NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE

91

HIGHWAY ACCIDENT ANALYSIS SYSTEMS

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **91**

HIGHWAY ACCIDENT ANALYSIS SYSTEMS

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TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. JULY 1982

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

NCHRP SYNTHESIS 91

Project 20-5 FY 1980 (Topic 12-03)
ISSN 0547-5570
ISBN 0-309-03452-3
Library of Congress Catalog Card Number 82-50975

Price: $7.60

Subject Areas
Administration
Transportation Safety

Mode
Highway Transportation

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This report will be of particular interest to transportation administrators and others concerned with highway safety. Detailed information is presented on procedures for storage, retrieval, and analysis of information on highway accidents.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single concise documents pertaining to specific highway problems or sets of closely related problems.

Highway agencies use data files to identify high accident locations and to institute countermeasures as well as for other purposes. The primary types of data files are accident files, traffic files, and highway files. This report of the Transportation Research Board contains information on highway accident analysis systems including procedures for storing, retrieving, and analyzing information on highway accidents.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Paul E. Irick, Assistant Director for Special Technical Activities Division. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. This synthesis was edited by Nancy A. Ackerman.

Special appreciation is expressed to Charles V. Zegeer, Goodell-Grivas, Inc., Southfield, Michigan, who was responsible for the collection of data and the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Philip Brinkman, Physicist, Office of Research, Federal Highway Administration; David B. Brown, Professor, Department of Industrial Engineering, Auburn University; Benjamin V. Chatfield, Chief, Accident Analysis Division, Office of Highway Safety, Federal Highway Administration; Robert E. Craven, Engineer of Traffic Operations, Illinois Department of Transportation; John E. Evanco, Traffic and Programs Engineer, Louisiana Department of Transportation and Development; Russell R. Fleming, Chief, Accident Data Division, Wisconsin Department of Transportation; and Donald E. Orne, Engineer of Maintenance, Michigan Department of Transportation.

James K. Williams, Transportation Safety Coordinator, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

HIGHWAY ACCIDENT ANALYSIS SYSTEMS

SUMMARY

A highway accident analysis system is the total set of procedures for storing, maintaining, retrieving, and analyzing information related to highway locations. These procedures include the reference method used along highways (e.g., milepost method), merging or interfacing data files, processing accident and other data files, identifying problem locations, and evaluating the effectiveness of completed projects. Roadway and traffic files (including selective-enforcement data) are also used in highway accident analysis systems as well as for safety research purposes.

In order to successfully perform accident analysis, an appropriate highway location reference method for the highway network must be selected. The types and uses of highway location reference methods vary widely among highway agencies. Reference methods include the milepost and reference post methods (using posts in the field) and document-oriented methods. The manner in which the referencing method is applied is a major factor in ensuring locational reporting accuracy.

One way to improve the accuracy and efficiency of location referencing and data processing is to use a computerized accident data system, which, at the least, is a computer file containing the route numbers and/or names within the highway network along with linear distances between intersection points.

The three basic types of data files that are referenced to specific highway locations are accident, traffic (e.g., speeds, volumes, traffic mix), and highway files (e.g., roadway geometrics, roadside obstacle data, traffic control information). Accident and roadway data files are used primarily to identify high accident locations and features, produce systemwide accident summaries, process information for countermeasure selection, and evaluate the effectiveness of accident countermeasures. Also, the data may be used for accident research or by police agencies for selective-enforcement activities.

The merging of data files is useful both for accident analysis and research purposes. Data interfacing or linking is commonly conducted for routine analysis activities, such as computing accident rates for specific highway classes. The essential element of data merging is a compatible referencing method.

Numerous types of data summaries, statistical reports, and publications can be generated from computerized accident analysis systems. Several statistical software packages currently in use, including SPSS, SAS, DART, and RAPID, can provide a wide range of statistical analyses for systemwide accident data summaries for use in problem identification and for other purposes.

One of the primary applications of accident analysis is the identification of problem (hazardous, unsafe, abnormal, etc.) locations. The commonly used identification methods are the frequency, accident rate, frequency rate, rate quality control, and accident severity methods. In addition to identifying and reviewing locations that have high accident experience (i.e., high accident numbers, rates and/or severity), it is important to identify and correct locations with a high accident potential. A hazardous roadway features inventory can provide information on potential accident problems. The criteria for selecting a method (or methods) to identify problem locations include the types of data available and the level of sophistication desired.

After problem locations have been identified, field visits are usually conducted along with a wide range of safety engineering studies to help in the selection of accident countermeasures. The final selection of an improvement is based on the expected cost of the project, the available budget, and the desirability of the project. Many agencies compute expected accident savings (benefits) for each project and apply economic measures (incremental benefit-to-cost ratio, net benefits, rate of return, etc.) to make final project selections. Dynamic or integer programming is also used to select projects in an attempt to obtain the most safety benefits under a given funding level.

After projects have been completed, accident data can be used to evaluate their effectiveness in reducing accident frequency and/or severity. The results of safety evaluations are useful in the selection of future projects. Traffic exposure, past accident trends, and other external factors that can affect the evaluation results should be considered. Control or comparison sites have been used to improve the reliability of evaluations. Although most agencies do not maintain a data base readily suitable for performing project or program evaluations, a few agencies have developed computer software to facilitate accident-based evaluations.

Recommendations for the improvement of accident analysis systems include (a) increased emphasis on the accuracy of accident information, particularly with respect to the accident location, (b) development and use of computerized roadway networks; (c) use of more appropriate reference methods, improved field referencing, log reference books, and closer interaction between safety engineers and police personnel, which can result in more accurate accident information; and (d) streamlining accident report forms, which can ease the burden on the reporting officers and office data handlers but still ensure that essential data are obtained.

For data processing, the development of compatible reference methods is recommended to allow for interfacing or merging data files. The use by agencies of one or more available software packages can provide most or all the required types of statistical summaries without developing new software. Most states and cities could benefit substantially by taking advantage of the model analysis systems of other agencies to supplement their own efforts.

To enforce a standardized accident analysis system would be totally inappropriate, because of the wide differences among highway agencies with respect to resources, level of expertise, overall goals, and size and type of highway network. However, agencies can minimize duplicated or wasted efforts both by publicizing their own successes and failures and taking advantage of the efforts of others.

CHAPTER ONE

INTRODUCTION

The purpose of highway safety programs is to reduce the level of human and economic losses on the nation's highway system. Specific guidelines for planning, implementing, and evaluating highway safety programs were established by the U.S. Congress in the Highway Safety Act of 1966, and later modified by such legislation as the 1973 Highway Safety Act and the 1978 Surface Transportation Assistance Act. In addition to this significant legislation, numerous federal programs and guidelines developed in recent years have helped to define the actions needed for improving highway safety.

SAFETY STANDARDS

Federal safety efforts are intended to supplement state, local, and private efforts. To provide guidance to state and local agencies in conforming with highway safety programs, the U.S. Department of Transportation developed the *Highway Safety Program Manual* (*1*). Of the 18 safety standards listed in the *Highway Safety Program Manual,* those most related to data processing and highway accident analysis are Standards 9, 10, 13, and 18 (*1*).

Standard 9, Identification and Surveillance of Accident Locations, requires each state to develop a program to identify accident locations and maintain surveillance of locations with high accident rates. The state is required to take appropriate measures to reduce the number of accidents at those locations and to evaluate the effectiveness of the safety improvements. The standard also calls for the development of corrective treatments for "potentially" high accident locations. Periodic evaluations of the program are also required.

Standard 10, Traffic Records, requires states to maintain a traffic records system containing statewide data on drivers, vehicles, accidents, and highways for use in analysis and corrective treatments. Local governments should have systems that are compatible with the state system, and states are required to provide accident summaries and special analyses to the local agencies on request.

Standard 13, Traffic Engineering Services, requires that states have a program for applying traffic engineering measures and techniques, including traffic-control devices, to reduce accident frequency and severity. A manpower development plan is required to ensure that adequate traffic engineering capability is available. Development of a plan to inventory and maintain traffic-control devices according to federal guidelines is also required. A program must also be established to maintain surveillance of the highway system for potentially high accident locations, such as sharp curves, steep grades, and railroad crossings, and to develop appropriate countermeasures for such locations.

The purpose of Standard 18, Accident Reporting and Investigation, is to establish a uniform comprehensive program for gathering information related to motor-vehicle accidents. Each state and political subdivision is required to collect, store, and process accident information and to provide information required by users. The standard requires each state to establish procedures for entering accident information into the statewide traffic records system. Informational items that must be included for each accident are also specified.

DATA FILES

There are three basic types of files for which information on the highway network should be maintained based on highway location reference methods:

1. *Accident files.* Information on location, time, type, severity, environmental conditions, contributing circumstances, and other factors related to traffic accidents.
2. *Highway files.* Information on the physical highway environment, including traffic-control devices, location of roadside obstacles, roadway curvatures, pavement and shoulder widths, and other geometric characteristics.
3. *Traffic files.* Information on the traffic stream, including vehicle speeds, traffic volumes, vehicle classification counts, and the like.

Additional files that are not usually referenced to specific points on the highway network are vehicle and driver files.

HIGHWAY LOCATION REFERENCE METHODS AND SYSTEMS

To effectively meet the requirements of the highway safety standards and properly utilize the various types of data files, highway agencies must have the capabilities to collect, maintain, and utilize the data related to their highway systems. Highway agencies not only need to collect such data, but they must have the capability to sort and store information by highway location. This requires the development and use of efficient methods for referencing specific highway locations.

NCHRP Synthesis of Highway Practice 21: Highway Location Reference Methods (2) provides a comprehensive report on reference methods and systems. In this report, a highway location reference *system* is defined as "the procedures that relate all locations to each other and includes techniques for storing, maintaining, and retrieving location information"; and a highway location reference *method,* which is only one part of the total reference system, is defined as "a way to identify a specific location with respect to a known point" (*2*). Three elements common to all location reference methods are also identified (*2*): "(a) identification of a known point, (b) a measurement from the known point, and (c) a direction of measurement." The two basic categories of location reference methods are sign-oriented methods (using field signs) and document-oriented methods (referencing information on office records) (*2*).

Many different types of reference methods and data analysis systems are currently used by state and local highway agencies for highway and accident analysis. The selection and use of an appropriate system is one of the key elements in the success of an agency's traffic records system. However, many of the accident data analysis systems in use today are inefficient, cumbersome, and unsuitable for file merging due to incompatible location reference information. Some states that have the capability to merge two or more data files may do so only for planning or research purposes, but not for safety analysis. Often, the data systems are not utilized in an optimal manner to provide a list of the locations that are most in need of investigation and improvements. Even after highway improvements are made, adequate project evaluations are often not conducted, as many data systems are not designed to readily allow for such evaluations.

Because of the need for effective traffic records systems and the many problems inherent to data systems in general, appropriate system modifications are necessary. However, before modifications can be considered by agencies, both successful and unsuccessful past experiences with reference systems should be examined. Agencies need to select or develop a system that is most compatible with current and future needs. The system must be sensitive to the specific data elements desired for safety analyses. Then the appropriate processing techniques can be formulated to produce the desired information. However, unless there is a commitment to establishing and maintaining an adequate data base, no highway accident analysis system will be of much value.

PURPOSE OF SYNTHESIS

There is a pressing need among state and local highway agencies to develop better highway accident analysis systems. This report is intended to expand on *NCHRP Synthesis 21 (2),* which is a detailed summary of the types and uses of highway location reference methods. The total highway accident analysis *system* is discussed here, including the storing, maintaining, retrieving, and analysis of information related to highway locations. This report focuses on the use of data files to (a) identify high accident locations and features, (b) produce desired accident summaries, (c) process information for countermeasure selection, and (d) evaluate the effectiveness of countermeasures. The use of data systems by police agencies and for research purposes is also discussed. The required resources and the impediments to data processing and analysis are addressed, based on information supplied by state and local highway agencies. Finally, recommendations for improving highway accident analysis systems are provided.

Sources of Information

The information on which this synthesis is based was gathered from two basic sources. First, an in-depth review of the available literature was conducted. More than 60 references that specifically address one or more of the relevant topics were reviewed. Second, a survey was conducted of selected state highway agencies known to have progressive data processing systems and/or to place emphasis on the efficient operation of data files. On-site interviews were conducted with state agencies in California, Illinois, Alabama, and Michigan. Detailed information was also obtained from Wisconsin and West Virginia, from FHWA officials, and from state police agencies within selected states.

DEFINITIONS OF TERMS

Definitions of commonly used terms relating to data processing, highway location reference methods, and highway accident analysis systems are given below.

Coordinate reference method. Method for locating individual highway locations by grid coordinates.

Data base. Collection or file of information that serves as the basis of an information retrieval system.

DIME/GBF (dual independent map encoding/geographic base file). Geographic base file originally prepared by the Bureau of Census for use in coding census data to specific areas. This is basically a computerized version of a street map.

File interfacing. Process of sorting and/or manipulating two or more data files to obtain and process data for one or more common referencing units (e.g., highway locations, drivers, or vehicles).

File merging. The joining of two or more data files into a common file using a common referencing unit.

Hazardous location. Highway spots, intersections, or sections with an abnormally high accident experience (frequency, severity, or rate) or potential.

Roadway features inventory. List of various highway characteristics for use in planning activities or in highway safety analysis, which can include such characteristics as highway alignment; gradient; lane width; pavement width; surface conditions; location of traffic-control devices, bridges and culverts; and such variables as narrow bridges, steep roadside slopes, rigid, fixed objects close to roadway edge, etc.

Highway location reference method. Specific technique used for referencing a highway point or segment either in the field or in the office with respect to a known point.

Highway location reference system. 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 related to points and segments on the highways (*2*).

Link-node reference method. Method for locating individual accidents by longitudinal distance along the highway from a referenced node.

Loran C. Method for locating *x-y* coordinates of a highway location using radio signals from transmitting stations.

Milepoint. Term for the numerical value of the mileage displacement from a base point to any location (*2*).

Location dictionary processor. Conversion routine that can be used to automatically convert one highway location reference method to another for use in data interaction and processing.

Reference point. Fixed, identifiable feature, such as an intersection, railroad crossing, or bridge from which a location can be measured or referenced (*2*).

Traffic records system. The personnel, equipment, facilities, information, and procedures necessary to correlate accident data with vehicle, driver, and/or highway data.

CHAPTER TWO

HIGHWAY LOCATION REFERENCE METHODS

The purpose of a highway location reference method is to permit the designation, recording, and storing of specific geographic highway information. The availability and use of an accurate location reference method provides for highway information to be modified or updated when necessary and the merging of various types of highway data files for analysis purposes.

TYPES OF REFERENCE METHODS

A variety of highway location reference methods are used today, and the terminology and applications of the methods vary widely.

Reference methods are discussed in detail in *NCHRP Synthesis 21 (2)* under the following categories:

- Sign-oriented methods
  - Milepost method
  - Reference post method
- Document-oriented methods
  - Document Method I
  - Document Method II
- Other methods
  - Coordinate method
  - Referencing to roadway features (bridges, utility poles, railroad crossings, mailboxes with addresses, etc.)

Also, three basic types of reference methods are described in Standard 9 of the *Highway Safety Program Manual (1):* (a) linear method; (b) coordinate method; and (c) links and nodes method. In addition, five reference methods are mentioned in the 1982 Federal Highway Administration's report to Congress (*3*): (a) mileposting; (b) paper mileposting; (c) grid system; (d) link-node system; and (e) physical features. Most of the methods are self-explanatory or are explained later in this chapter.

Sign-Oriented Methods

Milepost Method

The milepost method is the reference method most commonly used by state highway agencies for locating accidents on the highways (*2*). This method involves using physical milepost signs in the field to represent the distance from a base point to any location. The base (zero) point may be a county or state line, the beginning of a route, or another clearly defined highway feature. Milepost field markers are often placed at even intervals (e.g., 1 mile apart) on Interstate or major state routes. Milepost signs may provide only the milepoint of the location or may also include the route number and county. Due to construction changes in the length of a highway route, mileposts may not indicate the true milepoint of a location. In such cases, an equation is often used in the office to relate the milepost number to the true milepoint of the route, and the reported mileposts of accident sites can be converted to the true milepoints. States using the milepost method include Oregon, California, Washington, and Nevada.

A summary of the characteristics, use, advantages, and disadvantages of the milepost method is given in Table 1. A typical milepost is shown in Figure 1.

Reference Post Method

The reference post method is different from the milepost method, as the reference post itself does not usually provide locational information in terms of miles (*2*). Therefore the location of a highway point (accident location) is given in terms of the distance and direction from the nearest reference post marker. This information is then converted in the office to the corresponding milepoint number from appropriate maps or route logs. The reference post method was developed to minimize the problems caused by changes in route lengths, which affect milepost numbers. States using the reference post method include Arizona, Wisconsin, and Maine (*2*). A summary of the characteristics, use, advantages, and disadvantages of the reference post method is given in Table 1.

Document-Oriented Methods

The document methods involve the referencing of highway locations on office maps and/or files and do not utilize

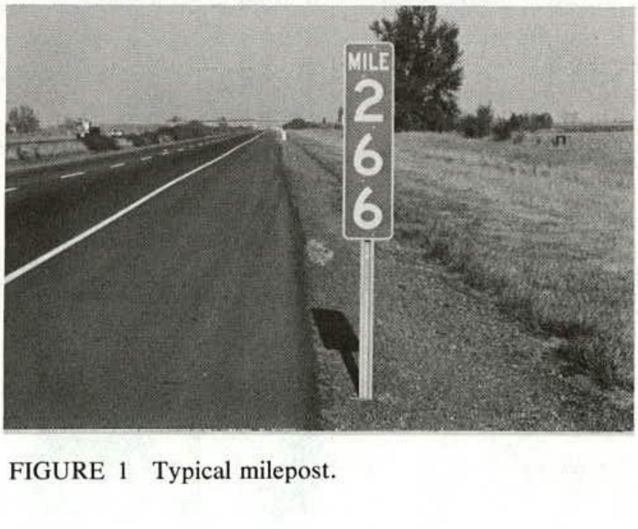


FIGURE 1 Typical milepost.

TABLE 1
COMPARISON OF MILEPOSTS AND REFERENCE POSTS (2)

	Characteristics	Use	Advantages	Disadvantages
MILEPOSTS	• Signs may be placed at any spacing (usually 1 mile). • Signs contain the actual milepoints or approximate mileages of the locations. • Zero points are usually at route beginnings, at county lines, or at control section limits. • The messages on the signs may or may not be readable from a moving vehicle.	• Because this method incorporates signs containing milepoints, the actual milepoint for a location of interest on a highway can be readily determined in the field. The distance from the location to a sign is added to or subtracted from the number on the sign, depending on the direction of travel. • An alternate procedure is to record the distance, direction of measurement, and sign number, leaving the computation of the actual milepoint to office procedures.	• Because the signs reflect mileage, which is familiar to most people, this method can be easily learned. • The motoring public is usually provided information for charting progress along the roadway. • There is fairly uniform spacing, so the user does not have to proceed more than some fixed distance to find a marker. • The numerical sequence provides easy orientation.	• Changes in the length of a route after initial placement of signs result in numbers not reflecting true milepoints. • Where there are concurrent routes, the numbers on the signs reflect mileages for only one of the routes. • The placement of signs along highways can create problems for maintenance forces.
REFERENCE POSTS	• Signs may be placed at any spacing. In some cases, placement is at major intersections and jurisdictional boundaries, at fixed uniform intervals, or a combination of these two plus placement at special roadside features. • Central office records containing the true milepoints of reference post signs must be kept. • Signs ordinarily contain numbers that are not related to a milepoint. The signs also may include route number and jurisdictional 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.	• The milepoint is not computed in the field when this method is used. The distance, direction of measurement, and sign number must be recorded, leaving the computation of the actual milepoint to office procedures.	• Changes in route lengths caused by construction do not affect the placement of signs or the validity of the numbers on them. • The signs apply to all concurrent routes. • Spacing of the signs is frequent enough so that users will not have to travel long distances without encountering one.	• Depending on the sign numbers, the motoring public may not be provided information for charting progress. • The placement of signs along highways can create problems for maintenance forces.

field reference signs. A summary of the characteristics, use, advantages, and disadvantages of the document-oriented methods is given in Table 2.

Document Method I

The Document Method I involves the use of diagrams or route logs of physical roadway features with milepoints (*2*). Paper strip maps or logs, containing milepoint numbers of intersections, bridges, railroad crossings, or other features, are used in the office to convert an officer's narrative site description to the corresponding milepoint number. This method is comparable to that called a "paper milepost" or "paper milepoint" method by some agencies, and is used in many states on the portions of the highway network where field markers do not currently exist.

Document Method II

The Document Method II is based on the use of street maps to locate a highway point by street name and the distance and direction to the nearest intersecting street (*2*). In many cases, the site can be converted to the corresponding milepoint number by office personnel if such milepoint information is provided on the maps. The Document Method II is widely used for locating accidents on city streets as well as on many low-volume roads. In some cases, street names and addresses may be referenced in the field. In many cities, the referencing of accidents to the nearest intersection is an informal use of this method.

Coordinate Method

The coordinate method involves locating an accident site with a unique set of x and y coordinates. Before this method can be used, a complete set of grid coordinate maps must be available. The x and y coordinates of a field location are determined in the office by using a location description to plot the point on a grid map. U.S. Geological Survey (USGS) topographic maps are considered appropriate for determining x and y coordinates. In most states, such maps are available at a scale of 1 in. = 4,000 ft. At this scale, a 50-ft field distance is represented by 0.01 in.; thus accuracy may be somewhat limited. However, in some states, USGS maps are available with a scale of 1 in. = 2,000 ft, which provides a higher degree of accuracy (*4*). Coordinate methods can be costly to implement and cumbersome to maintain compared to other reference methods because of reliance on detailed maps and plotting capabilities.

Loran-C Method

One of the applications of the coordinate method involves the loran-C (long range navigational) method that was developed by the U.S. Coast Guard for marine navigation in U.S. coastal waters. This method is essentially a radio system using three transmitting stations (a master and two or more secondary stations) in a triangular pattern. The transmitting stations are located about 500 miles apart and broadcast low-frequency radio pulses. For highway location referencing, a loran receiver automatically measures and displays the numeric code for the x and y coordinates of a highway location. The number displayed is the numeric difference in arrival time between the master signal and its secondary stations. These time differences describe hyperbolic lines of position by which the exact location of the loran receiver is indicated (*5*).

The loran-C method has been tested on an experimental basis in Los Angeles (*6*) and by several states, including Kentucky, Tennessee, and Ohio, to determine its potential for use in accident reporting; further testing of loran-C is necessary regarding feasibility of the method for accident location.

The accuracy of the loran-C method (or any coordinate method) can be described in terms of relative and absolute accuracy. Relative accuracy refers to the accuracy in finding a location in the field that was found and reported previously. With the loran-C method, the reported geographic coordinates may be less accurate than the true coordinates due to distortions in the transmission of radio waves. Absolute accuracy refers to the ability to accurately define a location in terms of its true geographic coordinates. Previous testing of loran-C for highway referencing has shown this method to be better in terms of relative accuracy than absolute accuracy.

Linear Methods

Linear methods are described in Standard 9 of the *Highway Safety Program Manual* (*1*):

> Linear methods reference the locations on each street and highway by measuring the distance from the beginning of the road or some other origin to the desired location. Ordinarily the measurement is expressed in miles, stations, or feet. However, street and house numbers or other consecutive numbering systems can be used if other records, such as traffic volumes and geometrics, can be identified with accident locations specified in this manner. Linear referencing of accident locations depends upon the existence of reference points in the field. Field references include:
>
> A. Milepost markers
> B. Log mile markers
> C. Log mileage signs or stickers on structures and/or signs
> D. Street names and house numbers
> E. Intersections
> F. Easily recognizable landmarks

It is obvious from the above statements that the broad category of linear methods cannot be totally equated with any of the referencing methods mentioned previously. However, the milepost, reference post, and Document I and II methods are all based on the recording of linear distances of an accident site from a known point, and these points can often be converted to linear milepoints.

Links and Nodes Method

The links and nodes reference method is described in Standard 9 of the *Highway Safety Program Manual* (*1*):

> Links and nodes referencing is basically a combination of the coordinate and linear referencing systems. Accident loca-

TABLE 2
COMPARISON OF DOCUMENT METHODS I AND II (2)

	Characteristics	Use	Advantages	Disadvantages
DOCUMENT METHOD I	• The true milepoint is assigned to each identifiable feature shown on a strip map or straight-line diagram. • Printed logs list identifiable features, using the name by which the feature is known in the field. The true milepoint of each feature is printed following the name. The log generally is in order by route number. • A variation of the foregoing two methods is use of a reference number in place of the true milepoint. • The method can be employed either in the field or in the office.	• Because this method does not employ special signs along the highway, the actual milepoint of a location is determined by: (1) identifying a topographic feature on a diagram or log that is nearest to the location in the field, and (2) measuring the distance and recording the direction from the location to the feature as identified on the diagram or log. The milepoint is then calculated by adding to or subtracting from the milepoint of the feature on the log the measured distance from the location. The calculation may be done either in the field or in the office. • An alternative approach is to use reference numbers in lieu of milepoints for the features on the diagram or log. When reference numbers are used, the procedure followed is generally the same as that for the reference post method.	• Special signs are not needed.	• When construction changes require revisions to diagram or log milepoints and street maps, steps must be taken to ensure that users of the method receive the revisions. • The motoring public is excluded as a potential user of the method. • There may be instances of misspelled names, street and road names that are similar or identical, roads and streets with no names or numbers, or roads with more than one name that require special consideration.
DOCUMENT METHOD II	• Names of intersecting streets as seen on maps are used as reference points. Names of streets shown on maps in conjunction with addresses recorded in the field may also be used to identify locations. • The method is especially applicable in urban areas, but it is often applied on low-volume rural roads as well. • The method can be employed either in the field or in the office.	• The name of the street (or highway) on which the location of interest lies and the name of the intersecting street that is nearest to the location are recorded, as well as the distance from the location to the intersecting street. A milepoint number may be determined by office personnel, using maps or logs showing the true milepoint of the intersection. Where the milepoint of the location is not desired, the recorded information is retained in the submitted form. • An alternate procedure uses street names and addresses. The name of the street on which the location of interest lies and the street address number closest to the location are recorded. Office personnel then determine the position of the location with respect to the beginning of the street or to a particular block.	• Special signs are not needed.	• When construction changes require revisions to diagram or log milepoints and street maps, steps must be taken to ensure that users of the method receive the revisions. • The motoring public is excluded as a potential user of the method. • There may be instances of misspelled names, street and road names that are similar or identical, roads and streets with no names or numbers, or roads with more than one name that require special consideration.

> tions are referenced by linear measurements from a given node. Field markers, intersections, or any easily identified landmarks may be designated nodes in the system and the sections of highway between nodes are the links. The nodes are fitted into a theoretical grid system which is particularly applicable to electronic data processing. Other highway records can be referenced by the same system.

The links and nodes method of locational referencing does not necessarily depend on any physical field reference posts and, therefore, can be considered, in most cases, as a document-oriented method. In principle, the link-node system (as normally used by highway agencies) most closely resembles the Document II Method, as both methods are usually based on the referencing of locations to intersections. However, differences in the strict definitions of these methods prevent the terms from being used interchangeably.

Other Methods

In addition to the reference methods described above, roadside objects and features, e.g., railroad grade crossings, bridges, telephone and light poles, and mail boxes, are sometimes used for location referencing. For example, in Illinois reference numbers are placed on light poles along urban freeways that have continuous lighting (Figure 2).

Summary

The discussion of the various reference methods can be summarized as follows (*2*):

> To the casual user of a highway location reference method, there appear to be many widely different methods in use today. There is a tendency to "see" significant differences between methods on the basis of different names. To make matters more confusing, terms such as "straight-line diagram," "route log," "coordinates," "milepoint," and even "milepost" and "reference post" are used rather loosely in connection with location reference methods. The initiate confronted with this situation must somehow determine the "best" method for his particular agency.
>
> The preceding discussion has attempted to show that there really is not a great deal of fundamental difference between the several most commonly used methods. The method that incorporates the use of both milepost signs and strip maps is virtually the same as the method that is based on the use of reference posts and the same strip maps. Further, a nodal sign at an intersection or, for that matter, any sign at all, really is a landmark like any other, such as a bridge or even an intersection itself.
>
> Regardless of the name assigned to the method, all use a distance measurement from an "incident" to a known point, the direction of measurement, and a description of the known point. The characteristics are the same whether the calculation for true milepoint is done in the field, accomplished manually in the office from a straight-line diagram, or performed by the computer.

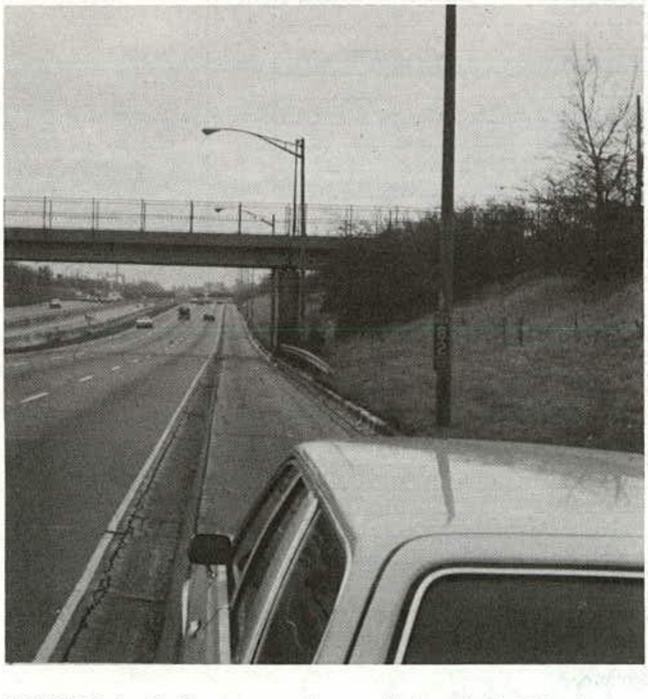


FIGURE 2 Reference marker on light pole in Illinois.

STATUS OF THE USE OF REFERENCE METHODS

The percentage of the highway network on which reference methods are used varies widely among states. In 1982, the FHWA reported to the U.S. Congress that state-numbered highway systems are completely referenced in 90 percent of the states, and local highway systems are referenced in only 58 percent of the states (*3*). The following is a summary of the status of the use of reference methods throughout the country (*3*):

STATUS	NO. STATES*
All highways complete	31
Incomplete	21
Not reporting	3

EXPECTED COMPLETION DATE	NO. STATES*
1981–1982	2
1983–1985	6
Unknown	10
Not reported	3

*The 50 states plus the District of Columbia, Puerto Rico, Samoa, Guam, and the Virgin Islands.

A summary of the percentage of highway coverage by location reference systems in each state is given in Table 3. The percentage of coverage is given for each highway class and, if less than 100 percent, the expected completion date is also provided (*3*).

ACCURACY OF ACCIDENT LOCATION REPORTING

An accurate highway location reference method is a key element of a traffic records system. If an agency cannot pinpoint the location of accidents or other roadway data, then problem locations cannot be accurately identified and analyzed.

TABLE 3
PERCENT COVERAGE OF HIGHWAY LOCATION REFERENCE SYSTEMS (*3*)

STATE	MILES COVERED (PERCENT)					EXPECTED COMPLETION (YEAR)				
	INTERSTATE	STATE - F.A.	STATE - N.F.A.	LOCAL - F.A.	LOCAL - N.F.A.	INTERSTATE	STATE - F.A.	STATE - N.F.A.	LOCAL - F.A.	LOCAL - N.F.A.
ALABAMA	100	100	100	100	100	-	-	-	-	-
ALASKA	-	100	100	100	*	-	-	-	-	*
ARIZONA	100	100	100	85	75	-	-	-	[1]	[1]
ARKANSAS	100	100	100	30	30	-	-	-	1985	1985
CALIFORNIA	100	100	100	100	100	-	-	-	-	-
COLORADO	100	100	100	100	100	-	-	-	-	-
CONNECTICUT	100	100	100	100	100	-	-	-	-	-
DELAWARE	100	100	100	-	-	-	-	-	-	-
FLORIDA	100	100	100	68	26	-	-	-	[2]	[2]
GEORGIA	100	100	100	100	100	-	-	-	-	-
HAWAII [3]	100	100	100	37	0	-	-	-	1983	UNK
IDAHO	100	100	100	100	100	-	-	-	-	-
ILLINOIS	100	100	100	90	90	-	-	-	1985	1985
INDIANA [4]	100	100	100	100	2	-	-	-	-	1985
IOWA	100	100	100	100	100	-	-	-	-	-
KANSAS	100	100	100	0	0	-	-	-	1984	1984
KENTUCKY	100	100	100	0	0	-	-	-	UNK	UNK
LOUISIANA	100	100	100	*	*	-	-	-	*	*
MAINE	100	100	100	100	100	-	-	-	-	-
MARYLAND	100	100	100	100	100	-	-	-	-	-
MASSACHUSETTS	100	100	100	100	100	-	-	-	-	-
MICHIGAN	100	100	100	100	100	-	-	-	-	-
MINNESOTA	100	100	100	100	100	-	-	-	-	-
MISSISSIPPI	100	100	100	100	100	-	-	-	-	-
MISSOURI	100	100	100	UNK	UNK	-	-	-	UNK	UNK
MONTANA	100	100	100	100	100	-	-	-	-	-
NEBRASKA	100	100	100	100	100	-	-	-	-	-
NEVADA	100	100	100	100	100	-	-	-	-	-
NEW HAMPSHIRE	100	96	93	75	75	-	1985	1985	1985	1985
NEW JERSEY	100	100	100	100	100	-	-	-	-	-
NEW MEXICO	100	100	100	100	100	-	-	-	-	-
NEW YORK	100	100	100	80	80	-	-	-	1981	1981
NORTH CAROLINA	100	100	100	100	100	-	-	-	-	-
NORTH DAKOTA	100	100	100	100	100	-	-	-	-	-
OHIO	100	100	100	100	100	-	-	-	-	-
OKLAHOMA	100	100	100	100	100	-	-	-	-	-
OREGON	100	100	100	90	75	-	-	-	UNK	UNK
PENNSYLVANIA	100	100	88	UNK	UNK	-	-	UNK	UNK	UNK
RHODE ISLAND	100	100	100	100	100		-	-	-	
SOUTH CAROLINA	100	100	100	100	100	-	-	-	-	-
SOUTH DAKOTA	100	100	100	100	100	-	-	-	-	-
TENNESSEE	100	100	100	100	58	-	-	-	-	1983
TEXAS	*	100	100	100	*	*	-	-	-	*
UTAH	100	100	100	100	95	-	-	-	-	1982
VERMONT	*	*	*	*	*	*	*	*	*	*
VIRGINIA	100	80	10	UNK	UNK	-	UNK	UNK	UNK	UNK
WASHINGTON	100	100	-	100	100	-	-	-	-	-
WEST VIRGINIA	100	100	100	-	-	-	-	-	-	-
WISCONSIN	100	100	100	100	100	-	-	-	-	-
WYOMING	100	100	100	100	95	-	-	-	-	UNK
DIST. OF COL.	100	100	100	-	-	-	-	-	-	-
PUERTO RICO	-	100	100	100	100	-	-	-	-	-
SAMOA	-	65	0	-	-	-	UNK	UNK	-	-
GUAM	*	*	*	*	*	*	*	*	*	*
VIRGIN ISLANDS	*	*	*	*	*	*	*	*	*	*

UNK = Unknown.
- = Not applicable.
* = Not reported.

