NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE

128

METHODS FOR IDENTIFYING HAZARDOUS HIGHWAY ELEMENTS

TRANSPORTATION RESEARCH BOARD
National Research Council

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METHODS FOR IDENTIFYING HAZARDOUS HIGHWAY ELEMENTS

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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.

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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 National Research Council 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 National Research Council and its Transportation Research Board.

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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 synthesis will be of interest to highway designers, administrators, and others concerned with highway safety. Information is presented on practices used by agencies to identify hazardous highway elements and to set priorities for improving those elements.

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.

Almost all highway agencies use accident data to identify high-accident locations on highways. In some cases, however, accidents may be associated with elements of the highway environment (roadside obstacles, geometrics, pavement friction, etc.) that may not be at high-accident locations but may be associated with high-accident frequency system-wide. This report of the Transportation Research Board explains what agencies are doing to identify those elements that may be hazardous.

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.

CONTENTS

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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.

METHODS FOR IDENTIFYING HAZARDOUS HIGHWAY ELEMENTS

SUMMARY

A highway element is any physical roadway feature, obstacle, device, or condition that can be measured or inventoried. Examples of highway elements include pavement friction, intersections, railroad grade crossings, geometrics (e.g., lane widths, shoulder widths, grades, curvature, superelevation, side slopes), roadside obstacles (e.g., bridge supports and parapets, guardrails, crash cushions, trees, sign and luminaire supports, drainage structures, utility poles), traffic control devices, and others. Although states are required by law to identify hazardous locations, sections, and elements along highways, most highway agencies devote their efforts to identifying high-accident locations by reviewing measures of accident frequency, accident rate, and accident severity. Although these efforts are an important part of a highway safety program, an equally important safety need is to identify and correct hazardous highway elements that, at individual sites, may not yet have an abnormal experience of accidents, but, in aggregate, have the potential for high accident frequency or severity.

Highway elements may be viewed in terms of their degree of hazard, which is a function of the probability of that element being associated with an accident or injury. For example, the degree of hazard of a roadside obstacle is a function of its type and rigidity, its distance from the roadway edge, its exposure to traffic, and nearby roadway characteristics (e.g., pavement width, curvature, grade, side slope). Thus, a combination of many roadway features and conditions affect the degree of hazard of an element. Although there are probably hundreds of highway elements that could be named as "potential hazards" under certain situations, approximately 40 specific elements were most often mentioned by state and local highway agencies as being of primary concern.

The determination of hazardous elements by a highway agency should be based on the agency's roadway characteristics (terrain, density, traffic volume, roadway designs, driver characteristics, climate, etc.) as well as guidelines and standards [Manual of Uniform Traffic Control Devices (MUTCD), AASHTO standards, etc.]. An agency should also rely on past experience and consider elements that have been associated with high accident frequency or severity. Roadway elements that are commonly associated with high-accident locations are often considered as potential hazards without waiting for accidents to happen. An accurate highway inventory is a valuable tool to assist in the systematic identification of highway elements of concern.

Many agencies have no formal procedure for identifying hazardous elements, although hazardous elements seen in the field are reported by maintenance workers, police, and safety personnel. Some agencies perform routine field inspections and have specific pre-defined highway elements in mind during these inspections. The use of more formal procedures includes computerized system-wide inventories of roadway

elements, such as narrow bridges, roadside obstacles, railroad grade crossings, sight-distance deficiencies, and others. From these inventories, elements are then identified that are considered to be deficient.

The methods used to collect inventory data include manual methods, photologging, videologging, and automated or semi-automated devices. Manual data collection and photologging are most commonly used for collecting data on highway elements. Computer data storage and processing are used by approximately 75 percent of the agencies responding to a survey made for this synthesis. New and improved data storage and processing techniques are now in use, such as laser videodiscs for handling photolog information. Each agency should determine which types of data collection and processing methods are most feasible and cost-effective for the variables of concern. Current inventory data bases can be used whenever possible and supplemented with information on other relevant highway elements. There may also be a need to enhance or modify the data files and software to allow for data sorts and searches and to enhance capabilities for locating potential hazards.

The improvements to highway elements are made either: (a) as a part of a larger project, (b) where the individual element(s) are the target of the improvement, or (c) through blanket improvement. Examples of blanket improvements that have been made successfully include: (a) resurfacing roads with low friction numbers, (b) replacing spear-end guardrails with crashworthy ends, (c) installing breakaway sign posts and light poles, (d) flattening steep side slopes, (e) clearing rigid obstacles from roadsides or freeway gore areas, and many others. Such blanket improvement programs allow for correcting hazards without waiting for accidents to happen at each site.

There are numerous problems and limitations in identifying and correcting hazardous highway elements. The most critical problem was reported to be a lack of funding for making safety improvements, although limited personnel was the second problem most often cited. Other problems included difficulty in justifying improvements for highway elements (unless accident experience is high), inaccuracies in data collection, lack of clear guidance on which hazards to correct, and lack of support from top management.

Numerous funding sources and programs, such as the 3-R Program, the Hazard Elimination Program, Rail-Highway Crossing Program, reconstruction programs, maintenance programs, and others can be used in combination to gradually correct many of the hazards that currently exist on the highway system. State and local agencies should carefully review all types of highway hazards and take action to correct them in a systematic, organized manner.

Many highway agencies already treat perceived hazards at railroad crossings, and also make "yellow book-type" improvements to their Interstate system. However, more emphasis should be placed on the hazards on state and local routes, and on urban streets.

Numerous training courses are currently available and recommended for state and local highway officials relative to administering highway safety programs, safety improvements, maintenance of safety features, correction of highway features, project and program evaluations, and related topics. Finally, the effects of treatments of hazardous elements should be routinely evaluated by states with well-planned project and program evaluations. The results of such evaluations will provide valuable insights into which types of improvements are successful and which ones are not.

CHAPTER ONE

INTRODUCTION

Federal law (23 USC 152) requires states to identify hazardous locations, sections, and elements along the highway. Most highway agencies devote their efforts to identifying high-accident locations by reviewing measures of accident frequency, accident rate, and accident severity. Although these efforts are important to a highway safety program, an equally important safety need is to identify hazardous highway elements, or features, that may not have an experience of accidents, but have the *potential* for high accident frequency or severity.

Most of the total accidents on a highway network typically occur at locations that have *not* been labeled as high-accident locations. Certain highway *elements* may be associated with such accidents. A highway element is any physical roadway feature, obstacle, device, or condition that can be measured or inventoried. These features include pavement friction, intersections, railroad grade crossings, geometrics (lane width, shoulder width, grades, curvature, etc.) roadside obstacles (bridge parapets, guardrail, poles, drainage structures, etc.), and traffic control devices, and may be on or off the roadway.

It is important to note that not all highway elements are hazardous. However, statistics have shown that highway elements play a major role in the nation's accident problem, even though these elements may not be found at a high-accident location. For example, in 1981 49,268 people were killed in traffic accidents in the United States. Of those people, 33.2 percent were involved in collisions with fixed objects. Therefore, each agency should be aware of hazardous elements along the roadway and must determine what elements deserve consideration for possible improvement (*1*).

PURPOSE AND SCOPE OF THE SYNTHESIS

The purpose of this project was to survey the methods that are currently used by highway agencies to identify and treat hazardous highway elements and to determine which methods have been most successful. The synthesis specifically focuses on: (a) defining a hazardous highway element, (b) discussing methods of identifying elements that are strongly associated with accident frequency or severity, and (c) addressing funding issues and problems relative to these elements.

The information for this synthesis was gathered from several sources. More than 50 references that addressed this topic were reviewed. A questionnaire (Appendix A) was developed and distributed to each state agency and several local agencies. The questionnaire was also distributed to selected highway agencies in other countries to obtain their perspectives on this topic. Telephone and personal inteviews were also conducted to gain additional insights.

Responses to the questionnaire were received from 40 state agencies (39 states, plus the District of Columbia). These included:

Alabama	Nebraska
Alaska	New Hampshire
Arkansas	New Jersey
California	New York
Connecticut	North Carolina
Delaware	North Dakota
District of Columbia	Ohio
Florida	Oklahoma
Georgia	Oregon
Illinois	Pennsylvania
Indiana	South Carolina
Iowa	South Dakota
Kansas	Tennessee
Louisiana	Texas
Maryland	Utah
Massachusetts	Vermont
Michigan	Virginia
Mississippi	Washington
Missouri	West Virginia
Montana	Wyoming

A summary of road mileage under the jurisdiction of these 40 agencies included:

Mileage	Number of States
≤ 5000	6
5,001 to 10,000	13
10,001 to 20,000	13
≥ 20,000	8

Questionnaires were also sent to local agencies that were considered to have possible interest or involvement with hazardous highway elements. Responses were received from 17 local agencies in 9 states and 1 Canadian province. These agencies included:

Charlotte, North Carolina
Douglas County, Kansas
Douglas County, Nebraska
Hawaii County, Hawaii
Honolulu City/County, Hawaii
Indiana Local Governments
Maui County, Hawaii
Oakland County, Michigan

Ocean County, New Jersey
Oklahoma City, Oklahoma
Omaha, Nebraska
Passaic County, New Jersey
Phoenix, Arizona
Regina, Saskatchewan, Canada
Tempe, Arizona
Tulsa, Oklahoma
Winston-Salem, North Carolina

The organization representing the Indiana local governments reported 80,360 miles of roadway under its jurisdiction. Eight of the local agencies had between 1,000 and 4,250 miles of roadway under their control. Of the agencies remaining, 2 agencies did not indicate mileage, and 6 agencies were responsible for 624 roadway miles or less.

Information was also received from highway agencies outside the United States, including:

Alberta, Canada Transportation Safety Board
Australian Road Research Board
Japan Highway Public Corporation
New Brunswick, Canada Department of Transportation
Saskatchewan, Canada Department of Highways and Transportation
South Africa: Two Provincial Road Departments

RELATED SAFETY STANDARDS

There are several federal laws and programs that relate to agency requirements in identifying hazardous elements. The first such law enacted was the Highway Safety Act of 1966, which required that highway safety programs include the "detection and correction of high or *potentially* high-accident locations." The 1973 Highway Safety Act established specific highway safety programs intended to reduce the number and severity of accidents caused by hazardous highway locations, sections, and *elements* through the use of engineering improvements (*1*).

Categorical safety construction programs were continued and revised through subsequent legislation. For example, the 1978 Highway Safety Act provides continued funding for (*1*): the Pavement Marking Demonstration Program, the Rail-Highway Crossings Program, the Hazard Elimination Program, and the Safer Off-System Roads Program.

The 1978 Highway Safety Act merged the High-Hazard Locations and Elimination of Roadside Obstacles Programs into the Hazard Elimination Program. This program now provides federal funding "for safety improvement projects on all highway systems, except the Interstate System, to eliminate or reduce hazards associated with identified locations, sections, and elements, including roadside obstacles and unmarked or poorly marked roads constituting a danger to motorists and pedestrians" (*1*). Thus, funding is also available under this program for treating various types of hazardous elements (*1*).

The Highway Safety Act of 1982 provides continued funding for the Hazard Elimination and the Rail-Highway Crossings Programs through fiscal year 1986. Both programs have provisions for addressing hazardous roadway elements. For example, the Rail-Highway Crossings Program provides federal funding for "signing, protective devices, surface improvements, grade separations, and relocations, both on and off the Federal-aid systems, except the Interstate System, to eliminate the hazards of rail-highway grade crossings" (*1*).

HAZARDOUS ELEMENTS AND A HIGHWAY SAFETY IMPROVEMENT PROGRAM

Based on guidelines for highway safety programs, as established in the Highway Safety Act of 1966 and later acts, the Federal Highway Administration (FHWA) has administered many safety programs. On March 5, 1979, the FHWA defined a Highway Safety Improvement Program (HSIP) in Federal-Aid Highway Program Manual, Volume 8, Chapter 2, Section 3, or FHPM 8-2-3 (*2*). The policy of FHPM 8-2-3 is that, "each State shall develop and implement, on a continuing basis, a highway safety improvement program which has the overall objective of reducing the number and severity of accidents and decreasing the potential for accidents on all highways" (*2*). Thus, reducing accident potential was mentioned as one of the three major objectives of a highway safety program.

A comprehensive HSIP consists of planning, implementation, and evaluation components. Within the planning component are processes to: (a) collect and maintain data (including accident, traffic, and roadway data), (b) identify hazardous locations and elements, (c) conduct engineering studies (including countermeasure selection at identified hazardous sites and elements), and (d) establish project priorities (i.e., to select projects that will result in the greatest possible benefit for each dollar spent). An illustration of the HSIP structure is given in Figure 1 (*3*).

The identification of hazardous locations and elements (Process 2 of an HSIP) is discussed in detail in the HSIP Users Manual (*3*). Six procedures are discussed for this process related to the use of accident data (i.e., frequency method, accident-rate method, frequency-rate method, rate quality control method, accident severity methods, and hazard index method). Procedure 7 is termed as "Hazardous Roadway Features Inventory Method." This method is described as comparing existing roadway features with safety and design standards, such as the AASHTO "Yellow Book" (*4*). Examples are given of hazardous features (spear-end guardrail, slippery pavements, steep roadside slopes, etc.) (*3*).

In Process 3 of an HSIP, engineering studies are conducted at those identified hazardous locations and elements. This involves determining appropriate highway improvements to reduce accident experience and correct roadway hazardous elements. Process 4 involves the allocation of safety funding on safety projects to optimize the benefits that should result for each dollar spent (*3*). However, the correction of many types of hazardous elements would be difficult to justify with the traditional benefit-cost analysis. Therefore, Process 4 must also consider the accident potential of hazardous elements.

WHAT IS A HAZARDOUS LOCATION OR ELEMENT?

There is not necessarily one correct definition of a hazardous location or element. In fact, most safety personnel recognize *many* types of roadway locations and elements that, if not corrected, are likely to be associated with high accident frequency

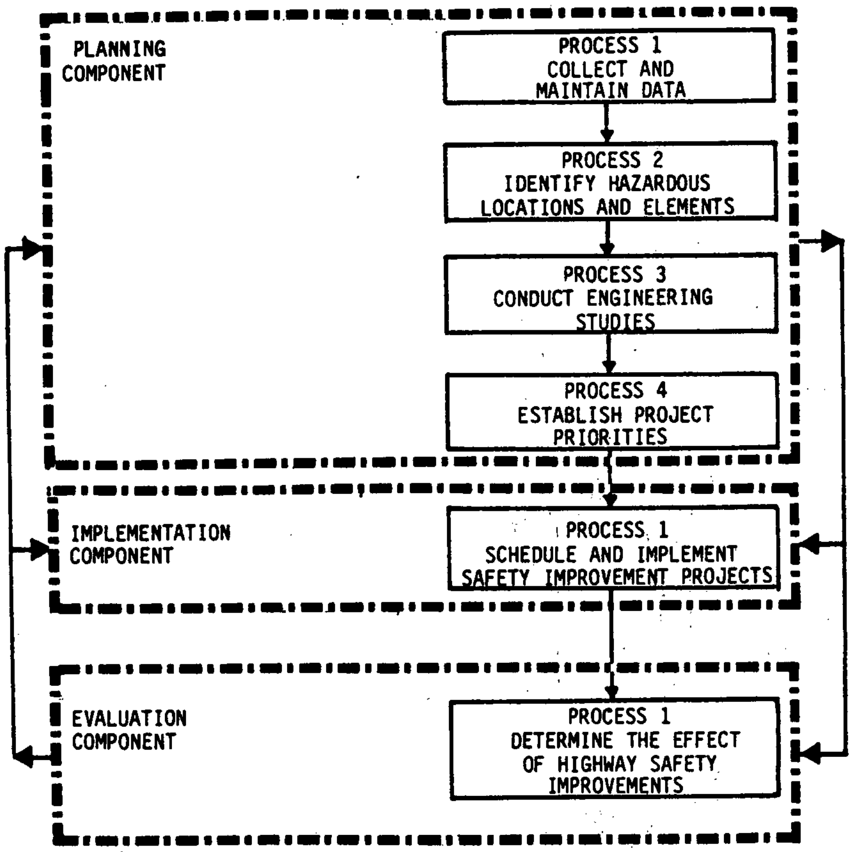

FIGURE 1 Highway Safety Improvement Program at the process level.

or severity in the future. For example, obstacles close to the roadway on curves, and roadway sections with low skid resistance properties may have a high potential for accident frequency.

Other hazardous locations or elements may have the potential for highly *severe* accidents. For example, spear-end guardrails, rigid light poles, and unprotected bridge piers next to the roadway could lead to a severe injury and/or fatal accident if struck by a vehicle travelling at a high speed. A drop-off of several inches from the pavement edge to the shoulder could also cause a hazardous situation if not treated. Freeway gore areas with rigid, non-breakaway obstacles are also a hazard when entered by vehicles.

The AASHTO Select Committee on Highway Safety initiated the establishment of a generally accepted group of hazardous roadway elements through publication of the booklet "Highway Design and Operational Practices Related to Highway Safety" (*4*). This publication indirectly identified specific types of hazards through the description of countermeasures, such as the closing of twin-bridge openings and the use of slip-base connectors for sign supports and light poles. The definition of a hazardous site was suggested as being established by accident history or field observation (to compare elements and their surroundings with those of known accident experience), by Congressional mandate through the establishment of programs to modify highway elements in the interest of safety, and by the personal opinions of drivers, maintenance personnel, and the general public.

The FHWA also established a similar identification of "hazardous elements" through the issuance of Highway Safety Standard 12 on "Highway Design, Construction and Maintenance." Chapter 2 provides examples of elements that are considered by some highway agencies as hazards or potential hazards.

