP #5 - Prepare Administrative Data Summary Tables

This step involves organizing the evaluation data in a format which allows the evaluator to efficiently conduct the evaluation. Manpower, cost, time, material and other resource information obtained in STEP #4 should be summarized in a table similar to that shown in Figure 44. Four summary tables should be prepared for each project to be evaluated; one each for scheduling, design, construction and operational review. The manpower categories, activities, milestones, and materials listed in the Detailed Administrative Issues listing (developed in STEP #3) should be transferred to the appropriate summary table.

STEP #6 - Evaluate Administrative Issues

Answers to the questions on actual resource expenditures may be taken directly from the summary table. Issues on planned versus the actual resource expenditures may be addressed by computing the percent differences between planned and actual quantities and costs. Issues relating to the productivity may be obtained by computing ratios between project output measures and input measures.

STEP #7 - Prepare and Distribute the Evaluation Report

A brief written report on the evaluation results should be prepared and copies of the reports should be distributed to the appropriate personnel.

STEP #8 - Develop and Update Data Base

An administrative evaluation report provides information on a specific project or program which is usable in future planning and implementation decisions.

MANAGERIAL CONCERNS

- What is the manpower required for the method?
- What is the amount of time required to complete specific activities?
- What is the quantity of materials required?
- What are the cost of manpower and materials?

INPUTS AND OUTPUTS

Management Input

- A knowledge and understanding of administrative evaluation techniques

Resource and Equipment Input

- Manpower
- Time
- Materials
- Funding

Project No.____________
Evaluation No.__________

__Scheduling
__Design
__Construction
__Op. Review

ADMINISTRATIVE DATA SUMMARY TABLE

MANPOWER

| Category | Role | Manpower Involvement | | | | | | Comments |
|---|---|---|---|---|---|---|---|---|
| | | Planned | | Actual | | Differences | | |
| | | #Persons | Person Hrs. | #Persons | Person Hrs. | Hrs. | % | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

ACTIVITY COSTS

| Major Activity | Activity Costs | | Differences | | Comments |
|---|---|---|---|---|---|
| | Planned | Actual | $ | % | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

TIME SCHEDULE

| Event or Milestone | Time Duration | | Differences | | Comments |
|---|---|---|---|---|---|
| | Planned | Actual | Time | % | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

MATERIAL

| Item | Material Requirements | | Differences | | Comments |
|---|---|---|---|---|---|
| | Planned | Actual | Amount | % | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

PRODUCTIVITY

| Input Measure | Output Measure | Ratio | Comments |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

COMMENTS

| |
|---|
| |
| |
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| |
| |

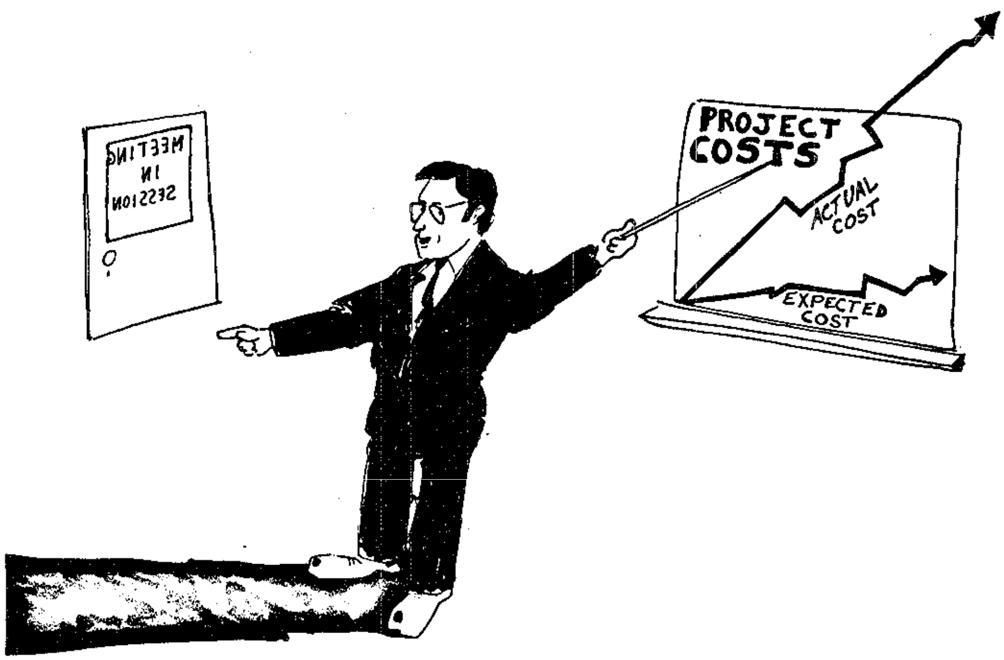
Figure 44. Administrative data summary table.