[1] Continual update.

[2] Complete coverage not planned.

[3] All intersections covered for local roads.

[4] Future plans call for all local N.F.A. routes to be covered; however, only 5–10% are expected to be covered by 1985.

The following information on accuracy in accident reporting is from Standard 9 of the *Highway Safety Program Manual* (*1*):

> Levels of accuracy for locating the site of an accident should be adequate to identify sufficiently for later purposes of corrective action the roadway design and other environmental features that may have contributed to the hazard at the location. Both the points of initiation and termination of the accident sequence should be located by the investigating official, utilizing as a frame of reference any significant physical features of the crash site and its immediate vicinity. Recommended as minimum levels of accuracy are:
>
> a. Measurement should be made to the nearest 1/100 of a mile for residential and commercial streets in urban areas, urban expressways and freeways, rural roads within the area of influence of an intersection, and all other locations where there is a convenient reference.
>
> b. In all other cases it is desirable to obtain as much accuracy as practicable under the conditions. Generally, it is practical to measure accident locations to the nearest 1/100 of a mile using hundredth mile odometers. Odometers should be calibrated regularly in order to maintain accuracy.

In the 1977 FHWA report "Evaluation of the Highway-Related Safety Program Standards" the following accuracy criterion for identifying accident locations was specified (*7*): "All states should be able to identify accident locations accurately to within one-tenth of a mile in rural areas and within 100 feet in urban areas on their Federal and State highway systems by December 31, 1973, and by December 31, 1975 for all public roads."

The actual reporting accuracy varies widely among state and local agencies, but, at the least, many states attempt to determine accident locations to the nearest 0.1 mile (0.16 km) in rural areas and/or 100 ft (30 m) in urban areas. Some state agencies indicate that a sizable portion (10 to 30 percent) of accidents cannot be located due to obvious locational coding errors or omission of location referencing information. The accuracy or completeness of the locational description as recorded by the police officer is largely a function of the importance placed on the accuracy of this particular item of data and an awareness of this importance by the police agency/officer. In some instances, police officers are aware of the need for accurate location description of each accident. In other cases, little effort is made to accurately measure the distance from a field reference point. Also problems arise because many police agencies are understaffed and must attend to other police duties, and thus accident report accuracy may not have a high priority.

The identification of an accident location from a known point can be accomplished in several ways:

- Measuring with a tape measure or wheel;
- Stepping off by the officer;
- Using a vehicle odometer;
- Measuring with a DMI (distance measuring instrument);
- Estimating distances (e.g., counting pavement lane stripes or roadway delineators).

The specific method of determining accident locations may vary widely even within a jurisdiction.

Officers frequently round off the distance from an accident to the closest identifiable feature to the nearest 0.1, 0.5, or 1.0 mile. If distances are measured from field milepost markers and recorded to the nearest 0.1 mile, an accident could be expected to occur 0.5 miles from a bench mark only one-tenth of the time (*8*). Where the average spacing of bench marks is less than 1 mile, the distribution of distances from a marker should be larger at 0.1- and 0.2-mile distances than at 0.5 and 1.0. Figure 3 shows the number of reported accidents in one state (1972–1977) and the distances from reference points (*8*). It appears that two of the most dangerous locations are at 0.5 and 1.0 mile from a milepost marker. This study demonstrates the inaccuracies that can occur in location reporting due to the rounding of accident locations to the nearest 0.5 or 1.0 mile (*8*).

Another important factor in accurately reporting the accident location is the level of effort made in office coding and/or checking of milepoints or other reference numbers to each accident site. In California, for example, a team of about 10 to 12 office personnel work full time assigning milepoint numbers to the nearest 0.01 mile. Detailed milepoint maps and corresponding route referencing logs are important components of accurate location reporting in many states. These route logs provide a sequential list of the milepoint numbers of roadside features, including stores, residences, commercial businesses, intersections, city limits, etc. Updating the route logs is necessary to maintain accuracy.

The levels of accuracy attained with each location reference method can vary greatly, depending on how the method is used. With any method, the accuracy in reporting an accident location can only be as accurate as the site description given on the accident report form. The accurate determination of the designated distance and direction from the point of reference (as recorded on the accident report form) is the key to the accuracy of accident locational information.

Although most of the reference methods have the potential of providing high degrees of accuracy in many cases, often this is not the actual case. Many agencies use the officer's estimate of a location (e.g., about 0.5 mile north of milepost number 24, or about 5 miles north of Central City). These

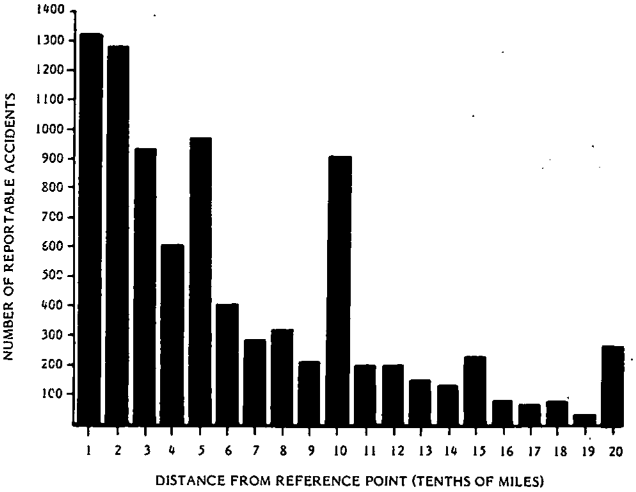


FIGURE 3 Number of reported Interstate accidents in North Carolina (1972–1977) and the reported distances from the nearest mileposts (*8*).

estimates may be in error by as much as 1 mile or more, particularly in low-volume rural areas where identifiable reference points are infrequently spaced. Also, at complex highway junctions or routes, such as at multilevel freeway interchanges (see Figure 4), a single milepoint number is not sufficient to properly describe the location of an accident. As it is desirable to determine the specific ramps where accidents are occurring, the use of specific reference points or nodes (e.g., each overpass, underpass, and entrance and exit ramp junction point may be assigned a unique reference number) at such locations generally results in greater accuracy than using only a milepoint value or approximate *x* and *y* coordinates.

Another factor that influences the accuracy in reporting accident location is the form of the coded locational description. For example, with the coordinate method, the *x* and *y* coordinates must be assigned to each accident by office personnel, which can be a tedious task. Locational accuracy is dependent not only on the officer's description but also on the level of detail and accuracy of the maps used. With any reference method, data checks are necessary to minimize human error.

The subject of accuracy in accident reporting was addressed in a 1981 report by the U.S. Department of Transportation (*9*). Specific findings of the report include:

- A manual review or edit of the State officer's report is made in most States at both the field level (98 percent) and at the headquarters level (94 percent). It is manually checked for accuracies and inconsistencies in all but 1 State.
- A manual review or edit of the local officer's report is believed made in all States upon receipt at local headquarters. It is manually checked for accuracy and inconsistencies in 92 percent of the applicable States. Two States have no local reporting agencies.
- Feedback is routinely provided by the State central accident records repository to the State reporting agency in 43 percent of the applicable States (22). One State has no State reporting agency.
- Feedback is routinely provided by the State to the local reporting agency in 32 percent of the applicable States (16). Two States have no local reporting agencies.
- There is a value check or valid code check made on all reports by the computer in 94 percent of the States (49). A two dimensional check was provided by the computer in 75 percent of the States (39).
- The estimated overall error rate from the computer checks was not stated or unknown in 29 percent of the States (15). Of the 37 States that reported, there was a range of 0.1 to 40 percent; 38 percent reported it was 2 percent or less, 65 percent reported 5 percent or less, 19 percent reported more than 10 percent were in error.

The overall conclusion of this report is that although most states make a reasonable attempt at reporting accuracy, routine feedback, which is essential for improving accuracy in reporting accident locations, is usually not conducted in most state agencies. Such feedback was found to be performed by fewer than half of the state reporting agencies and even fewer local reporting agencies (*9*).

FIGURE 4 Freeway interchanges can cause problems in accurate reporting of accident locations (Virginia Department of Highways and Transportation).

Location Tolerance

Not only is accident location information not reported within acceptable levels of accuracy in most states, but the degree of accuracy is unknown after the information is in the computer. For example, suppose that two accidents are both coded as having occurred at milepoint 10.50 along a specific route. However, one of the accidents involved hitting a bridge located exactly at milepoint 10.50, whereas with the other accident, the police officer did not know the milepoint, but estimated that the accident occurred somewhere between milepoint 10.0 and milepoint 11.0 and thus coded it as occurring at milepoint 10.5. Unless office personnel can review the locational description (e.g., 200 ft east of Ridge Road), both accidents will be keyed into the computer as occurring at the same location.

One way to assess the degree of accuracy in the identification of an accident location is the use of a location tolerance. In West Virginia, if the exact accident site is reported as occurring between two known locations, the milepoint is computed as the midpoint of the two known locations. The tolerance is computed as half the difference of the known mileposts. For example, if an accident is reported as occurring on Route 29 between the post office (known milepost 3.5) and the intersection of Route 80 (known milepost 6.3), the midpoint is $3.5 + (6.3 - 3.5)/2 = 3.5 + 1.4 = 4.9$ with a tolerance of 1.4 miles (*personal communication*, R. Lewis and C. Kendrick, West Virginia Department of Highways). Other tolerance values in West Virginia are computed in the following manner:

If location is:	Tolerance (in miles) is:
1. Tied to straight-line maps directly in *feet*	0.02
2. Tied to straight-line maps in *tenths of a mile*	
a. 0.1–0.9 mile	0.05
b. 1.0–2.9 miles	0.10
c. 3.0–4.9 miles	0.20
d. 5.0–9.9 miles	0.30
e. 10.0 or more miles	0.40
3. Tied to straight-line maps *approximations*	
a. Less than 1 mile	0.10
b. 1–3 miles	0.20
c. 3–5 miles	0.30
d. 5–10 miles	0.40
e. Over 10 miles	0.50

Examples of the use of these tolerance values are given below:

Location	Tolerance
150 ft east of Jack's Exxon	0.02
About 0.5 mile south of County Route 25	0.10
0.8 mile west of Fairview Drive-In	0.05
4.2 miles east of Wheeling City limits	0.20
About 2.5 miles north of County Route 19/4	0.20
About 12 miles above Charleston	0.50
In front of the Ponderosa	0.02

The assignment of such tolerance values to each reported accident location may be desirable, particularly when the accident file contains a wide range of accuracy levels in the reporting of accident locations.

COMPUTERIZED HIGHWAY NETWORKS

A computerized highway network is a computer file containing the route numbers or names within the highway network, along with the linear distances between intersection points. The file may or may not contain linear x and y coordinates of intersections and other points of reference. When using any of the highway location reference methods, it can be beneficial to develop a computerized highway network to:

- Improve the accuracy of the coded locational information;
- Reduce the number of office personnel required for assigning location information to accidents; and
- Improve the ease and accuracy and reduce the costs of merging different data files.

There are a number of ways to develop and utilize a computerized highway network to aid in accident and highway data processing. Examples of computerized location networks currently used by some agencies are the Michigan Accident Location Index (MALI) and the Dual Independent Map Encoding/Geographic Base File (DIME/GBF). One of the basic differences between these two systems is that the MALI system involves the use of linear coordinates (distance along a route) and the DIME/GBF system uses geographic (x and y coordinates) information.

Michigan Accident Location Index

The MALI system was developed in Michigan to provide fast and accurate traffic accident information for all public roadways within the state. The system generates a computerized description of all accident locations by assigning a milepoint number directly from the physical location information reported by the police officer (*10*). The street index consists of a description of the street network that is stored on the computer. The midpoints of each intersection and the distance between intersections serve as the basis for locating accidents. The police officer in the field merely codes the distance and direction of each accident from the nearest intersection, and the exact milepoint number is generated by computer. The gathering of additional information at the accident scene is not required, nor are maps, logs, or indexes necessary. Only those accidents rejected by the system edit checks require manual processing (*10*). In a pilot test of the reporting accuracy in one county, 97 percent of the accidents were located correctly by the MALI system, compared to 81 percent correctly located by the manual procedure (*11*).

The cost for coding 85,000 miles (136,000 km) of the street network in 72 counties in Michigan in 1978 and 1979 by a consulting firm was reported to be about $6.75 per mile ($4.18/km). The cost included network coding for congested urban areas, such as Detroit and Wayne County, as well as sparsely populated areas in northern Michigan. Coding of the street network took about 18 months (*12*).

Dual Independent Map Encoding/Geographic Base File

The DIME/GBF is a geographic highway base file originally developed for the Bureau of the Census for coding census data to specific areas, but it also has application to locating accident sites. The file is essentially a computerized version of a street map composed of segment records specified in the system as a length of street between two nodes. In the system used by Rhode Island, the segments are described by street name, node numbers, *x* and *y* coordinates for each node, geographic area codes, block number, municipality code, census tract number, county and state code, zip code, and the lowest and highest address ranges for city streets. A typical DIME map, as used in Rhode Island, is shown in Figure 5 (*13*).

In order to use the DIME/GBF for accident location, an intersection file must be generated. The traffic accidents must be reported according to specific intersection or nonintersection locations. The location description of the accident is then compared to the intersection file to locate the accident on the network. The intersection file uses such location information as city, census tract, block, street name, and node number. Computer programs such as the UNIMATCH program allow for a probable match, wherein minor misspelling and other shifting of characters can sometimes be handled (*13*).

In 1974 the DIME/GBF was applied to the Providence-

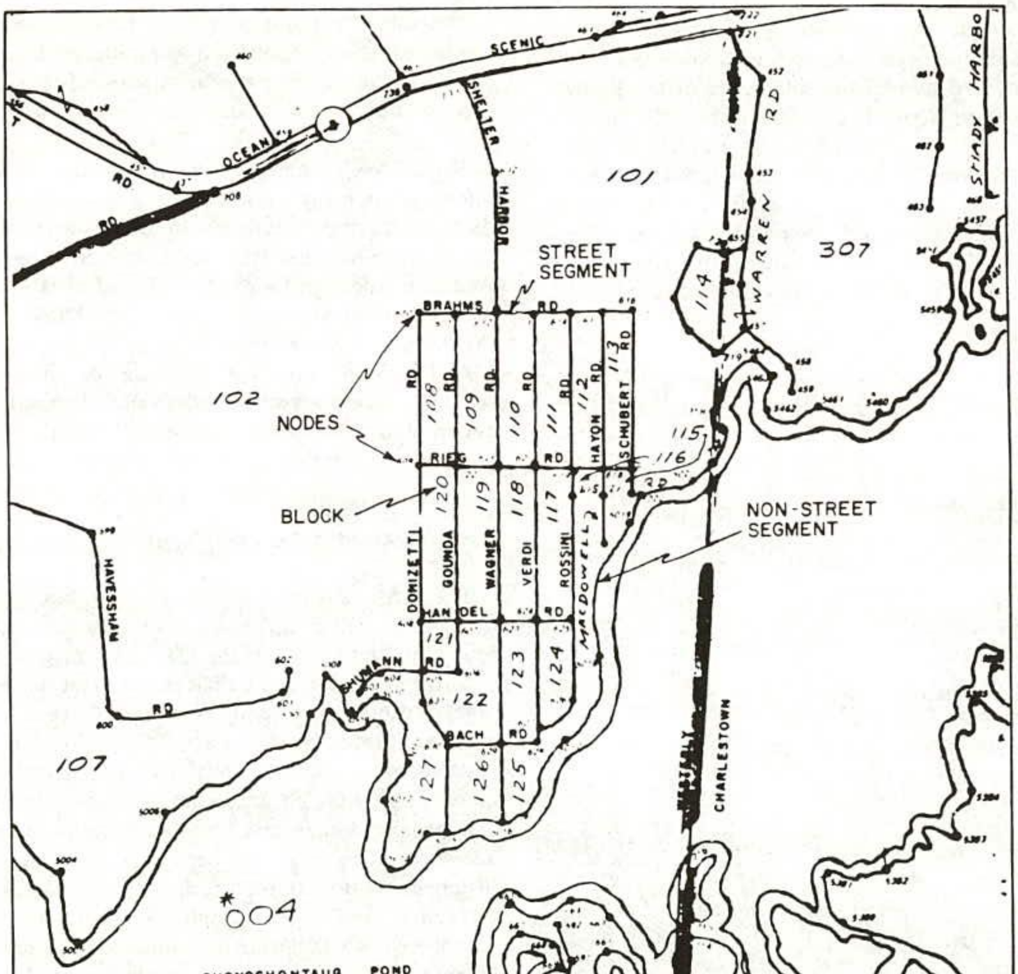


FIGURE 5 Typical DIME map (*14*).

Pawtucket-Warwick metropolitan area to match 17,430 accidents. The following results were reported by Crevo and Manning (*14*):

> The first matching operation resulted in a match rate of 49 percent (8,585 of 17,430). These were perfect matches on city/town, first street name, first street prefix and suffix, second street name, and second street prefix and suffix.
>
> The second match operation produced a 22 percent match (3,751 of 17,430). These were probabilistic matches where certain differences in spelling were allowed.
>
> The third match was between the remaining non-geocoded accidents and a special file prepared for unusual places and names such as schools, churches, and parking lots, not in the original DIME/GBF. The result of this operation was a 9 percent match (1,594 of 17,430).
>
> The remaining 20 percent of the accidents (3,500 of 17,430) was reported with whatever information was available. Approximately one-half of these non-geocodable locations were not matched because the second street name was missing. This type of location could not be geocoded in a manual system either, because of lack of information.

The computer processing for the accidents in Rhode Island was done on an IBM S 370/155 system. The cost summary for this processing, as reported in 1976 (*14*), is given below:

	Cost per Accident
Data Processing (Labor Costs)	
Data transcription	0.68
Handling, editing, corrections	0.51
	$1.19 (labor)
Computer Costs	
Intersection reference file processing	0.09
Accident records file processing	0.03
Match intersections and accidents	0.15
Generate reports	0.03
	$0.30 (computer)
Total cost per accident (labor + computer)	$1.49

IMPACT ON SOFTWARE PROCESSING AND FILE MERGING

In order to process accident data, the locational information must include the route name and/or number and the distance and direction from a known point of reference. With most of the reference methods, an accident location can be converted to the appropriate milepoint number or directly tied to a specific intersection or other feature (e.g., bridge, railroad crossing, driveway).

The assignment of a milepoint description permits a search of the computer accident file in variable increments of length (0.1 mile, 0.3 mile, 1 mile, 3 miles, etc.) to identify highway segments that have experienced an abnormally high number of accidents in a given time period. Any specified lengths can be chosen to "float" sequentially through the accident data file, which is desirable for location identification purposes. Data files that use milepoint values can be cross-referenced with other data bases that use such referencing units as *x* and *y* coordinates, node numbers, intersection names, etc., only if a location conversion file is available.

A problem in using milepoints for data processing is that data related to intersections and interchanges are usually more difficult to process than data tied to other highway locations. For example, when scanning the accident file for high accident locations, the accidents occurring at an intersection often cannot be distinguished from those occurring at other locations, and this may preclude the use of different identification criteria for intersections. As previously discussed, many data processing problems can be solved by the use of a computerized network file.

The use of coordinates alone can present problems when merging files or processing data. If only route number and *x-y* coordinate information are used, utilizing the accident file for automatic identification of high-accident locations becomes complicated, unless other referencing units (e.g., milepoints) are used in combination with the coordinates. An example of a combined reference method is the Quasi-Coordinate Link Node system as developed and used in Iowa (*15*). The assignment of node numbers and corresponding coordinates of each node allows for accident referencing by node numbers; coordinates for each node are obtained for the highway network and stored on the computer file.

The processing of data files referenced to intersections or other physical reference features (nodes) has both advantages and disadvantages. If accidents are referenced to appropriate nodes, the processing of data related to spot locations (intersections, bridges, interchanges, railroad crossings, etc.) is usually feasible as long as the data files (accident data file, traffic volume file, etc.) are similarly tied to the same nodes or reference points. This allows for easier data processing, file interaction, and/or file merging of data at specific highway points. However, without sequential mileage-based information (i.e., milepoints) tied to each reference point, the processing of data is limited to specific highway points or to full section lengths between those points. This may be acceptable when the points of reference are closely spaced (such as in urban areas), but is inadequate where adjacent nodes are spaced several miles apart.

CHAPTER THREE

CHARACTERISTICS OF DATA FILES

Various types of data files are currently maintained by the states for highway systems and/or highway uses, including files on (*16*):

- Accidents
- Highway and Traffic
- Driver Licensing
- Motor-Vehicle Registration
- Financial Responsibility
- Motor-Vehicle Inspection
- Traffic Law Enforcement
- Emergency Medical Services

The files typically linked to a highway location reference method include the accident, roadway (highway), and traffic files.

ACCIDENT FILES

Accident Reports

In general, traffic accident reports are submitted to a central agency, which may be the State Police Department, Department of Motor Vehicles, or the State Highway or Transportation Department. These reports include police reports from state, local, and county agencies, which in some jurisdictions are supplemented by driver reports. The police reports and corresponding citizen reports are matched, and a unique accident case number or report number is assigned to the documents relating to each accident. Next, the accident data are coded on data processing punch cards or directly keyed into the computer accident data file.

In some states, the police report is the only source of information pertaining to an accident. In other states, police and motorist reports are reviewed and used for data entry. In such cases, most locational and accident-related information (time of day, location, driver at fault, roadway conditions, accident type, etc.) is generally taken from the officer's report. In some states, such as Illinois, the driver and occupant information (driver age, address, type of vehicle, etc.) is taken from the motorist report and added to the computer accident data file.

Statewide accident information is usually stored by highway location for use in identification and analysis of high accident locations. However, some agencies, particularly in small and medium-sized cities, store computer accident data (and also accident report forms) by date, accident number, or driver name.

Incomplete or inaccurate reports are handled in different ways: (a) The reports may be processed as they are received with little or no effort to correct errors. (b) They may be returned to the reporting officer and/or agency for modification. (c) Office coders and clerks may check and modify certain data items (e.g., assigning a location reference code based on the officer's verbal description of the site). (d) Additional information from the police officer and location referencing codes from office personnel may be obtained and coded in a follow-up effort.

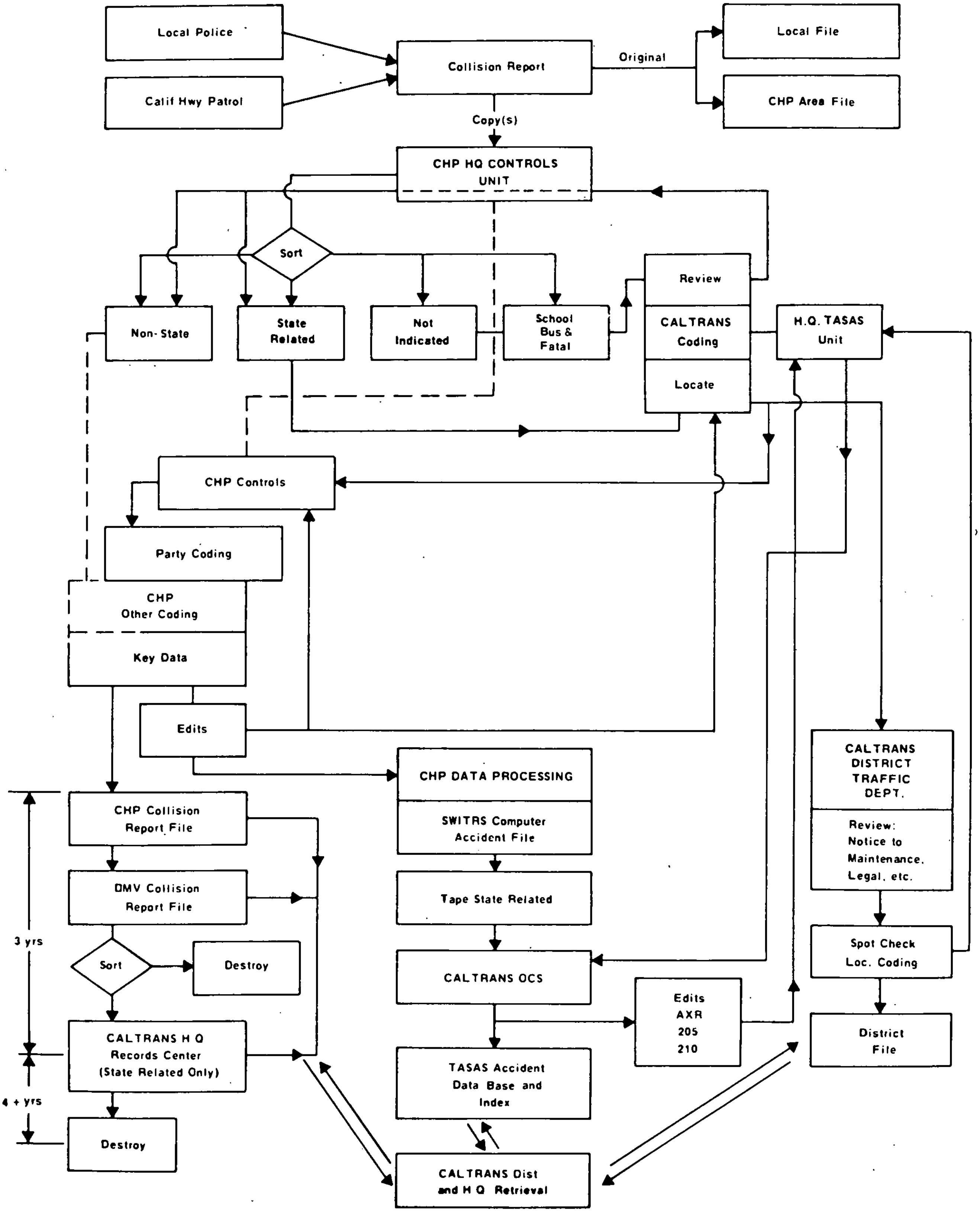
After accident information is coded into the computer, the actual report forms are usually filed and maintained for additional review in the selection of countermeasures at the identified high accident locations. After a set time period (usually 2 to 5 yr), and often after being microfilmed, the accident reports are destroyed. Computer accident data are usually maintained on computer tape for 3 to 5 yr; many states maintain the data longer for other uses, such as in the evaluation of safety projects several years after completion. The steps involved in processing accident data in California are shown in Figure 6 (*17*).

Content of Computer Accident Files

The accident file generally contains data on reported traffic accidents within a state or local agency, and is usually maintained by a state's Department of Transportation or Police Agency. The data for each accident are usually obtained from the information reported on a statewide, uniform accident report form, although a few local agencies use individual and/or abbreviated report forms.

The format and content of computer accident files vary widely among cities and states. One of the basic differences involves fixed versus variable file length. This is a particularly important issue in multivehicle accidents. For each reported traffic accident, there is a combination of variables (date, time, location, etc.) unique to that accident. In addition, each vehicle or individual involved in the accident will have a separate set of data variables, such as the person's date of birth, vehicle type, etc. A fixed file length format, which is commonly used, may be limited only to information for two or three vehicles (or injured persons) per accident.

Other information from the accident report form may also be omitted from the computer file. For example, the narrative portion of the report form is not usually entered into the computer file (North Carolina does enter portions of the narrative accident description). In many states, although a 2- to 5-page form is used for reporting accident data, much of the recorded data is not used for safety analysis purposes. One state reported that 131 data elements are currently recorded on the accident report form. Of the 1100 card columns developed for each accident, only about 7 percent of the data variables are actually used by the state for traffic or safety engineering purposes.



COLLISION REPORT FLOW CHART

FIGURE 6 Procedure for processing accident data in California (*17*).

ADIP Study

The specific characteristics of state accident record systems were investigated in the Accident Data Improvement Plan (ADIP) project, initiated in 1978 by the National Highway Traffic Safety Administration (NHTSA) in cooperation with the FHWA. The results of the study on state accident data bases were summarized in a 1981 report (*9*). Considerable variation was found with respect to criteria (or thresholds) used to define a reportable accident. Whereas all accidents involving injuries and fatalities must be reported in all states, the reporting threshold for property damage ranged from $0 to $500. Some state accident report files also include nontraffic (parking lot) and motorist reports. Specific findings on accident reporting include (*9*) ("states" include the District of Columbia and Puerto Rico):

- Accident reporting thresholds are set by law or regulation in 51 States.
- The time period for including a death as attributable to a motor vehicle accident varies among the States; 48 percent (25) use 30 days, 29 percent (15) use 90 days, 2 percent (1) use 6 months, 19 percent (10) use 1 year, and 1 State did not report.
- Using ANSI D-16 as a standard, the accident classification by "First Harmful Event" was stated as in agreement in 67 percent of the States (35). The classification of "Injury Severity" was stated as in agreement in 73 percent of the States (38). In 4 States, the status of the accident classifications could not be determined from the ADIP reports.
- For property damage thresholds both towaway and dollar amounts are used. Towaway is used in 4 percent of the States (2). Ten different dollar amounts are used with a range of $0 to $500; 23 percent of the States (12) use between $0 and $150, 60 percent (31) use $200 to $300, and 13 percent (7) use $350 to $500.
- 46 percent of the States (24) include nontraffic (e.g., parking lot) accidents in their accident files. The percent of the file represented by these nontraffic accidents varies from 2 to 25 percent. Two-thirds (16) of the 24 States reported the percentage as "unknown."

In the ADIP study (*9*), accident report forms were found to vary considerably among the states; there is no standardized national accident report form. Although nearly all states have a statutory requirement for the use of a statewide, uniform report form, only about two-thirds of the states report that a uniform accident report form is used in all jurisdictions. Specific findings in the ADIP report (*9*) regarding uniformity of data collection within each state include:

- 88 percent of the States (46) reported a State agency is responsible by statute or regulation for obtaining statewide uniform accident data. Twenty-five percent of the States (13) have a penalty for noncompliance; however, it is not enforced.
- 65 percent of the States (34) reported that a uniform report form is used by all jurisdictions. In the 18 States reporting the use of a nonuniform accident form, 10 did not report or did not know the percent of accidents reported on the nonuniform form. In the other 8 States the range of accidents reported on nonuniform forms ranged from 1 to 100 percent of the accident report file.

The ADIP study (*9*) also attempted to determine the timeliness of states in terms of obtaining accident data and entering the data into the automated accident file.

- A reporting time is set by State law in at least 79 percent of the States (41). In 5 States the existence of a State law could not be determined from the ADIP report. The time ranged from 1 to 10 days for police and from 3 to 30 days for operators.
- The range of lapsed time for State reporting fell within 1 to 30 days in 94 percent of the States (49) and within 2 weeks for 71 percent of the States (37). One State has no State reporting agency.
- The range of lapsed time for local reporting fell within 1 to 30 days in 73 percent of the States (38) and within 2 weeks for 33 percent of the States (17). Two States have no local reporting agencies.
- The average elapsed time from the accident occurrence to entry on the system ranged from 12 to 360 days, with 37 percent of the States (19) averaging 30 days or less, and 73 percent (38) averaging 60 days or less.

The types of data elements (including accident, occupant, nonoccupant, driver, vehicle and roadway information) recorded in state accident files were also reviewed in the ADIP study. No individual state recorded all of the 112 data elements considered to be important by the ADIP task force; the number of data elements not recorded on the state accident forms ranged from 13 to 65. A total of 34 or more data elements were not recorded in 28 states. The recording of roadway-related data was the most incomplete among the various types of accident data elements (*9*).