NEED FOR IDENTIFYING HAZARDOUS HIGHWAY ELEMENTS

One of the questions commonly asked about hazardous elements is, "Why should I spend time finding hazardous features along roadways where there are not any accidents, when I have more accident locations to treat than funds permit?" This question implies that high-accident locations must be treated first because these locations are more hazardous than others. However, although high-accident locations often represent problems on the roadway, other similar locations may also have an equally high potential for a catastrophic event, even though accident experience is not yet abnormally high. Moreover, on a systemwide basis a particular element may have a high accident experience; thus it may be more cost-effective to make a systemwide correction of a common element than to correct a high-accident location.

To illustrate this concept, Figure 2 represents all highway locations, including safe locations and hazards, for a given agency. This figure illustrates that a large portion of the highway

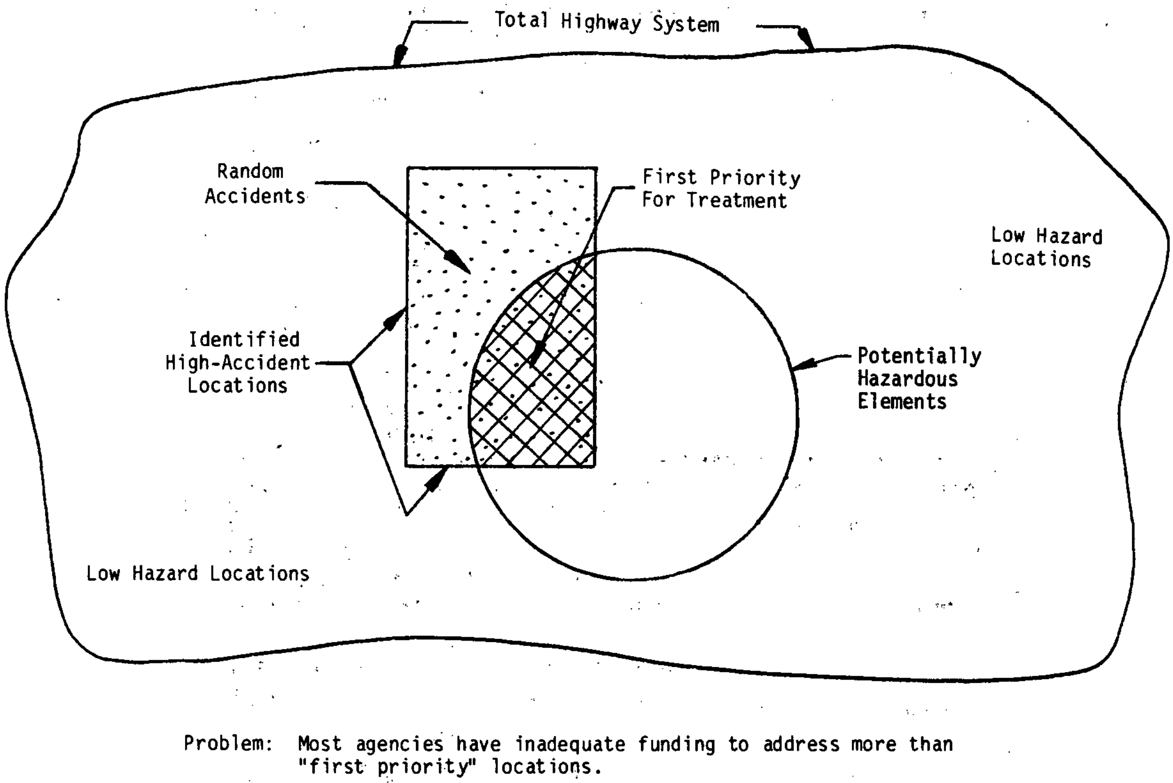

FIGURE 2 Illustration of highway hazards, high-accident locations, and hazardous elements.

system is reasonably safe (i.e., the area outside the circle and rectangle). In other words, much of the highway system has low-accident experience and is not associated with impending danger. The area within the circle represents all hazardous elements, including those with and without abnormal accident experience. The rectangle represents locations with high-accident experience (which may or may not be hazards). The area with the cross-hatching represents the true hazards that are identified through accident analysis techniques. Notice that many of the other true hazards (i.e., non-high-accident elements) would go unnoticed with accident analysis methods alone.

The figure illustrates that the hazards traditionally identified by accident location methods (accident frequency, accident rate, rate quality control, accident severity methods, etc.) are only a subset of the total hazards on the highway system. A comprehensive highway safety analysis system would identify the potential hazards as well as the locations with critically high-accident experience. However, many highway agencies pay less attention to potential roadway hazards, partly because of inadequate funding and/or the lesser concern for non-high-accident hazards.

The need for a comprehensive program to address hazardous roadway elements is discussed by Labadie and Barbaresso in their 1982 study (*5*):

> Efforts to remove or protect roadside hazards are generally performed on the basis of public complaint, construction projects, and/or traffic accidents and not on the basis of a planned, ongoing program. This approach often results in sporatic work efforts and ignores many severe hazards. Substantial litigation expenses and settlements are often incurred by operating highway agencies, since a planned correction program for highway hazard abatement generally does not exist.

An example of a potentially hazardous element that is often identified is a roadway section with a low friction number. This condition can be identified in two ways: by searching for sites with high wet-weather accident experience and then checking skid resistance properties of those sites, or by friction testing sites throughout the highway system and listing sections with low friction numbers. If only the "high-accident" sections with low friction numbers are selected and improved, the problem has only been partly corrected. The likely result is that other sections with low friction numbers will develop high-accident experience in the future. Thus, the ideal solution is to systematically identify all of the problem sections and improve those with the greatest need.

Another example of potentially hazardous elements are spear-end guardrail terminals. Safety engineers recognize that treating only those spear-end guardrails that have experienced accidents does not truly solve the problem. Instead, system-wide replacements of these with safer devices (e.g., breakaway or flared ends) would more appropriately solve the problem. In conclusion, a review of the features and elements within a system is important so that the highway system can be improved to the greatest extent possible.

Accident data provide a valuable source of information for safety analysis and can provide valuable information for identifying high-accident locations, selecting appropriate accident countermeasures, and evaluating the effectiveness of completed projects and safety programs. Despite these advantages, accident data have certain weaknesses and limitations that must also be recognized, as discussed by Zegeer in a 1982 report (*6*):

1. Large variations exist among agencies in accident reporting thresholds (the minimum amount of vehicle damage, represented in dollars, that must occur before an accident is reported by police). This results in many property-damage-only accidents not entering the system. Therefore, these accidents are underrepresented in the accident data base.
2. Data errors and inconsistencies are sometimes found within the accident records themselves. For example, contributing circumstances, such as the presence of alcohol and other factors, may or may not be known by the officer who arrives on the scene of the accident.
3. Accurate location of accidents, particularly in rural areas, varies widely among state and local agencies. The location referencing methods may not be used properly. Also, many accidents are never reported to a specific location and, therefore, cannot be tied to a known point along the roadway.
4. In some states, it may take a year or longer for accident data to become available for analysis.
5. Many accidents are not caused by problems with the roadway environment, but may result from vehicle malfunction (e.g., brake failure), driver error (e.g., drunk driving), or severe weather (e.g., heavy fog, icy roads). These accidents may not indicate a treatable safety hazard at a given location.

Because of these and other characteristics, inventories of roadway hazards are needed with high-accident location lists to locate and correct all possible highway hazards.

One of the other factors that has made many highway agencies more sensitive to the need for identifying and correcting hazardous highway elements has been the recent increase in tort liability claims against public highway agencies. This increase has been caused, in part, by an erosion of sovereign immunity. Billions of dollars in tort claims are currently pending against highway agencies as a result of highway accidents. Many of these accidents resulted in severe injuries or death after a motorist struck such highway elements as trees, utility poles, culverts, or bridge abutments.

David C. Oliver, Office of Chief Counsel, Federal Highway Administration, makes this statement about tort liability and the obligations of highway managers (*7*):

> The overriding concept in the legal process with which highway management officials must be familiar is that there is a duty to maintain a roadway in a reasonably safe condition for an ordinary prudent driving public.

In terms of roadway defects or hazardous elements, Oliver stated (*7*):

> There are, however, certain basic elements of responsibility common to each action and foreknowledge of these elements is essential to the development of good management practices. The law requires an anticipation of defects. This in essence requires an efficient and almost continual system of inspection. It doesn't matter if the project is a construction, reconstruction or maintenance project, or if there is no project currently under way. The central element of modern-day highway management is the ability to know your system needs and requirements—because if you don't know your system you cannot take precautionary action nor even responsive action to system breakdown.

Oliver also stated that the courts in many cases consider generally accepted engineering practices and standards, such as the Manual of Uniform Traffic Control Devices (MUTCD), AASHTO standards, guidebooks, and other technical publications only as *minimum* specifications (*7*). The courts in some states consider the standard that applied at the time of last construction. Therefore, hazardous elements (as defined by current practice and standards) are usually eliminated whenever a roadway is reconstructed. The recent trend toward adverse judgments and higher settlements against highway agencies has increased the awareness of highway elements that may present a hazard to the motoring public. Information on minimizing tort liability is provided in NCHRP Synthesis 106 (*8*).

DEFINITION OF TERMS

Definitions of commonly used terms relating to highway elements and hazardous locations are:

- **Accident Potential**—Probability or chance of an accident event, based on the highway characteristics or condition.
- **Accident Surrogate**—An operational or physical feature of a highway site that has some logical relationship to accidents and that may be used as a substitute for or in place of accident experience.
- **Hazardous Highway Element**—A physical roadway feature that presents a risk of a severe injury on impact, an unusually high risk of an accident occurrence, or both.
- **Hazardous Location**—Highway spots, intersections, or sections with an abnormally high accident experience (frequency, severity, or rate) or with a high potential for accident severity or frequency based on characteristics of the site.
- **Highway Element**—Any physical roadway feature, obstacle, device, or condition that can be measured or inventoried. This includes pavement friction, intersections, railroad grade crossings, geometrics, roadside obstacles, and traffic control devices, and can be on or off the highway.
- **Highway Location Reference Method**—A technique for referencing highway points or segments with respect to a known point along the highway. This referencing can be done at a highway location or at an office.
- **Highway Safety Feature**—Any device or design feature outside of the roadway pavement surface that, when struck by a run-off-the-road vehicle, causes less damage than if the device or design feature had not been used.
- **Potential Hazard**—A highway feature with one or more characteristics that appear to present a hazard but that may or may not be indicative that a hazard truly exists.
- **Roadway Features Inventory**—A list of various highway characteristics for use in planning activities or in highway safety analysis. This list includes such characteristics as alignment, gradient, lane width, pavement width, surface condition, and location of traffic control devices, bridges and culverts, and potential hazards such as narrow bridges, steep roadside slopes, and rigid fixed objects close to the roadway edge.

CHAPTER TWO

WHAT IS A HAZARD?

Before identifying hazardous highway elements, a safety analyst must first have specific definitions of what is and is not hazardous. No universally accepted definition of "hazardous" exists. Instead, within an agency, past accident experience with an element or a combination of elements and engineering judgment commonly help determine what elements are considered hazardous and whether correction is necessary.

Some believe that a highway element is not a hazard until it is struck by a vehicle. However, one or more accidents do not necessarily mean that a site is deficient. Also, strong evidence suggests that many types of highway elements pose hazards, even if they are not struck very often.

The problem of defining hazardous elements is largely a question of degree of hazard. For example, a large oak tree may be a severe hazard if located within a foot of a sharp horizontal curve on a narrow paved roadway with no shoulder. A similar tree may be considered as having a low degree of hazard if located 50 feet from a wide roadway tangent section with wide, paved shoulders and a mild side slope. Similarly, a narrow bridge may pose a high degree of hazard if located near a sharp curve with no guardrail or delineation, but could be considered a low degree of hazard on a low-speed, tangent roadway with good sight distance, proper delineation, and adequate transition guardrail.

The degree of hazard of an element may be defined by the probability of that element being associated with an accident or injury. Thus, the likelihood of both accident *frequency* and accident *severity* must be considered. For example, a particular spear-end guardrail on a high-speed roadway may be struck an average of only once every 10 years, but each impact may cause a fatal or severe-injury accident. On the other hand, slippery pavement on a low-volume street, if not corrected, may cause numerous rear-end accidents of low severity.

The degree to which a *roadside object* may be considered hazardous is dependent on numerous factors, including:

- The type and rigidity of the obstacle.
- The distance from the obstacle to the roadway edge.
- The traffic exposure (the traffic volume that has an opportunity to strike the obstacle).
- Other roadway characteristics that interact with the obstacles (the type and condition of the roadway shoulder and side slope, roadway curvature, pavement width, roadway cross slope, etc.).

Thus, a combination of many roadway elements and conditions may affect the degree of hazard of a highway element.

FEATURES OF CONCERN TO STATE AND LOCAL AGENCIES

In the questionnaire, highway agency personnel were asked to give specific examples of hazardous highway elements. Responses are summarized in Table 1, which includes some groupings of similar or related elements.

The most frequent response was the narrow bridge element, including abutments, piers, and bridge approaches. Other elements mentioned by 12 or more agencies were deficient guardrail, sharp curves, restricted sight distances, fixed objects, utility and signal poles, inadequate signing, and trees.

Note that some responses were general in nature (e.g., fixed objects, obsolete geometric designs, etc.) and could include numerous specific elements. For example, the fixed-object category could include utility poles and trees and could be the largest response group. In other cases, however, the proper combinations may be more difficult to determine. Therefore, no attempt was made to seek further details or combine all related elements. For example, five responses indicated deficient bridge rail and connecting guardrail problems, but the responses were not listed with guardrail deficiencies or narrow bridges. This is because the bridge rail and guardrail may be a separate issue of concern to bridge and safety engineers.

Narrow shoulders (and shoulder dropoffs and dips) were mentioned by 11 agencies, although lane or pavement width was only mentioned by three respondents. Trees were eighth in frequency of response, even though trees are the most commonly struck roadside object in the nation's fatalities. Several agencies stated that they considered accident experience and citizens' complaints in determining hazardous roadway elements.

EXAMPLES OF POTENTIAL HAZARDS FROM THE LITERATURE

Opinions differ greatly on what highway features are hazardous or cause undue risk to the motoring public. What may be considered an extreme highway hazard to some people may be a normal condition of little concern to others.

Despite these inconsistent definitions of a hazard, many sources in the literature contain considerable information on highway elements of concern. Some publications describe certain elements as "hazards," "potential hazards," or "safety problems." Other publications (such as Ref. 9) provide an array of safety improvements for various roadway conditions (implying that such conditions are hazards or should be corrected for

TABLE 1

SUMMARY OF IDENTIFIED HIGHWAY ELEMENTS

Element	Number of Agencies		
	State	Local	Total
Narrow bridges, abutments, piers, and bridge approaches	27	5	32
Guardrail deficiencies	14	1	15
Sharp curves (poor vertical and/or horizontal alignment)	11	4	15
Fixed objects (roadside obstacles)	12	2	14
Sight distance restrictions (e.g., vegetation)	8	6	14
Utility and signal poles	10	3	13
Poor, inadequate, or nonuniform signing and posts	9	4	13
Trees	11	1	12
Narrow shoulders and shoulder drop-offs	10	1	11
Smooth, slippery pavements	9	1	10
Culverts, headwalls, drainage facilities	7	3	10
Steep side slopes, high fills, ditches	7	2	9
Substandard railroad crossings (e.g., no protection)	6	2	8
Deficient intersections (e.g., blind approaches)	5	3	8
Inadequate or worn pavement markings or delineation	3	4	7
Substandard geometrics	5	0	5
Deficient bridge rail and connecting guardrail	4	1	5
Substandard traffic signals or signal timing	3	2	5
Rough pavement surface (potholes, etc.)	3	2	5
Rigid mailbox supports	2	1	3
Lane drops and roadway discontinuities	1	2	3
Narrow lanes and pavement	3	0	3
Rocks	1	1	2
Barriers, fences, and stone walls	1	1	2
Obsolete geometric design	0	2	2
Poor superelevation	1	1	2
Nonuniform traffic control devices	0	2	2
Gore areas	2	0	2
Buildings	1	0	1
Lack of storage lanes	1	0	1
Traffic circles	1	0	1
Poor illumination	1	0	1
Dumpster boxes	1	0	1
Abandoned autos	1	0	1
Hydrants	0	1	1
Short tapers	0	1	1

safety reasons). For example, the 1982 Operations Manual of the Nevada Safety Engineering Division defines a hazardous (or potentially hazardous) location as: (a) a highway section where environmental or highway characteristics create hazards; (b) a point on the highway, such as a narrow bridge, a driveway entrance, or a place where a fixed object is immediately adjacent to the road pavement; (c) an intersection with another highway; (d) a rail-highway grade crossing; (e) a location that may require fence; and (f) a location with accidents involving guardrail.

In the following sections, a few examples of the literature sources that discuss roadway elements considered as hazards are summarized, including:

- The 1974 AASHTO Yellow Book ("Highway Design and Operational Practices Related to Highway Safety") (*4*);
- The 1977 FHWA "Maintenance and Highway Safety Handbook" (*10*);
- The 1983 edition of Florida's Highway Safety Improvement Program Manual (*11*);
- The Oakland County, Michigan Roadside Hazard Program (*5*);
- Railroad-Highway Grade Crossing Hazards (*12*).

Although there are many other documents that give examples of hazardous highway elements, the above sources discuss many types of commonly recognized features and potential hazards.

AASHTO Yellow Book

The 1967 version of the AASHTO Yellow Book (*4*) is intended to serve as a "guide to good practices," and contains AASHTO's recommendation to all highway and transportation agencies. It is a guide (not a rigid standard) and focuses primarily on high-speed roads (although the same principles are desirable on roads with speeds of 50 mph or below). The report discusses many topics related to enhancing safety with respect to roadway design, roadway appurtenances, traffic operations, construction and maintenance, and programming of safety improvements.