Data or Informational Input

- Data on planned implementation resource expenditures:
  - Construction schedules
  - Milestone and CPM charts
  - Bid quotations
  - Plan, Specification and Estimates (PS and E) documents
  - Project files
- Data on actual resource expenditures:
  - Invoices
  - Inspection reports
  - Progress reports
  - Data maintained as a funding requirement
  - As-built drawings
  - Project files

Output

- "Summary Tables" which provide a full description of the actual resource and planned resource expenditure and information on implementation productivity
- Administrative Data Base



# CHAPTER XI

## GLOSSARY OF TERMS

AASHTO - American Association of State Highway and Transportation Officials.

ACCIDENT - Any unplanned event that results in injury, property damage, or loss.

ACCIDENT-BASED EVALUATION - The assessment of a Highway Safety Project or program in terms of the extent to which the number and severity of accidents are reduced.

ACCIDENT CAUSALITY CHAIN - The chain of events (major causal factor - major contributor factor - safety problem) which lead to accident experience or accident potential.

ACCIDENT POTENTIAL - An impending accident situation characterized by an unsafe roadway condition.

ACCIDENT RATE - The number of accidents which occur during a specified period of time, divided by a measure of the degree of vehicular exposure over the same period.

ACCIDENT REDUCTION FACTORS - Values of percent accident reduction derived from the observed accident reduction on one or several highway safety projects.

ACCIDENT REPORT - A written report containing data concerning an individual accident including time, place, location description, property damage, injuries, violations, and possible cause. Such reports are submitted either by the investigating officer or the involved motorists.

ACCIDENT SEVERITY - A measure of the seriousness or violence of an accident or all accidents at a highway location. Accident severity may be expressed in terms of the number of fatalities, injuries, or property damage accidents or involvements which occur during a specified period of time.

ACCURACY - The degree of freedom from error by which a measurement is taken or an operation performed. For example, if a measurement is stated as $1.02 \pm 0.05$, accuracy is plus or minus five hundredths.

ADMINISTRATIVE EVALUATION - The assessment of project or program implementation activities exploring such issues as resource expenditures, planned versus actual resource expenditures, and productivity.

ADMINISTRATIVE ISSUES - Areas of interest related to project/program implementation, which are subject to administrative evaluation. These issues are: 1) Manpower Categories, 2) Activities, 3) Time Schedule, 4) Materials, 5) Productivity, and 6) other specific administrative issues.

ANALYSIS OF VARIANCE - A statistical technique that tests for significant differences in the dispersion characteristics between two or more data sets.

ASTM - American Society of Testing Materials.

AVERAGE ANNUAL DAILY TRAFFIC (AADT) - The total yearly volume divided by the number of days in the year.

BENEFIT-COST RATIO - The economic value of the reduction in fatalities, injuries, and property damage divided by the cost of the accident reducing measure.

CHI-SQUARE DISTRIBUTION - Distribution of test statistics used to test the null hypothesis of "independence" for the two classifications of a two-way table. Also has many other statistical applications.

COLLECTOR STREET - Provides for traffic movement between major arterials and local streets, with direct access to abutting property.

COLLISION DIAGRAM - A schematic drawing that shows the direction of travel, prior to contact, of the vehicles and/or pedestrians whose presence contributed to the collision.

CONDITION DIAGRAM - A scaled drawing of the important physical conditions of a highway spot or section. It is used to relate the accident patterns on a collision diagram to the roadway and operational event at the hazardous location.