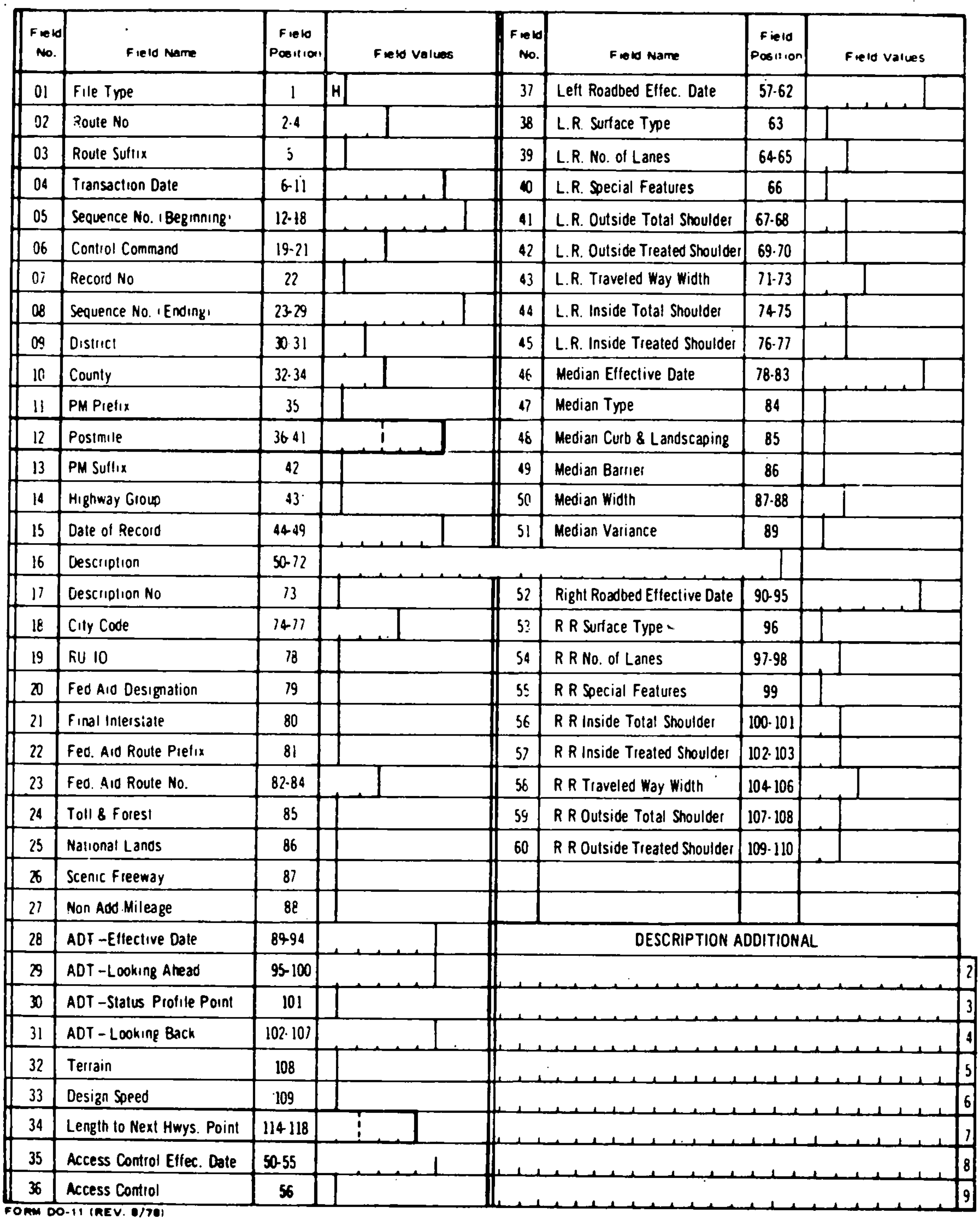
A summary of the recording of data elements by state is given below (*9*):

		NO. STATES		
CATEGORY	NO. ELEMENTS	100% ELEMENTS AVAILABLE	75% ELEMENTS AVAILABLE	50% ELEMENTS AVAILABLE
Accident	27	2	34	52
Occupant	9	9	36	46
Nonoccupant	12	2	23	46
Driver	14	0	16	46
Vehicle	18	0	15	40
Roadway	32	1	9	33

TRAFFIC AND ROADWAY FILES

Traffic File

The traffic file may or may not be a part of an agency's roadway file. The basic information contained in this file includes traffic volumes for each highway section and/or intersection on the highway system. Traffic volumes are generally input as average annual daily traffic (AADT) values based on projecting short-term counts with seasonal and hourly adjustment factors. In some states, more detailed information, such as turning movements, volumes by time of day, vehicle speed data, or vehicle classification counts, may also be contained in these files. Because of the dynamic nature of traffic volumes, it is desirable to update the volume data as funding and manpower are available. However, the types and amount of data to be collected should be carefully determined to help ensure maximum use of monetary and manpower resources.



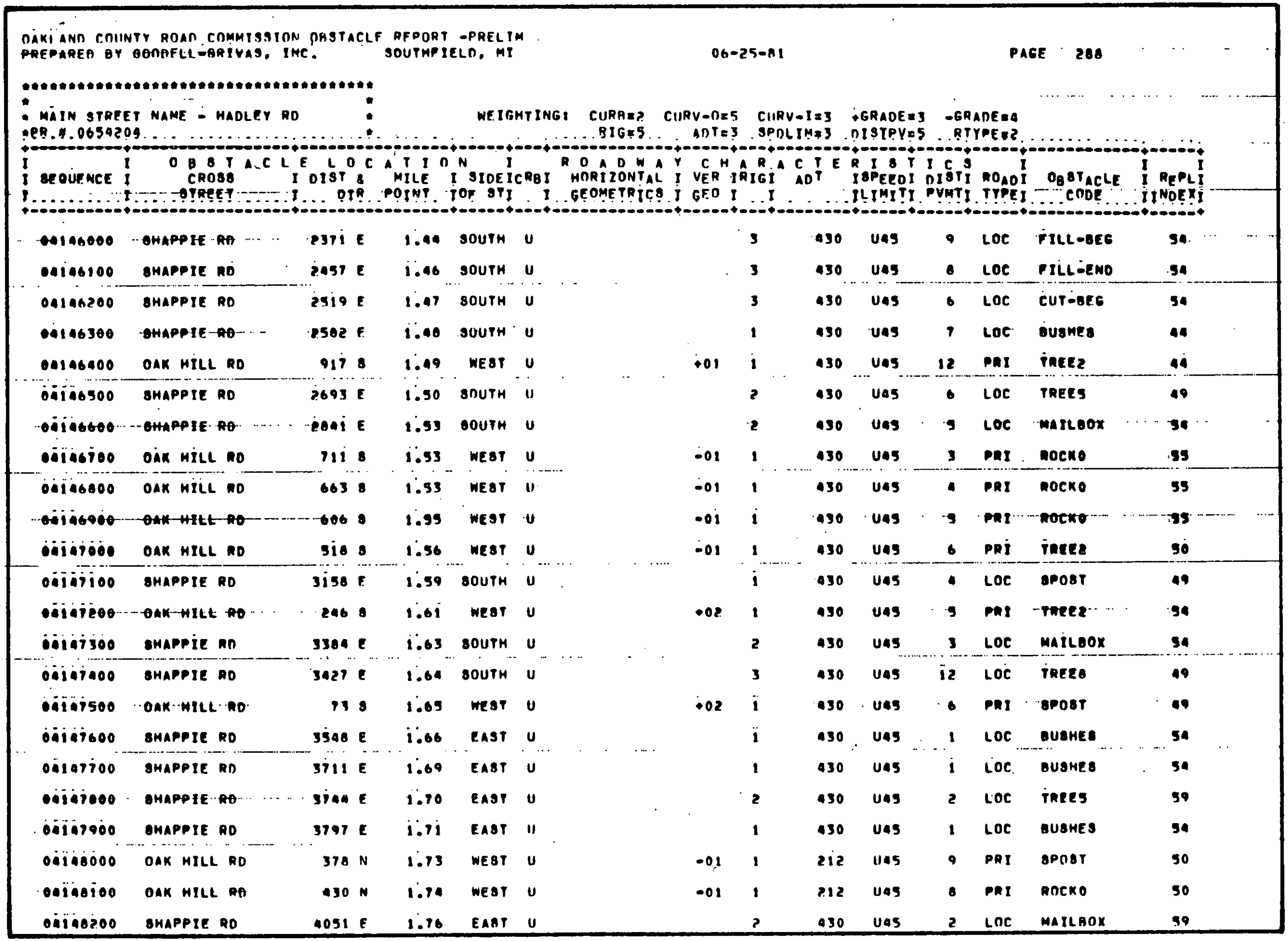
TASAS

HIGHWAY DATA

Field No.	Field Name	Field Position	Field Values	Field No.	Field Name	Field Position	Field Values
01	File Type	1	H	37	Left Roadbed Effec. Date	57-62	
02	Route No	2-4		38	L.R. Surface Type	63	
03	Route Suffix	5		39	L.R. No. of Lanes	64-65	
04	Transaction Date	6-11		40	L.R. Special Features	66	
05	Sequence No. (Beginning)	12-18		41	L.R. Outside Total Shoulder	67-68	
06	Control Command	19-21		42	L.R. Outside Treated Shoulder	69-70	
07	Record No	22		43	L.R. Traveled Way Width	71-73	
08	Sequence No. (Ending)	23-29		44	L.R. Inside Total Shoulder	74-75	
09	District	30-31		45	L.R. Inside Treated Shoulder	76-77	
10	County	32-34		46	Median Effective Date	78-83	
11	PM Prefix	35		47	Median Type	84	
12	Postmile	36-41		48	Median Curb & Landscaping	85	
13	PM Suffix	42		49	Median Barrier	86	
14	Highway Group	43		50	Median Width	87-88	
15	Date of Record	44-49		51	Median Variance	89	
16	Description	50-72					
17	Description No	73		52	Right Roadbed Effective Date	90-95	
18	City Code	74-77		53	R R Surface Type	96	
19	RU IO	78		54	R R No. of Lanes	97-98	
20	Fed Aid Designation	79		55	R R Special Features	99	
21	Final Interstate	80		56	R R Inside Total Shoulder	100-101	
22	Fed. Aid Route Prefix	81		57	R R Inside Treated Shoulder	102-103	
23	Fed. Aid Route No.	82-84		58	R R Traveled Way Width	104-106	
24	Toll & Forest	85		59	R R Outside Total Shoulder	107-108	
25	National Lands	86		60	R R Outside Treated Shoulder	109-110	
26	Scenic Freeway	87					
27	Non Add Mileage	88					
28	ADT -Effective Date	89-94		DESCRIPTION ADDITIONAL			
29	ADT -Looking Ahead	95-100					2
30	ADT -Status Profile Point	101					3
31	ADT - Looking Back	102-107					4
32	Terrain	108					5
33	Design Speed	109					6
34	Length to Next Hwys. Point	114-118					7
35	Access Control Effec. Date	50-55					8
36	Access Control	56					9

FORM DO-11 (REV. 8/78)

FIGURE 7 Accident data processing form used in California.



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PREPARED BY GOODELL-GRIVAS, INC.        SOUTHFIELD, MI                          06-25-81                          PAGE  288

****************************************
*                                      *
* MAIN STREET NAME - HADLEY RD         *              WEIGHTING:  CURB=2  CURV-O=5  CURV-I=3  +GRADE=3  -GRADE=4
*PR.#.0659204                          *                           BIG=5     ADT=3  SPDLIM=3  DISTPV=5   RTYPE=2
+-----------+-----------------+--------------+-----+---+-----------+-----+---+--------+-----+-----+-----+-------------+-----+
I           I   O B S T A C L E   L O C A T I O N   I   R O A D W A Y   C H A R A C T E R I S T I C S    I             I     I
I SEQUENCE  I      CROSS      I DIST &   MILE I SIDEICRBI HORIZONTAL I VER IRIGI  ADT    ISPEEDI DISTI ROADI  OBSTACLE   I REPLI
I           I      STREET     I    DIR  POINT TOF STI   I GEOMETRICS I GEO I   I         ILIMITI PVMTI TYPEI    CODE     IINDEXI
+-----------+-----------------+--------------+-----+---+-----------+-----+---+--------+-----+-----+-----+-------------+-----+

 04146000   SHAPPIE RD         2371 E   1.44  SOUTH  U                        3     430   U45     9   LOC   FILL-BEG      54

 04146100   SHAPPIE RD         2457 E   1.46  SOUTH  U                        3     430   U45     8   LOC   FILL-END      54

 04146200   SHAPPIE RD         2519 E   1.47  SOUTH  U                        3     430   U45     6   LOC   CUT-BEG       54

 04146300   SHAPPIE RD         2582 E   1.48  SOUTH  U                        1     430   U45     7   LOC   BUSHES        44

 04146400   OAK HILL RD         917 S   1.49   WEST  U                 +01    1     430   U45    12   PRI   TREE2         44

 04146500   SHAPPIE RD         2693 E   1.50  SOUTH  U                        2     430   U45     6   LOC   TREES         49

 04146600   SHAPPIE RD         2841 E   1.53  SOUTH  U                        2     430   U45     5   LOC   MAILBOX       54

 04146700   OAK HILL RD         711 S   1.53   WEST  U                 -01    1     430   U45     3   PRI   ROCKO         55

 04146800   OAK HILL RD         663 S   1.53   WEST  U                 -01    1     430   U45     4   PRI   ROCKO         55

 04146900   OAK HILL RD         606 S   1.95   WEST  U                 -01    1     430   U45     5   PRI   ROCKO         55

 04147000   OAK HILL RD         518 S   1.56   WEST  U                 -01    1     430   U45     6   PRI   TREES         50

 04147100   SHAPPIE RD         3158 E   1.59  SOUTH  U                        1     430   U45     4   LOC   SPOST         49

 04147200   OAK HILL RD         246 S   1.61   WEST  U                 +02    1     430   U45     5   PRI   TREE2         54

 04147300   SHAPPIE RD         3384 E   1.63  SOUTH  U                        2     430   U45     3   LOC   MAILBOX       54

 04147400   SHAPPIE RD         3427 E   1.64  SOUTH  U                        3     430   U45    12   LOC   TREES         49

 04147500   OAK HILL RD          73 S   1.65   WEST  U                 +02    1     430   U45     6   PRI   SPOST         49

 04147600   SHAPPIE RD         3548 E   1.66   EAST  U                        1     430   U45     1   LOC   BUSHES        54

 04147700   SHAPPIE RD         3711 E   1.69   EAST  U                        1     430   U45     1   LOC   BUSHES        54

 04147800   SHAPPIE RD         3744 E   1.70   EAST  U                        2     430   U45     2   LOC   TREES         59

 04147900   SHAPPIE RD         3797 E   1.71   EAST  U                        1     430   U45     1   LOC   BUSHES        54

 04148000   OAK HILL RD         378 N   1.73   WEST  U                 -01    1     212   U45     9   PRI   SPOST         50

 04148100   OAK HILL RD         430 N   1.74   WEST  U                 -01    1     212   U45     8   PRI   ROCKO         50

 04148200   SHAPPIE RD         4051 E   1.76   EAST  U                        2     430   U45     2   LOC   MAILBOX       59
```

FIGURE 8 Sample computer printout from Oakland County (Michigan) roadside obstacle inventory.

Roadway File

The roadway file consists of physical information on the highway environment. Most state roadway files consist of such basic highway information as number of lanes, roadway alignment, access control, and cross-section information (lane width, shoulder width, etc.). Some files also contain information on intersections, bridges, traffic control devices, roadside obstacles, etc. The roadway file is useful in systemwide planning and may be utilized to identify for possible improvement locations or features that do not conform to acceptable design standards or that appear to have a high potential for accidents.

The types of roadway data collected by an agency depend on the uses made of the data, the size of highway network, and the available resources. Roadway data are often contained in many files, and problems commonly occur in the merging of the files, including differing reference methods, outdated information, and incomplete data files. A list of the data elements contained in California's roadway file is shown in Figure 7.

Photologging

Desired roadway data elements may be collected either manually (physical measurements) or, in many cases, with the use of photologging (or videologging). Photologging involves taking photographs of the roadway and its environment at equal increments (usually at 0.01 or 0.005 mile with a 35-mm camera) from a moving vehicle (*18*). A dual-lens camera system is generally used: the primary lens provides a view of the highway and the secondary lens records such information as the date, route number, direction of travel, and highway reference point. Videologging allows for incorporating sound on the tape during data collection; the tape is reusable, but the photographic image on the video tape is generally not as clear as that on the 35-mm photolog film. With both photologging and videologging, the film can be viewed in the office, and visual roadway information can be coded and entered into a computer file.

One example of the use of photologs for recording basic roadway information is the system used in Oakland County, Michigan. Using photologs of the highways, the county developed sign, roadway obstacle, and roadway features inventories. A sample computer printout from Oakland County's roadside obstacle inventory is shown in Figure 8. Each obstacle is referenced to the street and distance and direction from the nearest cross street.

The roadway environmental data system developed for use in Maryland combines basic photolog inventory capabilities for 11,585 miles photologged in both directions with additional data-collection capabilities. This system, which is referred to as a "second generation" photolog system, is based on the use of an instrumented photolog vehicle for the collection of additional roadway data, including side friction, compass direction, horizontal and vertical curvature, grade, cross slope, long- and short-term roughness, altitude, and speed (*19*). The system consists of external sensors, an operator's control panel, a display unit, an instrumentation unit, and magnetic tape recorders. A data recorder unit will ultimately be used to directly input the data by magnetic tape into Maryland's computerized highway data base (*19*).

CHAPTER FOUR

PROCESSING OF DATA FILES

FILE MERGING AND INTERFACING

There are two basic types of data merging. For safety research or statistical studies, it may sometimes be desirable to have a complete merging of data onto a single data file. For informational or investigative purposes, it may be necessary only to link or interface data files so that appropriate data elements may be pulled off each file and used for the desired analysis. The merging or interfacing of data files is desirable for several reasons. States usually link accident files with traffic volume files to compute accident rates for specific highway locations. Highway safety research studies commonly involve linking and/or merging of accident files with roadway files in order to assess the effect of various traffic and roadway features on accident experience.

To adequately make use of files containing accident, highway, and traffic data, it is usually necessary to interface files to allow for the utilization of various types data at individual locations. For example, to compute accident rates at specific locations on a highway network, a computer program must identify accident locations (from the accident file) and then search the traffic volume file for the volume at the corresponding location. The accident rate can then be calculated for each location.

It may also be desirable to compute average statewide (or citywide, countywide, etc.) accident frequencies and rates by highway classification (intersection or midblock, urban or rural, number of lanes, divided or undivided, etc.), which requires the interfacing of computer files containing accident, traffic volume, and geometric information.

With the interfacing or merging of files, the location reference method should be compatible among data files. If the accident information is stored on computer file by milepoint numbers, then the volume and/or geometric files should also be stored by milepoint. Otherwise a location conversion file (cross-referencing file) must be available for translating one reference method to the other. In some state highway agencies, highway reference methods are not used consistently for various types of data files. In other states, comprehensive data banks utilizing a common highway location reference method have been or are being developed.

The degree to which highway and traffic volume data can be correlated with the accident file is significant in achieving an efficient data processing system. In most states, volume files can be correlated with accident files for interstate and state highways. However, less than half of the states have this capability for local roads. A summary is given below of the status of the correlation of accident and traffic volume data (as of June 30, 1981) (*3*):

	CORRELATION STATUS (NO. STATES)		
HIGHWAY SYSTEM	100%	1–99%	0%
Interstate	41	4	3
State—Federal Aid	45	4	3
State—Non-Federal Aid	41	4	6
Local—Federal Aid	23	8	14
Local—Non-Federal Aid	13	11	19

The capability to correlate highway data files with accident files is even less prevalent than the capability to correlate traffic volume and accident files. However, this procedure is under development in several states. A summary is given below of the status of the correlation of highway inventory and accident data as of June 30, 1981 (*3*):

	CORRELATION STATUS (NO. STATES)		
HIGHWAY SYSTEM	100%	1–99%	0%
Interstate	29	8	10
State—Federal Aid	30	9	10
State—Non-Federal Aid	27	8	13
Local—Federal Aid	10	8	22
Local—Non-Federal Aid	5	9	25

A summary is given in Table 4 of the capabilities of the states with respect to merging accident files with other data files (*3*).

The most common type of data merging is that between accident and traffic volume data for the computation of accident rates. Many agencies also merge basic geometric information with the accident records to compute the accident experience for each type or class of highway. This is necessary in order to compare the accident rate at a location with the average rate for all locations within the same highway group or class.

Whereas about 50 percent of the states have the capability to interact various data files through common location methods using computer programming, few states have developed a comprehensive merged data file. North Carolina is currently building a merged file of accident records and roadway characteristics (*20*).

Michigan has also developed a merged data file—the Michigan Dimensional Accident Surveillance (MIDAS) system. The MIDAS system consists of a single computerized data base containing four types of data for each highway segment or intersection: geometric, environmental (including traffic volumes), cross-section, and accident. The

TABLE 4
MERGING CAPABILITIES OF DATA FILES FOR EACH STATE (*3*)

STATE	HIGHWAY DATA CORRELATION (PERCENT)					VOLUME DATA CORRELATION (PERCENT)				
	INTERSTATE	STATE - F.A.	STATE - N.F.A.	LOCAL - F.A.	LOCAL - N.F.A.	INTERSTATE	STATE - F.A.	STATE - N.F.A.	LOCAL - F.A.	LOCAL - N.F.A.
ALABAMA	0	100	100	0	0	0	100	100	0	0
ALASKA	-	100	100	100	*	-	100	100	100	*
ARIZONA	95	90	90	80	50	100	100	100	60	10
ARKANSAS	100	100	100	0	0	100	100	100	100	100
CALIFORNIA	100	100	100	100	100	100	100	100	100	100
COLORADO	100	100	100	0	0	100	100	100	0	0
CONNECTICUT	100	100	100	0	0	100	100	100	0	0
DELAWARE	0	0	0	-	-	100	100	100	-	-
FLORIDA	100	100	100	1/	1/	100	100	100	20	9
GEORGIA	100	100	100	0	0	100	100	100	100	10
HAWAII	100	100	100	0	0	100	100	100	15	0
IDAHO	0	0	0	0	0	100	100	100	100	2/
ILLINOIS	4	7	0	0	0	100	100	100	90	90
INDIANA	100	100	100	100	2	100	100	100	100	2
IOWA	0	0	0	0	0	0	0	0	0	0
KANSAS	0	0	0	0	0	100	100	100	0	0
KENTUCKY	100	100	100	0	0	100	100	100	0	0
LOUISIANA	100	100	100	*	*	100	100	100	*	*
MAINE	100	100	10	100	0	100	100	10	100	0
MARYLAND	100	100	100	100	100	100	100	100	100	25
MASSACHUSETTS	100	100	100	100	100	100	100	100	100	100
MICHIGAN	100	100	100	0	0	100	100	100	100	100
MINNESOTA	97	93	93	90	90	100	100	100	100	100
MISSISSIPPI	100	100	100	100	100	100	100	100	100	100
MISSOURI	50	50	50	UNK	UNK	100	100	100	UNK	UNK
MONTANA	100	100	0	100	0	100	100	0	100	0
NEBRASKA	100	100	100	0	0	100	100	100	0	0
NEVADA	0	0	0	0	0	100	100	0	100	0
NEW HAMPSHIRE	1	9	1	1	4	0	0	0	0	0
NEW JERSEY	100	100	100	0	0	100	100	100	0	0
NEW MEXICO	100	100	100	0	0	100	100	100	100	100
NEW YORK	100	100	100	80	80	100	100	100	0	0
NORTH CAROLINA	55	61	0	0	0	55	61	0	0	0
NORTH DAKOTA	100	100	100	0	0	100	100	100	100	100
OHIO	100	100	100	100	100	100	100	100	50	10
OKLAHOMA	*	*	*	*	*	100	100	100	0	0
OREGON	100	100	100	30	0	100	100	100	100	100
PENNSYLVANIA	100	100	100	UNK	UNK	100	100	100	UNK	UNK
RHODE ISLAND	0	0	0	0	0	50	15	10	10	0
SOUTH CAROLINA	85	85	85	85	85	85	85	85	85	85
SOUTH DAKOTA	0	0	0	0	0	100	100	100	0	0
TENNESSEE	100	100	100	100	25	100	100	100	100	25
TEXAS	*	*	*	*	*	*	100	100	100	100
UTAH	100	100	100	20	20	100	100	100	100	50
VERMONT	*	*	*	*	*	*	*	*	*	*
VIRGINIA	100	80	10	UNK	UNK	100	100	100	VAR	VAR
WASHINGTON	100	100	-	UNK	UNK	100	100	-	100	100
WEST VIRGINIA	100	100	100	–	–	100	100	100	–	–
WISCONSIN	75	75	75	75	75	100	100	100	50	50
WYOMING	0	0	0	0	0	100	100	100	100	100
DIST. OF COL.	0	0	0	-	-	2	2	2	-	-
PUERTO RICO	-	UNK	UNK	UNK	UNK	-	100	100	100	100
SAMOA	-	UNK	UNK	-	-	-	25	25	-	-
GUAM	*	*	*	*	*	*	*	*	*	*
VIRGIN ISLANDS	*	*	*	*	*	*	*	*	*	*

UNK = Unknown.
- = Not applicable.
* = Not reported.

[1] Complete coverage not planned.
[2] Limited.

program is currently being used to explore relationships of variables and to identify variable combinations that explain accident experience. In the future, the MIDAS system will be used to calculate the expected cost effectiveness of each potential accident countermeasure, and to select countermeasures that will optimize accident reduction within available funding levels. Plans have also been made to expand the MIDAS data base to include driver and vehicle records, weather bureau information, and other data (*21*).

Ohio's Statewide Accident Identification and Reporting System (STAIRS) was developed to locate and graphically display accident and roadway data (*letter*, dated January 27, 1982, to E. H. Reich, Director, Ohio Department of Highway Safety, from D. L. Weis, Director, Ohio Department of Transportation). An interactive process is used, whereby the system generates maps of the roadway system (and/or political jurisdiction) and displays roadway data (pavement width, guardrail, etc.) and corresponding accident and traffic volume data. The file interfacing capabilities allow for computing accident rates and other accident statistics and graphically displaying them for various types and classes of roadway.

File merging and/or interfacing of data files related to highway locations can provide many benefits to the user. Substantial savings in time and manpower for performing routine accident analyses can result from this process. For example, the computation of accident rates for locations on the entire highway network can be generated by computer by interfacing the accident and traffic volume files. The computation of systemwide accident rates by highway classes (required for the rate-quality control method and other identification methods as described later) is possible through interaction capabilities of the accident, traffic volume, and roadway geometrics files. Without file interfacing, such computations would require hand calculations, which, in many cases, would be cost-prohibitive.

Another benefit of file merging and/or interfacing is the capability to perform safety research studies or to investigate the effect of certain geometric features on accident experience. This process has been used to perform numerous large-scale safety research efforts that have led to improved design standards and safety practices during the past 30 yr. The interfacing of the accident and the geometrics files permits a comparative analysis of accident experience for various geometric conditions. For example, in a 1981 study by Zegeer et al. (*22*) conducted to determine the effect of lane and shoulder width on accident experience of rural two-lane roads in Kentucky, merging of the existing accident, geometric, and traffic data was completed for about 15,000 miles (25,000 km) of roads. Relationships were determined between various types of accidents and combinations of lane and shoulder widths while controlling for other traffic and geometric features. Run-off-road and opposite-direction accidents were the only types of accident found to be related to lane and shoulder width. Relationships between accident rates and various lane (Figure 9) and shoulder widths (*22*) were established. Expected accident reduction due to various levels of widening was determined, and a cost-effectiveness model was used to develop criteria for future widening projects. Lane widening to 11 ft and shoulder widening to 5 ft were found to be optimal in terms of cost effectiveness for rural two-lane roads with relatively low traffic volumes (*22*). This type of research study, in which large data samples are required, is often possible only through data interfacing or merging. The results of this kind of study can be used to modify future safety and design standards and to permit wiser expenditure of funds for highway improvement projects.

Although file merging and/or interfacing is often highly desirable or necessary for successfully performing certain accident analysis activities, care should be exercised in attempting to process existing data files. In many cases, the cost of the file merging and data refinement may exceed the cost of a new data collection effort, particularly if a relatively small sample of geometric data is required. For accident research purposes, for example, geometric data on existing computer files may not be of sufficient accuracy or properly formatted for the specific need. Therefore, before time and money are spent on data merging, the specific purpose for such merging should be clearly defined, and a comparison made of the costs of file merging or interfacing with the costs for the collection of fresh data.

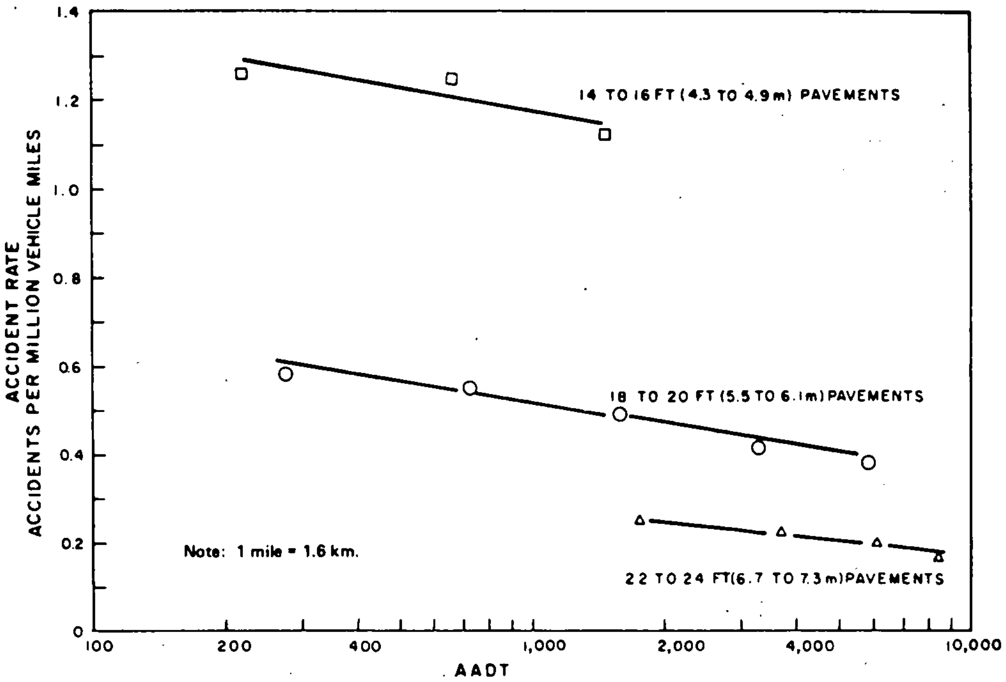
It should also be noted that a common problem with any data processing activity is the frequent lack of proper documentation of files and software. This is particularly true of programs developed by state or local agencies that are intended for infrequent use (once or twice per year). Also, the failure to publish or report the availability and capabilities of certain software has limited their use by agencies.

SYSTEMWIDE DATA SUMMARIES

Computerized data files are used in accident analysis to provide:

- Periodic lists of all accidents by location (often on a monthly, quarterly, or annual basis). City or county spot maps may also be prepared for distribution to local agencies.
- Periodic lists of all high accident spots and sections, which may be priority ranked by accident frequency, rate, or other accident measures. In some states, high accident locations are spotted on detailed county maps.
- Detailed summaries of the accidents that occurred at each high accident location for use in preparing collision diagrams and/or selecting appropriate safety improvements.
- Summaries for use in problem identification. These summaries may be made for any variable coded from the accident record and commonly include information on accidents involving alcohol use; pedestrian accidents; accidents by type of vehicle (motorcycle, bicycle, auto, etc.); use of seat belts or helmets; accidents by pavement condition (e.g., wet-pavement accidents); and many other variables (*23*).
- Computer summaries of highway sections with an abnormally high experience of accidents involving speeding, drunk driving, and certain types of driver violations for purposes of selective police enforcement (e.g., speed monitoring).
- Special report summaries of accidents on freeways and expressways and fatal accident data, and official summary publications and announcements of accident statistics for public distribution (e.g., newspapers).

a. Rate of opposite-direction accidents versus traffic volume by lane width.



b. Rate of run-off-road accidents versus traffic volume by lane width.

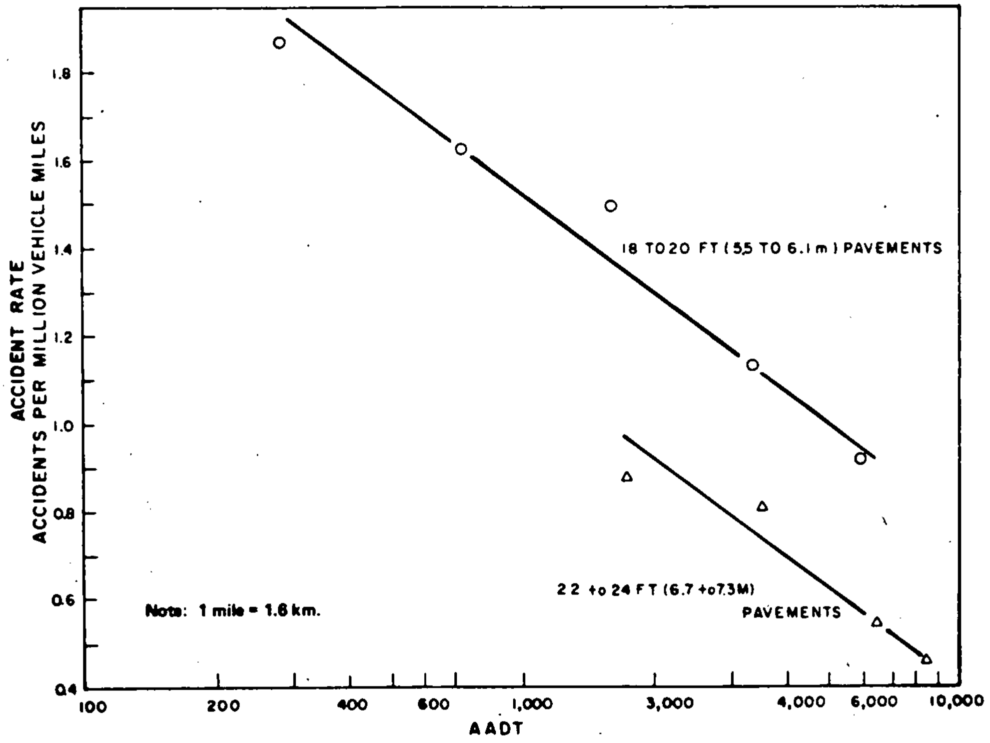


FIGURE 9 Relationships between accident rates and lane widths (*22*).

- Statistical summaries of accidents or lists of high accident locations by city or county for distribution to the appropriate city or county agencies (usually once per year).
- Summaries of accidents involving roadside obstacles or other hazardous features.
- Information for research studies conducted by state research organizations, local universities, or other research groups.

COMPUTER PROGRAMMING LANGUAGES AND SOFTWARE

Different types of computers, with various memory sizes and equipment controls, have been used to process traffic, accident and roadway data. Various programming languages are used, including (*24*):

- COBOL (Common Business-Oriented Language). Widely used, particularly suited for management and administrative information systems.
- FORTRAN (Formula Translator). Designed to facilitate the programming of mathematical equations and the processing of numerical data.
- BAL (Basic Assembler Language). Closely resembles the computer's internal language and often used for programming generalized software, e.g. data-sorting routines.
- PL / 1 (Programming Language 1). An IBM Corporation language that combines the data handling and output features of COBOL with the mathematical computing capabilities of FORTRAN.

A number of data-processing problems have been reported by various agencies, including tape deterioration due to age, hardware and software idiosyncracies related to different manufacturers, and the need to convert from one program language to another. Examples of the data-processing costs in four states are discussed in Chapter 7.

Numerous standard statistical software packages are used to provide cross tabulations, histograms, and other statistical summaries of accident data bases for accident analysis purposes. Examples of some of the computer software programs currently in use are listed below (*25–27*):

Statistical Package for the Social Sciences (SPSS)
National Opinion Research
University of Chicago

Statistical Analysis System (SAS)
North Carolina State University

Data Analysis and Reporting Techniques (DART)
Software System
National Highway Traffice Safety Administration

Records Analysis for Problem Identification and
Definition (RAPID)
Department of Industrial Engineering
Auburn University

OSIRIS IV
University of Michigan

P-Stat
Princeton University

Biomedical Programs (BMD and BMDP)
University of California

Box-Jenkins Univariate, Bivariate Time
Series Program (Batch Version)
Ohio State University

Box-Jenkins Univariate, Bivariate Time
Series Programs
National CSS, Inc.
Norwalk, Conn.

Data Text
Rand Corporation
Santa Monica, California

Table Producing Language
Bureau of Labor Statistics
Washington, D.C.

Ths SPSS package, which was designed for use in the analysis of data related to the social sciences, is one of the most widely used data analysis systems. The types of analysis procedures contained in SPSS include (*28*):

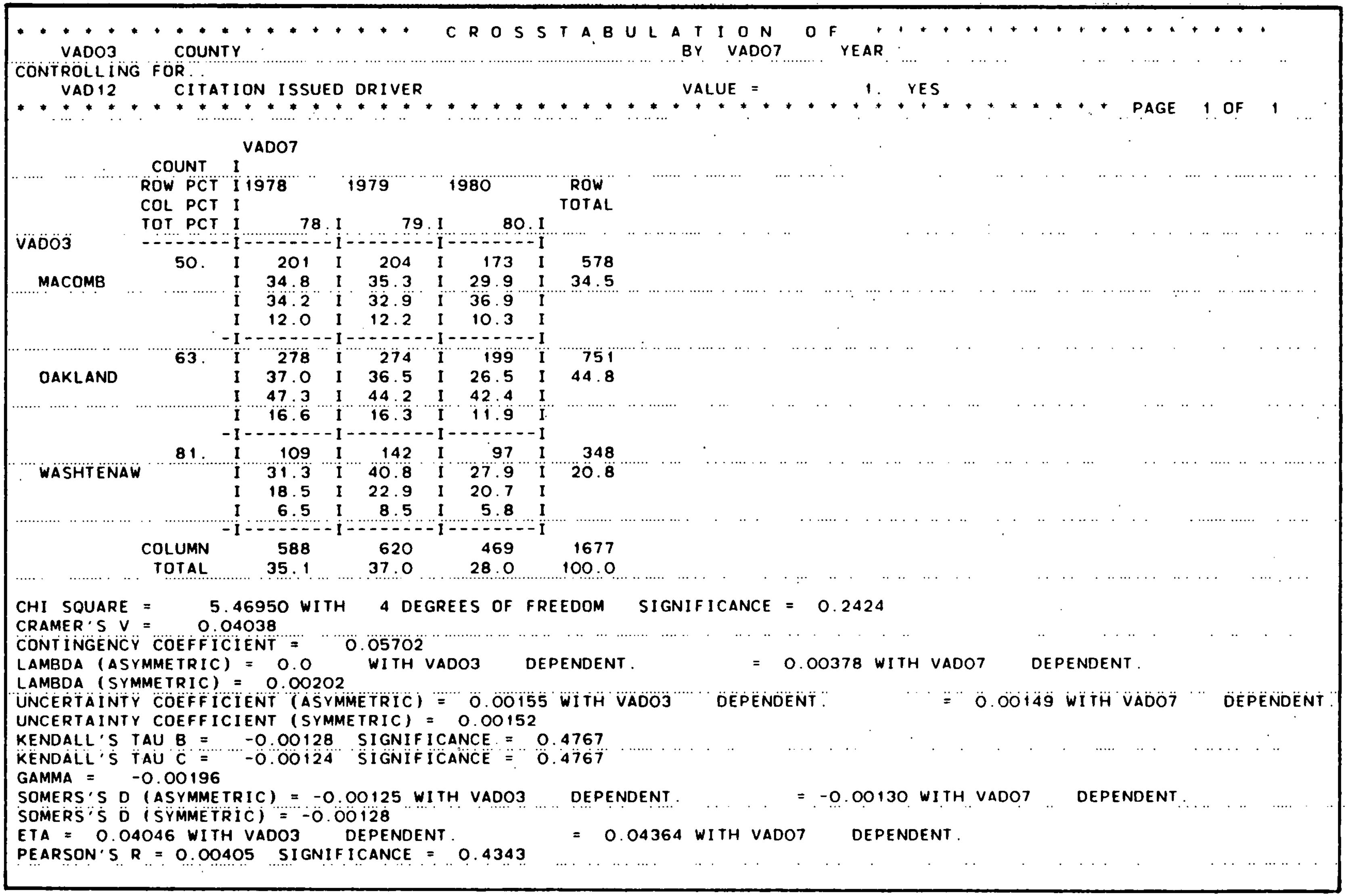
- Frequency distributions;
- Cross tabulations (including statistical tests such as chi-square and Kendall's tau);
- Simple and partial correlation;
- Descriptive statistics (mean, variance, standard error, standard deviation, range, skewness, etc.);
- Analysis of variance;
- Scatter diagrams;
- Factor analysis; and
- *T*-test;

The SPSS package is widely used by highway agencies not only for routine accident analysis, but also for highway research. An example of a cross-tabulation table and statistics from the SPSS package is shown in Figure 10.

The SAS is a package of statistical and data management procedures. The SAS contains all the basic statistical programs, is more powerful and flexible than SPSS, and has an advantage over other statistical program packages in that it has extensive capabilities with respect to data management. The SAS package, which uses a language similar to PL / 1, is useful for sorting, merging, and updating files in a number of ways (*27, 29*). It also includes a variety of computer plotting capabilities (Figure 11).

The P-Stat, developed at Princeton University, is an integrated package of statistical programs. It is useful for managing large data sets, for sorting, merging, updating, and collating data sets, and for overall maintenance of data files (*27*).

The OSIRIS IV is the latest version of a computer package developed by the Institute for Social Research at the University of Michigan. One of its advantages is the ability to handle data bases that are structured in a hierarchy. For complex data bases with expanding sample size, structuring