Numerous types of roadway elements are discussed along with hazards and recommended treatments, including (*4*):

- Roadway discontinuities—abrupt major changes in design speeds, transitions in cross-section, introduction of a short-radius curve in a series of longer-radius curves, a change from full to partial control of access, constrictions in roadway width caused by narrow bridges, intersections with inadequate sight distance, and other conditions.
- Narrow roadways—narrow lanes or no shoulders.
- Bridge deficiencies—bridge railing that is structurally inadequate and inadequate bridge width.
- Railroad-highway grade crossings.
- Low pavement skid-resistance properties. The four primary conditions mentioned as associated with poor pavement friction properties are worn or polished pavement, flushing or bleeding of bituminous materials, build-up of a film of water between the pavement and tires, and dirty pavements.
- Ramps—specific problems mentioned or implied in the publications were short auxiliary lanes in advance of exits, limited sight distance to the exit gore, ramps that "drop out of sight" (listed as a potential hazard), short entrance ramps, and others.
- Lane drops—the abrupt ending of a through lane at an exit. The Yellow Book states that, "these have been found to be very hazardous locations."
- Gore areas—the area between through lanes and exit ramps or at major lane splits, which have been the scene of many accidents. Specific problems include steep slopes, heavy sign supports, rigid light poles, curbs, and bridge components on elevated structures.
- Roadside obstacles—elements of roadside design that are cited as of particular concern are unyielding landscaping, drainage facilities, and unyielding highway hardware such as sign and luminaire supports and utility poles.
- Roadside slopes—problems include steep slopes, a sharp angle of break to a side slope and rock outcroppings.
- Median crossovers—these are mentioned as "... potential accident locations if used by the public."

• Roadside appurtenances—items mentioned in this category include unnecessary signs, large sign supports, obstacles in gore areas, guardrail installations (including end treatments and the need for transition to bridge rails), median barrier designs, impact attenuators to protect fixed obstructions, and highway lighting.

FHWA Maintenance Handbook

A 1977 publication by the Federal Highway Administration entitled the "Maintenance and Highway Safety Handbook" discusses and gives specific examples of highway defects, particularly those that may be corrected by maintenance practices (*10*). The general topics addressed in that publication, which may involve hazardous elements, include:

- Roadway pavements (skid and other pavement hazards)
- Roadway elements (shoulders, road approaches, median crossings, curbs, and other roadway hazards)
- Drainage
- Roadside (tree and brush, mowing, and trash and debris)
- Structures
- Guardrails and guideposts
- Highway signs and pavement markings

For these categories, many road problems and deficiencies are termed as hazardous or unsafe, while others are simply mentioned as being correctable by certain treatments. Although FHWA's use of the term hazardous is apparently based on subjective assessment, many of the examples could clearly create a danger for the motorist.

Roadway Pavements

The publication discusses several pavement conditions that "can slow traffic and add to travel hazards." Such conditions include potholes, pavement depressions, ruts, corrugations, shoving, frost heaves, bumps, slab settlements, bleeding asphalt, polished aggregates, and surplus roadway materials (e.g., gravel, dirt).

According to the publication, hazardous pavement slipperiness is caused by worn-out textured surface, polished surface aggregates, a collection of water in the tire-pavement contact area, asphalt bleeding in hot weather, or pavement contamination by oil spillage, mud, clay, loose aggregate, or other materials.

In addition to the pavement and skid hazards discussed above, the publication also mentions other pavement deficiencies (*10*):

- Improper patching (resulting in poor pavement surfaces).
- Failure to carry the surface overlay to the gutter line (could cause severe dropoff and wheel trap, and may block drainage).
- Nonuniform or incomplete pavement cross-section width (could create traffic hazards).
- High crown or improper superelevation (contributing to less vehicle control, particularly on horizontal curves).

Roadway Elements

Highway shoulders can contribute to highway safety by providing for emergency stopping, parking off the traveled way, temporary detours from maintenance areas, or as a recovery area for out-of-control vehicles. However, highway shoulders, under certain conditions, can also pose safety hazards. Such shoulder conditions mentioned include (*10*):

- Low shoulders
- Pavement dropoffs
- Raised ridges of grass and excess materials where water ponds
- Shoulder ruts
- Unstable and eroded shoulders

The lack of any shoulders on rural roads was also mentioned as associated with high accident potential on many roadways.

Road approaches, or highway access points, also occasionally create unsafe conditions where there are severe pavement dropoffs (e.g., at unpaved surfaces in the path of turning movements, and where loose aggregate or mud collects on paved intersections). Median crossings reportedly create problems where many unauthorized traffic movements occur.

According to the publication, other roadway elements of concern include (*10*):

- Curbs that are disintegrated, settled, misaligned, or covered with vegetation;
- Unrepaired and cluttered gore areas;
- Large rocks along the road side slope;
- Concrete bases for light fixtures;
- Road equipment parked next to the roadway.

Drainage

Lack of proper drainage can result in water collecting on the roadway surface and possibly severe erosion of the lane and shoulders. In turn, severe erosion can cause a deep dropoff next to the pavement edge, which can become a traffic hazard.

Roadside

Some of the more common roadside hazards cited in the FHWA publication include:

- Steep side slopes;
- Large trees or other unprotected obstructions close to the pavement;
- Improperly placed guardrail;
- Brush or high weeds that obstruct vision, particularly at intersections;
- Trash and debris.

Foliage, trees, and vegetation are mentioned as causing problems such as obstructing signs, blocking illumination, or reducing sight distance. The hazards of large obstacles (e.g., trees) close to the roadway are also mentioned, particularly with steep slopes (*10*).

The publication also mentions several potentially hazardous forms of trash and debris along the roadway including:

- Rocks or earth slides,
- Fallen branches,
- Articles dropped from vehicles, and
- Trash and debris on the road (including dead animals).

Structures

The authors discuss "typical hazardous conditions" that may be found during bridge inspections, including structural problems. Examples of safety problems that could contribute to bridge-related accidents include:

- Lack of warning signs and guardrail protection,
- Loose aggregate along bridge rail,
- Damaged bridge rail and guardrail, and
- Narrow bridge widths.

Guardrail and Guideposts

Possible safety problems mentioned relative to guardrail and guideposts are:

- Improper guardrail connections to the bridge structure,
- Non-crashworthy guardrail ends,
- Damaged guardrail or improper guardrail installation (i.e., improper height, weak parts, etc.), and
- Rigid reflectorized guideposts used as a replacement for guardrail.

Highway Signs and Pavement Markings

When the MUTCD standards are not followed, the following problems may occur with regard to various traffic control devices.

- Damaged signs.
- Unnecessary, unauthorized, or nonstandard signs.
- Rigid sign supports as opposed to breakaway supports.
- Dirty or damaged sign faces and delineators.
- Signs that become roadside obstacles because of misplacement.
- Inadequate delineators, hazard markers, and edgelines at narrow bridges.

Florida DOT HSIP Manual

The Florida DOT identifies hazardous elements by using its 1983 Highway Safety Improvement Program Manual (*11*). In this manual, the Florida DOT describes how to identify hazards. The manual also explains how to develop, implement, and evaluate a safety improvement project. To identify hazards, criteria are determined, based on accident data and field observations. Hazardous "elements" identified in the Florida manual include (*11*):

- Skid-Prone Locations—The manual gives the relative adequacy of friction numbers.
- Other Cross-Section and Pavement Deficiencies—Some of the possible deficiencies mentioned as worthy of consideration are (*11*):
  - Shoulder dropoffs of more than three inches.
  - Evidence of water in traffic lane.
  - Build-up of water on the highway shoulder.
  - Rutted shoulder.
  - Serious erosion of ditches or side slopes.
  - Nontraversable ditch sections.
- Inadequate Signing and Pavement Markings—Highway deficiencies that have "accident-causing potential," as listed in the manual are (*11*):
  - Traffic queues that extend beyond signs that warn of lane drops or exclusive lane use.
  - Routing signs that are not far enough from traffic queues to allow for decision making and nonconflicting lane manuevers.
  - Route markers that do not direct a driver through an urban area continuously (this may create driver indecision).
  - Signs that are blocked by vegetation, other signs, bus stop benches, etc.
  - Too many signs for drivers to comprehend.
  - No advance warning signs when needed for stop signs.
  - Pavement markings not visible at night when drivers use low beams.
  - Incorrect color codes on markings.
  - Incorrect marking patterns.
  - Hazards in the roadway that are not delineated.
  - Worn rumble strips.
- Highway Safety Features—A list of "common" deficiences relative to highway safety features and maintenance inspection that should be recognized in the field is in the Florida DOT Manual and includes guardrail and barriers (height, location, assembly, etc.); signs (location, breakaway features, etc.); crash cushions (number of units, damage, location, etc.); traffic signals (location, clearance, displays, etc.); luminaires (bases, wiring); and drainage structures (location, operation).
- Rail-Highway Grade Crossing Hazards—Locations are also identified as hazards based on data collected in the U.S. DOT-AAR Rail-Highway Crossing Inventory. This is used to prioritize locations based on a mathematical accident prediction model. The procedure allows each grade crossing to be rated on a scale from 0 to 90. If a crossing receives a safety index of 70 or greater, it is considered safe.

Oakland County Roadside Hazard Program

The Oakland County (Michigan) Road Commission identifies hazardous elements on its roadway system by using a computerized priority program (*5*). This program uses a roadside inventory to rank hazards according to their need for removal, repair, or protection. A weighting scheme ranks obstacles by the degree of hazard based on the following criteria:

1. Whether or not the roadway is curbed.
2. The presence of horizontal curves (inside or outside).
3. The presence of vertical curves (positive or negative grade).
4. The rigidity of the object.
5. Average daily traffic (ADT).
6. Speed limit.
7. Distance from pavement edge.
8. Roadway type (county primary, local, etc.).

The factors (1 to 5) for rigidity of the object, given in Table 2, are taken from a 1979 publication by Horodniceanu and Cantilli (*13*). For each of the eight criteria, a hazard rating (from 0 to 5 points) was assigned based on in-house determination by the Oakland County Road Commission, as summarized in Table 3.

TABLE 2

SEVERITY FACTORS FOR FIXED OBJECTS OF VARYING RIGIDITY (*13*)

FIXED OBJECT	FACTOR
Utility Poles (wood)	4
Supports - Rigid (steel)	4
Supports - Breakaway	1
Guardrail	3
Bridge Abutment/Wall Face	3
Bridge Abutment & Pier End	5
Bridge Rail Faces	1
GM Barrier	1
Bridge Rail End	5
Fill Slopes	
2:1	5
3:1	4
4:1	3
5:1	2
6:1	1
Cut Slopes	
.5:1 - 1:1	5
1.5:1	4
2:1	3
3:1	2
4:1 or flatter	1
Hydrant	3
Signposts	1
Trees (diameter)	
Greater than 13"	5
11" - 12"	4
8" - 10"	3
5" - 7"	2
2" - 4"	1
Rocks & Boulders (diameter)	
Greater than 3'	5
2' - 3'	4
1' - 2'	2
Less than 1'	1
Steel beams, concrete posts, etc.	3
Wood posts	
8" x 8"	2
6" x 6"	2
4" x 4"	1
Guy Wire	3
Wood Posts	
6 x 8" guardrail	2
7" round marker post	2

An overall *priority factor* was then defined for each of these criteria using the following weighting scheme:

Curbing = 2
Curve section (outside) = 5
Curve section (inside) = 3
Upgrade section = 3
Downgrade section = 4
Rigidity = 5
Average daily traffic = 5
Speed limit = 3
Distance from pavement edge = 5
Roadway type = 2

The priority factor (PF) is calculated from the hazard ratings and the corresponding weighting factors, as follows (*5*):

$$PF = \sum_{i=1}^{n} H_i V_i$$

or

$$PF = H_1V_1 + H_2V_2 + H_3V_3 + H_4V_4 + H_5V_5 + H_6V_6 + H_7V_7 + H_8V_8 \quad (1)$$

where

V_1 = Curb rating,
V_2 = Curve rating,
V_3 = Grade rating,
V_4 = Rigidity rating,
V_5 = Average daily traffic rating,
V_6 = Speed limit rating,
V_7 = Distance from pavement edge rating,
V_8 = Roadway type rating, and
H_1 .... H_8 = Corresponding weights (as described earlier).

Thus, greater relative hazard corresponds to higher priority factors.

The Oakland County Road Commission primarily uses this system for its tree removal program. It is also used to determine obstacle removal needs for construction projects and also as a research tool. A sample printout is shown in Figure 3.

Railroad-Highway Grade Crossing Hazards

Like many other types of highway elements, railroad-highway grade crossings typically are not associated with high accident frequency. However, collisions between trains and highway vehicles are usually quite severe and often result in fatalities or severe injuries to motor vehicle occupants. Thus, some crossing locations may be considered as serious hazards if the conditions present the potential for only one or two accidents each year.

Many highway agencies have developed programs to compute a hazard index for each railroad crossing location. The index may or may not include consideration of past accidents. For example, the New Hampshire formula computes the Hazard Index as the product of average 24-hour traffic volume, average

TABLE 3

SUMMARY OF HAZARD RATINGS FOR VARIOUS ROADWAY CONDITIONS (*5*)

	HAZARDOUSNESS RATINGS					
CRITERIA	0	1	2	3	4	5
Curbed or Uncurbed		Curbed	Uncurbed			
Curve Section	Straight	1^o - 5^o	6^o - 10^o	11^o - 15^o	16^o - 20^o	21^o over
Grade Section	Flat	1% - 3%	4% - 6%	7% - 9%	10% - 12%	13% - over
Rigidity		SEE TABLE 1				
Average Daily Traffic		1000 or less	1001-8000	8001-15000	15001-20000	20,000 or greater
Speed Limit		25	30 - 35	40 - 45	50	55
Distance from Pavement edge	Greater than 30 ft.	30' - 21'	20' - 11'	6' - 10'	3' - 5'	2' or less
Roadway Type		Subdivision	Collector Subdivision		Local	Primary

24-hour train volume, and a protection factor (*14*). The Utah formula involves a mathematical expression containing 14 different variables. The Maryland Department of Transportation uses the TSC (Transportation Systems Center) Method, which provides for predicting the expected number of accidents per year for crossings with various classes of warning devices (stop signs, crossbucks, flashing lights, etc.). The prediction is based on the number of trains per day, the number of cars per day, the number of through trains per day, the number of main tracks, whether the road is paved or not, the functional classification of the road, and the number of traffic lanes.

SELECTION OF HAZARDOUS ELEMENTS

Elements to be considered hazardous must be carefully determined by each highway agency for purposes of identification and treatment. The decision should be based on information from several sources, such as:

- Highway design standards [AASHTO (*15*) and state standards].
- The MUTCD (*16*).
- The AASHTO Yellow Book (*4*).
- The AASHTO Barrier Guide (*9*).
- Information from reliable research studies (every research study should not be accepted at face value, because many have serious flaws and limitations).
- The elements found by the agency to be associated with high frequency or severity of accidents within its own jurisdiction.

It should be noted that an element that violates some type of standard or guideline does not necessarily present a safety hazard.

Examples of some potentially hazardous highway elements are given in Figures 4–40. These do *not* include all possible hazards, but only illustrate situations that some have considered as potential hazards along with high-accident locations for possible improvement. The following is a random list of some of these hazards, based on information from the literature and agency survey responses:

- Slippery pavements (from low friction numbers, snow or ice on pavement, debris or oil on road, etc.).
- Rigid drainage structures.
- Concrete or rigid bridge abutments.
- Rigid supports for signs, luminaires, and signals.
- Large rocks or rock walls close to the roadway (particularly along winding roads).
- Large trees next to roadway.
- Utility poles near roadway.
- Improperly placed urban street furniture (plant boxes, benches, etc.).
- Rigid rural mailboxes.
- Locations where large animals often cross the road (deer, cattle, etc.)
- Fire hydrants.

OAKLAND COUNTY ROAD COMMISSION OBSTACLE REPORT
TIA750BR 03/22/82

MAIN STREET NAME - GAGE RD
PRIMARY ROAD NUMBER =0651310

WEIGHTING: CURB=2 CURV-O=5 CURV-I=3 +GRADE=3 -GRADE=4 RIG=5 ADT=3 SPDLIM=3 DISTPV=5 RTYPE=2

SEQUENCE	OBSTACLE LOCATION: CROSS STREET	DIST & DIR	MILE POINT	SIDE OF ST	CRB	ROADWAY CHARACTERISTICS: HORIZONTAL GEOMETRICS	VER GEO	RIG	ADT	SPEED LIMIT	DIST PVMT	ROAD TYPE	OBSTACLE CODE	PRTY FACTR
03387900	OAKLAND CITY LI	110 E	0.02	NORTH	U		+03	1	131	U40	5	LOC	TREE2	52
03388000	OAKLAND CL	256 E	0.05	SOUTH	U		-01	1	131	U40	3	LOC	SPOST	53
03388100	OAKLAND CL	309 E	0.06	SOUTH	U		-01	1	131	U40	2	LOC	TREE2	58
03388200	OAKLAND CITY LI	331 E	0.06	NORTH	U		+03	3	131	U40	6	LOC	TREE8	57
03388300	OAKLAND CL	304 E	0.06	SOUTH	U		-01	1	131	U40	3	LOC	TREE2	53
03388400	OAKLAND CL	336 E	0.06	SOUTH	U		-01	1	131	U40	1	LOC	SPOST	58
03388500	OAKLAND CL	341 E	0.06	SOUTH	U		-01	3	131	U40	0	LOC	GUARDR-BEG	68
03388600	OAKLAND CL	294 E	0.06	SOUTH	U		-01	1	131	U40	3	LOC	TREE2	53
03388700	OAKLAND CITY LI	374 E	0.07	NORTH	U		+03	3	131	U40	1	LOC	GUARDR-END	67
03388800	OAKLAND CITY LI	399 E	0.07	NORTH	U		+03	1	131	U40	1	LOC	SPOST	57
03388900	OAKLAND CITY LI	394 E	0.07	NORTH	U		+03	3	131	U40	1	LOC	GUARDR-BEG	67
03389000	OAKLAND CL	356 E	0.07	SOUTH	U		-01	3	131	U40	0	LOC	GUARDR-END	68
03389100	OAKLAND CL	414 E	0.08	SOUTH	U		-01	2	131	U40	7	LOC	WOOD POST	53
03389200	OAKLAND CITY LI	475 E	0.09	NORTH	U		+03	1	131	U40	1	LOC	SPOST	57
03389300	KURTZ RD	508 W	0.12	SOUTH	U			1	131	U40	10	LOC	TREE2	44
03389400	KURTZ RD	440 W	0.14	SOUTH	U			4	131	U40	10	LOC	TREE11	59
03389500	KURTZ RD	382 W	0.15	SOUTH	U			5	131	U40	9	LOC	TREE13	64
03389600	KURTZ RD	302 W	0.16	SOUTH	U			1	131	U40	8	LOC	TREE2	44
03389700	KURTZ RD	241 W	0.17	NORTH	U			1	131	U40	7	LOC	TREE2	44
03389800	KURTZ RD	198 W	0.18	NORTH	U			4	131	U40	12	LOC	TREE11	54
03389900	KURTZ RD	196 W	0.18	SOUTH	U			4	131	U40	7	LOC	TREE11	59
03390000	KURTZ RD	171 W	0.19	SOUTH	U			3	131	U40	5	LOC	TREE8	59

FIGURE 3 Sample output from Oakland County roadside hazard abatement program (5).