CONTINUOUS DATA - Possible data values that can take on an infinite number of values within a defined range.

CONTROL OF ACCESS - The condition where the right of owners or occupants of abutting land or other persons to access, light, air, or view in connection with a highway is fully or partially controlled by public authority. Full control of access means that authority to control access is exercised to give preference to through traffic by providing access connections with selected public roads only and by prohibiting crossings at grade or direct private driveway connection. Partial control of access means that the authority to control access is expected to give preference to through traffic to a degree that, in addition to access connections with selected public roads, there may be some crossings at grade and some private driveway connections.

CONTROL SITE(S) - A site or group of sites with similar characteristics which are not exposed to the same countermeasure as the project site, used to aid in determining if the results achieved by the treatment group are a consequence of the countermeasure rather than the result of some outside influence.

COORDINATE REFERENCING SYSTEMS - Methods for accurately locating individual accidents by grid coordinates.

COST/BENEFIT ANALYSIS - A form of economic evaluation in which input is measured in terms of dollar costs and output is measured in terms of economic benefit of a project as compared to the incurred cost of the project.

COST-EFFECTIVE ANALYSIS - A comparison study between the cost of an improvement (initial plus upkeep) and the benefits it provides. The latter may be derived from accidents reduced, travel time reduce, or increased volume of usage, and translated into equivalent dollars saved.

CRITICAL PATH METHOD (CPM) - A network diagramming technique in which it is assumed that time estimates are readily obtainable from past experience and the network is a progression of activities arranged in logical paths to the ending node.

COUNTERMEASURE - A specific activity intended to improve one or more aspects of the traffic safety or contribute to the solution of a specific accident problem.

DATA BASE - The document collection or file of collected data which serves as the basis of an information retrieval system.

DATA COLLECTION - The process of accumulating statistical information relating to the empirical effects of a highway safety project.

DATA SET - A set of data pertaining to a single set or a single data collection period.

DATA TABULATION - The process of displaying experimental results in a table so that the information can more readily be interpreted.

DIVIDED HIGHWAY - A highway with separated roadways for two directional traffic.

"DO NOTHING" ALTERNATIVE - An alternative which refers to the existing state of the system.

DYNAMIC PROGRAMMING - A mathematical theory of a multi-stage decision process used to allocate money to obtain the maximum possible benefits under a fixed budget.

EFFECTIVENESS EVALUATION - A statistical and economic assessment of the extent to which a highway safety project or program achieves reduction in the number and severity of accidents (accident-based evaluation), or the intermediate impact of a project on observed traffic operations and road user behavior (non-accident based evaluation).

EFFECTIVENESS MEASURES - Indications of the extent to which program objectives are being attained.

EIS - Environmental Impact Statements.

ENGINEERING - Pertaining to highway and traffic engineering, includes design, construction, maintenance, and traffic engineering and other branches having to do with the physical highway plan.

ENVIRONMENTAL BASED STUDIES - A study that involves collection and analysis of all information related to the physical features of the roadway for specific spots, sections, and elements.

EPDO - Equivalent Property Damage Only (Accidents). A measure of accident experience based on attaching weights to accident severity categories as multiples of property damage only accidents.

ERRATIC MANEUVER - An unusual action by a road user which could lead to a traffic accident.

EVALUATION - A comparison process that measures an item of activity against certain predetermined standards or criteria. A judgement of value or worth.

EVALUATION COMPONENT (HSIP) - The third of three HSIP components. This component consists of one process and four subprocesses which involves the determination of the effect of Highway Safety Improvements through the appropriate use of 1) non-accident based project evaluation, 2) accident based project evaluation, 3) program evaluation, and 4) administrative evaluation.

EVALUATION OBJECTIVE - A brief statement describing the desired outcome of an evaluation study.

EXPERIMENTAL PLAN - A method of evaluation involving alternate techniques which will allow for a determination of project impact. The experimental plan selection criteria depends on project characteristics and data availability.