```
* * * * * * * * * * * * * * * * * *   C R O S S T A B U L A T I O N   O F   * * * * * * * * * * * * * * * * * * * * *
    VADO3     COUNTY                                                        BY  VADO7      YEAR
CONTROLLING FOR..
    VAD12     CITATION ISSUED DRIVER                                        VALUE =          1.  YES
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *   PAGE   1 OF   1


                      VADO7
            COUNT   I
           ROW PCT  I1978      1979      1980       ROW
           COL PCT  I                               TOTAL
           TOT PCT  I      78.I      79.I      80.I
VADO3      ---------I---------I---------I---------I
              50.   I   201   I   204   I   173   I   578
  MACOMB            I  34.8   I  35.3   I  29.9   I  34.5
                    I  34.2   I  32.9   I  36.9   I
                    I  12.0   I  12.2   I  10.3   I
                   -I---------I---------I---------I
              63.   I   278   I   274   I   199   I   751
  OAKLAND           I  37.0   I  36.5   I  26.5   I  44.8
                    I  47.3   I  44.2   I  42.4   I
                    I  16.6   I  16.3   I  11.9   I
                   -I---------I---------I---------I
              81.   I   109   I   142   I    97   I   348
  WASHTENAW         I  31.3   I  40.8   I  27.9   I  20.8
                    I  18.5   I  22.9   I  20.7   I
                    I   6.5   I   8.5   I   5.8   I
                   -I---------I---------I---------I
           COLUMN       588       620       469      1677
             TOTAL      35.1      37.0      28.0     100.0

CHI SQUARE =     5.46950 WITH    4 DEGREES OF FREEDOM   SIGNIFICANCE =  0.2424
CRAMER'S V =    0.04038
CONTINGENCY COEFFICIENT =    0.05702
LAMBDA (ASYMMETRIC) =  0.0      WITH VADO3    DEPENDENT.          =  0.00378 WITH VADO7    DEPENDENT.
LAMBDA (SYMMETRIC) =  0.00202
UNCERTAINTY COEFFICIENT (ASYMMETRIC) =  0.00155 WITH VADO3    DEPENDENT.          =  0.00149 WITH VADO7    DEPENDENT.
UNCERTAINTY COEFFICIENT (SYMMETRIC) =  0.00152
KENDALL'S TAU B =   -0.00128  SIGNIFICANCE =  0.4767
KENDALL'S TAU C =   -0.00124  SIGNIFICANCE =  0.4767
GAMMA =    -0.00196
SOMERS'S D (ASYMMETRIC) = -0.00125 WITH VADO3    DEPENDENT.          = -0.00130 WITH VADO7    DEPENDENT.
SOMERS'S D (SYMMETRIC) = -0.00128
ETA =  0.04046 WITH VADO3    DEPENDENT.          =  0.04364 WITH VADO7    DEPENDENT.
PEARSON'S R = 0.00405  SIGNIFICANCE =  0.4343
```

FIGURE 10 Example of SPSS cross-tabulation.

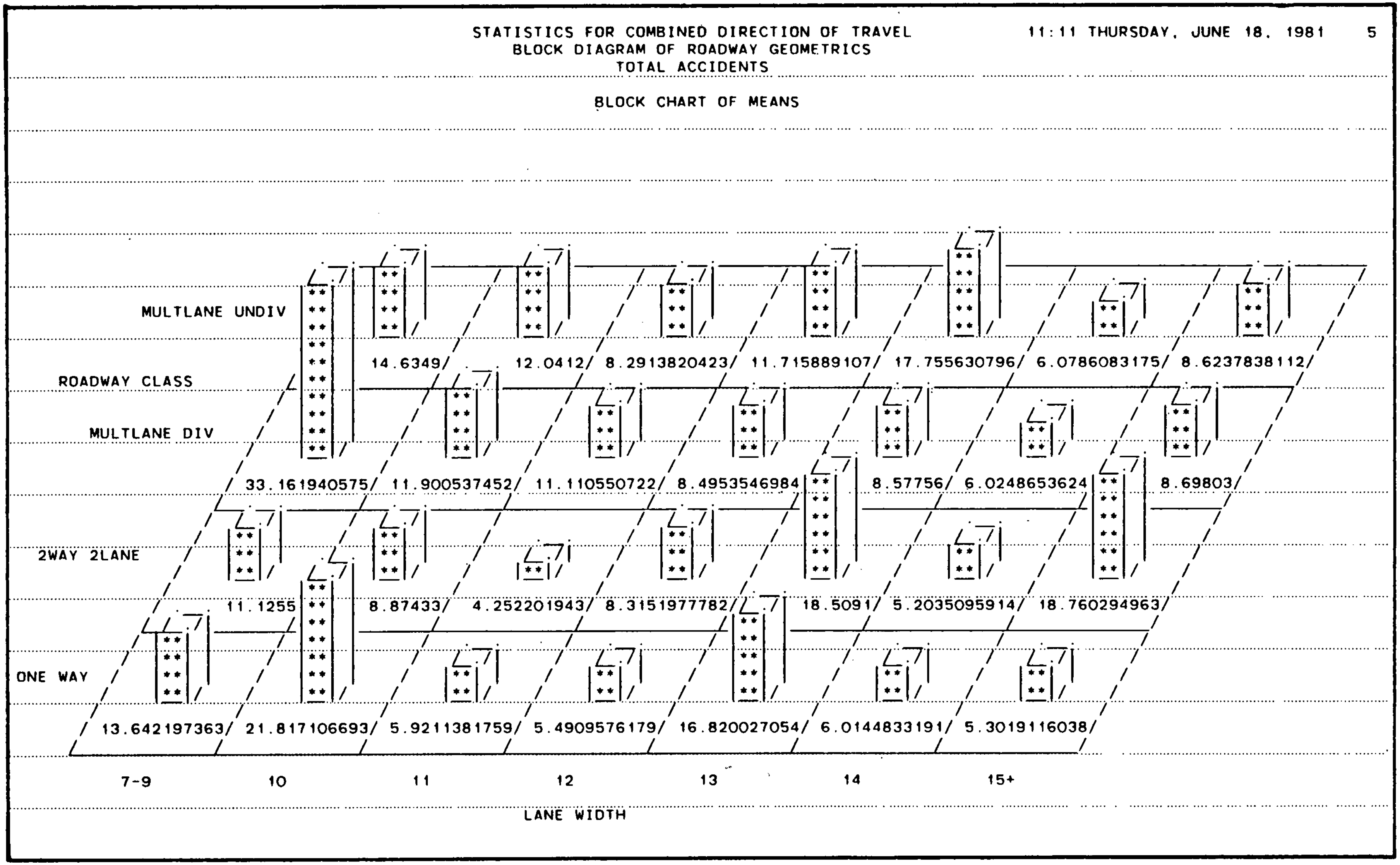


FIGURE 11 Typical SAS three-dimensional plot.

of data bases in an ordered hierarchy can improve the efficiency of data storage and manipulation. Another advantage of the OSIRIS IV package is that it can be used interactively; this is useful for quick and simple runs following the initial analysis, or to test the accuracy of a newly created data base (*27*). The capabilities of OSIRIS IV include (*30*): storing, retrieving, and analyzing hierarchically structured data bases having variable length records; editing and correcting data; generating frequency distributions and related statistics; producing scatter plots; computing rank order statistics; performing correlation and multiple regression analyses; and performing analysis of variance and covariance.

The DART system was established by NHTSA to assist the states in the analysis of computer-maintained accident data by generating reports related to problem identification and program evaluation. The types of statistics that can be generated with the DART package include frequency tables, histograms, basic statistics, *F*-probabilistics, normal probabilities, analysis of variance, and correlations. The DART system was designed specifically for the analysis of accident data, which is not the case with many statistical software packages. Operating instructions are geared for the non-ADP user; English is the operating command language (*31*).

The RAPID program was originally developed for use in identifying problems related to highway safety. It is geared for quick retrieval of information from computer records, and the analysis procedures are basically similar to those of the SPSS package. The program also has the capability to find high accident locations according to user-specified criteria by road code and/or milepost number. Various types of accident summaries can be generated either on a systemwide basis or only for certain locations. Demographic information can also be integrated, for example, to produce priority lists by political or geographic areas (*26*).

In addition to the software packages discussed above, many other programs are currently used to provide a wide variety of summaries and statistical analyses. State and local highway agencies often develop their own computer software to perform special types of analyses, such as identifying problem locations and/or evaluating highway improvement projects. However, usually existing program packages (from commercial sources or from other agencies) can be readily adapted to accomplish most or all of the desired analyses. In many cases, the use of existing analysis packages can save thousands of dollars in software development costs. However, agencies must be aware of the existence of such programs. Continued efforts should be made by individual agencies not only to find out more about available analysis systems, but also to discuss and publicize currently used systems that could benefit potential users.

CHAPTER FIVE

IDENTIFICATION OF PROBLEM LOCATIONS

An important use of the computerized highway accident analysis system is the identification of problem locations. A high accident location is usually defined as a location that experiences abnormal frequencies, rates, or severities of accidents. However, such high accident experience may not necessarily mean that the location is truly hazardous. High accident experience may be caused by:

- Random occurrence;
- High traffic volume, which can result in high accident frequency (however, the accident rate and/or accident severity may be relatively low compared to other high-volume locations);
- High accident rate due to the occurrence of only one or two accidents at a location with low traffic volume (e.g., an ADT less than 500); or
- High accident severity (e.g., fatal or A-type injury accidents) at a location caused by specific accident circumstances, not necessarily the result of a dangerous highway site (e.g., seat belts not used, occupants in poor health, etc.).

A hazardous location (problem location, dangerous location, abnormal location, etc.) is one that presents a risk to the driver in terms of high probability of accident occurrence or high accident severity. This risk may or may not be reflected in past accident records. Many locations, i.e., slick pavements, narrow bridges, or with rigid fixed objects near the highway, etc., may have a high accident potential without necessarily having a history of high accident occurrence.

Most state and local highway agencies currently utilize accident records to identify high accident segments. Locations having only a high accident "potential" are not always identified on a routine basis. This procedure involves the use of a highway features file and/or field surveillance to obtain a list of deficient roadway variables. The identification of these features is often called a hazardous roadway inventory and can supplement the listing of high accident locations.

The following items must be addressed when identifying high accident locations from a computerized accident data file:

- Identification methods
- Selection of methods
- Length of spot or section
- Fixed versus floating segment
- Time period for accident analysis
- Highway classification schemes

IDENTIFICATION METHODS

Methods for identifying problem highway locations, which have been well documented in recent years (*32–36*), require the use of data from accident files and, in many cases, from the traffic volume files and/or highway files.

Accident Frequency Method

The accident frequency method is used to search the accident file for concentrations of accidents within a fixed or variable segment length. Usually one or more segment lengths (0.01-mile, 0.3-mile, 0.5-mile, 1-mile, 3-mile, etc.) are used to "float" through the accident file in which accidents are ordered by location (e.g., by county, route number, and milepoint, or by sequential reference points with the distance and direction from each reference point), and sections that meet or exceed a predefined accident criterion are identified. Such floating segments generally advance in 0.1-mile increments through the file. When a roadway segment that meets the user-specified frequency criteria is identified, the location is printed out along with the corresponding accident information.

For example, the search may begin in county 01 on the lowest state route number at milepoint 0.00. If a 0.5-mile segment is used to float in 0.1-mile increments in a search for sections where at least 10 accidents have occurred (per 0.5 mile), the first length reviewed on computer file will be milepoint 0.00 to 0.50. If the first segment does not meet the criterion of 10 or more accidents, then the segment of 0.10 to 0.60 is searched, followed by 0.20 to 0.70, and so on. As the search continues along the route, the first segment meeting the accident criterion occurs at milepoint 1.10 to 1.60, where 12 accidents are counted. This segment is then printed out along with desired accident summaries, such as total number of accidents, number of injury accidents, number of fatal accidents, number of people hurt or killed, etc. Depending on the particular program, the next segment to be reviewed might be 1.20 to 1.70, where overlapping would take place over the already identified high accident segment. In such a case, it is likely that several subsequent segments will be identified, even though only one truly hazardous spot exists. Another procedure is to search the segment directly adjacent to (but not overlapping) the identified location. In this case, the next segment tested after 1.10 to 1.60 would be 1.60 to 2.10.

Several different segment lengths and/or years of accident data (usually 1–5 yr) are often used by an agency for file searches. Also the accident criteria for selecting highway segments usually vary by area type (urban, rural) or other classification variables (number of lanes, functional class, etc.). The computer program is generally written to rank the identified highway segments in descending order by accident frequency. Many agencies utilize the frequency method as a preliminary accident file search and then apply another method (rate-quality control, severity, rate, etc.) to rank locations for further analysis.

A sample of an accident histogram, as generated from Michigan's MIDAS data file, is shown in Figure 12 (*37*). Accident distributions are given for locations on the Michigan state highway system with the following characteristics: two-lane/two-way tangents; passing zones; fringe area; no traffic signals; 11-ft lanes; and 8- to 10-ft shoulders. The MIDAS data file provides for the selection of locations in this manner, since the file contains information on accidents, and traffic and roadway data for each highway segment (*37*).

Accident Rate Method

The accident rate method consists of simply dividing the accident frequency at a location by the vehicle exposure to determine the number of accidents per million vehicles at intersections and other spots (generally defined as 0.3-mile segments or less). For highway sections, the accident rate is computed in terms of accidents per million (or hundred million) vehicle-miles of travel. Spots or sections are priority ranked in order of descending accident rate.

The accident rate for highway spots can be computed as follows:

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

where

R_{sp} = accident rate for a spot (in accidents per million vehicles entering the spot),
A = number of accidents for given analysis period,
T = time of analysis period (in years or fraction of years),
V = average annual daily traffic (AADT) during study period (for intersections, V is commonly defined as sum of entering volumes on all approaches).

The equation for computing the accident rate of highway sections is as follows:

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

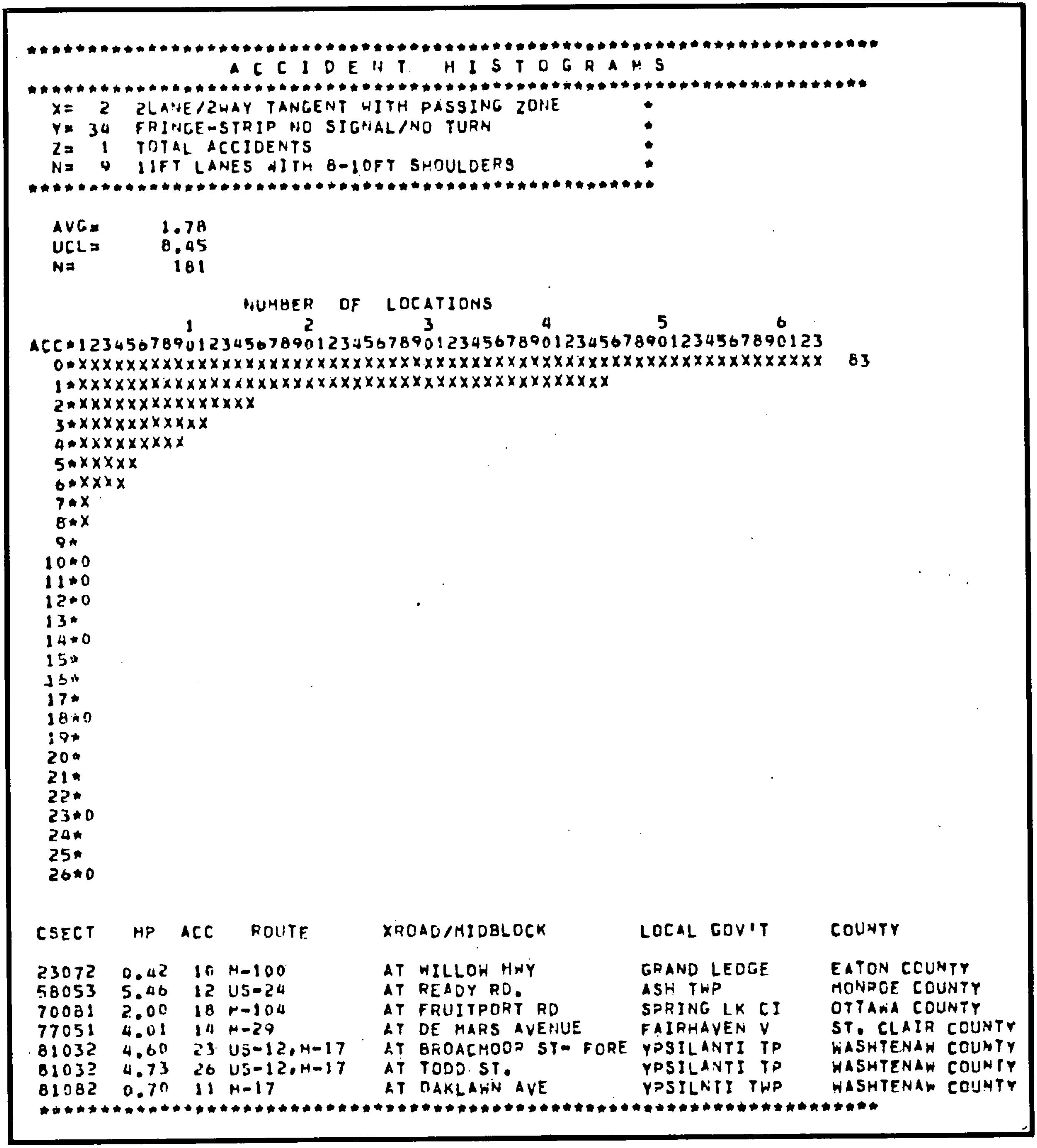
where

R_{se} = accident rate for highway section (in accidents per million vehicle miles), and
L = length of section (in miles).

If the rate is expressed in terms of accidents per hundred million vehicle miles, the equation becomes:

$$R_{se} = A\,(100{,}000{,}000)/(365)(T)(V)(L).$$

When the computer accident file is used in implementing the accident rate method, interfacing with the traffic volume file is required. The highway reference method is the controlling variable in the program. The search through the acci-



```
*********************************************************************
                  A C C I D E N T   H I S T O G R A M S
********************************************************************
  X=  2  2LANE/2WAY TANGENT WITH PASSING ZONE         *
  Y= 34  FRINGE-STRIP NO SIGNAL/NO TURN               *
  Z=  1  TOTAL ACCIDENTS                              *
  N=  9  11FT LANES WITH 8-10FT SHOULDERS             *
***************************************************

  AVG=      1.78
  UCL=      8,45
  N=         181

                      NUMBER  OF  LOCATIONS
             1         2         3         4         5         6
ACC*123456789012345678901234567890123456789012345678901234567890123
  0*XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX  83
  1*XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
  2*XXXXXXXXXXXXXXX
  3*XXXXXXXXXXX
  4*XXXXXXXXX
  5*XXXXX
  6*XXXX
  7*X
  8*X
  9*
 10*0
 11*0
 12*0
 13*
 14*0
 15*
 16*
 17*
 18*0
 19*
 20*
 21*
 22*
 23*0
 24*
 25*
 26*0

CSECT   MP  ACC   ROUTE        XROAD/MIDBLOCK         LOCAL GOV'T      COUNTY

23072  0.42  10 M-100          AT WILLOW HWY          GRAND LEDGE      EATON COUNTY
58053  5.46  12 US-24          AT READY RD.           ASH TWP          MONROE COUNTY
70081  2.00  18 M-104          AT FRUITPORT RD        SPRING LK CI     OTTAWA COUNTY
77051  4.01  14 M-29           AT DE MARS AVENUE      FAIRHAVEN V      ST. CLAIR COUNTY
81032  4.60  23 US-12,M-17     AT BROADMOOR ST- FORE  YPSILANTI TP     WASHTENAW COUNTY
81032  4.73  26 US-12,M-17     AT TODD ST.            YPSILANTI TP     WASHTENAW COUNTY
81082  0.70  11 M-17           AT OAKLAWN AVE         YPSILNTI TWP     WASHTENAW COUNTY
********************************************************************
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FIGURE 12 Sample accident location listing from Michigan's MIDAS data file (*37*).

dent file may be started in a similar manner as that described for the accident frequency method. However, in a pure accident rate calculation, every highway segment identified with one or more accidents will be located. The traffic volume file must be formatted by a compatible location reference method in the same order as the accident file.

After the first highway segment with one or more accidents is identified, the traffic volume of the section is read from the volume file and an accident rate is computed. The entire accident file is handled in this manner until the rates for all sections (with at least one accident) are computed. Again, floating or fixed sections may be queried in the accident file. All rates may not be printed (e.g., if only rates above two accidents per million vehicles are to be considered for further review).

Problems can arise in merging the data from the volume file for purposes of rate calculation. First, the volume data are normally input by specific links. A problem can occur when the end points of an identified accident location overlap two or more segments in the traffic volume file. In this case, the average or weighted traffic volume within the identified accident location must be determined. The West Virginia Department of Highways employs a weighting factor based on the length and volume of each traffic link within the identified highway section in the calculation of accident rates (*personal communication,* R. Lewis and C. Kendrick, West Virginia Department of Highways).

The most significant problem, however, involves the overlap of the intersection itself. It is desirable for the volume file to be arranged to include the cross-street volumes along the major street. Without such cross-street volumes, the computed rate for intersections from the merged files will not include the cross-street volume, and the rate will be erroneously computed, which could cause large errors in the true accident rate value, particularly when accident rates for short highway sections (less than 1 mile) are computed. In California, intersection records contain cross-street volumes, and high-accident intersections are analyzed separately from highway segments and are not duplicated in the segment analysis.

When conducting a computer search for long sections, problems can also occur, even if cross-street volumes are available in the traffic volume file. For example, suppose that a 2-mile section is used to float through the accident file and accident rates are computed by interfacing with the traffic volume file. There should be some mechanism to account for the intersections within the section. Most accident files do not allow for easy recognition of the locations of intersections along a route. An exception to this is when a reference method of links and nodes is used and accidents and volumes are tied to those nodes and links. Then intersection accidents and corresponding volumes may be interfaced. In a similar manner, accident rates for the links can be computed by retaining the full link distances between nodes.

Frequency Rate Method

The frequency rate method is used for identifying locations based on both accident numbers and rates. Usually, this method is applied by selecting a sample of locations that meet the accident frequency criterion and then ranking the selected locations by accident rate. However, some agencies identify locations by rate and then rank them by frequency. In some agencies, to be considered for further analysis, a location must meet or exceed both a minimum number of accidents and a minimum accident rate.

The frequency rate method may also be applied by developing a plot of accident frequency categories (0–2, 3–5, 6–10, etc.) and rate categories. This results in a two-dimensional accident data matrix, in which any highway location may be placed in a single matrix cell representing a given level of accident frequency and rate. The matrix cells in the upper right corner represent the most hazardous locations, which will be given top priority for further analysis. The matrix cells in the lower left corner denote the locations with the lowest priority. The frequency and rate categories on the x and y axes can be changed to best suit the type of highway, the time period of the accidents analyzed, and other user needs. To use the frequency rate method in this manner, the user must define the combinations of frequency and rate corresponding to priority 1, priority 2, etc. (*38*). A frequency rate matrix is shown in Figure 13.

Rate Quality Control Method

The rate quality control method not only entails the calculation of the accident rate at each location, but also a statistical test to determine if that rate is significantly higher than accident rates for other locations with similar characteristics. The statistical test is based on the commonly accepted assumption that accidents follow a Poisson distribution. For each location, a critical accident rate is computed as follows (*33, 35*):

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

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, and

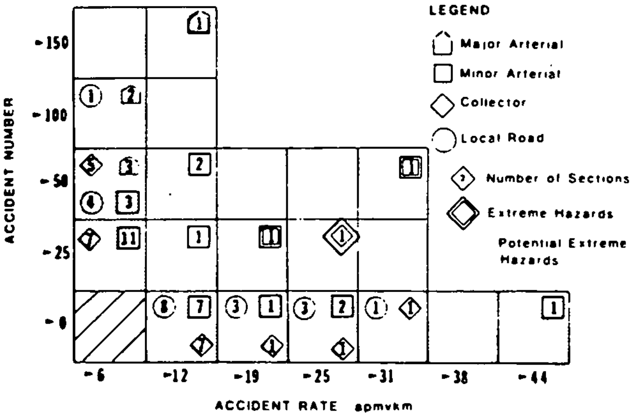


FIGURE 13 Frequency rate matrix (*38*).

K = a probability factor determined by the desired level of significance for the equation. The values of K corresponding to various levels of probability are:

P	0.001	0.005	0.0075	0.05	0.075	0.10
K value	3.09	2.576	1.96	1.645	1.440	1.282

Common values of K used by highway agencies are 2.576 ($P = 0.005$) and 1.645 ($P = 0.05$). A probability level, P, is selected to ensure that an accident rate is sufficiently large so that it cannot be reasonably attributed to random occurrences. Selecting higher confidence levels (higher values of K) results in fewer locations being identified as having critically high accident rates (*35, 39*).