- Trash and abandoned vehicles next to roadway.
- Narrow tunnels, particularly in conjunction with horizontal curves.
- Rigid overpass supports or bridge piers.
- Buildings near road or street.
- Spear-end guardrail or inadequate guardrail (too low, structurally inadequate).
- Gore areas with rigid obstacles or steep slopes.
- Narrow bridges with restricted sight distances or near horizontal curves.
- Bridges that are structurally deficient.
- Railroad grade crossings, particularly on high-speed roads with restrictive geometrics and inadequate motorist warning.
- Sight-distance restrictions caused by severe horizontal curvature, steep grades, or foliage near road.
- Rough or uneven pavement surface.
- Rigid barriers, stone walls, and fences.
- Intersections that are hidden, that have multiple (i.e., 5 or more) approaches, or that have restricted sight distances.
- Sharp horizontal curvature, particularly with narrow roadways and little or no roadside recovery area.
- Points of intersection between the paths of auto traffic and other highway users (bicyclists, pedestrians, etc.).
- Shoulder or pavement dropoff.
- Narrow lanes and shoulders, particularly in conjunction with sharp curvature, cluttered roadside, and steep side slope.
- Roadway discontinuities (lane drops, change from two-way to one-way roads, drastic change in roadway cross-section, etc.).
- Numerous driveways, particularly on high-speed or high-volume roadways.
- On-street parking too close to intersections or on narrow streets.
- Construction zones.
- Combinations of elements (e.g., narrow lanes and no shoulders at sharp curve locations with steep side slopes and numerous rigid roadside obstacles).
- Inadequate illumination.
- Steep grades.
- Steep roadside slopes.

- Short tapers and/or lack of turn lanes.
- Improper signing, delineation, or signal timing.
- Traffic circles.

Many other hazards or potential hazards could be added to this list, depending on the locational and area-wide features. For example, a 10-degree curve may be considered as a hazard in areas with predominately flat terrain, whereas it may be considered mild and little problem in mountainous states. Also, a traffic signal may be difficult to see at night because of placement and/or low contrast with surrounding background illumination.

FIGURE 4 Unprotected concrete bridge parapet.

FIGURE 5 Steep roadside slope.

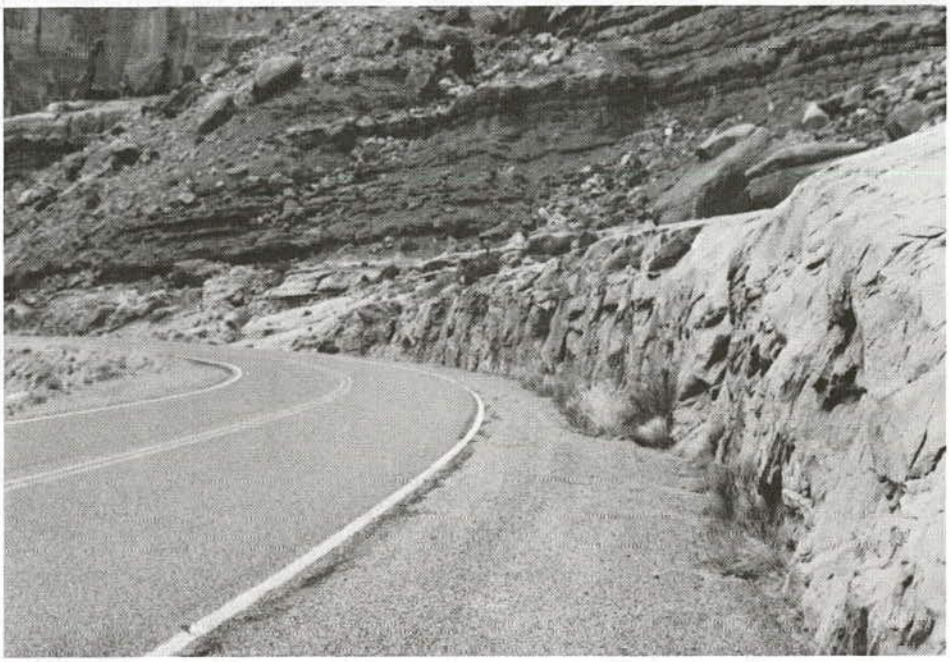

FIGURE 6 Rock cut on horizontal curve.

FIGURE 7 Large trees near roadway.

FIGURE 8 Utility poles near street.

FIGURE 9 Mailbox.

FIGURE 10 Fire hydrants and light poles.

FIGURE 11 Trash and abandoned vehicles.

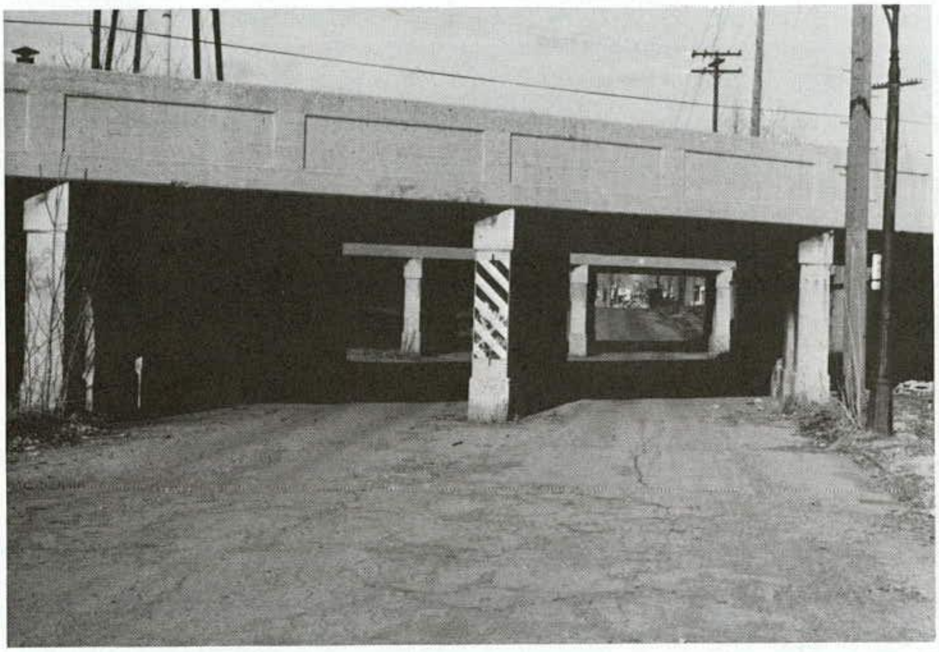

FIGURE 12 Rigid overpass supports.

FIGURE 13 Rigid drainage structure.

FIGURE 14 Rigid barrier.

FIGURE 15 Parked cars blocking intersection.

FIGURE 16 Building near street.

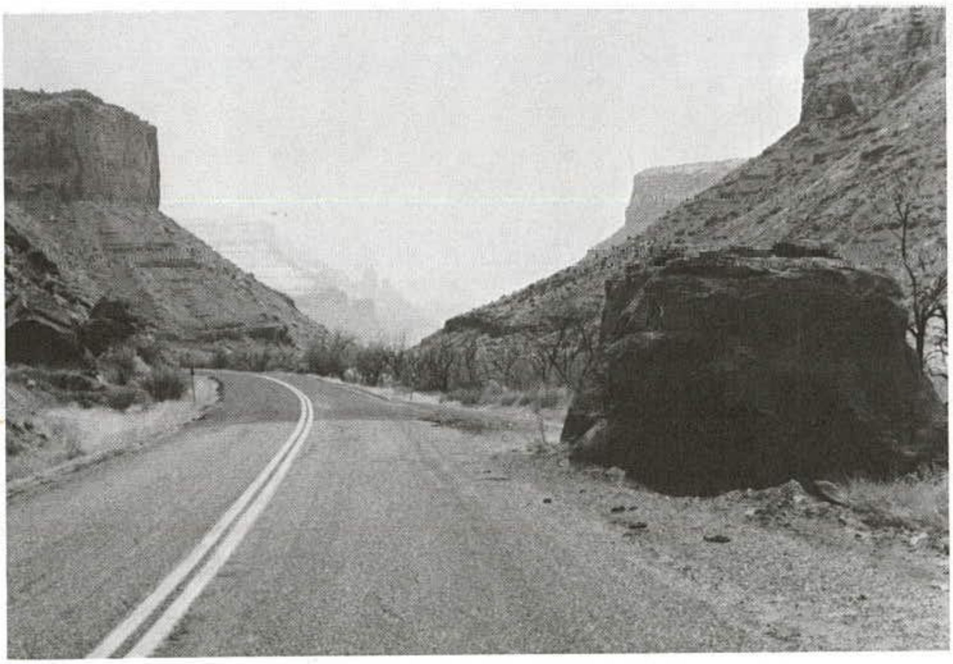

FIGURE 17 Other rigid point obstacles.

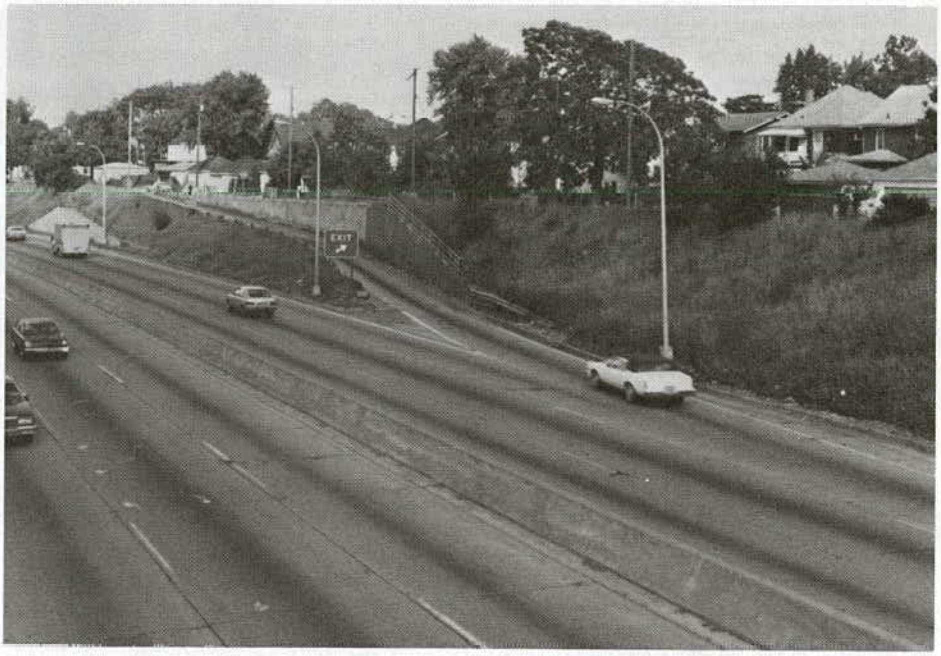

FIGURE 18 Non-clear gore area.

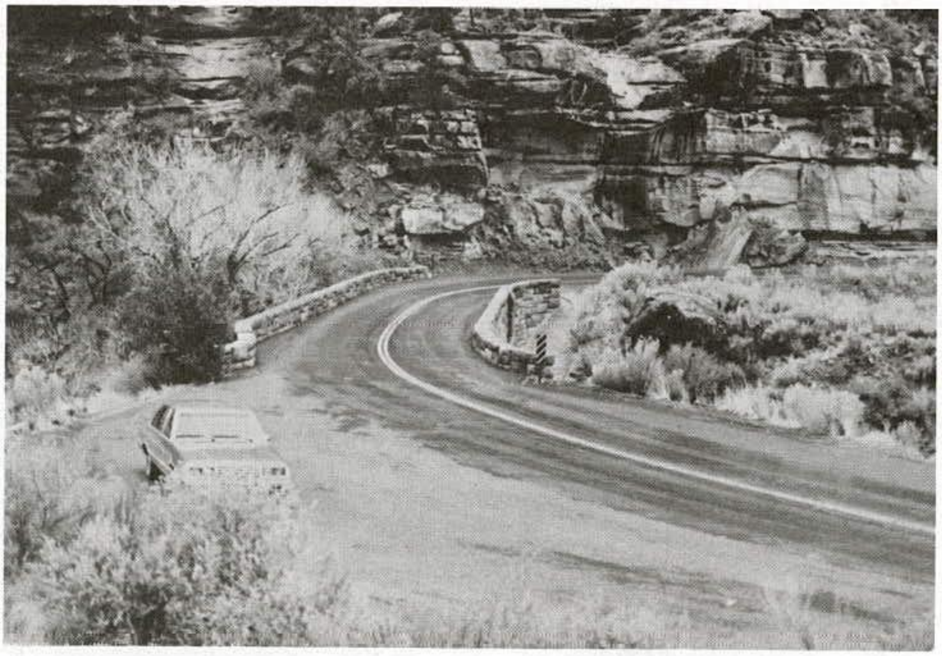

FIGURE 19 Narrow bridge on curve.

FIGURE 20 Bridge with limited structural stability.

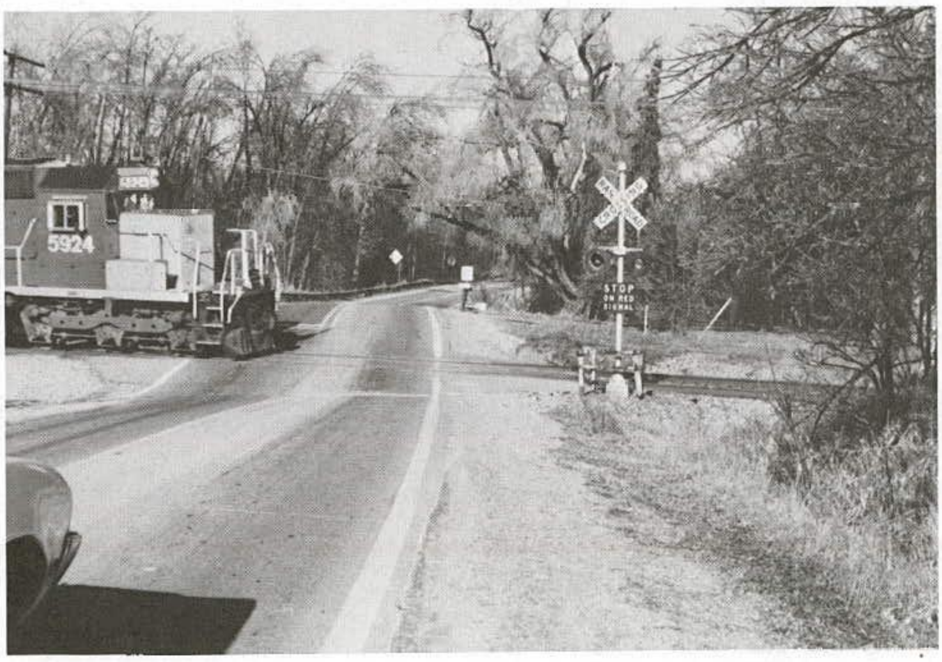

FIGURE 21 Rail-highway grade crossing.

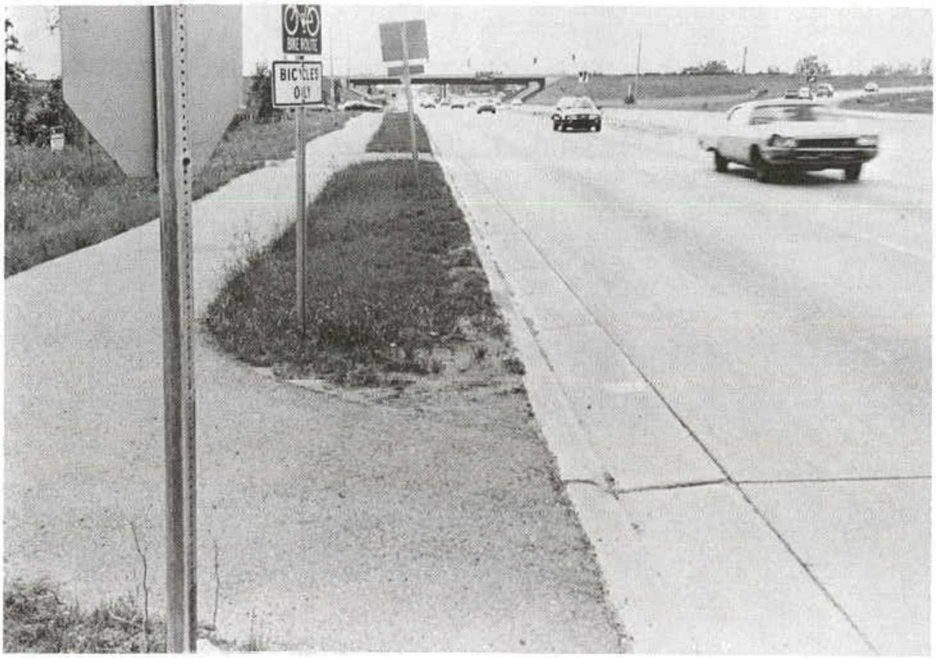

FIGURE 22 Intersection of highway and bike path.