EXPOSURE - The quantity of vehicles, vehicle miles of travel or other volume and/or time related factor which measures the degree of vehicular exposure to a particular situation.

EXPRESSWAY - A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at major intersections.

F-DISTRIBUTION (F-TEST) - Distribution of test statistic used to compare variances from two normal populations. (See ANALYSIS OF VARIANCE).

FAULT TREE ANALYSIS - A technique which utilizes logic in an attempt to trace all events and combinations of events which may result in an accident.

FHPM - Federal-Aid Highway Program Manual.

FREEWAY - An expressway with full control of access.

FREQUENCY - Number of observations falling in a cell or classification category.

FREQUENCY METHOD - A technique that identifies and ranks hazardous locations on the basis of number of accidents.

FREQUENCY RATE METHOD - A technique normally applied by first selecting a large sample of high accident locations based on frequency method followed by ranking based on accident rate.

FUNCTIONAL CLASSIFICATION - Division of a transportation network into classes, or systems, according to the nature of the service they are to provide.

FUNDAMENTAL OBJECTIVES - Four evaluation objectives which should always be included in Accident-based evaluation. These objectives are to determine the effect of the project/program on; 1) total accidents, 2) fatal accidents, 3) injury accidents, and 4) property damage accidents.

GAP STUDY - A study conducted to measure the time headway or GAP between vehicles along a highway section (or at a point), and to analyze the Gap acceptance characteristics where a minor or alternate traffic stream intersects a major traffic stream.

GRADIENT - Ratio of vertical to horizontal lengths.

HAZARD - Conditions which exist on the highway system which are conducive to future accident occurrences.

HAZARD INDEX METHOD - A technique which employs a formula to develop a rating index for each suspect site. Factors used in the formula are; number of accidents per year, accident rate, sign distance, etc.

HAZARDOUS LOCATION - Highway spots, intersections or sections experiencing abnormally high accident occurrences or potential.

HAZARDOUS ROADWAY FEATURES INVENTORY METHOD - A technique of selecting sites with a potential for high accident severity or numbers on the basis of identification of hazardous roadway features: Narrow Bridges, Steep Roadside Slopes, etc.

HIGH COST PROJECT - Major highway safety projects which require a significant initial cost outlay. Examples include lane additions, bridge replacements, roadway alignment changes, constructing highway grade separations, etc.

HIGHWAY LOCATION REFERENCE METHOD - The technique used for the identification of linear position of a specific point or segment of a highway either in the field or in the office with respect to a known point.

HIGHWAY LOCATION REFERENCE SYSTEM - The total set of procedures for determining and retaining a record of specific points along a highway. The system includes the location reference method(s) together with the procedures for storing, maintaining, and retrieving location information about points and segments on the highway.

HIGHWAY SAFETY GOAL - Expected safety improvements resulting from a highway safety program.

HIGHWAY SAFETY PROJECT - One or more remedial countermeasures instituted to improve specific safety deficiencies on the highway or its environs.

HIGHWAY SAFETY TREATMENT - A single remedial countermeasure instituted to improve the overall safety environment of the highway system.

HISTOGRAM - Graphical method for describing a set of data.

HIGHWAY, STREET, OR ROAD - A general term denoting a public way for purposes of vehicular travel, including the entire area within the right-of-way.

HSIP - Highway Safety Improvement Program, defined in FHPM 8-2-3.

HYDROPLANING - A condition where one or more tires of a moving vehicle are separated from the pavement by a film of water; usually due to a combination of depth of water, pavement surface texture, vehicle speed, tread pattern, tire pressure, and other factors.

IMPLEMENTING COMPONENT (HSIP) - The second of three components. This component consists of one process and three subprocesses which involve; 1) the scheduling, 2) the design and construction, and 3) the operational review of project(s).

IMPLEMENTATION SCHEDULE - A listing of the events needed to complete a particular project activity. The listing is arranged in a chronological sequence according to the time for initiating each event and with an estimated time of completion.

INTEGER PROGRAMMING - A linear programming problem in which some or all of the decision variables are restricted to integer values. Programming problems in general deal with the use or allocation of scarce resources in a manner such that costs are minimized or profits are maximized.