Note that the critical rate is computed for each location and compared to the actual accident rate. If the actual accident rate exceeds the critical rate, then the location may be considered for improvement.

A series of critical rate curves was developed in Kentucky for urban intersections of arterial and collector streets (Figure 14) (*39*). For each city class (based on city population groups), one curve was developed of the critical accident rate for intersections for a range of traffic volumes (entering volumes of through-street plus cross-street). As the traffic volume at a location decreases, the data are less reliable, and the critical rate increases. Note that two intersections in the same city class with different traffic volumes will have different critical rates. Similar sets of critical rate curves could also be constructed based on other intersection classifications (e.g., signalized or unsignalized, number of lanes) if information was available regarding average accident rates (R_a values) for each of those intersection classes. Each state (or city) agency should develop its own critical rate curves based on its own average rates (R_a values).

As an example of the use of the quality control method, assume that an intersection in a city with a population of 10,000 has an AADT of 6,000 and an accident rate of 2.7 (accidents per million entering vehicles) in a particular year. The problem is to determine if the accident rate of that location is critical (i.e., significantly higher than other intersections in the same class). Using Figure 14, the critical rate for the intersection (in Group 4 with an AADT of 6,000) is about 2.1. Since the actual accident rate (2.7) at the location exceeds the critical rate (2.1), the accident rate at the location may be considered to be significantly higher than other intersections in its class (at a confidence level of 99.5 percent).

In practice, some states select locations for further analysis if the accident rate is 2 or 3 times higher than the critical rate (or the K value is increased until a manageable number of critical locations are identified for further analysis).

Accident Severity Methods

The accident severity methods are used to identify and/or rank locations based on the number of severe accidents at each location. Accident severity is defined by the National Safety Council and many states in the following categories (*40*):

- *Fatal Accident.* One or more fatal injuries.
- *A-Type Injury (Incapacitating) Accident.* Bleeding wound, distorted member, or person carried from scene.
- *B-Type Injury (Nonincapacitating) Accident.* Bruises, abrasions, swelling, limping.
- *C-Type Injury (Probable Injury) Accident.* No visible injuries but complaint of pain.
- *PDO Accident.* Property damage only.

One of the severity methods used for comparing highway locations is called the equivalent property damage only (EPDO) method. The equivalency factors vary by state. The following formula is used in Kentucky (*41*):

$$\mathrm{EPDO} = 9.5\,(F + A) + 3.5\,(B + C) + PDO$$

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, and
PDO = number of PDO accidents.

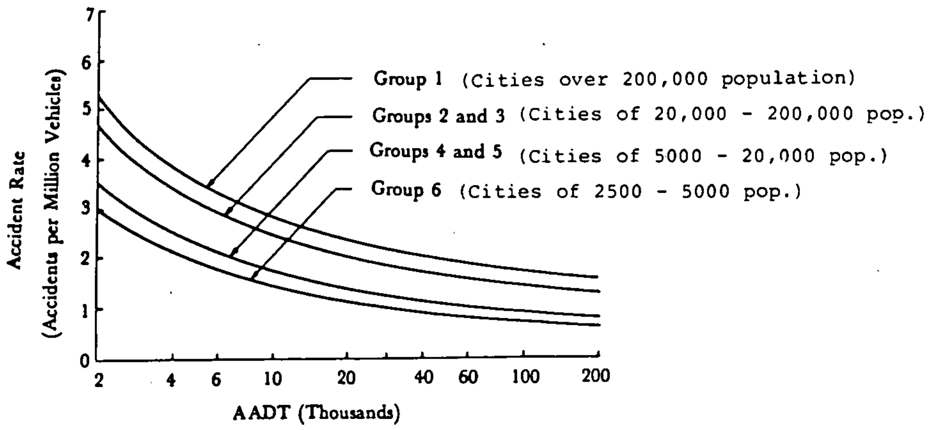


FIGURE 14 Rate quality control curves for urban intersections on arterial and collector streets in Kentucky (probability level of 0.995) (*39*).

With this equation, each accident is classified by the most severe injury that occurred, and an accident is counted only once in the equation. Locations are ranked by their computed EPDO number. In North Carolina, an EPDO rate is computed by dividing the EPDO value (using a slightly different formula) at a location by the traffic volume at that location. This takes into account both frequency of severe accidents and vehicle exposure.

Another accident severity method, called the relative severity index (RSI), is used to compute average accident costs for a particular accident type. Accident costs are based on the distribution of fatal, injury, and property-damage accidents that occur on each type of highway. RSI values can also be computed for each accident type (right-angle, rear-end, etc.) within each highway type.

Another accident severity method for identifying problem locations involves the identification of locations with a minimum frequency of severe accidents (i.e., fatal plus injury accidents) in a given time period. This method can be classified as either a frequency or a severity method.

In using an accident severity method, the program is usually written to search all the severity columns and select the most severe injury to any driver or passenger in any vehicle. With a variable-length file of numerous vehicles and/or passengers, this involves searching the injury codes for each occupant. To compute a severity rate, interaction must be made with the traffic volume file.

Hazardous Roadway Features Inventory

The hazardous roadway features inventory is a method of identifying locations that do not necessarily exhibit a history of high accident experience, but may deserve consideration for improvement based on a potential for high accident frequency or severity. Such locations may be identified for several reasons, including (a) they do not meet current design standards or MUTCD guidelines; or (b) they constitute an obvious hazard to traffic.

Hazards can be located by routine field inventories or by special studies conducted to locate a certain type of hazard. Dangerous roadway features should be routinely identified to prevent accidents. In Illinois, improvements off the state system are considered at locations having a potential for a large number of accidents, such as (*42*):

1. Substandard horizontal curves
2. Improper superelevation
3. "Y" intersections
4. Poor sight distance
   a. Substandard vertical curves
   b. Need for "daylighting"
5. Bad intersection angle or intersection on curve
6. Roadside obstacle elimination
7. Bridges
   a. One- or two-lane bridges less than 20-ft wide
   b. Structure posted for less than a 10-ton load limit

In a recent survey, FHWA field offices compiled information on state highway safety programs (*43*). State agencies were queried on the types of hazardous highway features routinely identified for possible blanket safety improvements. Of 38 responding states, 26 identified these hazardous features (*43*):

NO. RESPONSES	TYPE OF HAZARD
14	Roadside
19	Narrow bridges
21	Slick pavement sections
10	Inadequate guardrail sections or terminals
4	Narrow highway lanes or shoulders
7	Gore areas at freeway exit ramps
2	Transition areas (drop in the number of lanes, etc.)
4	Other
3	Responded yes, but gave no specific details

Other Methods

Various other identification methods or combinations of methods are utilized by highway agencies. For example, besides applying the identification methods to a total accident data base, many agencies identify specific locations that exhibit an abnormally large amount of specific types of accidents. Michigan identifies locations with statistically high numbers of right-angle, rear-end, and left-turn accidents, etc. (*37*).

In West Virginia, listings are routinely obtained and reviewed regarding locations with an excessive number of wet-weather, run-off-road, fatal, and night accidents. Also, a "Delta Accident Change" listing is used to analyze locations and produce a list of segments with an unusually high increase or decrease in accident experience as compared to previous years (*personal communication,* R. Lewis and C. Kendrick, West Virginia Department of Highways).

SELECTION OF METHODS

A summary of the methods used in each state for identifying hazardous locations is given in Table 5 (*3*). Most states utilize several different methods for identification purposes. Nearly one-fourth of the states are currently developing a methodology for location identification for one or more types of highways. In addition, virtually all states consider for improvement all locations where a fatal accident has occurred.

Regardless of the specific method(s) used, the following guidelines are recommended for selecting methods for identifying high accident locations.

1. Although the accident frequency method alone does not consider traffic exposure and accident severity, it is useful in initially identifying a group of locations for further analysis and ranking. If the rate quality control method is used in conjunction with the frequency method, it is unnecessary to compute accident rates and critical rates for every location in the state having at least one accident. A sample could be selected of locations that exceed a fixed number of accidents per year before the rate quality control method is applied.

TABLE 5 METHODS FOR IDENTIFYING HAZARDOUS LOCATIONS (*3*)

STATE	INTERSTATE								STATE								LOCAL							
	A	E	L	R	S	Y	Z		A	E	L	R	S	Y	Z		A	E	L	R	S	Y	Z	
ALABAMA							X		X			X	X				X			X	X			
ALASKA								-	X			X	X				X			X	X			-
ARIZONA	X			X	X				X			X	X				X				X			
ARKANSAS	X			X	X	X			X			X	X	X									X	
CALIFORNIA	X			X					X			X					X			X				
COLORADO	X			X	X				X			X	X				X				X			
CONNECTICUT	X			X		X			X			X		X			X					X		
DELAWARE	X	X			X				X	X			X											-
FLORIDA			X									X												1/
GEORGIA	X		X	X	X				X		X	X	X				X							
HAWAII	X	X		X					X	X		X					X	X		X				
IDAHO	X		X	X					X		X	X					X		X	X		X		
ILLINOIS				X								X					X				X			
INDIANA	X						X		X						X		X						X	
IOWA	X	X		X	X				X	X		X	X				X	X		X	X			
KANSAS	X			X					X			X										X		
KENTUCKY	X		X	X					X		X	X					X							
LOUISIANA	X			X	X				X			X	X											*
MAINE	X			X					X			X					X			X				
MARYLAND	X	X	X	X	X				X	X	X	X	X				X							
MASSACHUSETTS	X		X	X	X				X		X	X	X				X		X	X	X			
MICHIGAN	X	X	X	X	X				X	X	X	X	X	X			X	X		X	X			
MINNESOTA	X			X	X				X			X	X									X		
MISSISSIPPI	X			X					X			X					X			X				
MISSOURI	X		X	X					X		X	X											X	
MONTANA	X			X	X				X			X	X				X		X	X	X		X	
NEBRASKA	X	X		X	X				X	X		X	X				X	X		X	X			
NEVADA	X			X	X				X			X	X				X			X	X			
NEW HAMPSHIRE	X				X	X			X				X	X			X				X	X		
NEW JERSEY	X	X	X	X	X	X			X	X	X	X	X	X			X	X		X	X			
NEW MEXICO	X			X					X			X											X	
NEW YORK	X	X		X	X				X	X		X	X				X	X		X	X			
NORTH CAROLINA	X			X	X				X			X	X				X			X	X			
NORTH DAKOTA	X		X	X	X				X		X	X	X				X			X			X	
OHIO	X			X					X			X					X			X				
OKLAHOMA				X	X	X						X	X	X			X				X			
OREGON	X	X		X	X				X	X	X	X	X				X	X		X	X			
PENNSYLVANIA	X			X	X				X			X	X				X				X			
RHODE ISLAND	X	X	X		X				X	X	X		X				X	X	X		X			
SOUTH CAROLINA	X			X	X				X			X	X						X	X				
SOUTH DAKOTA	X				X				X				X				UNKNOWN							
TENNESSEE	X	X	X	X	X				X	X	X	X	X				X	X	X	X	X		X	
TEXAS								*	X		X	X					X					X		
UTAH	X			X	X				X			X	X				X			X	X			
VERMONT								*								*								*
VIRGINIA	X	X		X	X				X	X		X	X				VARIES							
WASHINGTON	X			X	X				X			X	X				X			X				
WEST VIRGINIA	X			X	X				X			X	X									X		
WISCONSIN	X	X		X	X		X		X	X		X	X		X		X	X		X	X			
WYOMING	X			X	X				X			X	X				X			X	X			
DIST. OF COL.	X	X		X					X	X		X												-
PUERTO RICO								-					X								X			
SAMOA								-	X		X	X	X											-
GUAM								*								*								*
VIRGIN ISLANDS								*								*								*

- = Not applicable.
* = Not reported.
[1] = Complete coverage not planned.

Hazardous Location Identification Criteria Codes

A = Number of accidents.
E = Economic loss/accident cost.
L = A specific number of locations (e.g., top 100).
R = Accident rate, including rate-quality control.
S = Accident severity.
Y = Other.
Z = Under development .

Y Codes

Arkansas: Requests from district engineers, maintenance personnel, and law enforcement agencies.
Connecticut: Modified rate-number quality control method.
Idaho: Input from local jurisdictions.
Kansas: Pin maps, 402 safety studies.
Michigan: Accident patterns.
Minnesota: Local authorities criteria, priorities, and funding systems.
New Hampshire: Input from public and maintenance division offices.
New Jersey: For overlay projects—percent of wet-weather accidents, skid number, on-site investigation.
Oklahoma: Field reviews.
Texas: Safety improvement index.
West Virginia: Input from local jurisdictions.

2. It is desirable to consider accident severity at least as a supplemental method when identifying locations. Some high-speed locations consistently exhibit numerous injury and fatal accidents without necessarily meeting an established accident frequency or rate criterion. For example, a spot location with five fatal and severe-injury accidents should certainly justify a higher priority for further analysis than another location with six property-damage-only accidents. Although the severity of a particular accident is subject to many factors unrelated to the accident (use of seat belts, age and health of occupants, size of vehicles, etc.), a consistent history of severe accidents at a location should be the basis for further review.

3. The criteria (or level of confidence) for identifying and ranking locations should be based largely on the number of locations that can actually be handled by an agency. For example, if an agency can only realistically analyze and review 100 locations per year, it is unnecessary to identify and rank the top 1,000 locations. In this situation, it may be useful to set the criteria so that 150 to 200 locations are identified for further analysis.

Among the states surveyed for this study, the number of locations identified for further analysis ranged from fewer than 100 in one state to more than 2,000 (at three levels of confidence—high, medium, and low priority) in another state. The number of identified locations can be established primarily by raising or lowering the "cut-off" accident criteria (frequency, rate, etc.), or by modifying the level of confidence to be utilized. For example, California currently uses a probability level of 99 percent when using the rate quality control formula. By lowering the level to 95 percent confidence, it is estimated that an additional 1,300 locations would be added to the list each year, requiring 7 additional man-years of effort to analyze and review the locations (*memorandum,* dated July 20, 1978, to C. E. Forbes, Chief Engineer, California Department of Transportation, from the DOT Steering Committee). A change in the segment length (e.g., 0.3 mile, 1 mile, 3 miles) can also affect the number of locations that will be identified for further analysis.

4. It is desirable to consider various types of accident identification methods instead of relying on a single method. In general, a single identification method will allow only for the selection of a sample of locations worthy of further consideration. Consideration of several valid indicators (frequency, rate, statistical reliability, accident severity, roadway features, etc.) will help to improve the reliability of the identification process. The data requirements for each method must be considered before the method is selected.

5. It is important to look at the highway network as a total system rather than merely as a combination of independent segments. In many cases, the presence of several high accident spots on a highway section may be due to more than just an isolated roadway deficiency. A roadway safety problem that extends for several miles may exist, such as:

- A 2-mile stretch of heavy commercial development (numerous driveways along roadway).
- A series of substandard horizontal curves along a highway section.
- A series of traffic signals at adjacent intersections that restrict traffic flow and where numerous rear-end accidents are prevalent.
- A series of narrow bridges or roadside obstacles along a highway section.

These types of conditions require the consideration of improvements on a broader scale than would be considered for an individual high accident spot location.

The use of "blanket" improvements may be necessary to treat such systemwide safety problems as: (a) freeway gore areas lined with light poles, guardrail, or sign posts; (b) sections with low pavement skid-resistance properties; (c) blunt- or buried-end guardrail ends; and (d) rigid sign supports, light poles, or utility poles throughout the highway network.

6. The use of accident data files in combination with other data files is valuable in producing a list of sites that warrant further study for safety improvements. However, there is also merit in the identification of other types of locations suspected of having a high potential for accidents, such as locations with (a) numerous vehicles running off the edge of the roadway (near-accidents); (b) a high incidence of traffic conflicts and erratic maneuvers, e.g., vehicles running stop signs or red signals (possibly because of poor sight distance, excessive vehicle speeds, etc.); and (c) evidence of safety problems (multiple skid marks on pavement, numerous dents in guardrail sections, consistent damage to impact attenuators in gore areas, etc.).

The use of accident records along with the selection of potential problem locations is important to permit the identification of a wide range of hazardous locations: those with abnormal accident experience, and those with potential for high accident frequency or severity. After a list of these locations is compiled, a manual investigation of the sites should be conducted together with other appropriate engineering studies to determine which locations are "correctable" by safety improvements. Even though a location may be ranked high in terms of its accident experience, there is no guarantee that any improvement will be cost-effective or successful in significantly reducing accidents.

SPOT OR SECTION LENGTH

An important consideration in accurately identifying high accident locations is the selection of appropriate segment lengths for which accident data are to be accumulated. Segments are generally classified as either spots or sections. A spot is a short segment (usually defined as 0.3 mile or less) of highway used to identify problem "point" locations, such as short bridges, curves, intersections, and railroad crossings. A section is usually defined as a highway segment longer than 0.3 mile and is used to identify problems due to inadequate cross section, geometrics, pavement surface, a series of driveways, etc.

Most state agencies define 0.1-mile segments, 0.3-mile segments, or intersections (within a certain number of feet) as spots. The following summary of the use of spot lengths by state agencies (some agencies define more than one spot length) is from a 1981 FHWA publication (*43*):

NO. RESPONSES	SPOT LENGTH
3	Spots not identified
1	100 ft
1	200 ft
14	0.1 mile
2	0.2 mile
10	0.3 mile
14	Intersections
11	Other

Four states utilize variable spot lengths, and two states claim to identify spot lengths of 0.01 mile. Another state identifies clusters of fatal accidents. The distances used to define an intersection ranged from within 50 ft (Vermont) to within 528 ft (Louisiana) (*43*).

The FHWA report (*43*) also contains information on the selection of section lengths.

NO. RESPONSES	SECTION LENGTH
8	0.3 mile
6	0.5 mile
7	1 mile
20	Other

Seven states use varying lengths to identify high accident sections. North Carolina and Wyoming use lengths of 1 mile or more.

The following guidelines are recommended for the selection of an appropriate spot length:

1. A spot (or section) should have consistent characteristics in terms of geometrics, traffic volumes, and class of highway. Selection of such a spot can be best accomplished by using a traffic volume and roadway file to supplement the accident file (*35*).
2. The spot length should be no smaller than the minimum increment for reporting an accident location. For example, if accidents are reported to the nearest 0.1 mile, then the spot length should be no smaller than 0.1 mile (*35*).
3. The spot length should be selected to account for the suspected degree of error in reporting accident locations. If the degree of accuracy is low, then longer segment lengths will be needed to minimize the error (*35*). For example, if an agency estimates that, in general, accidents are located accurately to within 250 ft (about 0.05 mile), a segment of at least 0.10 mile (2 × 0.05) should be used for identification purposes. If a state estimates accident locations to be accurate only to within about 0.4 mile, a minimum segment length of about 0.8 to 1.0 mile should be used. Using a 0.1-mile segment in this case would likely pick up a large number of incorrect locations and would not identify the truly hazardous locations. Using Figure 15, assume that all 12 accidents occurred exactly at milepoint 1.20, but were reported at the locations as shown. Except for one accident, all were reported to within ± 0.10 mile of the true milepoint. Thus a floating segment length of 0.20 mile would identify milepoints 1.10 to 1.30 as having 11 accidents, which would be reasonably accurate for further analysis.
4. The spot length should be at least as large as the area of influence of a highway hazard. An accident scene may extend for several hundred feet, and a dangerous curve may often contribute to accidents that occur several hundred yards apart. Thus spot lengths of 0.2 or 0.3 mile often provide more appropriate results than spot lengths of 0.1 mile or less, particularly in rural areas where the area of influence of a hazardous spot (e.g., a horizontal curve or narrow bridge) may often extend for about 0.3 mile (*35*).
5. The length of a spot has a direct impact on the reliability of the identification of high accident locations. This is confirmed by plotting points of the Poisson distribution (see Figure 16). Deacon et al. (*35*) state:

> Assume that, for a particular class of highway, a hazardous segment is one having a long-term average of 30 or more accidents per mile per year. The probability that a given spot has 30 or more accidents per mile during a particular 12-month period is shown in Figure 1 [Figure 16] as a function of both spot length and the average long-term accident experience. The probability of correctly identifying truly hazardous locations (such as those represented by the curves for expected accidents of 50, 40, and 35 per mile per year) as hazardous generally increases as spot length increases. Furthermore, the probability of incorrectly identifying safe locations (such as those represented by the curves for expected accidents of 25, 20 and 10 per mile per year) as hazardous decreases as spot length increases. It is apparent, therefore, that errors in identifying hazardous locations caused by the random nature of accident occurrences can be minimized by the use of longer spots.

Whereas the above example assumes accident frequency as the measure of hazard, short segment lengths can also give erroneous results when accident rate or accident severity is the measure of safety hazard. Accident rates (in accidents per million vehicle-miles) become unstable and of questionable value for highway segments of short length (i.e., less than 0.3 mile) and/or with low traffic volumes (i.e., less than 500 vehicles per day), even when several years of accident and volume data are used.

6. If a defined spot is too short, there is little difference among highway sites in terms of accident experience. Assume, for example, that a spot length of 20 ft is used. Then virtually all spots on the total highway system would have either zero or one accident in a given year (except possibly for the midpoint of major intersections). The segment length should be long enough to account for this effect (*35*).
7. If a defined spot is too long, it is likely that some isolated locations that exhibit an abnormal number of accidents will be missed. For example, assume that a 0.5-mile spot is used to search the accident file for segments with 10 or more accidents per year. However, a 30-ft-long narrow bridge on

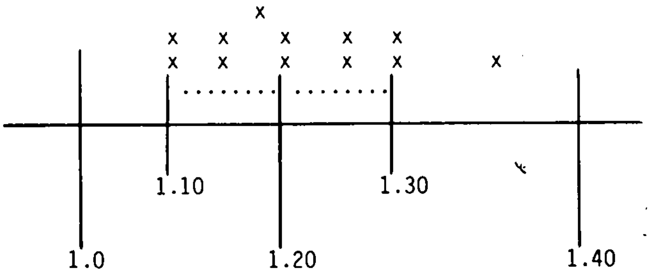


FIGURE 15 Accident location reporting error.

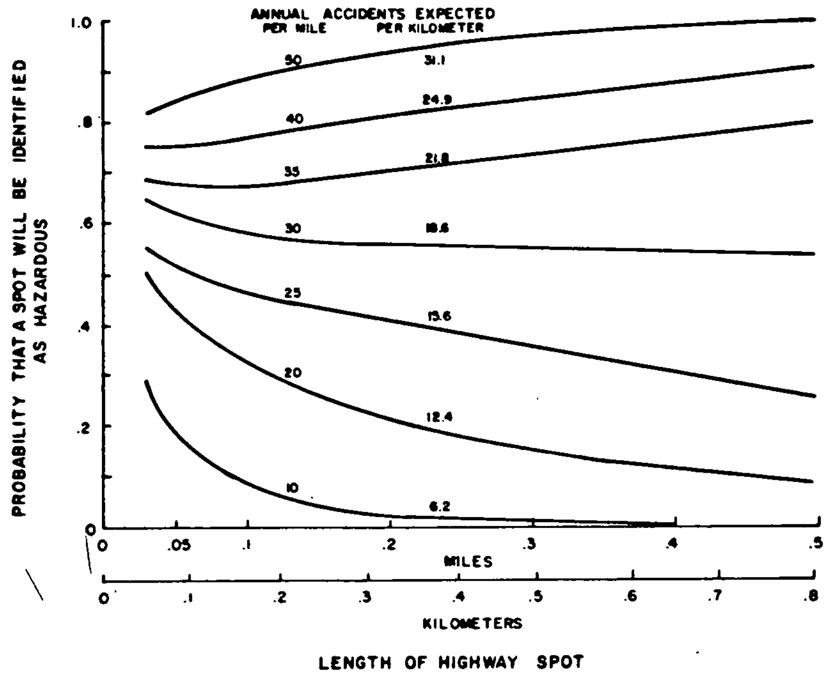


FIGURE 16 Effect of spot length on the probability of identifying a spot as hazardous (*35*).

one highway section has eight accidents per year and no other accidents within 0.5 mile in any direction. This hazardous isolated bridge likely will not be identified for possible improvement (*35*).

8. It is recommended that two or more segment lengths be used by an agency to identify locations for further analysis. One short spot length (0.2–0.3 mile) and one longer section (1–2 miles or a variable-length section) should be suitable for most agencies (*35*).

FIXED VERSUS FLOATING SEGMENT

Highway spots and sections may be identified from a computerized accident file using either a fixed or a floating segment. With a fixed segment length, a specified increment is used to query the accident file for locations exceeding a certain number (or rate) of accidents. For example, using a fixed 0.3-mile segment, a search could be made of each route for milepoints 0.0 to 0.3, 0.3 to 0.6, 0.6 to 0.9, etc. Problems with the use of a fixed segment arise when a hazard exists near the boundary of two spots (such as at milepoint 0.6 in the above example). In this case, some accidents would be reported in one spot and others in the adjacent spot. Thus neither of the two spots would be identified as hazardous, and the high accident location would remain undetected.

This situation can be partially prevented by using a floating segment length with which a search of the accident file is conducted as the segment length "floats" or moves sequentially by milepost or other reference numbers. For example, a floating 0.3-mile segment can be used to query the file for accident experience at the following segments: 0.0–0.3, 0.1–0.4, 0.2–0.5, etc. This would allow for the detection of the high accident spot at milepoint 0.5–0.7, which is centered at milepoint 0.6. In most cases, it is not difficult to develop programs that use floating spots and sections; this is recommended where feasible.

TIME PERIOD FOR ACCIDENT ANALYSIS

Another important consideration in the reliable identification of problem locations is the adequacy of the time period for accident analysis. The amount of exposure to traffic is an important factor in the calculation of accident rates for use in identifying locations with abnormally high accident rates. Traffic exposure for rate calculations is commonly expressed in terms of accidents per million vehicles (A/MV) for highway spots and accidents per million vehicle miles (A/MVM) for sections. These exposure measures are a function of roadway ADT and time period of the analysis (usually in years). The roadway section length is also a factor in MVM calculations.

Although the number of years of data is only one of the factors that affects vehicle exposure (besides ADT and section length) in accident rate calculations, it is the factor that agencies commonly use to establish a common base of analysis when conducting a systemwide search of locations with high accident rates. Low-volume sites may, therefore, have inadequate exposure for reliable rate calculations, even though several years of accident and volume data are used. On the other hand, adequate traffic exposure data may accumulate in a short time period (i.e., 6 months) at a site with a high ADT (i.e., greater than 20,000) and a section length of several miles. In short, the reliability of an accident analysis is enhanced as the exposure to traffic increases.

Based on responses from 42 state highway agencies to a survey by FHWA field offices (*43*), it appears that the most common time periods used for collecting data to identify problem locations are 1 yr and 3 yr.

NO. RESPONSES	LENGTH OF TIME FOR ACCIDENT ANALYSIS
0	6 months
20	1 yr
3	2 yr
13	3 yr
8	5 yr
3	Varies by type of location

Several states utilize more than one time period, depending on highway type, segment length, and other factors. Kansas utilizes a 5-yr period for Interstate and primary routes and a 2-yr period for some urban and local street systems. In North Carolina, high accident railroad crossings are identified based on 10 yr of data; a 3-yr period is used for other locations. In six other states, 1 yr of accident data is used to identify locations, and 3 yr of data is used for further analysis of those locations (*43*).

The following guidelines may be helpful for selecting a time period of accident data to be used in identifying problem locations:

1. A short time period is desirable (1 yr or less) to allow for identification of locations where sudden increases in accidents have occurred.

2. The time period should be long enough to ensure adequate reliability of the accident sample. Previous studies have shown that a period of 3 or 4 yr is generally adequate for such purposes.

A study of accident locations in Alabama was conducted in 1980 (*memorandum,* dated November 13, 1980, from D. B. Brown, Auburn University, to C. W. Colson, Alabama Highway Department) to determine an acceptable time period for analysis purposes (Table 6). For each roadway type, high accident locations were identified using time periods of 1,2,3,4, and 5 yr. The number of locations for 1, 2, 3, and 4 yr of accident data were expressed as a percentage of the number of locations identified for the 5-yr period. For the 3-yr period, between 86 and 98 percent of all 5-yr locations were identified, depending on the class of highway. Brown concluded that "an optimal number of years for a general statewide analysis is three years."

A study of 433 intersections over a 13-yr period was conducted by May (*44*) to determine the effect of time interval on reliability of accident trends. May concluded that little could be gained by increasing the time interval beyond 3 yr.

3. In most cases, multiples of 1 yr are desirable to avoid seasonal variations in accident patterns and frequencies.

4. Long time periods require large storage capacity and increase the costs of data processing. Also, after 3 or 4 yr, accident data may not be representative of current traffic volumes, pavement conditions, roadside development, travel patterns, or changes in accident reporting methods within a highway jurisdiction.

There are advantages to using both short and long time periods: short time periods allow for early warning of hazards, and long time periods help to ensure data reliability. It is suggested that dual time intervals (such as 1-yr and 3-yr periods) be used whenever possible for purposes of identifying and analyzing hazardous locations. This discussion of the time periods for accident analysis is addressed to the use of data to identify high accident locations. Desirable data periods may vary when the data base is used for other purposes, such as for the evaluation of completed accident countermeasures or for research.

HIGHWAY CLASSIFICATION SCHEMES

In general, highway spots and sections should be classified for purposes of identification. This is not always easy to accomplish when only an accident file is used, because most accident files do not contain reliable information regarding classification of the accident sites. However, various highway classes are designed and constructed to different standards, and expectations concerning acceptable accident

TABLE 6
NUMBER OF LOCATIONS IDENTIFIED FOR 1, 2, 3, AND 4 YR OF ACCIDENT DATA AS A PERCENTAGE OF THE NUMBER OF HIGH ACCIDENT LOCATIONS IDENTIFIED FOR A 5-YR PERIOD

Years of Accident Data	State Mileposted Accidents	Rural Segmental Accidents	Rural Intersectional Accidents	State Route Accidents
1	78%	64%	90%	48%
2	73%	73%	95%	53%
3	98%	91%	90%	86%
4	98%	100%	90%	98%
5	100%	100%	100%	100%

experience should take this into account. For example, low-volume, two-lane roads should not be expected to exhibit accident experience similar to freeways. Also, accident patterns, severities, and frequencies are different for rural roads in comparison to city streets.

The classification variables used by various states were reported by the FHWA (*43*) as follows:

NO. AGENCIES	CLASSIFICATION VARIABLES
6	None
8	Functional classifications
5	Number of lanes
3	Interstate or other
3	Access control
1	Roadway width
1	Lane configuration
2	Other

In Nevada and Minnesota, computerized systems are used, which allow for accident summaries by any desired scheme (*43*).

The following guidelines on the use of classification schemes for identification of high accident locations are recommended:

1. A distinction should be made between locations in rural and urban areas because of differences in accident patterns, frequencies, and severity.
2. Further classification is desirable according to number of lanes and/or such factors as median separation and access control.
3. Intersections should be distinguished, if possible, from other types of spots. Accident patterns at intersections are generally different from those at other spot locations, because exposure to traffic consists of vehicles entering the intersection on all approach legs. Many agencies report accident locations to the nearest intersection or with the distance to the nearest intersection. Some agencies define an intersection accident as one that occurs within a specified distance from an intersection. In Michigan, for example, an intersection area is normally defined as within 100 ft in any direction from the intersection, but it may be within a longer distance if the accident is determined to be attributable to the intersection (*45*).
4. The identification of spots or sections by highway class generally requires the interfacing of a roadway file with the accident file, as is the procedure in Michigan, West Virginia, and California.
5. With most identification methods, the comparison of locations within similar groups is highly desirable. With the rate quality control method, for example, a major factor in the computation of the critical accident rate is the average rate for locations with similar characteristics. This includes locations both with and without accident experience. It should also be emphasized that the use of too many classification groups is also undesirable. If the number of classification groups is large, the number of sites per group will be small, and few or no locations will be identified within each group as having accident numbers or rates significantly higher than the group average.

CHAPTER SIX

DATA ANALYSIS OF PROBLEM LOCATIONS

SELECTION OF APPROPRIATE IMPROVEMENTS

As previously discussed, Standard 9 of the *Highway Safety Program Manual (1)* calls for the surveillance of high accident locations (and potential high accident locations) after they are identified. In maintaining surveillance of these locations, further analysis of the sites is required to determine what (if any) improvements will be proposed to compete for improvement funds. For each identified location, the following information is often collected:

- Computer listings of selected data elements for each accident at the identified locations.
- Collision diagrams, either computer-generated or manually drawn. A computerized collision diagram and the corresponding printout are shown in Figure 17. Computerized collision diagrams have been used in Pennsylvania, Ohio, Illinois, Oklahoma, and Seattle, Washington.
- Copies of actual police reports of accidents at each location.
- Review of photolog film and data from site and/or field inspections conducted to observe obvious correctable deficiencies related to geometric or operational problems.
- Condition diagrams of the site showing all physical features of the location (road width, fixed objects, sign locations, signal timing, sight distance, pavement markings).
- Other traffic and roadway data available from computer files or other sources (skid numbers, ADT, turning movements, vehicle delay, roadway capacity, etc.).