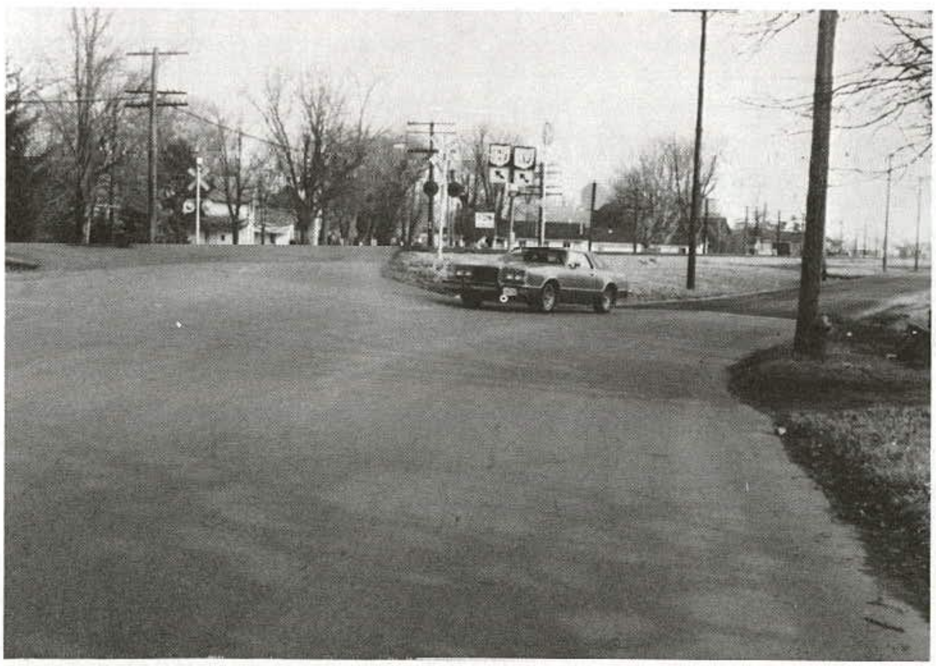

FIGURE 23 Potential intersection hazard.

FIGURE 24 Sight distance restriction.

FIGURE 25 Rough pavement surface.

FIGURE 26 Severe horizontal curvature.

FIGURE 27 Rigid sign and signal supports.

FIGURE 28 Steep grade.

FIGURE 29 Icy pavement.

FIGURE 30 Narrow tunnel on curve.

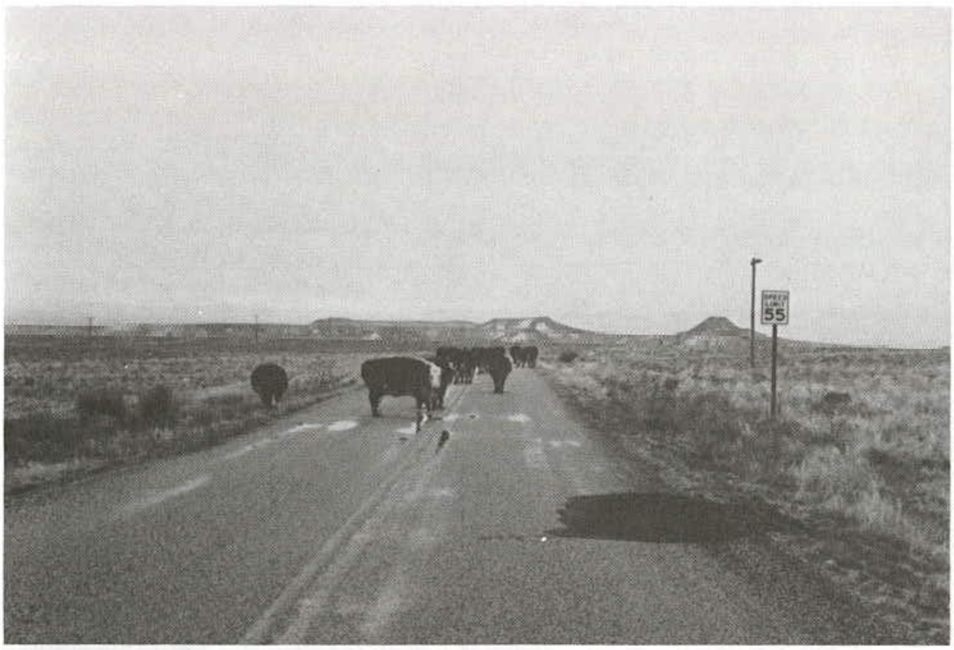

FIGURE 31 Animal hazards.

FIGURE 32 Low guardrail.

FIGURE 33 Pavement dropoff, tree, and steep slope.

FIGURE 34 Narrow roadway.

FIGURE 35 Unsafe guardrail ends.

FIGURE 36 Roadway discontinuity.

FIGURE 37 Driveways.

FIGURE 38 Debris on road.

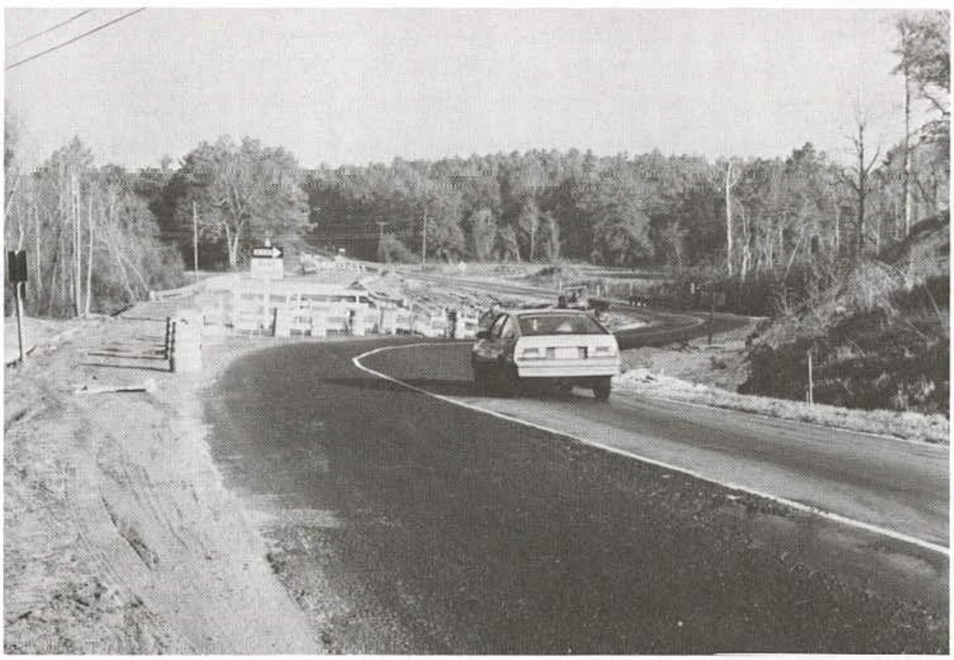

FIGURE 39 Construction zone.

FIGURE 40 Combination of potentially hazardous elements.

CHAPTER THREE

METHODS FOR IDENTIFYING HIGHWAY ELEMENTS

METHODS OF IDENTIFICATION

For an agency to properly treat hazardous elements, a conscious effort must be made to inventory these elements on a routine basis.

The practices by which highway agencies identify hazardous elements may be summarized in five general categories. The categories are given in Table 4. Note that for the 40 state agencies and 17 local agencies responding to the survey, more than one category applied in many cases. Of the 57 agencies (state and local) responding, 45 (79 percent) claim to inventory one or more types of roadway element in terms of a formal inventory (i.e., an inventory in which one or more predetermined data items is collected and updated on a routine basis). It is interesting to note, however, that 20 state agencies and 8 local agencies stated that roadway elements are *only* identified if they have high-accident experience. More commonly, agencies try, at least, to be aware of hazardous elements observed along the roadway (42 agencies). Eighteen agencies went a step further by making routine field inspections, which implies a conscious and planned effort to address hazardous elements.

Eighteen agencies pre-define roadway elements that may be hazardous before conducting routine field inspections. Of these 18 agencies, 8 inventory only those features considered to be deficient.

There are 31 state agencies and 14 local agencies that maintain some sort of routine inventory of roadway elements. More than 30 different highway elements are inventoried by state and local agencies, as summarized in Table 5. Of those agencies responding, the elements most commonly inventoried are narrow bridges (40 agencies), railroad grade crossings (38 agencies), number of lanes (32 agencies), slippery pavements (29 agencies), and roadway signs (28 agencies).

In addition to indicating the highway elements inventoried, agency personnel were also asked for the priorities they placed on highway elements. Thus, regardless of whether routine inventories existed or not, a summary was made of the highway elements rated as high or medium priority for identification purposes. The 12 most frequent *state* agency responses were:

1. Narrow bridges (32 states).
2. Railroad grade crossings (31 states).
3. Sight distance deficiences (29 states).
4. Slippery pavements (28 states).
5. Rough pavements (26 states).
6. Pavement markings and delineation (25 states).

TABLE 4

AGENCY PRACTICES RELATIVE TO IDENTIFYING HIGHWAY ELEMENTS

Typical Practice	Number of Agencies State	Local	Total
Elements are not identified unless they have high-accident experience.	20	8	28
No routine procedure is used to identify hazardous elements. However, if obvious roadway deficiencies are seen along the roadway by a safety engineer, maintenance worker, police officer, etc., they are considered for improvement.	32	10	42
Routine field inspections are made of the roadway system, although inspectors have no specific elements in mind before the inspection.	9	9	18
Routine field inspections are made of the roadway system. Specific predefined roadway elements are reviewed in these inspections.	13	5	18
Among these agencies, no formal inventory of roadway elements is made except those found to be deficient.	5	3	8
One or more types of roadway elements are routinely inventoried, such as signs, roadside obstacles, signals, pavement markings, bridges, etc.	31	14	45

7. Roadway signs and supports (25 states).
8. Guardrail and other barriers (25 states).
9. Existence/lack of turn lanes (22 states).
10. Bridge rails (21 states).
11. Shoulder dropoffs (21 states).
12. Dangerous gore areas (21 states).

The top priorities for element identification by *local* agencies were:

1. Pavement markings and delineation (14 agencies).
2. Railroad grade crossings (12 agencies).
3. Narrow bridges (11 agencies).
4. Roadway signs and supports (11 agencies).
5. Sight-distance deficiencies (11 agencies).
6. Sharp horizontal alignment (10 agencies).
7. Guardrail and other barriers (8 agencies).
8. Drainage facilities (8 agencies).

Personnel from the six foreign agencies also responded in regard to their basic methods for identifying hazardous elements. In Japan, 430 different roadway elements are reportedly inventoried (such as rutting, unstable stones on slopes, and surface drainage systems) and any types of deficient elements may be selected for possible improvement. In the two South African provinces and Saskatchewan, Canada, elements are primarily identified based on high-accident experience, although elements are also occasionally identified as deficient through routine inspections. In New Brunswick, routine inspections are conducted of highway elements such as lights, drainage structures, roadway surfaces, shoulders, signs, roadway features, snow and ice conditions, and traffic services.

METHODS OF COLLECTING INVENTORY DATA

Hazardous elements are identified by many types of inventory methods. The methods an agency uses depend on the agency's size, resources, and needs. When selecting inventory methods, the advantages and disadvantages of each method should be carefully weighed. The four procedures most commonly used by state, county, and local agencies are (*17*):

- Manual methods
- Photologging
- Videologging
- Automated or semi-automated devices

TABLE 5

HIGHWAY ELEMENTS THAT ARE INVENTORIED AND IDENTIFIED

	Number of Agencies			
	Element Is Included in Inventory File		Element is Medium or High Priority for Identification Purposes	
Element	State	Local	State	Local
Narrow bridges	30	10	32	11
Bridge rails	16	5	21	7
Roadside obstacles	3	3	18	7
Illumination	6	7	9	4
Superelevation and crown	3	3	12	3
Number of lanes	24	8	17	7
Existence or lack of turn lanes	8	6	22	7
Shoulder type and curb	21	2	17	3
Slippery pavements	28	1	28	4
Rough pavements	18	0	26	4
Railroad grade crossings	29	9	31	12
Guardrail and other barriers	8	3	25	8
Steep roadside slopes	4	0	14	4
Narrow lanes and shoulders	17	1	20	5
Shoulder drop-off	2	0	21	5
Unprotected overpasses	5	2	19	2
Sharp horizontal alignment	11	3	19	10
Steep grades	9	1	11	6
Gore areas	4	2	21	2
Drop lanes and discontinuities	8	2	18	7
Pavement markings/delineation	9	12	25	14
Roadway signs and supports	15	13	25	11
Pedestrian and bicycle facilities	3	4	9	7
Sight distance deficiencies	7	1	29	11
Drainage facilities	3	5	18	8
Combination of elements	3	0	15	5
Surface type	1	0	0	0
Bridge load limits	1	0	0	0
Rut depth	0	0	1	0
Vibrations	0	0	1	0
Approaches	0	0	1	0

Manual Methods

Manual methods involve one or more persons using various measuring devices to record features along a roadway section. Most manual methods involve the use of a vehicle equipped with a distance-measuring device, prepared data-collection forms, and devices such as a tape measure and measuring wheel. Manual methods have few equipment requirements, but may be quite labor-intensive. Most agencies still use manual methods for some types of routine data collection on their highway system, because these methods provide personnel with the opportunity for visual inspection. Some types of data variables, such as side slopes and location of drainage facilities, cannot be collected adequately by photologging or videologging, therefore manual methods are commonly used.

Photologging

Photologging involves taking a series of photographs of a roadway section at equal intervals (e.g., 100 frames per mile). This is done in a specially instrumented vehicle as it is driven along the road. These vehicles are equipped with a dual-lens camera system. The primary lens views the highway while the secondary lens records additional information, such as the date, description, direction, and mile point. A comprehensive discussion of photologging techniques is given in NCHRP Synthesis 94 (*18*). A typical photolog-equipped vehicle is shown in Figure 41 (*18*).

Photologs can provide an agency with information about the location, description, and condition of a highway element or feature. To determine the location, a grid or reference line must be used to obtain distance measurements from the camera. Such grids have been used for measuring lateral placement of utility poles and other roadside objects (*19*). Such grids can also help determine the heights of signs and longitudinal distances.

Photologging may be classified as first generation or second generation. First generation involves the filming of locational information, date, time, and direction information on the film. Second generation photologging includes additional roadway information on the film, as gathered by special instrumentation in the vehicle. Information such as pavement roughness, curvature, and grade may be collected and recorded on magnetic tape. It should be noted that use of photologging (or videologging) by an agency does not necessarily imply that data collected on hazardous highway elements are being used for locating roadway hazards.

Although photolog film has traditionally involved the use and storage of 35-mm film, the Connecticut Department of Transportation has made use of laser videodiscs, computer graphics, and a personal computer to maintain its photolog library as part of its maintenance management system. The photolog film for the 4,000-mile highway system and 600-mile rail system corresponded to more than 920,000 frames or 660 reels of photolog film but was transferred to only 15 laser videodiscs.

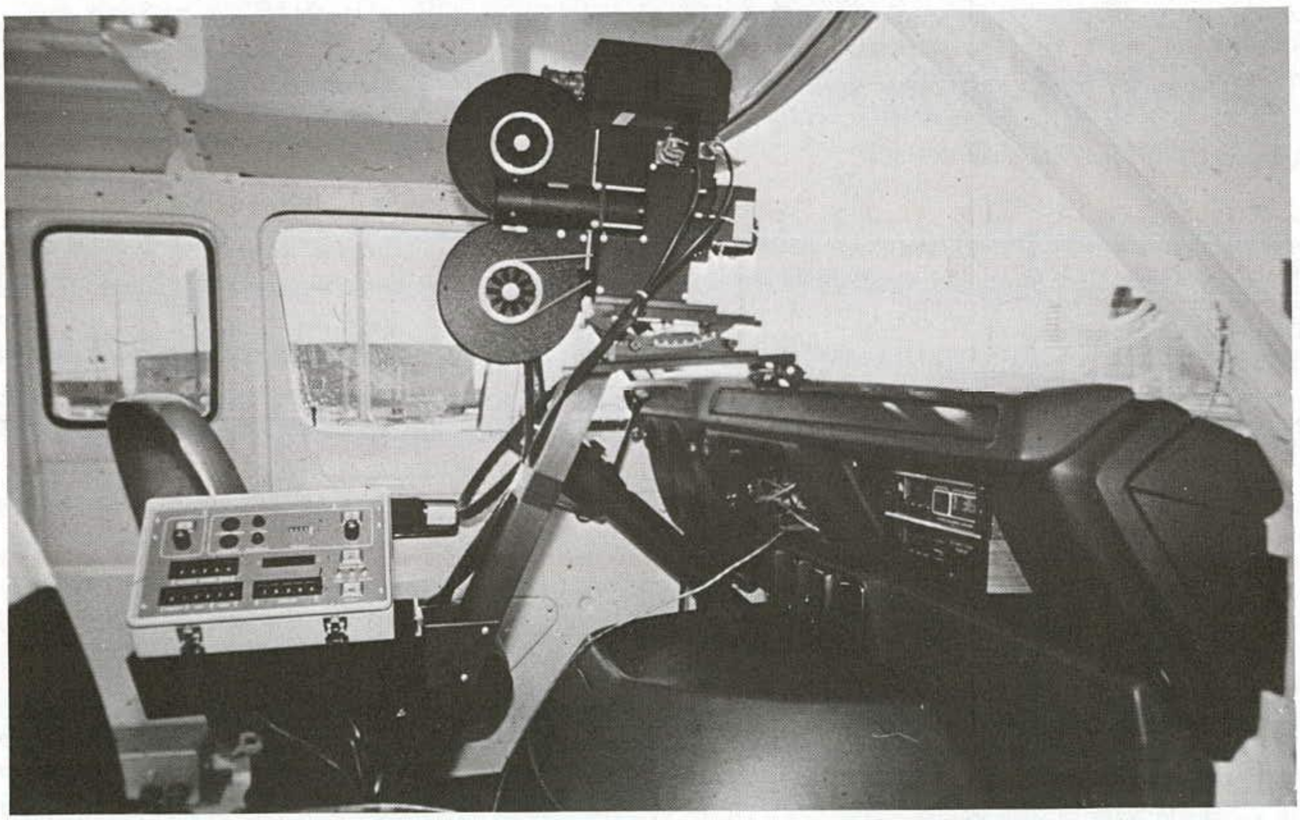

FIGURE 41 Photolog van and equipment (*18*).