INTERCHANGE - A system of interconnecting roadways in conjunction with one or more grade separations, providing for the movement of traffic between two or more roadways on different levels.

INTERMEDIATE OBJECTIVES - Expected short term improvements in the causal and contributory factors of a non-accident based project evaluation.

INTERSECTION - The general area where two or more highways join or cross, within which are included in the roadway and roadside facilities for traffic movements in that area.

INVENTORIES - Lists of items or occurrences such as roadway and roadside features, accidents, high accident locations, etc.

ITE - Institute of Transportation Engineers.

LEVEL OF SIGNIFICANCE - Refers to the outcome of specific statitistical test of hypothesis.

LINK - A highway segment between two nodes.

LINK AND NODE REFERENCE SYSTEMS - Method for accurately locating individual accidents by longitudinal distance down the highway from a referenced node.

LOCAL STREET OR LOCAL ROAD - A street or road primarily for access to residential, business, or other abutting property.

LOCATION - The name given to a specific point on a highway for which an identification of its linear position with respect to a known point is desired. A location may be where an accident occurred, where a roadway characteristic (such as surface width) changes, where an operational characteristic (such as traffic volume) changes significantly or where some maintenance activity started or ended.

LONG-RANGE TRANSPORTATION PLAN - A 10- to 20-year plan that has specific goals, is system- and major-project oriented, and includes the highest priority projects and a funding projection indicating that funds will probably be available for the plan's completion.

LORAN-C-BASED METHOD - An electronic, long range navigation system that allows determination of a position anywhere in the coverage area.

LOW COST PROJECT - Highway safety projects which require low or moderate initial cost outlays. Examples include pavement edgelining, traffic signal timing modifications, traffic sign installation, roadway delineator installations, etc.

MAJOR CAUSAL FACTOR - Specific hazardous elements associated with the highway, environment or vehicle, or actions associated with the road user which describe why an actual or potential accident problem exists.

MAJOR CONTRIBUTORY FACTOR - Elements or activities which lead to or increase the probability of a failure in the road user, the vehicle or the environment.

MAJOR STREET OR MAJOR HIGHWAY - An arterial highway with intersections at grade and direct access to abutting property and on which geometric design and traffic control measures are used to expedite the safe movement of through traffic.

MEAN - Average of a set of measurements. The symbol $\bar{X}$ is used to denote the mean of a sample.

MEASURE OF EFFECTIVENESS (MOE) - A measurable unit or set of units assigned to each evaluation objective. The data collected in the units of the MOE will allow for a determination of the degree of achievement for that objective.

MECHANICAL VOLUME COUNTER - A mechanical device used for volume data collection when data are to be collected over long periods of time.

MEDIAN - The portion of a divided highway separating the travelled ways for traffic in opposite directions.

MILEPOINT - The name given to the numerical value of middle measurement when a set is ordered according to numerical value.

MILEPOINT METHOD - The technique used to represent the distance from a point to any location.

MILEPOST - A physical entity, ordinarily a sign, placed beside a highway and containing a number that indicates the mileage to that point from some zero point on the highway.

MONITORING - The process of checking and actual progress and comparing it with the scheduled progress.

MULTI-DISCIPLINARY INVESTIGATION TEAM - A group of two or more analytical personnel with at least one representative from the engineering and enforcement agencies and, if desired, representatives from other agencies assigned to advise and assist in the analyses of crash occurrences and in recommendations and evaluations of corrective measures.

MULTI-PROJECT SCHEDULING SYSTEMS (MPSS) - A technique which provides the necessary information to control a group of projects by a highway agency. MPSS includes resource balancing and is a formal method of scheduling and monitoring the status of highway preconstruction and construction activities.

MUTCD - Manual of Uniform Traffic Control Devices.

NCHRP - National Cooperative Highway Research Program: an objective national highway research program supported by participating member states and the Federal Highway Administration.

NEED - A deficiency which should be corrected in the interests of public safety.

NET BENEFIT - A measure of cost-effectiveness, gross benefit minus improvement cost.

NHTSA - National Highway Traffic Safety Administration.