In addition to the data on high accident sites available in existing computer files or office records, most agencies per-

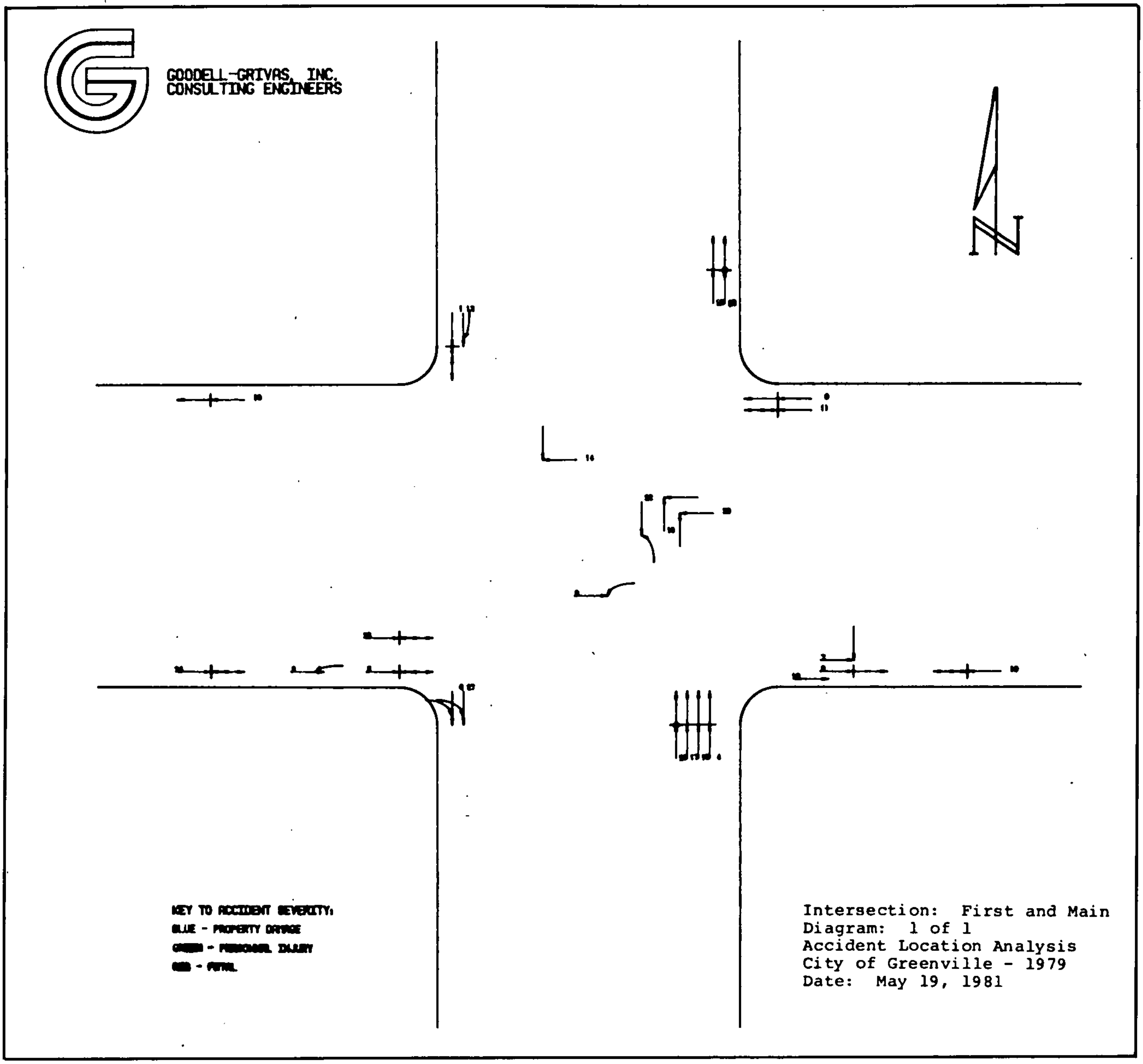


FIGURE 17 Sample computerized collision diagram.

form field inspections and conduct additional engineering studies as needed to aid in the selection of appropriate safety improvements. Generally the accidents at each site are studied to aid in pinpointing the accident patterns and characteristics. The specific accident studies most commonly performed are:

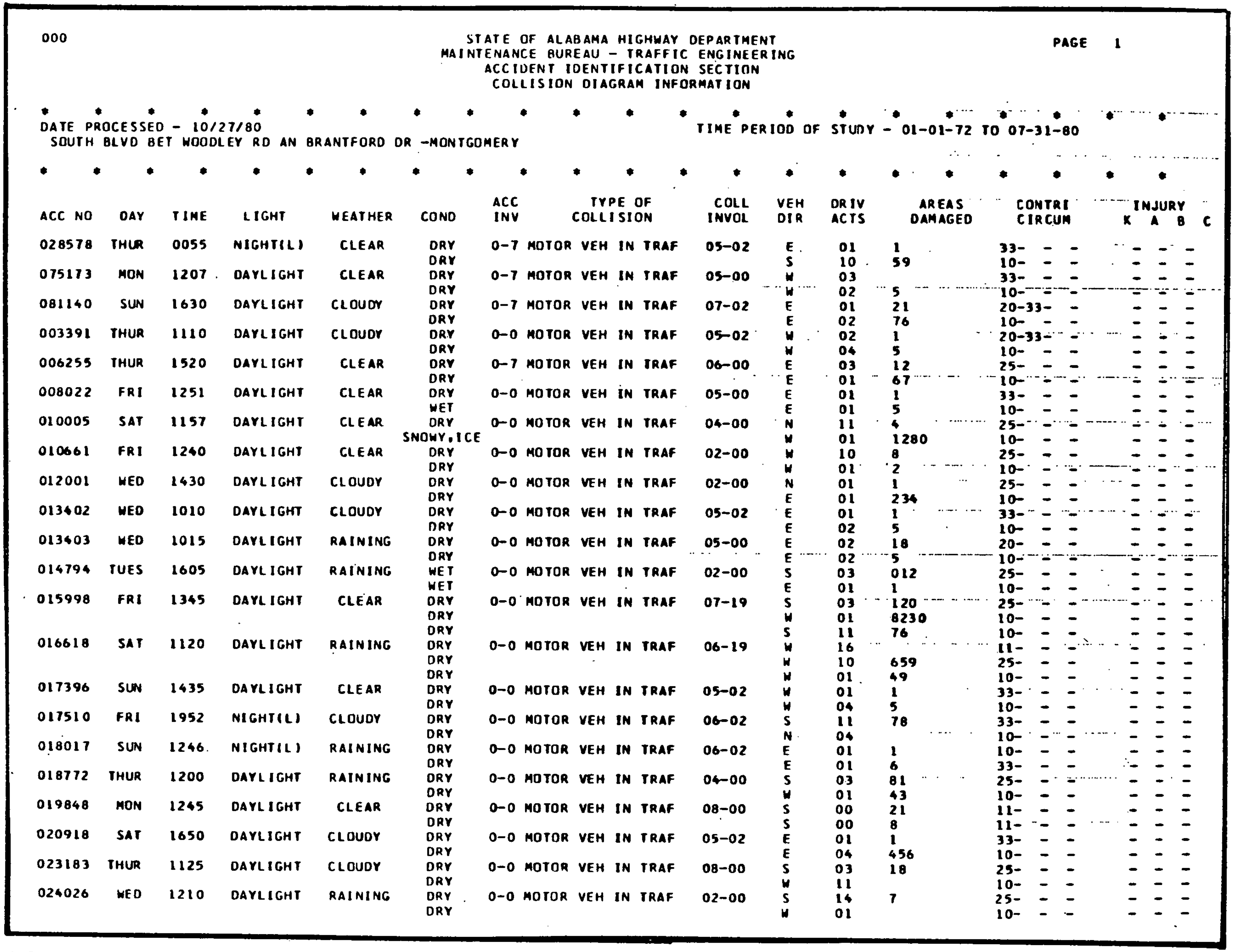
- Type (rear-end, left-turn, pedestrian, etc.),
- Severity,
- Contributing circumstances,
- Environmental conditions, and
- Time of day.

The study of overrepresented accident patterns and trends at a location can often lead to the selection of appropriate safety improvements. An example of an accident listing (Alabama) is shown in Figure 18.

After accident summaries are closely reviewed and all existing information for the site is studied, one or more other engineering studies may be performed to help further determine the geometric, operational, or environmental problems at the site, including (*46*):

TRAFFIC OPERATIONS STUDIES

- Safety Performance Studies
- Volume Studies (turning movements, etc.)
- Spot Speed Studies
- Delay and Travel Time Studies
- Roadway and Intersection Capacity Studies
- Traffic Conflict Studies



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000                                 STATE OF ALABAMA HIGHWAY DEPARTMENT                                PAGE  1
                                 MAINTENANCE BUREAU - TRAFFIC ENGINEERING
                                     ACCIDENT IDENTIFICATION SECTION
                                      COLLISION DIAGRAM INFORMATION

*    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *
DATE PROCESSED - 10/27/80                                              TIME PERIOD OF STUDY - 01-01-72 TO 07-31-80
 SOUTH BLVD BET WOODLEY RD AN BRANTFORD DR -MONTGOMERY

*    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *    *

                                                    ACC      TYPE OF      COLL    VEH  DRIV    AREAS    CONTRI          INJURY
ACC NO  DAY   TIME  LIGHT      WEATHER   COND       INV     COLLISION     INVOL   DIR  ACTS   DAMAGED   CIRCUM        K  A  B  C

028578  THUR  0055  NIGHT(L)   CLEAR     DRY        0-7 MOTOR VEH IN TRAF  05-02   E    01   1       33-  -  -      -  -  -
                                         DRY                                       S    10   59      10-  -  -      -  -  -
075173  MON   1207  DAYLIGHT   CLEAR     DRY        0-7 MOTOR VEH IN TRAF  05-00   W    03           33-  -  -      -  -  -
                                         DRY                                       W    02   5       10-  -  -      -  -  -
081140  SUN   1630  DAYLIGHT   CLOUDY    DRY        0-7 MOTOR VEH IN TRAF  07-02   E    01   21      20-33-  -      -  -  -
                                         DRY                                       E    02   76      10-  -  -      -  -  -
003391  THUR  1110  DAYLIGHT   CLOUDY    DRY        0-0 MOTOR VEH IN TRAF  05-02   W    02   1       20-33-  -      -  -  -
                                         DRY                                       W    04   5       10-  -  -      -  -  -
006255  THUR  1520  DAYLIGHT   CLEAR     DRY        0-7 MOTOR VEH IN TRAF  06-00   E    03   12      25-  -  -      -  -  -
                                         DRY                                       E    01   67      10-  -  -      -  -  -
008022  FRI   1251  DAYLIGHT   CLEAR     DRY        0-0 MOTOR VEH IN TRAF  05-00   E    01   1       33-  -  -      -  -  -
                                         WET                                       E    01   5       10-  -  -      -  -  -
010005  SAT   1157  DAYLIGHT   CLEAR     DRY        0-0 MOTOR VEH IN TRAF  04-00   N    11   4       25-  -  -      -  -  -
                                      SNOWY,ICE                                    W    01   1280    10-  -  -      -  -  -
010661  FRI   1240  DAYLIGHT   CLEAR     DRY        0-0 MOTOR VEH IN TRAF  02-00   W    10   8       25-  -  -      -  -  -
                                         DRY                                       W    01   2       10-  -  -      -  -  -
012001  WED   1430  DAYLIGHT   CLOUDY    DRY        0-0 MOTOR VEH IN TRAF  02-00   N    01   1       25-  -  -      -  -  -
                                         DRY                                       E    01   234     10-  -  -      -  -  -
013402  WED   1010  DAYLIGHT   CLOUDY    DRY        0-0 MOTOR VEH IN TRAF  05-02   E    01   1       33-  -  -      -  -  -
                                         DRY                                       E    02   5       10-  -  -      -  -  -
013403  WED   1015  DAYLIGHT   RAINING   DRY        0-0 MOTOR VEH IN TRAF  05-00   E    02   18      20-  -  -      -  -  -
                                         DRY                                       E    02   5       10-  -  -      -  -  -
014794  TUES  1605  DAYLIGHT   RAINING   WET        0-0 MOTOR VEH IN TRAF  02-00   S    03   012     25-  -  -      -  -  -
                                         WET                                       E    01   1       10-  -  -      -  -  -
015998  FRI   1345  DAYLIGHT   CLEAR     DRY        0-0 MOTOR VEH IN TRAF  07-19   S    03   120     25-  -  -      -  -  -
                                         DRY                                       W    01   8230    10-  -  -      -  -  -
                                         DRY                                       S    11   76      10-  -  -      -  -  -
016618  SAT   1120  DAYLIGHT   RAINING   DRY        0-0 MOTOR VEH IN TRAF  06-19   W    16           11-  -  -      -  -  -
                                         DRY                                       W    10   659     25-  -  -      -  -  -
                                         DRY                                       W    01   49      10-  -  -      -  -  -
017396  SUN   1435  DAYLIGHT   CLEAR     DRY        0-0 MOTOR VEH IN TRAF  05-02   W    01   1       33-  -  -      -  -  -
                                         DRY                                       W    04   5       10-  -  -      -  -  -
017510  FRI   1952  NIGHT(L)   CLOUDY    DRY        0-0 MOTOR VEH IN TRAF  06-02   S    11   78      33-  -  -      -  -  -
                                         DRY                                       N    04           10-  -  -      -  -  -
018017  SUN   1246  NIGHT(L)   RAINING   DRY        0-0 MOTOR VEH IN TRAF  06-02   E    01   1       10-  -  -      -  -  -
                                         DRY                                       E    01   6       33-  -  -      -  -  -
018772  THUR  1200  DAYLIGHT   RAINING   DRY        0-0 MOTOR VEH IN TRAF  04-00   S    03   81      25-  -  -      -  -  -
                                         DRY                                       W    01   43      10-  -  -      -  -  -
019848  MON   1245  DAYLIGHT   CLEAR     DRY        0-0 MOTOR VEH IN TRAF  08-00   S    00   21      11-  -  -      -  -  -
                                         DRY                                       S    00   8       11-  -  -      -  -  -
020918  SAT   1650  DAYLIGHT   CLOUDY    DRY        0-0 MOTOR VEH IN TRAF  05-02   E    01   1       33-  -  -      -  -  -
                                         DRY                                       E    04   456     10-  -  -      -  -  -
023183  THUR  1125  DAYLIGHT   CLOUDY    DRY        0-0 MOTOR VEH IN TRAF  08-00   S    03   18      25-  -  -      -  -  -
                                         DRY                                       W    11           10-  -  -      -  -  -
024026  WED   1210  DAYLIGHT   RAINING   DRY        0-0 MOTOR VEH IN TRAF  02-00   S    14   7       25-  -  -      -  -  -
                                         DRY                                       W    01           10-  -  -      -  -  -
```

FIGURE 18 Sample computerized accident listing (Alabama).

- Gap Studies
- Traffic Lane Occupancy Studies
- Queue Length Studies

ENVIRONMENTAL STUDIES

- Roadway Inventory Studies
- Sight Distance Studies
- Roadway Serviceability Studies
- Skid Resistance Studies
- Highway Lighting Studies
- Weather-Related Studies

SPECIAL STUDIES

- School Crossing Studies
- Railroad Crossing Studies
- Traffic Control Device Studies
- Bicycle and Pedestrian Studies

Other specialized studies, such as roadside development studies, may also be appropriate at some locations. Details of the studies and methodology are described by the FHWA (*46*) and the Institute of Transportation Engineers (*47*).

After all available information is studied for each high accident site, countermeasures expected to be effective in reducing future accident experience are recommended. Accident pattern tables for use in selecting effective countermeasures are currently available (*36, 48, 49*) or an agency may develop its own.

The selection of appropriate safety improvements requires the determination of the probable accident causes based on a careful analysis of all relevant accident data, operational measures, and physical site characteristics. Some agencies employ a multidisciplinary investigation team to study the site and select appropriate improvements. Such investigation teams may consist of a traffic engineer, safety engineer, local police officer, design engineer, maintenance engineer, construction supervisor, automotive expert, or personnel from other disciplines (*43*).

Some states collect accident "surrogate" data (accident substitutes) for use in selecting safety improvements at a site. For example, traffic conflict techniques (measures of vehicle braking and weaving) have been used by the states of Ohio, Washington, Virginia, and Kentucky for countermeasure selection (*43*). The formal traffic conflicts technique was originally developed by General Motors Corporation (*50*) and a major study has recently been completed by Glauz and Migletz (*51*) on the application of the traffic conflicts technique at intersections. The use of other accident surrogates has recently been investigated by Datta et al. (*52*) to determine the feasibility of using accident surrogate measures in highway accident analyses.

Economic analysis or cost-effectiveness techniques should be used in selecting the countermeasures with the greatest expected accident savings at the least cost. The calculation of accident benefits (savings) requires the use of accident-reduction factors, which are the percent reductions in related accident types to be expected from a specific highway improvement. Economic analysis techniques commonly used to select the most cost-effective countermeasures include the cost-effectiveness method, the benefit-to-cost ratio method, the rate-of-return method, the time-of-return method, and the net benefit method.

The next step involves priority ranking and selecting the projects to be implemented within a given budget. Techniques used to establish project priorities include:

- Ranking based on criteria similar to those used for hazard location identification.
- Ranking by incremental benefit-to-cost ratio, rate-of-return, cost-effectiveness, or other economic analysis method.
- Subjective ranking by a committee composed of members from many related disciplines (e.g., personnel in highway safety, maintenance, and design; police officials; management), based on a review of all available information and on current goals of the agency (as is currently done in Illinois).
- Incremental benefit-to-cost ratio method.
- Dynamic programming method.
- Integer programming method.

The dynamic programming, integer programming, and incremental benefit-to-cost ratio methods have been recommended by the FHWA (*53*) as preferable to other traditional methods. Dynamic programming, which provides for the optimal selection of projects in terms of accident benefits on a fixed budget, has been implemented in Alabama (*54*), Kentucky (*55*), and Maryland. This technique can have a considerable advantage over other methods, particularly when a large number of improvements (more than 40 or 50) are under consideration.

After projects are selected, they should be designed, scheduled, and constructed as soon as possible under given resource constraints.

COUNTERMEASURE EVALUATION USING COMPUTER DATA FILES

After improvements are selected and implemented, it is important to conduct evaluations of the project effectiveness. Guidelines for conducting evaluations have been established by the FHWA and the NHTSA (*8, 25, 56*). The purpose of evaluation is to determine the effectiveness of safety measures in reducing accident frequency, accident severity, or the potential for accidents. The results of the safety evaluations will aid in the selection of future improvements. The results are used to determine accident reduction (AR) factors for specific types of improvements. AR factors are expressions of the percent change in accident types or severity that is expected to result from a particular type of highway improvement or treatment. AR factors are useful to agencies for conducting economic analyses of proposed highway improvements, which aid in using highway funds effectively.

Evaluations should include detailed accident and exposure (i.e., traffic volume) information for each site. The amounts of exposure to traffic both before and after the improvements should be adequate. Similar data for control sites should also be obtained. The basis of comparison should be the "do-nothing" condition. It is also important to account for "regression to the mean" and to consider, if possible, the use of a time-series analysis to determine the real effect of the improvement on accidents.

Most states do not maintain a data base suitable for performing project or program evaluations. Problems in the performance of routine evaluations are often related to: (a) sufficient funding and manpower for performing proper evaluations; (b) the low priority placed on evaluation in many states; (c) difficulties in analyzing necessary data; and (d) difficulties in conducting proper evaluations (e.g., selecting control or comparison sites, conducting statistical analyses).

In most agencies, evaluations are conducted without the aid of a computer software package; however, in Alabama a group of computer programs termed ACE (accident countermeasure evaluation) was developed and first utilized in 1975. The ACE system basically allows for data reduction and manipulation of the statewide accident data base at specified locations. The programs in the ACE system, which were written in either COBOL or PL/1 programming languages for use on an IBM 370 computer, provide before-and-after accident summary data for each improved site (*57*). The RAPID (records analysis for problem identification and definition) program was developed in 1978 as a user-oriented software system to summarize accident data for evaluation purposes at specified locations or for statewide program evaluations (e.g., alcohol-related, pedestrian safety, and motorcycle safety programs) (*26*).

In Michigan evaluations are conducted by computer with an option to select comparison sites of similar traffic and geometric features through use of the MIDAS data base. This program permits the user to readily compare the before-and-after accident data at improved locations with similar statewide locations where no improvements were made. Thus accident trends and other factors can be accounted for when determining the true effect of the improvement on a high accident location. Computer output from the MIDAS file for a before-and-after study is shown in Figure 19 (*37*).

In addition to the evaluation of safety improvement projects at one or more locations, computer files are used for evaluating various types of programs or changes in laws or policies that may affect the frequency and/or severity of certain accident types on an areawide basis, such as:

- Passage or repeal of a mandatory helmet law for motorcyclists and the effect on head injuries.
- Laws requiring child-restraint systems (infant seats) (as passed in Michigan and other states) and the effect on infant accident severity.
- Selective police enforcement and the effect on certain types of accidents.
- Changes in vehicle design and the effect on the severity (and rate) of accidents involving those types of vehicles.
- Public-education campaigns (such as those in Seattle) and the effect on pedestrian safety.
- Statewide delineation treatments for certain types of highway systems and the effect on nighttime accidents.
- Use of new types of pavement texture (open-graded surfaces) and the effect on wet-weather accidents.

ACCIDENT ANALYSIS FOR LAW ENFORCEMENT PURPOSES

Selective enforcement is generally defined as enforcement that is provided proportionate to traffic accidents with reference to location, time, and type of violation (*58*). A major use of accident analysis is for purposes of selective law enforcement. The accident data needs of police agencies are not always as finite as the needs of highway safety engineers, but police agencies in many states have recognized the importance of using accident analysis results to aid in enforcement activities.

Determining Locations for Selective Enforcement

Enforcement efforts are commonly aimed at highway sections or jurisdictions that exhibit an abnormally high incidence of accidents involving drivers who were drinking or drunk, on drugs, asleep at the wheel, speeding, or cited for other traffic violations (disobeying traffic signals, making illegal U-turns, driving the wrong way on one-way streets or divided highways, etc.) or other unsafe driver actions. Summaries of temporal information (time of day, day of week and month) are also used to determine locations for selective enforcement.

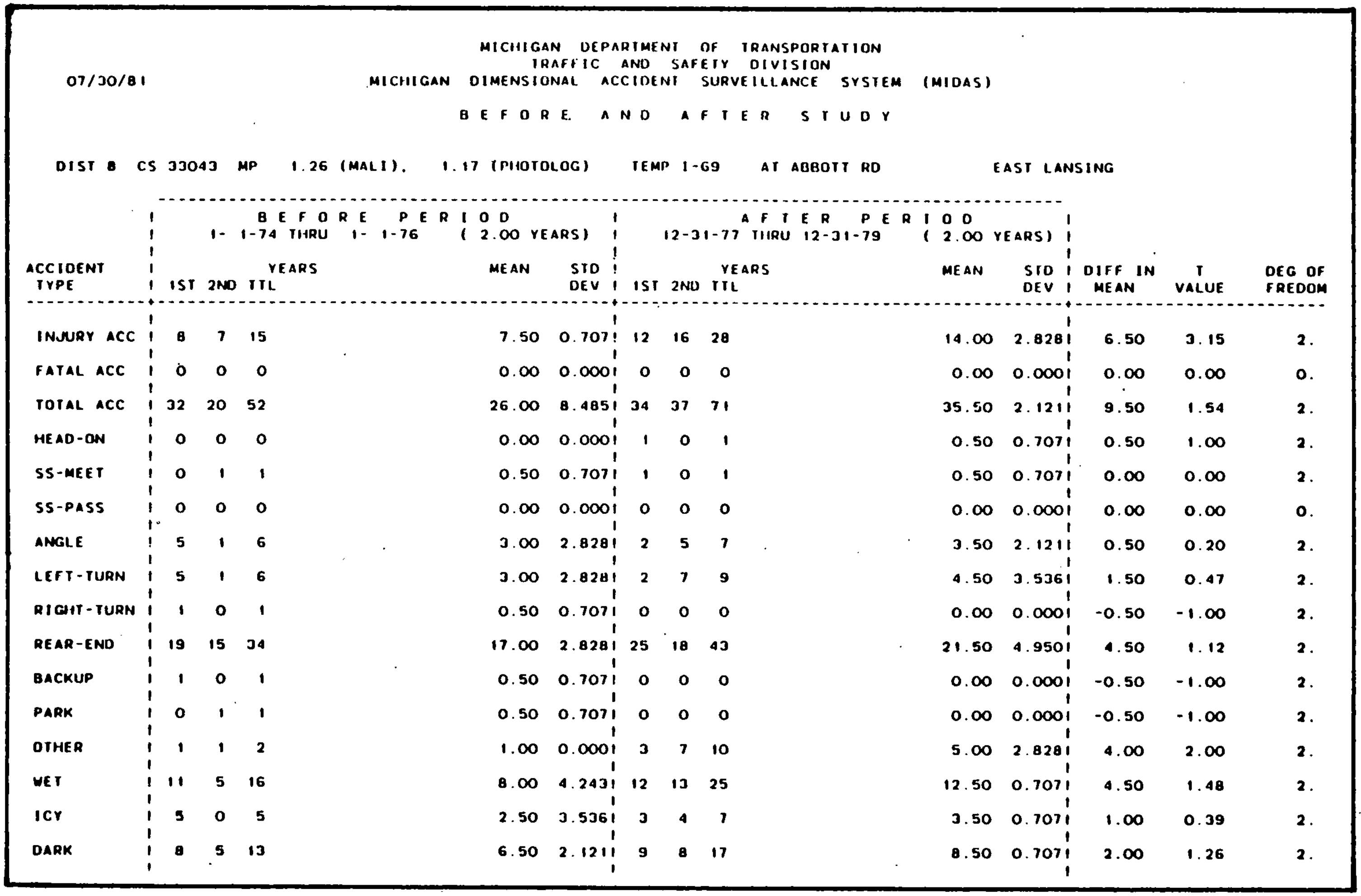
Agency Programs

Selected Traffic Enforcement Program (Tyler, Texas)

One example of the use of accident analysis in police enforcement is the Selective Traffic Enforcement Program (STEP), initiated in Tyler, Texas, in July 1980. Accident records for the city were analyzed, and summaries were made of the locations, times of day, and days of the week that were overrepresented in terms of accidents and that were believed to be amenable to improvement through selective enforcement. Three police vehicles were used for enforcement of 5.4 miles of road on weekdays between 10 a.m. and 6 p.m. During the first 11 months of the program, 2,627 citations were issued for hazardous moving violations (0.57 citations per manhour); 560 citations were issued for non-hazardous moving violations (0.12 citations per man-hour); and 1,644 warnings were issued (0.36 warning per man-hour). An evaluation of the program effectiveness showed that accidents were reduced by 27 percent for the locations, times of day, and days of week for which the STEP program was in effect (*59*).

Alcohol/Education Project (Oakland County, Michigan)

Another example of the use of accident analysis information in selective enforcement is the 4-yr Alcohol/Education Project, which was initiated in Oakland County, Michigan, to reduce alcohol-related accidents. The specific objective was to reduce alcohol-related fatal and injury accidents at least 15 percent countywide and at least 30 percent in selected target



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                                   MICHIGAN  DEPARTMENT  OF  TRANSPORTATION
                                        TRAFFIC  AND  SAFETY  DIVISION
 07/30/81                    MICHIGAN  DIMENSIONAL  ACCIDENT  SURVEILLANCE  SYSTEM  (MIDAS)

                                   B E F O R E   A N D   A F T E R   S T U D Y

 DIST 8  CS 33043  MP   1.26 (MALI),   1.17 (PHOTOLOG)   TEMP 1-G9   AT ABBOTT RD          EAST LANSING

             --------------------------------------------------------------------------------
             !           B E F O R E   P E R I O D       !            A F T E R   P E R I O D       !
             !      1- 1-74 THRU  1- 1-76    ( 2.00 YEARS) !   12-31-77 THRU 12-31-79   ( 2.00 YEARS) !
             !                                           !                                          !
ACCIDENT     !           YEARS               MEAN   STD  !          YEARS                MEAN   STD ! DIFF IN    T     DEG OF
 TYPE        ! 1ST 2ND TTL                          DEV  ! 1ST 2ND TTL                          DEV ! MEAN     VALUE   FREDOM
-------------+-------------------------------------------+------------------------------------------+------------------------
             !                                           !                                          !
 INJURY ACC  !  8   7  15                 7.50  0.707    !  12  16  28               14.00  2.828   !  6.50   3.15      2.
             !                                           !                                          !
 FATAL ACC   !  0   0   0                 0.00  0.000    !  0   0   0                 0.00  0.000   !  0.00   0.00      0.
             !                                           !                                          !
 TOTAL ACC   ! 32  20  52                26.00  8.485    ! 34  37  71                35.50  2.121   !  9.50   1.54      2.
             !                                           !                                          !
 HEAD-ON     !  0   0   0                 0.00  0.000    !  1   0   1                 0.50  0.707   !  0.50   1.00      2.
             !                                           !                                          !
 SS-MEET     !  0   1   1                 0.50  0.707    !  1   0   1                 0.50  0.707   !  0.00   0.00      2.
             !                                           !                                          !
 SS-PASS     !  0   0   0                 0.00  0.000    !  0   0   0                 0.00  0.000   !  0.00   0.00      0.
             !                                           !                                          !
 ANGLE       !  5   1   6                 3.00  2.828    !  2   5   7                 3.50  2.121   !  0.50   0.20      2.
             !                                           !                                          !
 LEFT-TURN   !  5   1   6                 3.00  2.828    !  2   7   9                 4.50  3.536   !  1.50   0.47      2.
             !                                           !                                          !
 RIGHT-TURN  !  1   0   1                 0.50  0.707    !  0   0   0                 0.00  0.000   ! -0.50  -1.00      2.
             !                                           !                                          !
 REAR-END    ! 19  15  34                17.00  2.828    ! 25  18  43                21.50  4.950   !  4.50   1.12      2.
             !                                           !                                          !
 BACKUP      !  1   0   1                 0.50  0.707    !  0   0   0                 0.00  0.000   ! -0.50  -1.00      2.
             !                                           !                                          !
 PARK        !  0   1   1                 0.50  0.707    !  0   0   0                 0.00  0.000   ! -0.50  -1.00      2.
             !                                           !                                          !
 OTHER       !  1   1   2                 1.00  0.000    !  3   7  10                 5.00  2.828   !  4.00   2.00      2.
             !                                           !                                          !
 WET         ! 11   5  16                 8.00  4.243    ! 12  13  25                12.50  0.707   !  4.50   1.48      2.
             !                                           !                                          !
 ICY         !  5   0   5                 2.50  3.536    !  3   4   7                 3.50  0.707   !  1.00   0.39      2.
             !                                           !                                          !
 DARK        !  8   5  13                 6.50  2.121    !  9   8  17                 8.50  0.707   !  2.00   1.26      2.
             !                                           !                                          !
```

FIGURE 19 Sample computer summary of evaluation results using the MIDAS system (*37*).

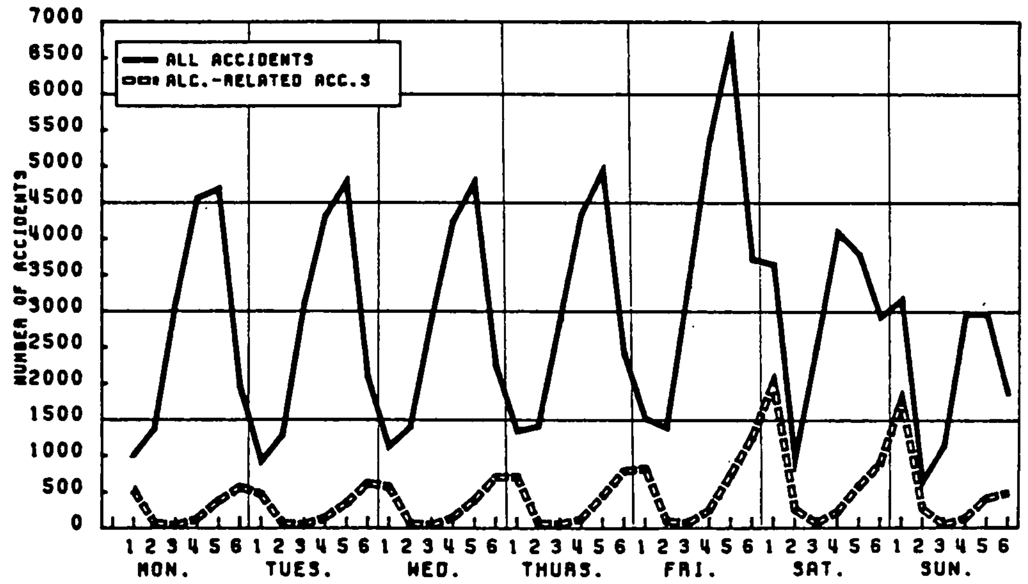


FIGURE 20 Summary of total and alcohol-related accidents by 4-hr time periods and day of week (Oakland County, Michigan, 1977–1979) (*60*).