The advantage of laser videodiscs include: (a) denser information storage, (b) fast random access, and (c) greater physical durability. Each side of the laser videodiscs resemble 12-inch phonograph records, but can store up to 54,000 frames of 35-mm film on each side. A laser videodisc player connected to a microcomputer is capable of searching to any of the 54,000 frames on a side of the disc in less than 3 seconds. Using the laser discs, film images can be enhanced, and zoom-in versions of the road are also possible for more detail. Also, graphic overlays including information about location, road roughness, engineering functions, etc. can be turned off and on (*20*). The major disadvantage is that the first (master) disc is expensive, but duplicates are less than $25.

Videologging

Like photologging, a videologging system is operated from a specially equipped vehicle as it is driven along the roadway. The vehicle is equipped with a video camera, video recorder, distance-measuring device, information display, and monitor. Some systems also include audio equipment so that personnel can record information orally.

Although videologging provides a more continuous picture of a roadway section, videotape does not typically provide as sharp a picture as photologs (although modern video cameras continue to be improved and videotape now approaches the visual quality of 35-mm film). Also, high-quality videologging equipment may be more expensive than photologging equipment. However, advantages of videologging are that (a) it can be reused, (b) it does not require processing, and (c) it can provide audio information. Some agencies (e.g., Washington State) have switched from photologging to videologging for highway inventory and monitoring purposes.

Automated and Semi-Automated Methods

Automated and semi-automated methods have been developed to enhance the collection and recording of hazardous elements. Using these methods, information can be automatically collected and stored by electronic or microprocessing equipment. These methods can be categorized as follows (*17*):

- Microcomputer recording systems, such as those used for obtaining inventories of signs, roadside obstacles, cross-sectional characteristics, etc.
- Pavement inventory systems, such as those used to measure skid resistance, structural integrity, and roughness/rideability of the pavement surface.
- Change sensing systems, such as those used to measure vertical and horizontal alignment.

Automated and semi-automated methods are often used to supplement manual, photolog, or videolog methods. They are particularly useful in collecting data on (*17*):

- Degree of curvature (horizontal alignment).
- Vehicle speed.
- Friction factors and skid resistance.
- Roadway roughness.
- Vertical alignment and clearance.
- Elevation and grade.
- Cross-section features.
- Pavement and subsurface conditions.
- Existence of underground utilities.
- Roadside or right-of-way features.

Uses of Data Related to Highway Elements

Of the four data-collection methods discussed above, manual surveys are most commonly used for collecting data for highway elements (used by 47 of the 57 responding agencies) as summarized in Table 6. However, photologging is used by 22 agencies for this purpose, while 2 agencies used videologging and 7 agencies used electronic equipment. Manual field surveys and photolog methods are both used in Japan, in one of the South African provinces, and in New Brunswick, Canada. Alberta, Canada uses a minimal amount of videologging, along with manual field surveys.

Computer files are used in 30 states and 10 local agencies for storing data on highway elements. Paper filming systems are used by 27 agencies, while 16 agencies use maps and other storage methods. Note that some states use more than one method for data collection and data storage. One South African province and Japan use a combination of computer inventory files, file cabinets, and maps for data storage. Alberta, Canada uses computer and file cabinet storage. In New Brunswick, Canada the following techniques are used for the storage of inventory data:

- Computer inventory files (for accident data and road surface traction),
- File cabinets (for most of the roadway inventory data).
- Maps (for signs and pavement markings),
- Photographs (for bridges, culverts, road surface conditions, and other elements),

TABLE 6

DATA-COLLECTION AND DATA-STORAGE METHODS USED BY STATE AND LOCAL AGENCIES FOR HIGHWAY ELEMENTS

	Number of Agencies		
Item	State	Local	Total
Data Collection Methods			
Manual field surveys	34	13	47
Photolog film	17	5	22
Videolog	2	0	2
Electronic equipment	6	1	7
Data Storage Methods			
Computer files	30	10	40
File cabinets	17	10	27
Maps	5	9	14
Other	0	2	2

- Binders (for data from bridge inspections), and
- Inventory cards (for some highway inventory data).

TYPES OF INVENTORIES

Numerous types of inventories are used by state and local agencies relative to highway elements. Examples of common inventory types include:

- Sign Inventories
- Roadside Obstacle Inventories
- Guardrail Inventories
- Bridge Structure Inventories
- Traffic Signal and Intersection Inventories
- Railroad Grade Crossing Inventories
- Roadway Features Inventories
- Pavement Management System Inventories

Sign Inventories

A damaged, missing, or inadequate (insufficient reflectivity, improper breakaway base, wrong location or orientation, etc.) sign is considered a highway hazard in many instances. Inventories of highway signs are maintained by numerous highway agencies for use in replacing, adding, or deleting signs as needed to keep the signing up-to-date. Agencies that maintain sign inventories include Missouri, North Dakota, Charlotte, Omaha, Phoenix, and Oakland County (Michigan). Sign inventories may be developed by manual field surveillance, but are commonly conducted by viewing photologs.

The sign coding form and output format from North Dakota include information for the sign location, type, size, shape, height, material, color, distance from road, data installed, and word message (Appendix B). The condition of the sign is also given in terms of its visibility, condition, and reflectivity. Information is also given on the sign post. This provides comprehensive information for determining sign replacement needs.

Another example of a sign inventory is the one used in Charlotte, North Carolina (Appendix B). This inventory is based on data extracted from photologs and consists of an easy-to-read listing that includes the expected life of the sign to assist in determining replacement needs.

Roadside Obstacle Inventories

As mentioned previously, the Roadside Hazard Abatement Program in Oakland County, Michigan, is one good example of identifying and ranking roadsides by priority. Roadside obstacle data were collected using existing photolog film. The film frames were reviewed using a photoviewer with a grid overlay that provided lateral distance measurements of the obstacle from the roadway edge. Then, information was coded for each roadside obstacle on the nearest cross street, obstacle type, side of street, frame distance, presence of curb, and lateral distance from curb or roadway edge.

Data were then coded on a computer terminal using an interactive program that instructs the data entry personnel to input each data item. Information such as road grade, object rigidity, traffic volume, and speed limit was also obtained from other sources, and merged with the photolog information. The system software allows four types of data processing functions:

1. Dummy Function—A printout of the complete roadside obstacle inventory may be produced (as illustrated earlier in Figure 3). An inventory of approximately 110,000 roadside hazards (or potential hazards) is maintained on computer file by road name. Each roadside obstacle is assigned a milepoint and line number for easy reference and access.
2. Search Function—A printout of data records for any desired parameter may be produced. For example, the user may query the file for all trees with diameters of one foot on horizontal curves of six degrees or greater.
3. Update Function—As roadside hazards are removed or protected, the inventory records can be altered or deleted, or a new record can be added.
4. Statistical Analysis Function—The inventory can be merged with other files and/or analyzed with the Statistical Package for the Social Sciences or other software packages. Thus, data records may be analyzed to produce frequency distributions, cross-tabulations, and other statistics.

The obstacle data coding form and update form are given in Appendix B.

Guardrail Inventories

Guardrail installations reduce the degree of hazard of run-off-road accidents. Thus, a guardrail should shield motorists from hazardous elements (steep embankments, rigid point objects, etc.). The AASHTO publication, "Guide for Selecting, Locating, and Designing Traffic Barriers," is one source commonly used for determining needs for guardrail and other barriers (*9*). However, the guardrail itself may also be labeled as a highway element and, in many cases, may present a roadway hazard. For example, spear or blunt guardrail end treatments may be considered as point hazards. Also, substandard guardrail sections may create a hazard.

The Michigan DOT has developed an inventory of guardrail that includes details of guardrail location, type, end treatment, purpose, length, height, part types, and other information. A sample output and summary of this guardrail inventory is given in Appendix B.

Bridge Structure Inventories

Virtually every state collects detailed information on bridge structures, according to the U.S. DOT criteria specified in the report entitled "Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges" (*21*). An abbreviated computer output format of bridge data from North Dakota and a more detailed structure inventory, as used by Michigan, are shown in Appendix B. Such inventories include dozens of geometric, structural, safety, traffic, and other characteristics of each bridge. Such information could be used to identify bridges that have one or more deficient characteristics.

Traffic Signal and Intersection Inventories

Intersections and traffic signal control are considered of major importance in the safety of many highways. Traffic signal inventories are maintained by some agencies to assist in signal maintenance and improvement efforts. A computer printout of a signal inventory in Missouri provides details of the signal location, hardware, timing, right-turn-on-red restrictions, date of installation, and other information (Appendix B). Phoenix, Arizona also maintains a computer inventory of signal locations. An inventory of intersections is maintained in Washington and other states.

Railroad Grade Crossing Inventory

A national inventory of rail-highway grade crossings is compiled by states according to the standard U.S. Department of Transportation-AAR Crossing Inventory Form (Appendix B). Information for all public grade crossings is collected on this form, including the location, ADT, accidents, type of protection, highway speed, train speed, number of tracks, track type, and many other items.

Some states also maintain additional or supplemental inventories and computer outputs on railroad crossings. The Nevada Surface Condition Rating Form for railroad crossings is used for selecting railroad crossings that deserve improvement (Appendix B) (*22*). Maryland maintains an inventory of rail-highway crossings ranked by predicted accidents and Vermont uses an inspection form for rail-highway crossings (Appendix B).

Roadway Feature Inventories

Many states and local agencies collect and maintain detailed traffic data on roadway geometrics and other features. Such data can be used for determining needs for pavement widening, curve improvements, or safety-related improvements. For example, Washington State uses an inventory work listing of roadway features along their state highway system. The information listed includes location, area type, lane and shoulder width and type, city code, median width, functional class, intersection, railroad crossing location, and other items (Appendix B). A separate inventory is maintained of horizontal and vertical curves, with detailed information of each curve (Appendix B).

Michigan's Dimensional Accident Surveillance System (MIDAS) contains roadway information regarding:

- Roadway sections (location, number of lanes, lane width, shoulder width, speed limit, roadside development, no passing zones, truck climbing lanes, etc.),
- Horizontal alignment (location, angle of curve, curve direction, degree of curve, bearing, etc.),
- Intersections (location, signal type, configuration, number of legs, number of right- and left-turn control, traffic volume, capacity, etc.).

A sample output from the MIDAS file is given in Appendix B.

Nebraska's Maintenance Management System includes an inventory of numerous roadway features and elements. These include pavement types, numbers of lanes, shoulder types, structures, signs, delineators, guardrail, acres of mowing within the right-of-way, length of highway fence, crash barriers, traffic signals, and other features. A data-collection form and a sample output are given in Appendix B.

Various other types of roadway elements are also inventoried by highway agencies. For example, pavement marking inventories are recorded by some agencies to keep track of striping problems or needs (turn arrows, stop bars, centerlines, edgelines, etc.). A sample of a pavement marking activity coding form and sample computer output from Charlotte, N.C. are shown in Appendix B. In Washington, D.C., an inventory is maintained of the impact attenuator replacement program. Thus, for gore areas and other sites where impact attenuators are installed, information is provided on the speed limit, street type, type of attenuator, the layout pattern, installation date, cost, and a listing of the repair needs of each attenuator for each date inspected (Appendix B).

EXAMPLES OF AGENCY INVENTORY PROGRAMS

Hawaii

An example of a state that has an active interest in addressing hazardous elements is Hawaii. In its 1983 annual report to FHWA regarding its Highway Safety Improvement Program, the state's efforts to inventory hazardous elements and the corrective treatments directed towards them are discussed (*23*). These inventories and treatments include the following:

- A statewide inventory of skid resistance is used to implement skid-proofing projects.
- An inventory of state highway bridges with substandard end treatments was taken, and a delineation program, as per the AASHTO Yellow Book, was planned for 340 bridges.
- An inventory of hazardous objects at highway gore areas on high-volume/high-speed state highways resulted in correction of all hazardous conditions.
- A sample survey has been completed of roadside obstacles for streets and highways under state jurisdiction, which is being used as the basis for long-term needs for obstacle elimination in the state.

In addition, inventories are maintained on traffic and roadway data such as the traffic volume, terrain, access control, presence of a median, surface type, number of lanes, pavement width, road width, functional class, and other items. Straight line diagrams and photologs have also been used during accident analysis and safety improvement projects.

Washington, D.C.

In Washington, D.C., numerous elements are carefully reviewed at high-accident intersections, bridges, and traffic circles. On Interstates and freeways, elements that are reviewed (regardless of whether they are high accident or not) include safety appurtenances (guardrail, bridge rail, and attenuators), lighting, shoulders, gore areas, sight-distance deficiencies, signing, and pavement markings. Typical improvements routinely made at non-high-accident locations include resurfacing, channelization (to improve overall operation of intersections or sections), and elements found to be deficient during inspection of fatal-accident sites.

Tennessee

Tennessee is typical in terms of its identification of hazardous elements. Its highway safety improvement program involves identifying and ranking hazardous locations based on accident experience. Then, investigations of the locations are made to determine what elements, if any, might be contributing to the problem. The intent is to identify elements (grade crossings, bridges, horizontal curves, roadside obstacles, and others) with high-accident experience.

In Tennessee, several types of data files are maintained, in addition to accident files, including:

- Systems file—contains information on functional class, administrative system, urban boundaries, federal-aid route numbers, etc.
- Route-feature file—includes features along a route such as intersections, bridges, county lines, etc.
- Geometrics file—contains information for a particular section, such as roadway width, surface type and width, types of median, number of lanes, etc.
- Bridge file—includes information for each bridge structure according to the National Structure Inventory and Appraisal File.
- Railroad-crossing file—contains information on each public railroad crossing, and follows the format of the National Railroad Highway Crossing Inventory.
- Road-history file—contains information on the original and current projects for each route, along with the name of the contractor from each project.
- Traffic file—contains data on average daily traffic, peak hour volume percentages, vehicle classifications, etc.
- Horizontal-alignment file—contains the degree of curvature for each horizontal curve of three degrees or greater.

CHAPTER FOUR

ESTABLISHING PRIORITIES FOR IMPROVING HIGHWAY ELEMENTS

Agency personnel must consider many factors when determining priorities for the improvement of highway elements. For instance, highway elements should conform to MUTCD and AASHTO standards and guidelines. However, an analyst may still need to question whether an element that does not conform to those standards is an immediate danger or whether it simply causes a condition that is not ideal. For example, a stolen stop sign or an inoperative traffic signal should be corrected quickly, without referring to a priority analysis. Also, some types of problems or conditions may be corrected through routine maintenance. However, the removal of a row of large trees next to the road may become a more complex issue, because public, environmental, and political forces may resist such a treatment.

GUIDELINES FOR IMPROVING HIGHWAY ELEMENTS

Based on the survey responses ranking specific elements from a very low to a high priority, there are four basic philosophies stated by state and local agencies regarding the priority of element improvements:

Statement	Number of Agencies	
	State	Local
1. Money is spent on improving highway elements only if the accidents exceed a certain level.	7	3
2. Improvements are made only if accident experience is high.	2	3
3. The agency is sensitive to deficient highway elements, as well as high-accident locations, and routinely improves a few of these elements each year.	30	11
4. A high priority is placed on identifying and correcting highway elements for locations both with and without high-accident experience.	17	8

These summaries indicate that most state and local agencies at least try to improve some deficient highway elements each year. However, a few responding agencies (seven states and three local agencies) rely solely on accident experience for placing priorities for safety improvements. On the other hand, several responding agencies indicated that they have a fairly high regard for hazardous elements, even those without accident experience (17 state agencies and 8 local agencies).

In addition to the responses summarized above, several state and local agencies indicated their own unique philosophy on highway elements for priority improvement purposes. For example, about one-third of the safety funding in New Hampshire each year is currently being used to upgrade guardrail and bridge approaches. Some of these bridge sites are selected according to accident histories, although others are considered if thought to be potentially hazardous. In Washington D.C., safety improvements, particularly those involving bridges, traffic circles, and intersections, are primarily based on accident data. However, on Interstate highways the treatments are made to elements whether the location shows high-accident experience or not. The Oakland County Road Commission ranks all potential resurfacing, restoration, and reconstruction (3-R) projects based on safety (accident) criteria. However, on all 3-R projects identified, potential hazards are treated regardless of associated accident history. The Oakland County Road Commission also has a "pink slip" program wherein employees report potential hazards that they observe on the road.