NODE - An intersection of two major streets.

NON-ACCIDENT-BASED PROJECT EVALUATION - An assessment of the intermediate effect of a project on observed changes in traffic operations and road user behavior.

NON-ACCIDENT MEASURE - A measurable unit of safety which is logically related to accident measures such as traffic performance and operation (travel time, delay and speeds) and road user behavior (traffic control violations and erratic maneuvers).

NON-PARAMETRIC METHOD - A statistical significance test where data points show marked departures from normality. Examples of non-parametric test are; 1) Wilcoxen rank sum test, and 2) Mann-Whitney U-Test.

NORMAL DISTRIBUTION - Bell-shaped probability distribution. The curve possessses a specific mathematical formula. Distribution of Z-statistic is used as a test statistic.

NSC - National Safety Council.

NULL HYPOTHESIS - The hypothesis, tested in statistical analysis, that there is no difference between the before and after accident experience.

OBJECTIVE - The specific accident or severity measures which are to be evaluated by the evaluation study. There are two types of objectives; 1) fundamental objectives refer to those measures which must be evaluated in all studies. They are total accidents, fatal accidents, personal injury accidents and property damage only accidents, 2) objectives relating to project purposes. These objectives may include one or more of the purposes of the project. (See PURPOSE).

PARAMETRIC METHOD - Statistical significance tests which assume normality of the parent distribution.

PERFORMANCE MEASURES - Indications of the extent to which programs are being performed in accordance with standards.

PERMANENT COUNT STATIONS - Stations that refer to the long term monitoring of traffic data at specific locations of interest either by manual or mechanical surveys.

PHOTOLOGGING - A technique that involves taking photographs of the highways and its environment from a moving vehicle at equal increments of distance.

PLANNING COMPONENT (HSIP) - The first of the three HSIP components. This component consists of four processes (and associated subprocesses) which involve; 1) identifying hazardous locations and elements, 2) conducting engineering studies, 3) developing candidate countermeasures, 4) developing projects based on the candidate countermeasures, and 5) prioritizing the developed safety improvement projects.

POISSON DISTRIBUTION - A distribution which often appears in observed events which are very improbable compared to all possible events, but which occur occasionally since so many trials occur, e.g., traffic deaths, industrial accidents, and radioactive emissions. The mean and variance of the poisson distribution are equal.

POLICY PLANNING - A conscious process leading to a set of coordinated policy decisions that, in turn, should lead to the achievement of a defined set of goals and objectives.

POPULATION - The total set of items defined by a characteristic of the items.

PRE-PROJECT (OR BASELINE) DATA - Data collected or maintained prior to project implementation for use in describing conditions before an improvement.

PRIORITIZING - The overall process of producing a rank order of priority projects and project sections, using technical and non-technical, quantifiable and non-quantifiable factors as the criteria for ranking.

PRIORITY RATING - A complex rating for evaluating or comparing projects.

PROBABILITY DISTRIBUTION - Representation of the theoretical frequency distribution for a random variable.

PROGRAM - A group of projects (not necessarily similar in type or location) implemented to achieve a common highway safety goal of reducing the number and severity of accidents and decreasing the potential for accidents on all roads.

PROGRAM EVALUATION AND REVIEW TECHNIQUE (PERT) - A network diagrammatic technique used for scheduling and controlling many activities throughout a project.

PROGRAMMING - The matching of available projects with available funds to accomplish the goals of a given period.

PROGRAMMED PROJECTS - A highway safety project, formally planned for implementation at some point in time. Projects contained in the Annual Work Program (AWP) are programmed projects.

PROGRAM/PROJECT BENEFITS - A measure of the positive effect of a highway safety program or project given in terms of accident measure reduction.

PROJECT - One or more countermeasures designed to reduce identified safety deficiencies at a highway location. For example, pavement deslicking may be selected as a single countermeasure to reduce wet-weather accidents at a site, and is termed as a project.

PROJECT IMPACT - Project effectiveness in achieving the evaluation objectives; also any unexpected consequences of the project such as public reaction.