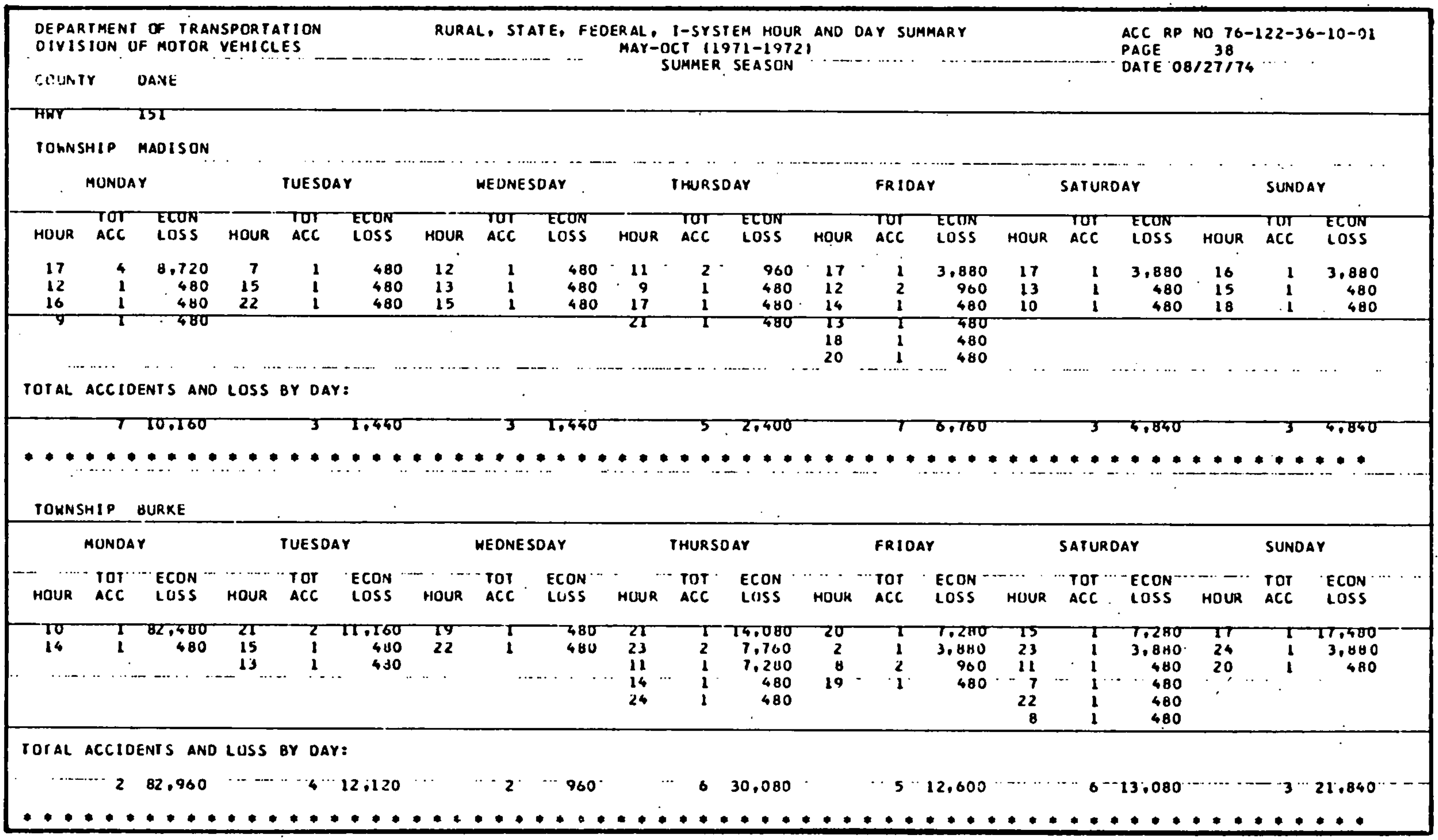
areas. Another objective was to increase drunk driving arrests 30 percent in the sheriff's department and 15 percent in the local police departments. Special police patrol personnel were deployed at the times and locations of previously large numbers of alcohol-related accidents. In 1978 and 1979, 22.2 percent of the accidents were alcohol-related; 5,600 drunk-driving arrests were made in Oakland County in 1979, including 387 by the sheriff's deputies. Figure 20 is a summary of all accidents, including those alcohol-related, by time and day of week. A survey of public opinion in Oakland County showed a significant awareness by the public of the special alcohol enforcement project. From April to September 1979, there was a 102 percent increase in drunk-driving arrests by the sheriff's department with only a 7 percent increase by local police agencies. At the time of the initial evaluation of the project (*60*), accident data were not yet available to evaluate the effect on alcohol-related accidents.

Wisconsin

An example of the statewide use of accident data for selective enforcement purposes is the program used in Wisconsin. Since 1969, the Wisconsin State Patrol has maintained color-coded maps that visually display the accident frequencies versus arrests for hazardous moving violations. Patrol enforcement assignments are continually adjusted based on changes in accident rates. Since 1972 the Wisconsin DOT has been required to furnish, every 6 months, to each county accident and citation data for state, federal, and county trunk highways. The computer data are listed by highway and township and include hazardous moving violation arrest rates; accident rates; possible contributing circumstances; economic loss rates; and hour and day of week accident summary (*58*). A computer listing of this kind of information is shown in Figure 21 (*58*).

The selective law enforcement efforts in Wisconsin were further expanded in 1973 with the establishment of the Fatal Accident Reduction Enforcement (FARE) program. The purpose of this program was to emphasize the enforcement of traffic laws commonly found to be violated in fatal accidents. From June through August 1973, 33 counties, 5 cities, and the Wisconsin State Patrol participated in the FARE program. Computer accident and violation data were used to select sites and enforcement schedules for increased patrol during the most critical hours and days. A total of 3,120 miles of highway (21 percent of the federal, state, and county trunk highways in 33 counties), which accounted for about 55 percent (over $12 million) of economic loss in the previous 3 yr, were patroled under the FARE program (*58*).

The FARE program involved an extra 26,099 hours of patrol, 4,176 citations issued, and about $225,000 in wage costs. The enforcement effort resulted in a 24 percent reduction in fatalities, a 9.2 percent reduction in injuries, and a 15.4 percent reduction in economic loss in comparison with highway sections not under the FARE program. Based on National Safety Council accident costs for accidents, injuries, and deaths, the accident savings per dollar invested was computed to be $8.60. Economic loss was reduced in 21 of the 23 counties where the FARE program was in effect (*58*).



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DEPARTMENT OF TRANSPORTATION          RURAL, STATE, FEDERAL, I-SYSTEM HOUR AND DAY SUMMARY           ACC RP NO 76-122-36-10-01
DIVISION OF MOTOR VEHICLES                            MAY-OCT (1971-1972)                          PAGE      38
                                                        SUMMER SEASON                              DATE 08/27/74
COUNTY    DANE

HWY       151

TOWNSHIP  MADISON

     MONDAY               TUESDAY              WEDNESDAY            THURSDAY              FRIDAY               SATURDAY             SUNDAY

       TOT   ECON               TOT   ECON             TOT   ECON             TOT   ECON             TOT   ECON             TOT   ECON             TOT   ECON
HOUR  ACC    LOSS       HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS

 17     4   8,720         7      1     480       12     1     480       11     2     960       17     1   3,880       17     1   3,880       16     1   3,880
 12     1     480        15      1     480       13     1     480        9     1     480       12     2     960       13     1     480       15     1     480
 16     1     480        22      1     480       15     1     480       17     1     480       14     1     480       10     1     480       18     1     480
  9     1     480                                                       21     1     480       13     1     480
                                                                                               18     1     480
                                                                                               20     1     480

TOTAL ACCIDENTS AND LOSS BY DAY:

        7  10,160               3   1,440              3   1,440              5   2,400              7   6,760              3   4,840              3   4,840

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TOWNSHIP  BURKE

     MONDAY               TUESDAY              WEDNESDAY            THURSDAY              FRIDAY               SATURDAY             SUNDAY

       TOT   ECON               TOT   ECON             TOT   ECON             TOT   ECON             TOT   ECON             TOT   ECON             TOT   ECON
HOUR  ACC    LOSS       HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS     HOUR   ACC    LOSS

 10     1  82,480        21      2  11,160       19     1     480       21     1  14,080       20     1   7,280       15     1   7,280       17     1  17,480
 14     1     480        15      1     480       22     1     480       23     2   7,760        2     1   3,880       23     1   3,880       24     1   3,880
                         13      1     480                              11     1   7,280        8     2     960       11     1     480       20     1     480
                                                                        14     1     480       19     1     480        7     1     480
                                                                        24     1     480                              22     1     480
                                                                                                                        8     1     480

TOTAL ACCIDENTS AND LOSS BY DAY:

        2  82,960               4  12,120              2     960              6  30,080              5  12,600              6  13,080              3  21,840

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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FIGURE 21 Sample computer output from selective enforcement program in Wisconsin (*58*).

CHAPTER SEVEN

DATA ANALYSIS PROBLEMS AND REQUIREMENTS

PROBLEMS IN DATA ANALYSIS

The many problems in data analysis, as related to reference methods, accident data, traffic and highway data, and data processing, need to be recognized in order to make the best possible use of available data files.

Reference Method Problems

1. In many cases, the location of an accident is recorded only for those accidents occurring on state-numbered or major routes. The location of accidents on other routes may only be recorded in terms of the route number or road name.
2. Lack of data identifying the distance from milepost markers prevents the accurate reporting of many accident locations on city streets and country roads.
3. Because state routes are commonly assigned different road codes inside and outside city limits, an analysis of the accidents along an entire route is often impossible. Also, in some cities and counties, a street can have several different names and/or route numbers, which can result in a variety of different codes being assigned to the same location.
4. Outdated location reference maps can cause significant problems with the office coding of referencing numbers.
5. Location codes of loop roads are difficult to process, as the same two streets may intersect several times.
6. A detailed description by the officer in the field is necessary to properly locate accidents at freeway ramps, and each individual ramp must be assigned a code number that can be identified in the office by trained coders.
7. Often the written description of the roadway site is not sufficient for office personnel to properly assign reference codes.
8. Many states do not use field reference markers in locating traffic accidents, except on the Interstate system. In some states, field markers are seldom spaced closer than 1.0 mile, and often may be knocked down and infrequently replaced. In many rural areas (off the state system), field markers, if they exist at all, may be 5 miles or more apart.
9. In urban areas, closely spaced intersections may have the same milepoint.

Accident Data Problems

1. Time lags of 1 yr or longer can sometimes occur before accident data are made available for analysis purposes.
2. Changes in the accident reporting thresholds within a jurisdiction can create problems when using the data. For example, when project evaluations are conducted after improvements have been made, the accident data from the before period may be based on a different accident reporting threshold than that from the after period. Also, there are obvious problems with any dollar-based accident reporting threshold as dollar damage estimates are highly subjective.
3. Informational items coded on the accident report form are commonly recorded incorrectly. Items mentioned by state agencies as often being miscoded include:

- Direction of travel (e.g., coded as eastbound on a north-south route);
- Number of lanes (e.g., four-lane, divided route coded as two lanes);
- Contributing circumstances (codes such as "following too close" or "inattentive" have become catch-all phrases for any rear-end accident and provide little or no useful information);
- Use of seat belts (this information can only be obtained from the driver and/or passengers, who are likely to respond in a positive manner even if they were not using safety belts because it is believed that using seat belts will make them appear to be safe drivers; and
- "Had-been-drinking" code (often not coded unless driver is cited for drunk driving).

4. In some agencies, because the minimum-damage criterion for accident reporting is high, a low percentage of property-damage-only accidents is reported. For example, in California only an estimated 40 percent of property-damage-only accidents are reported. Different reporting levels may exist even within the same state.
5. Large numbers of accidents (over 500,000 per year in some states) or lengthy accident-report forms (e.g., over 130 data elements on one state's form) require large amounts of manpower and make computer processing costly.
6. Coding errors are often not found or corrected because of few or no edit checks.

Data Processing Problems

1. Problems arise in data processing for such locations as intersections with five or more legs, offset intersections, traffic circles, and loop roads.
2. Problems with computer matching of street names occur because of the use of abbreviations, mispelled street names, and streets that have multiple names and/or numbers.
3. Computer accident summaries for identified problem locations often do not provide sufficient detail to determine accident causes and appropriate countermeasures.
4. Improper selection of appropriate time periods, segment lengths, classification schemes, or methods of identification can prevent the selection of locations most appropriate for further consideration for improvement.

5. A major problem in data processing is the lack of documentation of computer software by states that have developed and utilized various processing programs. While no single analysis system may be appropriate for all agencies, it is still important for agencies to learn more about the effective systems used by others in order to select and use the systems best suited to their needs.

6. Another major impediment to processing data files (computing accident rates, etc.) is the inability to correlate the accident file with the volume and highway file, primarily because of the lack of coordination within many state and local highway agencies. In this case, a sophisticated analysis of locations can only be accomplished by manual data handling.

7. Inconsistencies exist in locating and identifying accidents with respect to being intersection-related. The American Automobile Association surveyed U.S. cities with populations over 5,000 for a definition of intersection-related pedestrian accidents. The responses of 1,228 cities are summarized below (*61*):

RESPONSE	NO. CITIES	% RESPONSES
In intersection/crosswalk	195	15.9
0–10 ft away from intersection	461	37.5
11–20 ft away from intersection	252	20.5
21–50 ft away from intersection	196	16.0
51 ft or more away from intersection	56	4.6
Other	68	5.5
TOTAL	1,228	100

The ANSI D16 *Manual* (*40*) gives the following definition of an intersection;

> An area which (1) contains a crossing or connection of two or more roadways not classified as driveway access and (2) is embraced within the prolongation of the lateral curblines or, if none, the lateral boundary lines of the roadways. Where the distance along a roadway between two areas meeting those criteria is less than 10 meters (33 feet), the two areas and the roadway connecting them are considered to be parts of a single intersection.

The D16 *Manual* (*40*) also gives a definition of an intersection-related accident:

> A traffic accident in which the first harmful event (1) occurs on an approach to or exit from an intersection and (2) results from an activity, behavior or control related to the movement of traffic units through the intersection.

REQUIRED RESOURCES

The resources required for processing accident data files vary greatly for each agency and are mostly based on the following factors:

1. Number of police-reported accidents processed each year, and number of years of data used for analysis purposes;
2. Number of data items entered on each accident report form;
3. Amount of effort expended by the police or highway agency office personnel to check data codes, and to add or verify the highway location code (milepost number, etc.) of each accident;
4. Amount of data from each accident report form that is actually keyed into the computer file;
5. Amount of manual checking of data entries and/or the adequacy of the edit program (if any);
6. Number and types of accident data summaries produced for analysis purposes;
7. Efficiency of the computer software used to perform the required analysis of data (e.g., high accident location listings, systemwide accident summaries);
8. Number of locations identified, reviewed, and analyzed each year;
9. Types of data merging between accident files and traffic or roadway files and the compatibility between files;
10. Amount of duplication of efforts in processing or analyzing the data (in urban areas in some states, accident reports may be coded and processed by both the local agency and the state police or DOT);
11. Amount of traffic and highway information collected and processed and the extent to which the data are used for safety analyses;
12. Efficiency of activities within an organization (also the amount of wasted effort expended on entering or processing information that serves no useful purpose); and
13. Goals of an agency in terms of (a) types of summaries desired; (b) desired levels of sophistication and accuracy in locating highway sites; and (c) numbers and types of accident indicators (rate, severity, etc.) used for identifying high accident sites; and
14. Extent of evaluations performed after projects are implemented.

Case Studies

The four states visited as a part of this study (Alabama, California, Illinois, and Michigan) provided estimates of the resource requirements for various aspects of data processing. As the resources expended are a function of the widely varying characteristics, goals, and needs of each state, it would be totally inappropriate to make any generalizations regarding what resource requirements are typical or appropriate for any particular agency. The following information is presented only to provide examples of state requirements.

Alabama

About 125,000 accident reports are processed each year in Alabama. Annual manpower requirements for engineering analysis of accident data are 3 man-years. For each of nine highway divisions, approximately one person per year per division is required for analysis and review of accident data summaries. A total of about 10 man-years are required annually for data entry, with 1.5 man-years for programming functions. Data processing costs are estimated at $150,000 per year. An estimated $20,000 per year is expended for related computer services.

California

In California considerable emphasis is placed on ensuring the accuracy of the location of each accident (within 0.01 mile, whenever possible). A team of 10 to 12 office personnel is involved daily with checking the accuracy of the mileposts of some 135,000 accidents per year on the state highway system (out of about 490,000 total reported accidents per year on all routes). Detailed computer logs of milepost descriptions are used with maps to verify, correct, and/or add the accurate location of each accident. On the average, each coder can process about 12 accident reports per hour (verifying and/or adding the exact milepost of an accident). As many as 35 to 40 reports per hour can be processed by personnel for up to about 300 reports per day. These manpower estimates include only efforts to add and/or verify locational information. In each of the 11 districts, personnel are involved with reviewing problem locations and making recommendations for improvement. A total of about $1,000,000 per year is expended by CALTRANS for manpower and computer costs involving data processing related to high accident locations. This includes costs for computer personnel, but not the costs for collecting statewide traffic data.

Illinois

Through March 1980, Illinois had posted a total of 18,575 intersections with milepost markers in 25 counties at a total cost of $644,025, an average of $35 per intersection (*42*). Forty full-time employees key accident data into computer files on CRT terminals. Another 12 employees handle locational information for the roughly 500,000 to 600,000 accident reports per year. Two others microfilm the accident reports after data are keyed into the computer. Twenty-five man-months per year (mostly engineering time) is required to identify and process high accident locations. At each of the district levels, about 10 man-months per year are expended for accident summaries and recommending improvements.

Michigan

In Michigan an average of about 350,000 accident reports have been processed each year for the past 10 yr, and 13 yr of accident data remains on file. The Michigan Department of Transportation (MDOT) and the Michigan State Police (MSP) share much of the responsibility for data processing. The funding levels for data processing and analysis are estimated at about $62,860 for the MDOT and $1.2 million for the MSP. Costs for computer-related services amount to another $60,000 for MDOT and $200,000 for MSP.

Other Costs

As previously discussed, a large number of states do not have common referencing systems for all of their data files. In Alabama officials have estimated that it would cost about $2 to $4 million to convert all data files to a common reference system. Such costs are a function of the number of miles of highway and the complexity of the referencing method in use. At least one state attempted to convert its files to a coordinate method in recent years, but high costs (and possibly other factors) forced termination of the project.

In addition to data processing costs, there are other costs involved in highway safety analysis, including:

- Manpower and other costs for police officers to travel to accident sites to complete accident report forms at the accident scene;
- Costs of collecting, updating, and maintaining traffic volume and other traffic-related information (speeds, turning movements, vehicle classification counts), including costs for mechanical traffic counters, etc.;
- Costs of collecting, updating, and maintaining all required highway-related information; and
- Costs of fabricating and installing field location referencing signs or markers.

A part of these costs is recovered by some police agencies through selling data files or copies of accident report forms to insurance companies and the like.

A summary of the responses of six selected states concerning methods used for accident analysis is presented in Appendix A.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

A variety of techniques is used by state agencies for processing data related to accident location systems and accident analysis. The key factor in processing locational traffic records is the accuracy and efficiency of the location referencing method. The conclusions and recommendations presented below are based on a review of the literature and interviews with officials from several state agencies in which numerous weaknesses and problems with highway accident analysis systems, as well as solutions, were identified.

LOCATION ACCURACY

Inaccurate reporting of the locations of traffic accidents presents, for many states, one of the most pressing problems in accident analysis. The processing of accident data by highway location is dependent on the accuracy of the coded accident location. Thus it is highly desirable for agencies to improve accuracy in reporting accident locations in both urban and rural areas. In the six states surveyed for this synthesis, about 60 to 90 percent of the accidents in rural areas were believed to be reported with an accuracy of 0.10 mile or less. Location reporting is generally more accurate in urban areas than in rural areas because of the presence of closely-spaced intersections in cities.

It is often difficult to obtain precise locational information for all accidents. However, the following procedures are recommended to improve overall accuracy of accident location reporting:

- Use field referencing markers, particularly in rural areas.
- Develop log reference books for police agencies to use in recording locational information. Log books should give the milepost (or other reference number) for all identifiable field locations along a route, such as bridges, stores, cross streets, house numbers, etc.
- Provide training sessions for police officers on the importance of accuracy in reporting all accident locations and how to best obtain desired accuracy levels.
- Utilize trained office personnel within the police agency or the highway agency to carefully review each accident report to ensure location accuracy. In some cases, additional descriptions of the accident site should be requested from the reporting police officer. Appropriate milepoint maps and log books (frequently updated) can be used in this process.
- Modify the reference method used for office maps and/or files to include more reference markers for more accurate office coding of accident locations.
- Implement a highway location reference method that is more effective in meeting specific agency needs and characteristics. However, the manner in which a specific reference method is used is usually more of a determining factor in the accurate reporting of accident locations than the method itself. For example, some states report much higher levels of accuracy using the milepost method than do other states. (It should be noted that highway location reference systems have uses other than locating accidents. For example, highway referencing is required for highway construction and maintenance. Police agencies use highway referencing for selective enforcement, and emergency medical services also make use of quick and accurate highway referencing.)
- Develop and use a computerized highway file to improve the accuracy of coded accident locations and also to reduce processing costs. A system similar to the MALI system in Michigan is particularly desirable with respect to ease of data handling, measurement methods, accuracy of accident locations data, and reduced costs of data processing.

ACCIDENT DATA WEAKNESSES

One problem in the collection of accident data is the number of traffic accidents that go unreported and thus are not considered in safety analysis of the highway network. In addition, there are problems related to the data elements coded for many traffic accidents, which usually stem from insufficient planning. Also the large amount of information collected for all reported traffic accidents has forced some jurisdictions to raise the minimum dollar amount for accident reporting, which can severely reduce the number of accidents for which data are available for analysis purposes.

Increased interaction is needed between the accident investigators (police officers) and highway agency personnel with respect to the uses of accident data. Some states have held training sessions, in which a representative of the DOT discusses with police officers the importance of various data items and the purposes for which they are used, such as for countermeasure selection. In California, Alabama, and Michigan, close interaction between state police and highway officials is maintained. In California, a luncheon is given each month to bring police and highway officials together.

It is recommended that agencies streamline report forms to include only those data items actually needed and used, particularly for property-damage-only accidents. Michigan, for example, uses a one-page accident report form that is a shortened version of the previous form. Use of the short form saves considerable time and money on data collection and data entry. Agencies need to review each data element listed on the accident report form and revise the form, if necessary, to make it more useful (e.g., including categories that are useful in analysis activities).

Increasing the number of reported accidents is recommended to obtain a more comprehensive accident data base for analysis purposes. Accident reporting levels should be established to include a sizable portion of property-damage accidents as well as all injury and fatal accidents. This will allow for the identification of locations with a high frequency of minor accidents that otherwise would not be identified.

DATA INTERFACING AND MERGING

Difficulties in data interfacing and merging are caused by: (a) lack of the use of a uniform highway location reference method for the various highway data files, which, in many cases, is due to the lack of coordination within a state or local agency; (b) lack of resources to collect various types of data and to properly process the data; and (c) computer software and hardware problems.

The following procedures are recommended to improve agency data processing:

- Coordination among the various divisions or offices that handle highway-related data within highway agencies should be improved. Data collection and processing efforts should be properly coordinated to enhance utilization of the data. For example, a significant factor in the success of Michigan's program is the cooperation among various state agencies.
- A common location reference method should be developed for the interfacing of various types of traffic files. A "locational dictionary" can be developed to aid in converting data to one common system.
- Time lags in processing accident data should be minimized.
- Comprehensive computer software programs should be developed or program packages should be obtained to produce routine systemwide summaries of accident data. The development of such programs can be expensive with respect to computer costs and manpower requirements. Examples of software packages currently in use are SPSS, DART, and RAPID.
- Special efforts should be made to handle file merging for intersections, interchanges, traffic circles, and other locations with unusual characteristics or where abrupt changes in traffic volumes occur.
- Adequate edit programs should be developed for the detection and correction of erroneous information in each data file.
- A computerized system can reduce the problems and costs related to data interaction and merging.

IDENTIFYING HIGH ACCIDENT LOCATIONS

All procedures related to the identification of high accident locations should be considered by agencies, including identification methods, use of spot and section lengths and fixed versus floating segments, time period during which accident data are collected, and use of highway classification schemes for identification purposes. Although each state agency has developed a specific set of procedures, the following general guidelines are recommended for identifying locations requiring further analysis:

- Identification method(s) should, ideally, account for various accident indicators, including combinations of accident frequency, exposure to risk (e.g., rate quality control method), accident severity, and the potential for high accident experience (obtained from a hazardous highway features inventory).
- The length of the identified spots or sections should be selected to account for the suspected degree of error in reporting accident locations. In general, the spot length should be at least twice the suspected degree of error. A minimum of about 0.1 mile should be used to search the accident file for high accident locations. Spots that are 0.3 miles long are usually adequate for including the area of influence of a highway hazard.
- Floating segments are generally more desirable than fixed segments in scanning the accident file to identify high accident locations.
- Time periods of 1 to 5 yr are commonly used to obtain data for the identification and analysis of high accident locations. Generally, a time period of 3 yr is adequate for most purposes, when all aspects of the data base (data stability, reliability, changes in site conditions with age, etc.) are considered. However, it is sometimes advantageous to utilize the data collected for a 1-yr period for an "early warning" analysis.
- It is desirable to identify sections by type and/or class. For example, there are significant differences in the accident frequency and patterns of urban intersections and rural freeway spots. Thus different criteria should be used for identifying high accident sites on the various types of highways. Interfacing the roadway file with the accident file may be necessary to identify locations within various highway classes.
- It may be desirable to identify locations with an abnormal experience of one or more specific accident types (wet weather, run-off-road, right-angle, etc.).

DATA ANALYSIS OF PROBLEM LOCATIONS

After high accident locations are identified, the available traffic record files are used in selecting the appropriate improvements for each site. Also, in many cases, the detailed information on the actual accident report forms (which may not be available from the computer accident file) may be necessary in determining the true accident causes. The data required for each location include construction histories, computer accident listings, collision diagrams, condition diagrams, and other roadway and traffic information. Traffic engineering studies (delay studies, skid-resistance studies, sight-distance studies, etc.) may also be necessary as well as a field inspection to supplement existing information.

After countermeasures are selected, an economic analysis (benefit-to-cost ratio, etc.) of each countermeasure is desirable. Priority programming should be conducted to select the projects that will provide the greatest safety benefits within the available budget. After implementation, projects should be evaluated for effectiveness in accident reduction. The results from such evaluations can be used in the future selection of accident countermeasures at other locations and estimates of expected safety benefits. As previously discussed, routine summary reports should also be generated from accident data.

Various computer programs can be used to facilitate the data analysis of high accident locations. For example, computer programs are currently available for generating collision diagrams. Also computer software packages (e.g., SPSS) are available for producing summaries of accident experience for high accident locations. The accident listing generated by computer for each high accident location should be reviewed and modified, if necessary, in order to provide basic accident data for use in project selection. Computer software is also available for (a) conducting economic analyses of proposed countermeasures; (b) priority programming for the expenditure of funds for safety improvements (dynamic programming and integer programming are particularly useful for this task); and (c) evaluating project effectiveness after the improvement has been in place for 1 yr or longer (proper, formalized evaluation procedures should be followed to ensure reliable results).

INTEGRATED TRAFFIC RECORDS SYSTEM

The development of an accident analysis system should start with determination of the types of reports and information needed for decision making. The processing techniques to be used to produce these reports can then be determined in addition to the kind of data to be collected and the level of accuracy required. A few states have had success with the merging of data files for accident analysis. Other state agencies that have the ability to merge files for data analysis have done so only for planning or research purposes on a limited basis. A major problem in the development of an integrated traffic records system is limited resources. Therefore, it is important to place the most emphasis on the highway systems that have the greatest potential for benefits.

An integrated traffic records system can be developed for use in accident analysis in different ways. A study conducted in 1981 by the FHWA (*62*) recommends a system for handling the various data sets, which includes the following elements:

Element 1—Hazardous Site Data File
Element 2—Site Matching Process
Element 3—On-Site Engineering Study Process
Element 4—Implementation Process
Element 5—Field Evaluation Process
Element 6—Evaluation Data File
Element 7—Automatic Evaluation Process

The integral system proposed by the FHWA (*63*) involves processes and data files that could be modified or added to typical state data analysis systems. The system permits each state the flexibility to utilize specific methods for selecting and evaluating locations. (See Appendix B for an excerpt from the FHWA study.)

A concern often expressed is that state and local highway agencies appear to be moving in many different directions with respect to accident records processing. Although there are obvious disadvantages in this situation, it is far better than if the states were uniformly moving in the wrong direction. It appears that several states and local jurisdictions are doing an excellent job in many areas regarding accident-location data processing; in most states, one or more aspects of the system are exemplary; and several states are in the early stages of development of accident analysis systems.

Most state and local agencies could benefit greatly by making special efforts to obtain information on programs currently used by other agencies. However, a standardized accident analysis system would be inappropriate, if not impossible, to implement, because of the wide differences among highway agencies with respect to available resources, level of expertise, overall safety goals and objectives, and size and type of highway network.

The effectiveness of a highway accident analysis system is dependent on the level of commitment and effort addressed to developing and maintaining the system. Many of the techniques in use today by state and local agencies are successful in terms of accuracy and the types of information generated; however, in each agency problems with accident analysis systems exist that need to be resolved. Specific needs and available resources must first be identified before determining the kind of highway accident analysis system to be utilized.

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APPENDIX A

SUMMARY OF RESPONSES TO QUESTIONNAIRE BY SELECTED STATES

1. What is the accident reporting level in your State (e.g., $200 damage per accident, injury and fatal accidents only, etc.)?

State	Reporting Level	Comments
Alabama	$ 50.00	-
California	Injury and Fatal accidents	Approximately 40% of PDO accidents are reported.
Illinois	250.00	Per individual's property.
Michigan	200.00	All injury/fatal accidents also must be reported.
Wisconsin	400.00	Where state-owned property is damaged, the reporting level is $200.
West Virginia	250.00	Injury and fatal accidents also must be reported.

2. Is the reporting level the same for all counties and urbanized areas within the state?

Alabama	- Yes
California	- No, some cities use a different reporting level and many do not investigate unless an injury or fatality occurred.
Illinois	- Yes
Michigan	- Yes, legally the requirements are the same. In practice, variations occur with different localities, eg., Detroit forwards a large number of "walk-in" reports.
Wisconsin	- Yes
West Virginia:	- Yes

3. What types or severities of accidents are used in safety analysis?

Alabama:	All accident types.
California:	All fatal, injury and PDO accidents. Specific injury types (A,B, and C-type injuries) are not coded.
Illinois:	All, except private property.
Michigan:	Within Michigan Department of Transportation, some cursory analyses of property damage, injury accident categories are used. For in-depth analyses a further breakdown of A, B, and C type injuries is used (incapacitating, nonincapacitating, and possible injury). Michigan State Police practice is to use all severity data in their analyses.
Wisconsin:	All reportable accidents (total property of $500 or more per unit; special studies are sometimes conducted using non-reportable accidents).
West Virginia:	All accident types and severities, depending on analysis purposes.

4. What is (are) the highway location reference method(s) in use in your state in both urban and rural areas?

	Method				
State	Milepost	Reference Point	Link Node	Coordinate	Combination of Methods
Alabama	Urban and Rural X		Urban X		X
California	X		Some Cities X		
Illinois	Rural X	Urban X			X
Michigan		X MALI*			
Wisconsin		X			
West Virginia	X				

*MALI (Michigan Accident Location Index) is a road intersection reference point method.

5. To what precision are the locations of accidents reported by the police officer (to the nearest 0.01 mile, 200 feet, 0.1 mile, 0.5 mile, etc?

Alabama: 0.01 mile

California: 0.01 mile

Illinois: Rural - 0.1 mile; urban - 0.01 mile (at intersections)

Michigan: Police officers are instructed to give the actual distance in feet or miles from the nearest intersection. In practice, some distances are precisely measured, while most are estimated. In the computerized processing, mileages are computed to the nearest 0.01 mile.

Wisconsin: 0.01 mile

West Virginia: Varies widely. Most are reported to the nearest .01 mile.

6a. What percent of police reported accidents are not identified as to a specific location (milepost, intersection, etc.) in rural areas, urban areas?

State	Urban	Rural
Alabama	5%	1% (Some problems in small towns)
California	<1%	<1%
Illinois	4%	2%
Michigan	2%	2%
Wisconsin*	30%	60%

*These reporting percentages are improved considerably by office edits.

6b. Of those accident reports where the location is reported, what is your realistic estimate of the range of accuracy of the reported locations of accidents by State and local police officers in rural areas?

	Percent of Accidents					
Accuracy Level	Alabama	Calif.	Ill.	Mich.	Wis.*	W. Va.
Within 0.01 mile (50 feet)	Less than 10%	80	30	10	40	
0.05 mile (264 feet)	50	95		50	50	
0.10 mile (528 feet)	75	99	90	70	60	90
0.20 mile (1056 feet)	80			75	65	
0.30 mile (1584 feet)	90			90	70	
Within 0.50 mile (2640 feet)				99	90	
1 mile (5280 feet)					95	
2 miles (10560 feet)					99	
5 miles or less					99	

*These percentages are improved considerably by office review and edits.

7. Of those urban accident reports where the location is given, what percent do you think are reported within the following accuracy levels?

	Percent of Accidents				
Accuracy Level (Urban)	Alabama*	California	Illinois	Michigan	Wisconsin
Within: 10 feet			5	2	30
50 feet		80		30	50
100 feet				50	60
200 feet			95	75	90
300 feet		95		85	
400 feet				90	
Within: 500 feet				90	
1000 feet		99		95	
0.5 mile				99	
1.0 mile				99	

*Distance is not coded, accidents are listed by the link upon which they occurred and the distance from the nearest node (intersection) is given.

8. To your knowledge have any studies (formal or informal) ever been made to test the accuracy of location reporting accuracy? If so, please give details.