Responding foreign highway agencies cited a variety of guidelines on improving highway elements. In general, these agencies are sensitive to deficient highway elements and improve some of them each year.

Agencies were also asked whether highway elements that are not at high-accident locations are routinely considered for improvement. Of the 40 states responding, 34 indicated "yes," and 15 of 16 responding local agencies indicated "yes." All but one of the foreign agencies indicated "yes." Some reasons given by state and local agencies for considering hazardous element improvements are:

	Number of Agencies	
Survey Statement	State and Local	Foreign
1. "They appeared hazardous based on our past experience and judgment."	44	5
2. "They did not meet the current state or local guidelines or practices."	39	6
3. "They are based on citizen input or complaints."	37	5
4. "We have experienced accident problems at similar locations in the past."	34	3
5. "They did not meet any MUTCD guidelines for warrants."	33	3
6. "We fear possible problems in tort liability in case of an accident."	32	5
7. "They don't meet AASHTO blue book (or currently green book) standards or other design standards."	32	4
8. "We made improvements to maintain consistencies in our roadway system."	28	4
9. "They are based on 'political' pressure."	27	4
10. "Improvements are based on findings from articles in past research on dangerous elements."	22	3
11. "We make improvements to improve our public image."	11	1
12. "It keeps our maintenance personnel busy during periods of low work loads."	4	0

The responses shown were from the agencies that indicated a high or medium priority for considering highway elements in their improvement programs and operations. Other agency responses noted that certain circumstances could lead to identifying roadway elements as hazardous. These circumstances included when a roadway was to be resurfaced or reconstructed, when improved channelization would improve the operation at an intersection, or when fatal accidents indicate a need for improvement. The roadway deficiencies that were typically corrected by these agencies are:

- Trim tree and bush obstructions.
- Replace or repair missing or damaged signs.
- Repair damaged or substandard guardrails and guardrail ends.
- Repair rutting, potholes, rough pavement, and pavement dropoffs.
- Improve shoulder erosion and ruts.
- Upgrade or improve roadway delineation.
- Improve slippery pavements.
- Correct drainage problems.
- Remove fixed objects.
- Improve signal operations and repair signal knockdowns.
- Combine utility and signal poles into multi-use poles.
- Remove trees and other roadside obstacles.
- Reconstruct culverts and catch basins.
- Improve curvature, superelevation, and other substandard geometrics.

It should be noted that most of the roadway deficiencies listed above are typically corrected by highway maintenance activities that may be treated irrespective of accident data. In other words, many agencies recognize hazardous highway elements and take the initiative to address them even though a formal inventory procedure may not be available.

FUNDING CONSIDERATIONS

Priorities for treating hazardous highway elements are established, in many cases, based on an economic analysis required for federally funded projects. This is particularly true in cases where improvements must be shown in relation to an acceptable level of benefits for each dollar spent.

For example, the Hazard Elimination Program, established by the Surface Transportation Assistance Act of 1978, requires that capital projects demonstrate cost-effectiveness based on projected safety benefits. However, according to a 1983 FWHA memo (letter submitted to FHWA from the Bureau of Traffic Engineering and Operations):

1. "Minor installations of safety hardware, such as beam quardrail, impact attenuators, etc., do not require cost-effectiveness analysis. Installations must comply with current practices and procedures. . . ."
2. "Traffic signals must meet warrants in addition to a favorable cost-effectiveness analysis."
3. "Construction, such as intersections, left-turn storage lanes, and geometric improvements require cost-effectiveness justification."

In the 1983 Annual HSIP report in New York State by Bray et al. the authors state that safety benefits for hazard elimination projects can be calculated in two ways (*24*):

1. When accident history is used to identify a highway deficiency, accident reductions can be projected based on proposed improvements.

2. For improvements to roadside obstacles where accident data may or may not be available, a different methodology is applied. An obstacle index is computed and used to estimate annual benefits.

For projects or locations in either category above, a benefit-cost analysis is performed. Those meeting a benefit-cost ratio of 1.0 or greater qualify for hazard elimination funds. Unfortunately this requirement (meeting a B/C ratio of 1.0 or greater) makes it difficult for highway agencies to justify many types of improvements to hazardous highway elements.

When asked whether an economic analysis is conducted to justify making improvements to deficient highway elements, the agencies responded in the following manner:

Agency Type	Number of Responses		
	Yes	No	Sometimes
State	15	7	17
Local	2	5	9
Foreign	1	1	5
Totals	18	13	31

Further information received from the agencies to supplement the general responses above include the following:

- In California, spot improvements costing more than $25,000 are justified on the basis of economic analysis.
- In Florida, a benefit-cost analysis is conducted for a *location*, not just for one element. Minor improvements, such as removing an obstacle, or maintenance activities do not receive an economic analysis.
- Maryland does not perform an economic analysis for MUTCD-type improvements or "for which avoidance of tort liability is performed." However, an economic analysis is performed for locations that are improved as part of the Hazard Elimination Program.
- The Wyoming response mentioned that an economic analysis is performed if the element is in a high-accident area, but that the element would typically be upgraded to standard configuration in a reconstruction area if finances are available.
- Nebraska performs an economic analysis when safety funds are used, and a value engineering analysis is also conducted.
- Project costs are compared with accident costs in Japan.
- In Saskatchewan, Canada, an economic analysis is performed for larger projects, such as at interchanges and some signal installations.
- In New Brunswick, Canada, economic analysis is not performed to justify the improvement if a definite safety risk exists. When considering all deficient highway elements, however, each element is given a budget in which repairs are performed on the most justifiable deficiencies.
- The Ohio response mentioned that an economic analysis is not used for elements improved as part of 3-R projects, but it is used with hazard elimination projects.
- In Ocean County, N.J., costs are a major consideration for improving elements, but a full economic analysis is not conducted.
- An economic analysis is used for projects that are borderline or if funds are scarce in Winston-Salem, N.C.
- The city of Lawrence, Kansas uses an economic analysis in some cases, such as to justify guardrail placement.
- In Charlotte, N.C., economic analysis is performed for high-accident locations but not for correcting signs and markings.
- In Oakland County, Michigan, a cost-effectiveness analysis is performed for all highway construction improvements.

Many of the state and local agencies indicated that the funding source was a primary factor in determining whether an economic analysis was used. Some local agencies mentioned that they seek state aid for some projects.

The next question asked of the agencies was: "After elements are identified as deficient or in need of repair, must they compete with high-accident locations for improvement funding?" Of the 39 states responding, 22 indicated "yes," 14 indicated "no," and 3 indicated "sometimes." Of 17 responding local agencies, 8 said "yes" and 9 said "no." Four of the seven foreign agencies stated that high-accident elements must compete for funding. Elements need not compete, according to the two South African provinces. In New Brunswick, the deficiency does not have to compete for funding if it is thought to be more serious than the high-accident location.

The next issue asked of the state and local agencies involved the percentage of the safety improvement funding spent for each of the following four categories:

1. Citizens' complaints,
2. High-accident locations,
3. High-hazard elements (where accident data are not considered), and
4. Other considerations (political, etc.).

For state agencies, citizens' complaints were responsible for only about 4 percent of their expenditures, while high-accident locations involved approximately 78 percent of expenditures. Also, high-hazard elements were responsible for 14 percent of state expenditures, and 4 percent were attributed to other considerations. For the local agencies, citizens' complaints were responsible for approximately 14 percent of expenditures; high-accident locations, 43 percent; hazardous highway elements, 26 percent; and other considerations, 17 percent.

Responses indicate that local agencies actually spent a higher percentage of funds on hazardous elements than state agencies (26 to 14 percent). Also, the local agencies spent a higher portion of their funds based on citizen input and other considerations than did the state agencies. The state agencies spent a majority of their funding (78 percent) on identifying high-accident locations, compared with only 43 percent of the local funding.

The fact that local agencies consider highway elements more than state agencies could be the result of one or more of the following reasons:

1. The strong emphasis by many city agencies on MUTCD-type improvements (e.g., signing, striping, and signal improvements), which are justified independently of accident statistics, in many cases;
2. The lack of high-quality accident data by many local agencies;

3. The involvement of local politics in the selection of improvements without consideration to accident experience; and
4. Limited personnel to conduct a comprehensive safety improvement program, so that the improvements often consist largely of putting out "brush fires" (replacing damaged stop signs, repairing malfunctioning traffic signals, etc.).

It should be mentioned that state agencies also have to deal with the problems mentioned above but perhaps they are more serious at the local agency level.

FUNDING SOURCES AND PROGRAMS

The next issue involves the specific funding sources and programs used to treat highway elements not identified by accident experience. Several funding and construction programs are currently available for highway safety improvements that may relate to correcting highway elements. As discussed earlier, the Highway Safety Act of 1982 provides for continued funding through fiscal year 1986 for the Hazard Elimination Program and Rail-Highway Crossing program (*1*).

The 402 Safety Program was also extended through 1986. The number "402" refers to Section 402 of Title 23 of the United States Code and provides essential support for highway safety programs. Typical activities promoted by 402 funds include: (a) the collection of accident, highway, and traffic data to identify problems and evaluate improvements; (b) the development of necessary technical capabilities; (c) the procurement of safety improvement tools and equipment; and (d) highway safety training (*1*). As this program relates to highway elements, possible uses of 402 funds could include such activities as collecting data for highway elements; photologging or videologging; purchasing necessary equipment for collecting, analyzing, or maintaining highway element data; and training technical personnel to identify and correct roadway deficiencies.

The Federal-Aid Highway Act of 1976 authorizes the use of federal funds for resurfacing, restoration, and rehabilitation, which is commonly referred to as the 3-R program. Projects involving 3-R activities may be classified into two groups: (a) repairs to the road surface, and (b) geometric improvements. The 3-R program is limited to the federal-aid highway system and consists of three classes of highway systems: primary, secondary, and urban (*1,25*). Funds are provided on the basis of 75 percent federal and 25 percent state or local funding. In recent years there has been an increased emphasis on reducing "lost opportunities" for enhancing safety on 3-R projects. In addition to improving basic highway elements (lanes, shoulders, curves, grades, cross slopes, superelevation, etc.) numerous low-cost improvements have also been included in 3-R projects, such as trimming trees, guardrail improvements, and upgrading pavement markings and signing (*1,25*). Thus, the 3-R program can be another means to improve substandard or deficient highway elements.

State and local agencies were asked about funding sources commonly used to improve highway elements. As summarized in Table 7, the sources most frequently used by state agencies for improving highway elements include construction programs (21 states), 3-R funding (20 states), maintenance programs (16 states), and safety improvement funding (13 states).

Local agencies most frequently used construction programs

TABLE 7

FUNDING SOURCES AND PROGRAMS USED TO IMPROVE HIGHWAY ELEMENTS

Funding Source	Frequency of Use			
	Frequent	Sometimes	Infrequent	Never
State Agencies				
3-R	20	13	1	0
Safety Improvement	13	16	5	5
Maintenance	16	18	4	0
Construction	21	17	1	0
No funds	0	3	2	3
Channelization	0	1	0	0
Section 203 RR	1	0	0	0
Local Agencies				
3-R	2	4	1	0
Safety Improvement	4	9	3	1
Maintenance	9	5	1	1
Construction	10	5	1	0
No funds	2	1	1	3
Capital Improvement	2	0	0	0
Voter Approval Bond Fund	1	0	0	0
General revenue	1	0	0	0
Risk Management Countermeasure	1	0	0	0

(10 agencies) for improving highway elements, followed by maintenance programs (9 agencies), and safety improvement funding (4 agencies). In Japan, all "repairs" are funded from the agency maintenance budget. In Alberta, Canada, construction and maintenance funds are used. A variety of other funding sources are used by the other foreign agencies.

In using funds for improving highway elements, projects are generally established in one of three ways:

1. They are made part of larger projects.
2. Individual elements are the target of improvements.
3. Blanket improvements of one or more elements are made.

The first category involves elements that are improved as part of larger projects, such as with 3-R projects. The second general category involves improvements where the individual elements themselves are the target of the improvement. For example, many agencies focus their traffic engineering improvements on highway signs, traffic signals, markings, and other MUTCD-type improvements. Another example would be agencies that currently have routine maintenance practices aimed at correcting minor problems along the roadside. These problems include deficient sign posts or light supports, shoulders that drop off more than several inches from the pavement, trees or branches that obstruct signs, damaged crash cushions, damaged guardrails, or other problems correctable through maintenance practices.

A third type of improvement aimed at the hazardous elements are blanket improvements. Blanket improvements are currently being conducted by agencies around the country. The California Cure Program, for example, addressed hazards associated with environmental problems, such as light standards, bridge rail ends, signs, bridge piers, and abutments (*26*). This program was estimated to save approximately 680 lives over a 6-year period and cost approximately $20 million (*26*).

One advantage of a blanket improvement program is that an economic analysis can be used to justify element improvements. For example, it is very difficult to assign a benefit or accident reduction factor to the replacement of one spear-end guardrail. However, when a system-wide or blanket improvement program is initiated, dozens or even hundreds of similar projects may be lumped together into one program, thereby allowing the benefit and cost estimates to be calculated for the total program.

A 1979 study by Pigman et al. (*27*) documented benefits considering blanket improvements at high-accident locations for the entire Interstate system in Kentucky. Some of these blanket-type improvements included clearing gore areas, replacing rigid light poles and signs, cutting or shielding rock cuts along the Interstate, improving or removing median crossovers, delineation for wrong-way accidents, converting guardrail ends to breakaway or flared cable terminals, improving guardrail transitions to bridge piers, protecting median and shoulder piers, resurfacing slippery pavement sections, and various other improvement activities (Figure 42). A composite cost and benefit value was computed for individual improvements, as well as

NUMBER AND TYPE OF IMPROVEMENTS BY ROUTE

SAFETY IMPROVEMENT	I 24	I 64	I 65	I 71	I 75	I 264	I 275	UNIT COST
Clear Gore Area:								
Remove rigid signs	0	0	0	0	0	6	0	$1,000
Move light standard	0	13	23	9	38	20	2	$2,500
Replace dual channel post	0	17	15	4	10	0	1	$500
Remove guardrail	0	6	10	7	5	4	0	$1,000
Replace end treatment	0	2	3	2	1	10	0	$1,000
Replace Rigid Signs	0	6	20	0	5	63	0	$2,000
Replace Rigid Lightpoles	0	3	60	0	27	360	0	$2,000
Rock Cuts:								
Grading and/or shielding (Miles of rock cuts)	0	22.4	10.8	4.6	32.2	0	0	$70,400 per mile
Median Crossover Removal	17	15	18	23	30	2	5	$3,500
Delineation for wrong-way accidents	10	88	67	30	87	71	0	$400
Convert guardrail end treatments to breakaway Cable terminal	5	916	304	644	1239	144	48	$500
Guardrail transition to bridge end	0	9	40	16	21	16	0	$8,000
Median and shoulder pier protection:								
Shoulder pier unprotected	0	6	0	2	0	20	0	$5,000
Median pier unprotected	0	2[a]	2[a]	2[a]	0	9[b]	0	[a]$40,000 [b]$20,000
Guardrail at shoulder pier unattached	0	7	10	5	16	2	0	$1,000
Delineation for shoulders approaching bridges without full-Width Shoulders	0	82	116	20	76	26	0	$100
Upgrade Gap Between bridges:								
Upgrade guardrail	0	3	0	4	3	13	0	$10,000
Plant shrubs behind guardrail	14	64	60	25	49	19	8	$7,000
Fasten Seat Belts Signs at All entrance Ramps	12	78	67	30	85	71	0	$200

(a) Earth berms on both sides of bridge pier

(b) Crash cushions on both sides of bridge pier

FIGURE 42 Listing of blanket improvements and individual improvements from Kentucky Interstate Study (*27*).