PROJECT JUSTIFICATION STATEMENT - A formal statement of the perceived need for implementing a particular highway safety project. This statement is generally submitted to state funding agencies as a request for project funding. The statement generally provides a quantitative justification in terms of the existing adverse conditions (accidents) as well as the expected benefits to be derived from the project.

PURPOSE - The reason for which the highway safety project was implemented. The purpose refers to the reduction or elimination of a specific highway safety deficiency such as a type of accident, a severity class, a hazard potential indicator and/or a traffic performance variable.

QUEUE LENGTH STUDIES - A study that identifies the number of vehicles that are stopped in a traffic lane behind the stop line at an intersection.

RANGE OF A SET OF MEASUREMENTS - Difference between the largest and smallest members of the set.

RATE-OF-RETURN METHOD - A form of economic evaluation based upon the computation of the interest rate at which the net present annual worth of the project minus the improvement cost is equal to zero.

RATE QUALITY CONTROL METHOD - A technique of utilizing a statistical test to determine whether the accident rate at a particular location is significantly higher than a predetermined average rate for locations of similar characteristics.

REFERENCE POINT - A fixed, identifiable feature, such as an intersection, railroad crossing, or bridge, from which a location can be measured or referenced.

REFERENCE POINT METHOD - The technique used to identify a specific point or segment of highway for use in accident reporting.

REFERENCE POST - A physical entity, ordinarily a sign, placed beside a highway and containing a number that does not reflect a milepoint, but is an identification number for the point of location of the post. The identification number is associated with the actual milepoint of the location in office records.

REPORTING THRESHOLD - The extent of personal injury or vehicle damage at or above which all accidents are reported.

RIGHT-OF-WAY - A general term denoting land, property, or interest therein, usually in a strip, acquired for or devoted to transportation purposes.

ROADSIDE - A general term denoting the area adjoining the outer edge of the roadway. Extensive areas between the roadways of a divided highway may also be considered roadside.

ROADSIDE CONTROL - The public regulation of the roadside to improve highway safety, expedite the free flow of traffic, safeguard present and future highway investment, conserve abutting property values, or preserve the attractiveness of the landscape.

ROADWAY (general) - The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways. (In construction specifications, the portion of a highway within limits of construction).

ROUGHNESS INDEX - A number which provides a measure of roughness developed from the study of highly irregular pavement surface.

SAFETY PROBLEM (NON-ACCIDENT BASED EVALUATION) - Specific types of accidents or potential accidents which result from the existence of a causal and/or contributory factor.

SALVAGE VALUE - Estimated residual worth of program or project components at the end of their expected service lives.

SAMPLE - A subgroup of the population. A finite portion of a population or universe.

SERVICE LIFE - The period of time, in years, in which the components of a program or project can be expected to actively affect accident experience.

SEVERITY INDEX - A number computed from applying weighting factors to injury and fatality accidents based on their severity.

SHOULDER - The portion of the roadway continuous with the travelled way for accommodation of stopped vehicles for emergency use, and for lateral support of base and surface courses.

SKID NUMBER - The coefficient of friction times 100 (100X) of a tire sliding on wet pavement when tested at 40 mph with a two wheel skid trailer or equivalent device following the procedures outlined in ASTM E274-65T.

SPOT MAPS - Maps often used by police and other public agencies to provide a quick visual picture of accident concentrations identified through "spot" marks or pins on a street map.

STANDARD - One of the 18 Highway Safety Programs Standards promulgated by the Department of Transportation to implement the Highway Safety Act of 1973, 23 USC 402.

STANDARD DEVIATION - Measure of data variation. Square root of the variance. represents the population standard deviation. S represents the sample standard deviation.

SUPPLEMENTAL (BI-LEVEL) REPORTING - A prescribed minimum amount of information that would collected on every reportable accident and a supplemental report that would include additional data concerning items of special interest. The supplemental data are usually collected on a sample basis.

SYSTEMS PLANNING - A process under which transportation networks and corridors are defined in a "bottom-up" approach, starting from forecasts of population and economic growth and continuing through estimates of person and goods movement to a physical description of the systems required to meet the real or implied needs.