Alabama:	No documented study.
California:	Yes, the accuracy of reports is checked within the districts.
Illinois:	One formal check was performed and 95% of the reported locations were found to be accurate within 200 feet. However, since that check, reporting procedures have changed.
Michigan:	Periodic spot checks are made, and results have indicated a reasonably high level of reporting accuracy. Specific locating problems are usually quickly remedied by cooperative efforts of state police and the Michigan Department of Transportation.
Wisconsin:	An informal sample of 1,000 accidents was examined in 1978.
West Virginia:	No formal study conducted. Accuracy not a major problem.

9. At what spacing are rural field reference markers located on interstate highways? State primary routes? State secondary routes?

Reference Marker Spacing (Rural)

State	Interstate Highways	State Primary Routes	State Secondary Routes
Alabama	1 mile	1 mile	1 mile
California	1 mile	1 mile	1 mile
Illinois	400 ft.	0.5 mile	Each intersection (grid mile system)
Michigan	1 mile	NA	NA
Wisconsin	1 mile	Paper System	Paper System
West Virginia	1 mile	1 mile	Paper System

10. At what spacing are urban field reference markers located on freeway? Arterial streets? Collector streets? Local streets?

Reference Marker Spacing (Urban)

State	Freeways	Arterial Streets	Collector Streets	Local Streets
Alabama	NA	NA	NA	NA
California	1 mile	Intersection Only	Intersection Only	NA
Illinois	400 ft.	400 ft.	400 ft.	400 ft.
Michigan	1 mile	NA	NA	NA
Wisconsin	1 mile	NONE	NONE	NONE
West Virginia	1 mile	1 mile State maintained routes only	NA	NA

11. What is the normal sequence of events for processing each accident report for use in safety analysis? Please describe.

A flow chart of the system in California is presented in Chapter 3. Also see text for discussion.

12. What types of log books, maps, etc. (if any) are used by police officers to help them in accurately recording the location of an accident?

Alabama:	Maps and field markers
California:	Post mile markers, structures, intersections
Illinois:	None
Michigan:	No logs or maps are required as the officer uses common name or number of road and reference. However, the officers do use maps to pinpoint the proper township and section. The MALI system contains name variations for all roads.
Wisconsin:	Plat maps and intersecting street names.

West Virginia: Log books are used by highway department personnel which exist for all 37,000 miles of state-maintained highway. Log books are updated periodically, and give the milepoints of intersections, railroad crossings, bridges, and other features. More detailed information is given (house numbers, restaurant names, etc.) on sections which experience moderate to high numbers of accidents.

13. Is there a routine office procedure for correcting or modifying the location of an accident (or any other incomplete or erroneous data on the accident report form)? For example, if an accident is reported at milepoint 3.52 and next to Joe's Market, when Joe's Market is actually at milepoint 4.52, can such errors be routinely caught and corrected?

Alabama: No

California: Yes, a team of office technicians checks the location of each accident and verifies its location to the nearest 0.01 mile from maps and highway logs.

Illinois: Yes, location information is reviewed by office coders and revisions are made when necessary.

Michigan: References to an address or place are returned to the reporting agency for proper referencing, i.e. a given distance from a street.

Wisconsin: Yes

West Virginia: Yes, office coders utilize log books to denote accident milepoint location on the computer file. A detailed computer edit check is then made of each record to find any invalid milepoint entries based on street names, county, and city code. Invalid milepoint entries are flagged for corrections.

14. How are accidents "tied" to a highway spot? Are they measured by officer's odometer from nearest intersection, etc.?

Alabama: Officer's odometer is used.

California: Distances are determined by pacing, or by using measuring tape or odometer.

Illinois: Officer's odometer is used.

Michigan: In some cases a measuring wheel or tape is used; in others an educated guess is made; however, the most common measurement is by odometer.

Wisconsin: Estimated.

West Virginia: Officer's odometer is primarily used.

15. What accident criteria are used to initially identify and rank high accident spots and sections?

Alabama: A rural section with six accidents per year on a floating 0.4 mile section.

California: The Rate Quality Control method is used to identify locations with critically high accident numbers and critically high accident rates.

Illinois: Critical accident rates are computed (Rate Quality Control Method)

Michigan: The Michigan Department of State Police utilizes a computer program which ranks intersections by the number of accidents, the number of injuries, or by the number of fatalities on all roadways. The Michigan Department of Transportation has programs for the trunkline system which rank segments by number of accidents, by accident rates, and by severity ratio. Additionally, MIDAS programs identify intersections or segments which appear as outliers for their particular category.

Wisconsin: Frequency and frequency per selected distance. Rates per 100 MVM, frequency and type, manner of collision.

West Virginia: Several accident measures are used to scan the state system, including the accident rate, critical rate method, severity rate, and delta change in accidents. Locations with abnormal numbers of wet accidents, run-off-road accidents, and nighttime accidents are also flagged for further consideration.

16. Explain the exact technique or computer logic used to "flag" these high-accident segments (floating segment length, variable length, etc.).

Alabama: Variable length increment.

California: A floating segment is usually used, from 0.1 to 0.5 mile in length. A 0.2 mile floating segment is most commonly used.

Illinois: Variable length based on observed concentrations, 0.1 to 10.0 miles in length.

Michigan: The Department of State Police program interrogates for the intersecting street numbers and selects those locations that meet or exceed a predetermined threshold (currently four or more accidents) within a selected distance from the intersection (currently 150 feet).

One of the Michigan Department of Transportation segment programs uses a floating segment method which can be set from 1/10 to 1 mile length. Criteria for this method are attached.

The MIDAS program for intersections is used to review accidents at all intersections of a common type and lists only the outliers exceeding the 95th confidence level. The MIDAS segment program uses a fixed 2/10 mile for common roadway types and lists those outliers exceeding the 95th confidence level.

Wisconsin: Floating segment length.

West Virginia: A floating 0.5 mile segment floats through the file at 0.1 mile increments.

17. Does your state currently have a statewide uniform accident report form? Are all reported accidents submitted to one processing agency? Do the state's safety engineers maintain close contact with the state police agency to ensure that the accident data are collected to best suit the purposes of the Department of Transportation?

Alabama: A uniform statewide accident report form has existed since 1971. All reported accidents are submitted to one processing agency. State engineers, cities, and state police cooperate in data collection decision making.

California: A uniform statewide accident report form exists and approximately 80% of the reporting agencies use it. Los Angeles does not. All reported accidents are submitted to one processing agency. State engineers, district personnel, and state police cooperate in data collection procedures and decision making.

Illinois: Yes, on all counts.

Michigan: Michigan police agencies by law must use a standard accident report form (UD-10). Design of the form is the responsibility of the Department of State Police. By law, all "reportable" accidents must be submitted to the Department of State Police. The Departments of State Police and Transportation work together to ensure that accident data needs of both are met.

Wisconsin: Yes, on all counts.

West Virginia: Yes, on all counts.

18. What data variables are recorded by the police officer for each accident? Please provide a copy of a state police accident report with computer coding format.

See discussion in text.

19. To your knowledge, which items on the report form are not currently needed by your agency?

Alabama: None given.

California: None given.

Illinois: "Contributing circumstances" were taken off the form. "Seating in vehicle" and "Times notified" are not used. "Car-physical condition" is on the report form but generally not filled out.

Michigan: The highway accident file is condensed from the "Michigan State Police" data file and contains those items considered pertinent for Michigan Department of Transportation use. All data on the Michigan State Police files are used by various departments and agencies; therefore, no un-needed data are retained.

20. Are important data items missing? If so what are they?

Alabama: Initial point of impact; grade crossing number; accidents in construction zones; traffic control devices; oversize or overweight vehicles; vehicle classification scheme. Also, the reference-point system needs upgrading.

California: All information neededfor routine safety analysis exists on the current form. However, some special studies (wide load accidents, etc.) require collection of additional data elements.

Illinois: Yes, alcohol-related information such as blood alcohol level, which is only coded on fatal accidents.

Michigan: None.

Wisconsin: Local systems missing.

West Virginia: None.

21. What data items do you think are routinely coded incorrectly?

Alabama: Wet/dry conditions due to edit problem. Also, driver inattention is too often coded when no other information is known about the accident cause.

California: Location descriptions; movement preceding collision (which is often coded as vehicle moving "straight").

Illinois: Under the influence of alcohol; vehicle size and type; vehicle make, model information. Beginning in 1981 additional information will be collected regarding vehicle size and type.

Michigan: Most coding problems seem to be minor and occur randomly among the coded items. Items related to location coding are the only problems noted with any consistency.

Wisconsin: Direction of vehicles, driver intent, manner of collision, distance from fixed object.

West Virginia: No specific element.

22. Are accident data stored and maintained by computer? If so, for what time period are accidents maintained for identification and analysis purposes? For evaluation of completed improvements?

Alabama: Yes, accident records are maintained back to 1971. For evaluation purposes, records are maintained for one year currently, but will be held for three years in the future.

California: Yes, for analysis and legal purposes accident records are kept for five years. For purposes of surveillance, records are kept for three years.

Illinois: Yes, accident identification is based on one year of data. Countermeasure development is based upon three years of data. All data is available for seven years.

Michigan: Michigan Department of Transportation has trunkline accident data stored on magnetic tape from 1963 to date. 1979 and 1980 YTD data are also stored on disk. The Department of State Police maintains statewide data files for statistical purposes for the years 1972-current, and statewide data for identification purposes for the years 1978 to present.

Wisconsin: Yes, accident data are stored for 10 years (since 1970 but changes were made in 1973 to the data format).

West Virginia: Yes, five years are available for analysis purposes, although 1-year and 3-year periods are usually used for identifying high-accident locations.

23. Is the computerized accident file merged with any other highway or traffic information within the State Department of Transportation? If so, please describe the types of data and their uses.

Alabama: Skid characteristics, roadway geometrics, and volume data are merged with accident data.

California: Yes, roadway information files are interfaced with the accident files for computing systemwide average accident rates by highway class and type.

Illinois: Yes, as a pilot project, roadway files (volume and geometric information) have been interfaced with accident files for two of the nine highway districts.

Michigan: The Michigan Department of Transportation computerized accident files are merged with traffic volume files, structure files, roadway features files, etc. Traffic volumes are used primarily for computing rates. Structure files are used in gathering statistics for homogenous structure locations. Roadway features files are used in identifying homogenous cross section locations.

Wisconsin: Yes, with roadway log data and traffic volumes.

West Virginia: Yes, the traffic volume data and roadway geometrics file are linked with the accident file to automatically compute accident rates, critical rates, severity rates, etc. for each of 26 highway classes.

24. What type of computer facility is used for storage and maintenance of accident data, volume data, geometric data, and other data?

	State				
Data Type	Alabama	California	Illinois	Michigan	Wisconsin
Accident Data	UNIVAC; IBM 370	IBM 370 AMDAHL	IBM 370	Burroughs 6700	AMDAHL
All Other Data	UNIVAC; IBM 370	IBM 370 AMDAHL	IBM 370	Burroughs 7700	IBM 360 AMDAHL
Maintaining Agency	State D.O.T.; Dept. of Public Safety, & Data Systems Management Dept.	Div. of Computer Services	OMIC-Office of Management Information Control	Michigan State Police	Wisconsin D.O.T.

NOTE: West Virginia uses an IBM 370.

25. Are statewide or systemwide accident summaries produced routinely? If so, at what time increments (once every year, etc.)? Please provide a sample of any booklet, computer summary, or other form of statewide accident summary?

Alabama: Yes, annually.

California: Yes, some tables are produced quarterly, such as a list of high-accident locations. Others are annually produced, available upon request.

Illinois: Yes, general accident summaries are produced monthly.

Michigan: The Department of State Police produces statewide urban and rural summaries on a monthly basis as well as a comprehensive annual report. They also produce many specific item reports annually, such as for school bus or snowmobile related accidents. Michigan Department of Transportation produces numerous year-end summaries of trunkline accident data. Samples from both departments are enclosed.

Wisconsin: Semi-annual accident listings and annual summaries are produced.

West Virginia: Yes, each year all high-accident locations are found by computer search along with statewide accident summaries.

26. What types and lengths of high-accident sections and spots (and elements) are routinely identified for further analysis?

See discussion in text.

27. Are statewide accident summaries produced by highway type for use in determining a cut-off level for identifying high-accident locations? (For example, such criteria may be two times the statewide average accident rate, or the use of the Rate-Quality Control Method).

Alabama: Yes.

California: Yes, accident frequencies and rates of spots are compared with the expected and critical frequency and rates.

Illinois: Yes.

Michigan: Yes, see question number 16.

Wisconsin: There is no formal cut-off. Safety deficiencies are recognized when the accident rate for a segment is above statewide average.

West Virginia: Yes, for 26 different highway types.

28. Are traffic data (volumes, ADT, etc.) used in the computation of rates for identifying high-accident locations? If so, how are volume data merged with accident number to compute accident rates or other calculations?

Alabama: Yes, data files are interfaced with COBOL program to compute accident rates.

California: Yes, there is a program which does this task.

Illinois: Yes, volume data is manually merged with accident locations.

Michigan: Yes. In the number-rate-severity ratio program, a file is used in which the volumes have been appended. The volumes are stripped from a Trunkline Vehicle Miles (TVM) file. In the MIDAS programs separate volume files and accident files are interrogated for specific location related data.

Wisconsin: Volume data are merged with accident data using a MARK IV interface program.

West Virginia: Yes, interaction between the accident file and volume file allows for the automatic calculation of accident rate for each 0.5 mile highway segment.

29. Do police officers actually see any of the results from their accident reports? Do traffic engineers routinely send copies of reports (high-accident listing, research reports, etc.) to police departments?

Alabama: Yes, much interaction takes place between traffic engineers and law enforcement officials. Accident reports filed by police officers often lead to programs of "selective enforcement". Also, a 4-page "Public Safety Summary Report" is published to summarize accident findings. Feedback is also given to each city annually concerning accident summaries.

California: State DOT officials frequently interact with police officials. Accident data, speed zone survey and other problems are discussed frequently. A monthly luncheon is held to bring officials together.

Illinois: Police departments receive systemwide accident summaries from the Illinois DOT and use this data to determine areas for selective enforcement.

Michigan: Yes, the Department of State Police routinely sends summarized accident data to the individual police agencies. Periodically, high intersection accident location printouts are sent to the police agencies, and to numerous traffic related agencies, including Michigan Department of Transportation. Michigan Department of Transportation high accident location information is sent to Michigan Department of Transportation district traffic and safety engineers. The listings are sent to police agencies on request.

Wisconsin: Accident reports are utilized, to a limited extent, in determining areas of selective enforcement. Copies of reports are not routinely sent to police departments.

West Virginia: Yes, the Department of Highways annually sends copies of its annual report to State police, county sheriffs and numerous other highway agencies and various organizations. Also, summaries of all accident locations are sent to 56 cities throughout the State.

30. Are computerized highway data used in the identification of hazardous locations and features? If so, how?

The States surveyed do generally identify hazardous highway features with some consideration of accident data. However, in some cases, a hazardous feature (narrow bridge, blunt-end guardrail, etc.) may be identified and corrected as a part of a larger project.

31. How are the highway location reference systems used to merge accident files and other computer files? Please describe in detail.

Illinois: This has not yet been accomplished.

Michigan: Michigan Department of Transportation files are control section oriented in that specific sections of trunkline are assigned a unique identification number (control section). All files pertaining to a control section are ordered in a mileage within control section sequence.

Other States: See discussion in text.

32. How many accidents are reported in your State each year? In your opinion, what percent of all accidents go unreported each year or are not entered for analysis purposes?

State	Reported Accs./Yr.	Estimated Unreported Accs/Yr. (% of total)
Alabama	125,000	25%
California	490,000 (total) 135,000 (State maintained)	Fatal: 0% P.I.: 10% P.D.O.: 60%
Illinois	568,000 not including private property accidents	15%
Michigan	349,250 average per year for the past 10 years	2%
Wisconsin	166,461	17%
West Va.	62,000	Unknown

33. What are the resources required for processing data related to high-accident locations each year?

A. Manpower by personnel types
B. Money and/or funding levels
C. Costs for related computer services

Alabama:
A) Engineering- 3 man yrs./yr.
Division people - 9 divisions @ 1 man/yr./div.
Data Entry - 10 man yrs./yr.
Programming functions - 1 1/2 man years
B) $150,000/yr.
C) $20,000/yr.

California:
A) -
B&C) $1,000,000/yr. (TASAS - computer and manpower)

Illinois:
A) Data processing: 40 people
Locations: 12 people
Microfilm: 2 people
H.A. Locations: 25 man mos./yr;
District summaries: 10 man mos./yr.

Michigan:
Michigan Department of Transportation
A) Engineers, technicians, analysts
B) $62,860
C) $60,000

Michigan Department of State Police
A) Administrators, supervisors, general clerks, analysts
B) $1,200,000
C) $200,000

Wisconsin:
A) 4 code clerks, 5 keyers.

West Virginia:
A) About 15 people full time for data coding, keypunching, clerical work, typing, and personnel supervision. Another 4 people (half time) are utilized for roadway inventory work.
B) Total budget is about $300,000 per year
C) Computer costs are about $75,000 per year.

34. What are some of the problems associated with the processing of highway-related data? What suggestions do you have for improving such problems?

Alabama: A common reference system would solve many problems.

California: Some intersections may be missing. Restriping is difficult to maintain. Training programs are needed for young people in DOT, districts.

Illinois: Problems exist with interfacing data. Also, planning requires different types of data. More special summaries of accidents are also needed, e.g., intersections with more than 10 rear-end accidents per year, etc.

Michigan: Many current data are maintained independently with no common data base orientation. Many statewide roadway related files are maintained with no correlation with the MALI index. Suggest better file coordination through the use of a department file coordination unit whose role would be to assist all units maintaining files with broad application capabilities. Also strongly suggest changing the reference system of the statewide roadways-needs file to the MALI prime road numbering system.

35. What types of computer software packages (DART, RAPID, SPSS, etc.) are used to process data related to the highway system?

Alabama: RAPID

California: -

Illinois: Use SPSS (special studies) plus own programs. Have also developed computerized collision diagram program.

Michigan: The Michigan Department of Transportation utilizes BASIS, SPSS, NETSIM, QWEAVE, TRANSYT, MIDAS, SCREEN, GARLAND-FEISER PROGRESSION ANALYSIS, TIME/SPACE PLOT PROGRAM, INTERSECTIONAL CAPACITY ANALYSIS, MAXBAND, and numerous other statistical and graphics plot packages.

West Virginia: SAS (Statistical Analysis System) and other programs developed within the State for specific purposes.

APPENDIX B

EXCERPT FROM 1982 FHWA REPORT[1]

4

INTEGRAL SYSTEM

The previous chapter described the existing state systems in some detail. This review has found that the majority of states neither maintain nor effectively use project evaluations to assist in the selection of countermeasures at newly identified hazardous sites. This chapter describes minimum process requirements for an integral system which maintains and uses project evaluations.

Conceptually, this integral system maintains the general flow of information as collected, processed, and maintained through the existing state system. By either adding new processes or enhancing existing ones, information can be made available to assist management in their efforts to improve highway safety. Exhibit 2 summarizes the integral system by showing how the various elements are linked. Elements to be added to the existing system or to be enhanced are reference numbered and described in the following sections of this chapter.

ELEMENT 1—HAZARDOUS SITE DATA FILE

The existing state systems all begin with the collection of traffic accident information. Using a unique field reference system, each accident report is assigned a location code. This code is added to the accident data and maintained on an accident data file. Accident data along with corresponding information from the traffic volume file and the highway inventory file are used to identify hazardous sites. This process as currently performed by the states provides a hard copy list of accident sites at which an arbitrary number of accidents (determined by each state) has occurred.

At this point, the integral system creates a hazardous site data file (Element 1) containing the list of site locations identified as being hazardous along with selected information from the accident data, the traffic volume, and the highway inventory files. This hazardous site data file is maintained on magnetic tape or disk file to be used in the next process.

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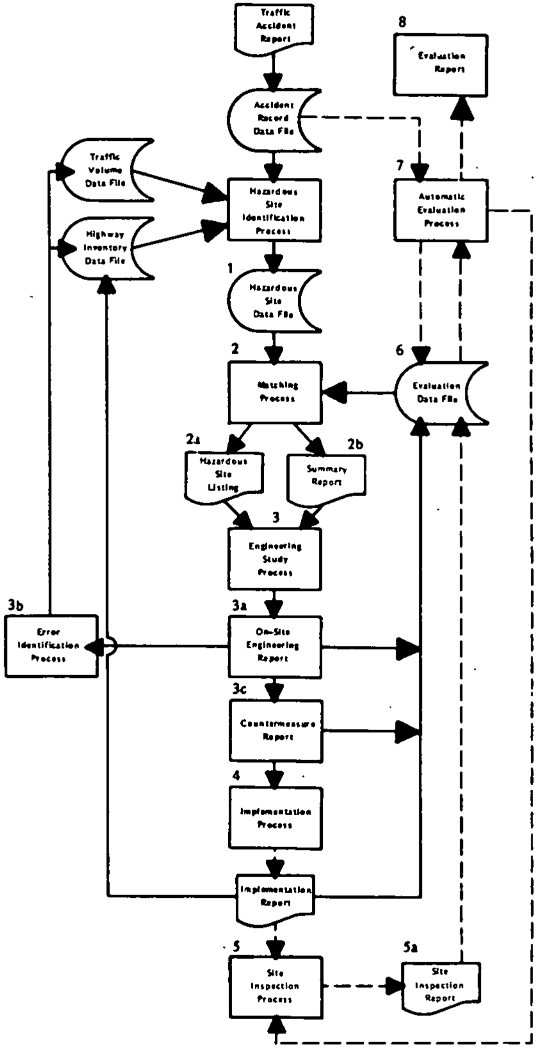
[1] C. G. Conley, F. P. Abbott, C. P. Brinkman, and J. Tom, "Model System for Evaluating Safety Projects Using State Record Systems." Final Report No. FHWA/RD-81/186. Prepared for Offices of Research and Development, Federal Highway Administration (Washington, D.C.: U.S. Department of Transportation, 1982).

Exhibit 2

INTEGRAL SYSTEM PROCESS FLOWCHART



ELEMENT 2--SITE MATCHING PROCESS

This process, a new element to be added to existing systems provides the link between newly identified hazardous sites and evaluations of previously implemented countermeasures. Its function is to match the sites listed in the hazardous site data file to evaluations of countermeasures implemented at similar sites. The two main outputs of this process are a Hazardous Site Listing (Element 2a) and a Summary Report (Element 2b) for each hazardous site.

The Hazardous Site Listing is exactly the same as the Hazardous Site Listing produced by existing state systems. The Summary Report (Element 2b), on the other hand, is a new report proposed for this integral system. This report contains a description of a newly identified hazardous site and a list of evaluation studies performed on similar sites giving the effectiveness of the applied countermeasures. This report enables the engineer to make a better informed selection of a countermeasure for the new site. In addition, the Summary Report (Appendix B) provides self-reporting forms to assist the engineer in maintaining the appropriate data flows. These include:

- On-site Engineering Report,
- Countermeasure Report,
- Implementation Report,
- Site Inspection Report.

Each of these forms contains descriptive data extracted from the data system at the time the hazardous site is identified (Element 1). Moreover, the forms are keyed to the hazardous site with a code number so that data the engineer adds can be entered into the data system and merged into the appropriate hazardous site record.

The On-site Engineering Report, for example, will include spaces for recording the results of an on-site visit. If the observed roadway characteristics or traffic patterns differ from those reported on the Summary Report, this portion of the form can be used as input into the error identification process (Element 3a), which includes correction of the appropriate data files. Similarly, the Implementation Report is completed after the appropriate countermeasure implementation and then used to update the highway inventory data file. Finally, the Site Inspection Report is completed by the engineer after an inspection of the implemented countermeasure and serves as an input document for the evaluation data file (Element 7). This procedure enables the effectiveness of the countermeasure at that hazardous site to be examined and used to assist in the selection of countermeasures at future hazardous sites.

The most crucial aspect of this process is the matching criteria. If the list of evaluations is to provide the engineer with useful information, the previously evaluated sites must match the current hazardous site as closely as possible. Therefore, both the hazardous site data file (Element 1), and the evaluation data file (Element 6), must contain sufficient accident, traffic, and highway characteristic data elements so there is confidence that similar sites are matched. Although other data elements may be added depending on a particular state's needs and the available data elements, the following list is an example of elements necessary for such a match:

- Type of Area
    - Urban
    - Rural
- Type of Highway
    - Freeway
    - Nonfreeway
- Highway Characteristics
    - Number of lanes
    - ADT
    - Divided/Nondivided
- Type of Section
    - Nonintersection
    - Intersection signalization
        - signalized
        - nonsignalized
    - Type of intersection
        - T section
        - crossroads
        - cloverleaf
        - diamond
        - other
    - Bridge
    - Tunnel
- Other

Evaluations of countermeasures for which these characteristics match the current hazardous site will be presented in the Summary Report.

To provide the engineer with a sufficient sample of matching sites, at least ten evaluations will be included in this report. If fewer than ten evaluations were performed on roads with the desired characteristics, matching elements can be dropped from the list, beginning with the least important element. For example, based on the suggested list, matching may be done excluding the 'intersection type' variable. If this less stringent matching criteria again fails to produce the minimum number of evaluations, additional variables will be excluded as matching criteria until ten evaluations are reported.

A second alternative to this supplemental matching scheme is to use a matching index. In its simplest form, such an index would compare all criteria variables for each record in the evaluation data file to the characteristics of a hazardous site. For each record, the number of matches is recorded. If the total number of criteria variables is n, the perfect match (all variables match) would be assigned the value n. The formula for such an index is:

$$M = \sum_{i=1}^{n} m_i$$

where m_i is 1 if the i^{th} hazardous site and evaluation characteristics match and 0 if they do not match. The first evaluation reports included in the Summary Report would be those for which M is the largest. If this group of evaluations does not provide the minimum number of evaluation reports, the reports with the next largest M will be included, until the minimum number of reports is obtained.

The matching index described in the previous paragraph is based on the assumption that a match in any variable is of equal value to a match in any other variable. Presumably, however, some variable matches are more important than others. For example, evaluations of countermeasures at sites with the same intersection type as that of the hazardous site may be more useful to the engineer than sites with a similar median strip, given all other variables the same. The matching index formula then becomes:

$$M = \sum_{i=1}^{n} w_i m_i$$

where w_i is the weight representing the importance of characteristic i. If characteristic j is more important than characteristic i, w_j will be greater than w_i.

Just as in the unweighted matching index, the evaluations with the largest index will be included in the matching site report first.

Mathematically, these three matching schemes (criteria dropping, equal weighting, and unequal weighting) are all part of a general spectrum of weighting schemes. Assuming that n matching variables are ranked so that variable 1 is the least important and variable n is the most important, the weights can be expressed as:

Criteria dropping	$w_i = 2^{(i-1)}$
Equal weighting	$w_i = 1$
Unequal weighting	$2^{(i-1)} \geq w_i \geq 1$

ELEMENT 3--ON-SITE ENGINEERING STUDY PROCESS

During this process the field engineer determines, just as in the existing system, the most effective countermeasure at a particular hazardous site. In the integral system, however, the engineer is assisted by a listing and evaluations of countermeasures used at similar sites. As part of this process, the engineer completes two reports. The On-site Engineering Report includes needed information not available from the various data files along with information to verify the accuracy of information taken from the files. Any additional data would be recorded on this report and entered into the evaluation data file. If an on-site survey reveals that the actual highway characteristics do not match recorded information for any of the matching elements, this error identification process (Element 3b) updates the relevant data files and again initiates the hazardous site identification process.

When a countermeasure is selected, the Countermeasure Report (Element 3c) is completed. This report signals the system that a countermeasure has been selected for one of the hazardous sites in the hazardous site data file. The report contains the hazardous site code, the type of countermeasure selected, expected date of implementation, and expected cost of implementation. These data are merged with descriptive data from the hazardous site data file to form a partial evaluation data file record. The blank elements of this record represent the implementation and evaluation data to be added during the implementation and evaluation phases. In the automatic evaluation process, the integral system will identify all sites for which countermeasure completion dates have passed but no Implementation Report (Element 4a) has been filed.

ELEMENT 3b--ERROR IDENTIFICATION PROCESS

After the matching process and the generation of the Hazardous Site Listing and the Summary Report, the local engineer performs an engineering study, just as in the existing state system, to determine the appropriate countermeasure. If the engineer determines the actual site characteristics are different than those reported (and used to identify the hazardous site and matched site evaluation reports), the error identification process updates traffic and highway inventory data. At this stage, the hazardous site will not be analyzed to select a countermeasure until the site has been reexamined with the revised data.

When inconsistencies are observed, the error identification process determines the type of error and implements the appropriate correction procedure. The most common errors are incorrect highway characteristic and traffic data and mislocated accidents. The first type of error is the easiest to identify, since data such as number of lanes, intersection type, traffic volume estimates, and signing and signals can be verified by observation. After such errors have been identified, the traffic volume data file and the highway inventory data file are corrected.

Accident location errors are more difficult to identify. An example of an obvious mislocation is a series of left turn accidents at a location where no intersection exists. Such an inconsistancy can result from miscoding of the location or inaccurate inventory and traffic data. For the former, a reexamination of each accident record may be required to relocate them while the latter indicates a need to edit the traffic and inventory files.

ELEMENT 4—IMPLEMENTATION PROCESS

The same activity occurs during this process that occurs in the existing state systems. In addition, the Implementation Report (Element 4a) which triggers the updating of the highway inventory and evaluation data files is completed. It contains the site code and data on the implemented countermeasure. It is sent to the group responsible for maintaining the highway inventory data file so it can be updated.

The Implementation Report also initiates the updating of the evaluation data file. It signals the system that a countermeasure has been implemented at one of the hazardous sites identified in the hazardous site data file. The report contains the hazardous site code, the type of countermeasure implemented, the date of implementation, and the cost of implementation. These data are merged with data already on the partial evaluation data file record. The remaining blank elements of this record contain the results of the countermeasure evaluation to be conducted in the future.

ELEMENT 5—FIELD EVALUATION PROCESS

The Site Inspection Report (Element 5) is optional. It is completed by the engineer and contains the results of a site inspection of the project. This inspection is usually performed within a year after the countermeasure has been implemented. It may include such measures as traffic conflicts and speed changes. These data are attached to the site record in the evaluation data file.

ELEMENT 6—EVALUATION DATA FILE

This data file, which is the key of the proposed integral system, formalizes the collection of the experience reflected by evaluations of countermeasures implemented throughout the state. Records of all hazardous sites at which some countermeasure has been implemented are maintained in this file. These records include:

- Location code,
- Pre-implementation site characteristics,
- Implemented countermeasure descriptors,
- Evaluation results.

Although each data category has a specific function within the integral system, the exact data elements within these categories can be varied by individual states to accommodate existing procedures and practices.

The location code is part of the field reference system used to identify accident locations. It provides a key for matching post-implementation accidents, which are also identified by location code, to those sites where new countermeasures were implemented. Accidents identified in this search will be input into the automatic evaluation process.

The pre-implementation site characteristics are used to match a hazardous site to records in the evaluation data file. The specific variables in this group parallel those descriptive variables in the hazardous site data file. In fact after the on-site engineering, implementation, and the field evaluation processes, these data are entered directly into the evaluation data file. A key part of the label assigned these data is "pre-implementation." When matching evaluations to hazardous sites, the system is looking for sites which were similar before a countermeasure was implemented and evaluated.

Implemented countermeasure descriptors include variables such as type of countermeasure, date installation was begun, date full installation was completed, and installation cost. These data are entered into the system at the conclusion of the implementation process. The dates are used to find relevant accidents from the accident record data file and to key an automatic evaluation to be conducted some time after implementation. This time period is at the discretion of the state. Part of this evaluation may be an analysis of the cost. The cost data also will be provided on the Summary Report, so that the expected cost of a particular countermeasure can be compared with its effectiveness.

Finally, the evaluation data file will contain the results of an evaluation of the countermeasure implemented at the site. The variables included in this section depend largely on the existing evaluation techniques accepted by the state. This information when matched with future hazardous sites with similar characteristics will provide in the Summary Report, some indication of the possible effectiveness of the proposed countermeasure in that situation.

ELEMENT 7—AUTOMATIC EVALUATION PROCESS

Like the implementation process, the evaluation process parallels the existing state system. To assist the evaluating engineer and to maintain proper data flows, a new feature is proposed. The implementation of a countermeasure and the creation of a partial evaluation data record for a particular hazardous site initiate the new feature. Periodically after the partial site record has been created, all accidents in the accident record data file which occurred at the relevant location since implementation of the countermeasure will be accessed. An evaluation of the countermeasure will be conducted by comparing the post-implementation accident data to pre-implementation accident data. These Evaluation Reports (Element 8) will be sent to the responsible engineer. The results of this evaluation will be stored in the evaluation data file.

SUMMARY

In this chapter, an integral system which uses evaluations of previously implemented countermeasures to help select effective countermeasures for use at other hazardous sites has been outlined. The discussion has centered around processes and data files which must be modified or added to the existing state systems described in Chapter 3. Since each state has the flexibility of selecting which evaluation methodology, hazardous site identification technique, location coding process, and criteria for matching similar sites, details about each have not been included. This chapter, however, does provide guidelines for developing a system which makes effective use of available information for selecting effective countermeasures.

In the next chapter, this integral system will be analyzed with respect to hardware, software, and personnel requirements for its implementation.

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