TEST OF PROPORTIONS - A statistical technique based on a contingency table to test the hypothesis that two proportions are or are not equal. The Z-Statistic calculated in this test is compared to a tabulated $X^2$.

THROUGH STREET OR THROUGH HIGHWAY - Every highway or portion thereof on which vehicular traffic is given preferential right-of-way, and at the entrances to which vehicular traffic from intersecting highways is required by law to yield right-of-way to vehicles on such through highway in obedience to either a stop sign or yield sign.

TIME-OF-RETURN (TOR) METHOD - A form of economic evaluation in which expected accident reductions are forecast using data from previous before-and-after accident studies and a TOR value is computed by dividing the estimated cost of the project by the computed annual benefit. Projects with the lowest TOR values are considered to be the best.

TRAFFIC CONFLICT - A traffic event involving two or more road users, in which one user performs some atypical or unusual 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 ENGINEERING MEASURES - Engineering procedures for controlling or regulating the movement, direction, speed, right-of-way, and parking of vehicular traffic and, where applicable, pedestrian traffic on streets and highways. This includes such elements as one-way streets, turn controls, reversible lanes, crosswalks, etc.

TRAFFIC LANE OCCUPANCY STUDIES - Studies that provide a measure of the traffic performance of a highway facility as a function of vehicles lengths, volumes, and speed.

TRAFFIC OPERATIONS-BASED STUDIES - Studies which provide essential information to assist in the selection of the most appropriate safety improvements at identified hazardous locations.

T-TEST (STUDENT'S t) - A statistical technique for testing the Null Hypothesis, i.e., that the mean scores from two groups do not differ in a statistically significant way. Applicable to the test of the hypothesis that a random sample of observations is from a normal population with the mean and variance unspecified. This test should be used when the sample size is less than 30.

ULTIMATE SAFETY OBJECTIVES - A significant reduction in the number and severity of accidents.

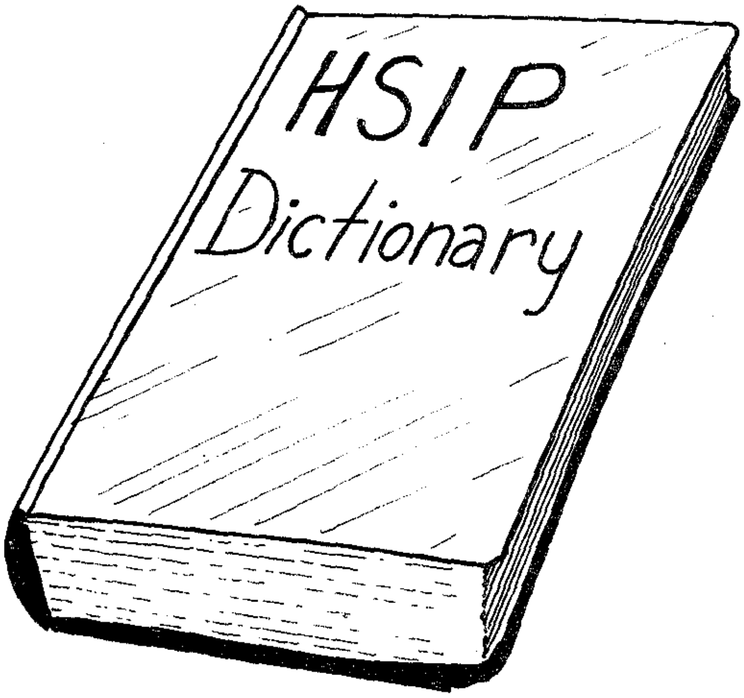
VARIANCE - Measure of data variation. $T^2$ represents population variance $s^2$ represents sample variance.

VIDEOLOGGING - A technique that involves taking video tape pictures of highways and its environment as a substitute for photologging.

VOLUME - The number of vehicles passing a given point during a specified period of time.

WARRANTS - The minimum conditions which would justify the establishment of a particular traffic control regulation or device, usually including such items as traffic volumes, geometrics, traffic characteristics, accident experience, etc.

Z-STATISTIC - Standardized normal random variable that is frequently used as a test statistic.



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