TYPE AND LOCATION OF IMPROVEMENT	NUMBER	ACCIDENT SEVERITY			PERCENT REDUCTION			IMPROVEMENT COSTS	ANNUAL MAINTENANCE COSTS	AVERAGE ANNUAL BENEFITS	REFERENCES	BENEFIT-COST RATIO	LIFE (YEARS)
		FATAL	INJURY*	PDO	FATAL	INJURY	PDO						
GENERAL IMPROVEMENTS													
CLEAR GORE AREA;			21 (34)	34	50	50	0	$350,000	$ 0	$ 79,900	10, 23, 31 34	3.44	20
REMOVE RIGID SIGNS	6												
MOVE LIGHT STANDARD	105												
REPLACE DUAL CHANNEL POST	50												
REMOVE GUARDRAIL	32												
REPLACE END TREATMENT	18												
REPLACE RIGID SIGNS	94		10 (16)	49	50	50	-10	$188,000	$ 0	$ 34,317	10, 31, 35	2.75	20
REPLACE RIGID LIGHTPOLES	450		41 (66)	58	50	50	-35	$900,000	$ 0	$141,499	10, 31, 36 38	2.37	20
REMOVE ROCK CUTS(7C MILES) MOVING BACK 10 FEET AT AN AVERAGE OF 12 FEET HIGH		3	83(131)	115	65	25	5	$5,00C,000	$ 0	$401,527	1, 31	1.21	20
VARIABLE MESSAGE SIGNS I 75; MP 188,9 - 191.6	9	1	79(126)	263	10	10	10	$225,000	$ 9,000	$ 89,341	10, 36	5.59	20
VARIABLE MESSAGE SIGNS I 65; MP 130.7 - 137.3	10	0	47 (75)	156	10	10	10	$250,000	$10,000	$ 45,702	1C, 36	2.36	20
VARIABLE MESSAGE SIGNS I 264 MP 9.0 - 18.0	18	0	108(173)	360	10	10	10	$450,000	$18,000	$105,430	10, 36	3.14	20
MEDIAN CROSSOVER REMOVAL	110	1	16 (26)	15	50	50	50	$385,0G0	$ 0	$128,625	10, 38	5.04	20
DELINEATION FOR WRCNG-WAY ACCIDENTS	355	5	8 (13)	6	20	20	20	$142,000	$ 0	$138,024	10, 31, 39 40, 41	2.76	3
GUARDRAIL END TREATMENTS TO BREAKAWAY CABLE TERMINAL	3300	2	36 (58)	50	75	50	-40	$1,650,000	$ C	$310,400	10, 11, 18 23, 42, 45	2.84	20
GUARDRAIL TRANSITICN TO BRIDGE END (102 BRIDGES)	408	1	21 (34)	15	75	50	-75	$816,000	$ 0	$166,113	10, 11, 18 23, 24, 45	3.07	20
MEDIAN & SHOULDER PIER PROTECTION SHOULDER PIER UNPROTECTED -- 28 MEDIAN PIER UNPROTECTED -- 3C GUARDRAIL AT SHOULDER PIER UNATTACHED -- 40	98	2	10 (16)	2	90	60	-300	$600,000	$ 0	$266,100	10, 11, 23 24	6.69	20
DELINEATION FOR SHCULDERS APPROACHING BRIDGES WITH-OUT FULL-WIDTH SHOULDERS	320	1	34 (54)	85	5	5	5	$51,000	$ C	$ 21,788	10, 24, 41	1.96	5
UPGRADE GAP BETWEEN BRIDGES - INCLUDES UPGRADING GUARDRAIL(46) AND PLANTING SHRUBS BEHIND GUARDRAIL(239)	285	1	4 (6)	5	90	60	-60	$1,900,000	$ 0	$127,410	10, 18, 23 24	1.01	20
FASTEN SEAT BELT SIGNS AT ALL ENTRANCE RAMPS	343	47	1412(2259)	4563	2	0	0	$70,000	$ 0	$235,000	10, 18, 45	25.31	10

FIGURE 43 Sample economic analysis output from Kentucky study (*27*).

programs and the overall benefit-cost ratio of these blanket-type improvements was calculated (Figure 43). This is one example of how hazardous highway elements can be priority-ranked in an economic analysis.

States that want to recognize and improve hazardous elements seem to use various funding sources and programs. This is illustrated very well by a quote from the Hawaii Highway Safety Improvement Program (*23*):

> It should be noted that some of the most cost-effective corrective measures of accident locations are minor traffic operation-type improvements, such as installing hazard warning signs, markings, or delineation, and adjusting traffic signals, and timing/phasing. These measures are often implemented by State and county highway/traffic forces with informal work orders as soon as suitable countermeasures are identified to rectify the hazardous condition without going through formal project listing and priority procedures.

Tennessee reports that it uses programs such as 3-R, the Rail-Highway Grade Crossing Program, Bridge Replacement and Rehabilitation Program, and regular maintenance and construction programs in making improvements to highway elements. Although many agencies may not consider "highway elements" as a special area of emphasis, they may treat them under numerous programs as a part of normal highway construction and maintenance activities.

Regardless of whether an economic analysis is used, agencies must also consider many other factors when determining the types of improvements of hazardous highway elements to be made. These other considerations include:

- Citizen opposition (e.g., citizens may violently oppose removing trees near their residences or streets),
- The effect on highway capacity,
- Possible implementation period,
- Energy conservation (e.g., signal timing changes),
- Effect on area surroundings,
- Effect on air and noise pollution,
- Effect on safety (e.g., some treatments, such as concrete barriers and traffic signals, may reduce accident severity but increase accident frequency), and
- Effect on future maintenance costs.

CHAPTER FIVE

AGENCY DATA COLLECTION PROBLEMS AND LIMITATIONS

State and local agencies have recognized numerous problems regarding the collection, analysis, and use of data relative to hazardous elements. A summary of the primary problems is given in Table 8. Agencies were asked to rate nine potential problem areas as being a major problem, a problem, a minor problem, or no problem. The table combines these responses into two categories: issues that are problems, and issues that are of little or no problem.

AGENCY PROBLEMS

The main problem indicated for state and local agencies was limited funding for improvements. In fact, approximately 95 percent of the agencies reported this problem. The second most critical problem identified by both state and local agencies was limited personnel, where 76 percent of state agencies and 69 percent of local agencies indicated this problem.

The remaining problems, beyond the first two, differ considerably for state and local agencies. For state agencies, the third most critical problem was inaccurate data collection for their system (indicated by 39 percent of the agencies). Following closely behind this was the problem that state agencies could not justify addressing highway elements unless the location had high-accident experience (38 percent). The next most frequently reported problem for states was that the highway system is too large to get a clear understanding of where all critical areas exist (31 percent). Following that, states reported the problem of finding or training good field people (28 percent). The seventh most frequent response was that state agencies have no clear direction or guidance on what procedures should be used to identify hazardous elements. A lack of interest or support from top management was not perceived as a major problem by state agencies (only 8 percent of the agencies indicated a concern). The least of the problems reported by state agencies was the lack of computer availability for identifying hazardous elements (6 percent).

For the local agencies, the third most frequently reported problem, after limited funding and personnel problems, was the lack of computer availability (59 percent indicated this problem). This problem was followed by a lack of clear direction or guidance on what procedures should be used for identifying haz-

TABLE 8

SUMMARY OF PROBLEMS RELATED TO IMPROVING HAZARDOUS HIGHWAY ELEMENTS

Problem Area	Ranking		Local Agencies			State Agencies			State and Local Agencies		
			Little or no	Is a problem		Little or no	Is a problem		Little or no	Is a problem	
	Local	State	problem	No.	%	problem	No.	%	problem	No.	%
Lack of interest or support from top management	9	8	15	2	12	33	3	8	48	5	9
Limited funds	1	1	1	16	94	2	37	95	3	53	95
Limited personnel	2	2	6	11	69	9	29	76	15	40	73
Cannot justify addressing elements unless accident experience is high	7	4	14	4	29	23	14	38	37	18	33
Inaccuracy in data collecting	8	3	12	5	29	22	14	39	34	19	36
Highway system is too large	6	5	11	6	35	25	11	31	36	17	32
No computer to process such data	3	9	7	10	59	34	2	6	41	12	23
No clear direction or guidance exists for element identification	4	7	9	6	40	30	8	21	39	14	26
Limited trained personnel	5	6	10	6	38	26	10	28	36	16	31

ardous elements (40 percent). The fifth most frequently reported problem was finding or training good field people (38 percent), followed by the perception of too large a highway system (35 percent). The last three problems for local agencies, in order of priority, were the inability to justify treating non-accident locations (29 percent), the problems with data-collection accuracy (29 percent), and the lack of interest or support from top management (only 12 percent).

It can be concluded, from the above information, that there are clear differences between state and local agencies in terms of barriers to identifying and correcting hazardous elements. Specifically, local agencies reported a major problem, not only with a lack of funds and personnel, but also with the lack of computer facilities and clear, technical direction on which hazardous elements should and should not be included in a comprehensive safety program. These last two issues were of minor concern to state agencies. States, however, reported more of a problem with funds, personnel, data collection accuracy, and the justification of treating non-accident locations.

Other problems and concerns mentioned by state agencies included the doubtful use or justification of hazard elimination funding for potential hazards, as opposed to sites with high-accident history. One state also expressed concern about tort liability resulting from deficient elements being identified but not corrected. This concern undoubtedly faces many highway agencies because of limited funding and questions as to how to utilize these funds in an optimal manner.

AGENCY NEEDS

Local agencies have indicated that their two primary needs are funding and personnel. However, ten states and four local agencies mentioned that improved identification or inventory methods were the most critical needs for safety enhancement. Also, two state agencies and three local agencies mentioned improved computer facilities as their most critical need regarding the identification of hazardous roadway elements. Finally, five state agencies indicated a need for more information on benefits resulting from the treatment and improvement of hazardous roadway elements.

In addition to these needs, several state and local agencies also indicated other needs relative to hazardous elements. For example, Alabama indicated the need to better merge roadway and accident files, while California mentioned the environmental considerations that must be addressed before removing hazardous trees, substandard guardrails, and other features with no accident histories.

One local agency indicated that many highway projects can be completed with minimal funding as long as personnel are available to perform the planning and engineering activities. In this situation, personnel limitations are more critical than funding limitations.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

The identification and correction of hazardous elements was investigated in this synthesis based on information in the literature (published and unpublished), discussions with agency representatives, and questionnaire responses received from 40 state agencies, 17 local (city and county) agencies, and 5 foreign countries. In particular, this synthesis discussed the following:

1. Definitions of a hazardous element,
2. Methods for identifying highway elements,
3. Priorities for improving highway elements, and
4. Agency problems and limitations.

The following is a summary of information obtained in these four categories along with related recommendations.

DEFINING A HAZARD

No universally accepted definition of a hazard exists. Highway elements may be viewed in terms of their degree of hazard, which is a function of the probability of that element being associated with an accident or injury. For example, the degree of hazard of a roadside obstacle is a function of its type and rigidity, its distance from the roadway edge, its exposure to traffic, and nearby roadway characteristics. Thus, a combination of many roadway elements and conditions affect the degree of hazard of an element. Although there are probably hundreds of highway elements that could be named as "potential hazards" under certain situations, approximately 40 specific elements were most often mentioned by state and local highway agencies as of primary concern.

Care should be exercised when labeling a certain type of element as a hazard. For example, narrow bridges are one of the elements most often mentioned as potential hazards. However, a bridge is not necessarily a hazard simply because it is "narrow." Instead, traffic, roadway, and environmental factors all play a role in determining whether the element would be a hazard. A narrow bridge would likely present a hazard if located on a curve in a two-lane highway with limited sight distance, inadequate delineation, and no approach guardrail, whereas a similar narrow bridge might not be a hazard under different circumstances. Similarly, the degree of hazard of a rigid roadside object depends on its nearness to the road, its rigidity, and roadway geometrics.

Numerous sources give direct or indirect indications of hazardous roadway elements. The documents selected for discussion purposes included the AASHTO Yellow Book, the FHWA "Maintenance and Highway Safety Handbook," documented material from Florida's Highway Safety Improvement Program and the Oakland County (Michigan) Roadside Hazard Program, and Hazard Index ratings of state rail-highway grade crossings (*4, 5, 10–12*). These and other sources present different perspectives on highway elements that are hazards or potential hazards.

It is recommended that, in addition to routinely identifying *high-accident* locations and sections, each state and local agency should also generate its own list of highway elements considered to be *potential* hazards. An example of a comprehensive list of potential hazards is the one developed by the Florida DOT (*11*).

The determination of hazardous elements should be based on each agency's roadway characteristics (terrain, density, traffic volume, roadway designs, driver characteristics, climate, etc.) as well as guidelines and standards (MUTCD, AASHTO, etc.). An agency must also rely on past experience and consider features that have been associated with a high frequency or severity of accidents. Roadway elements that are commonly associated with high-accident locations should be considered as potential hazards without waiting for accidents to happen. An accurate highway inventory is a valuable tool to assist in the systematic identification of highway elements of concern.

An effort should also be made to develop criteria for each element. For example, the degree of hazard represented by a line of utility poles located ten feet from the edge of a low-volume urban street would be substantially less than a similar line of poles located within the same distance of a high-volume, high-speed suburban street with poor alignment. A composite list of potential hazards was discussed in Chapter 2. These hazards were either recognized by highway agencies or identified in the literature. This list is given only for illustration purposes, but may be a good starting point for an agency wishing to define elements that deserve further consideration and possible improvement.

METHODS FOR IDENTIFYING HIGHWAY ELEMENTS

Traditional accident analysis techniques are commonly used for identifying high-accident locations. These were the subject of numerous documents, such as Synthesis 91 (*6*) and a training manual produced for the Federal Highway Administration on Highway Safety Improvement Programs (*3*). However, there is a need to identify highway elements that present hazards to motorists, even though accident experience is not yet abnormally high. Hazardous elements may be identified in many ways. Many agencies have no formal procedure, although hazardous elements seen in the field are reported by maintenance workers, police, and safety personnel. Some agencies perform routine field inspections and have specific pre-defined highway elements in mind during these inspections. The use of more formal procedures includes computerized system-wide inventories of roadway elements such as narrow bridges, railroad grade crossings, roadside obstacles, sight-distance deficiencies, slippery and rough pavements, and delineation and signs. From these inventories, elements are then identified that are considered to be deficient.

The methods used to collect inventory data include manual methods, photologging, videologging, and automated or semiautomated devices. Manual data collection and photologging are most commonly used for collecting data on highway elements. Computer data storage and processing are used by approximately 75 percent of the responding agencies. New and improved data storage and processing techniques are now in use, such as laser videodiscs for handling photolog information.

Good examples were found of numerous types of inventories related to highway elements. For example, inventories for submission to the U.S. Department of Transportation are maintained by nearly all states on railroad-highway grade crossing (AAR Crossing Inventory) and on bridge structures. Other examples of highway element inventories include computerized sign inventories, such as those by Charlotte (N.C.), North Dakota, Missouri, and other agencies. A comprehensive inventory of roadside obstacles, such as the one maintained by Oakland County, Michigan, provides a valuable listing of potential roadside hazards. A detailed guardrail inventory is used by the Michigan DOT, and inventories of traffic signals and intersections are used by Washington State, Phoenix, and others. Most states maintain a roadway features inventory for roadway segments, which may include such elements as lane width and shoulder width and type, median width, functional class, horizontal curvature, and other information. Michigan's Dimensional Accident Surveillance System (MIDAS) and Nebraska's Maintenance Management System are good examples of roadway feature inventories.

Several recommendations for identifying highway elements of concern are given below.

1. Current inventory data bases should be used whenever possible and supplemented with information on highway elements of concern. Virtually all agencies collect and maintain detailed inventories of bridge structures and railroad grade crossings. The hazard index models for rail-highway crossings could, for example, provide one way to determine the elements that deserve further attention. The bridge inventories, as maintained by the states, could be used to identify substandard bridges for treatments including not only possible high-cost bridge widening, but also lower-cost treatments (e.g., pavement delineation, advance warning signs, illumination, etc.). In summary, highway agencies already have these and other types of inventories, but not all of them are used for identifying hazardous elements. There may be a need to enhance or modify the inventory file and to conduct data sorts and searches to make the inventory more useful for locating potential hazards.

2. Agencies that spend large amounts of money and use large numbers of personnel on manual data collection for roadway inventories may wish to consider photologging, videologging, or electronic techniques for certain data elements. The use of new technology with these methods can also result in their efficient use in conducting highway element inventories. Photologging has been used for years by highway agencies and can be a highly efficient and cost-effective tool for developing inventories of signs, signals, roadway delineation, roadside obsta-

cles, and other physical roadway features. Also, advances in videologging systems have resulted in their use for highway surveillance by some states. Automated and electronic data-collection methods may also be highly desirable or essential for some types of roadway element information. Automated methods have been used successfully for collecting pavement skid resistance, road roughness, elevation and grade, degree of curvature, and other data. The use of laser videodiscs made from photolog film (as used in Connecticut) is one example of an advanced data storage and processing technique that can reduce costs and improve efficiency of information systems. Each agency should determine which types of data-collecting and processing methods are most feasible and cost-effective for the variables of concern.

3. Highway elements of concern may differ considerably for various highway agencies, depending on agency safety objectives and geographic, climatic, driver and highway characteristics. One suggested way of identifying elements of concern for a given highway agency is to analyze the highway system in terms of the types of highway elements and features associated with abnormally high accident frequencies and severities. Then, system-wide priorities can be established for the highway elements for which improvements are needed. A brief guide or manual could also be prepared (and regularly updated as priorities and procedures change) for use in identifying and improving highway elements of concern.

ESTABLISHING PRIORITIES FOR IMPROVING HAZARDOUS ELEMENTS

Although highway agencies generally have established programs for improving identified high-accident locations, hazardous roadway elements at non-high-accident sites get little or no consideration for treatment by some agencies. However, most state and local agencies (about 75 percent) try to be sensitive to hazards on their highway system and routinely improve a few of them each year.

Many types of hazardous highway elements are improved routinely without ever having any economic analysis or other formal priority ranking process. For instance, agency maintenance forces typically make improvements such as replacing damaged highway signs, grading low shoulders, and trimming trees and brush that restrict sight distance. Traffic engineering improvements routinely made for conformance to the MUTCD include signal installation and improvements, pavement striping and delineation, traffic control in work zones, and sign installation. Other examples of highway elements that are routinely improved include safety enhancements during 3-R-type projects and improvements of highway elements during major reconstruction projects.

Various categorical funding sources have been used for improving hazardous highway elements. The Rail-Highway Crossing Program is a form of categorical funding available for correcting hazards at rail-highway grade crossings. Funds from the Hazard Elimination Program have been used to eliminate many types of highway hazards on all highway systems, except the Interstate system. In general, projects under this program should be justified with an economic analysis.

Thus, the improvement of highway elements is made either: (a) as a part of a larger project, (b) where the individual element(s) are the targets of the improvement, or (c) through blanket improvements. Examples of blanket improvements that have been made successfully include: (a) resurfacing roads with low friction numbers, (b) replacing spear-end guardrails with crashworthy ends, (c) installing breakaway sign posts and light poles, (d) flattening steep side slopes, (e) clearing rigid obstacles from roadsides or freeway gore areas, and many others. Such treatments illustrate the recognition of hazardous (or potentially hazardous) elements that have been corrected in many cases without waiting for accidents to happen at each site. In other words, highway agencies did not wait for every spear-end guardrail or gore area on their Interstate system to be struck before improving those elements in a blanket program.

Several recommendations seem appropriate with respect to priorities for improving highway elements.

1. The use of numerous funding sources and programs is an excellent way to gradually correct many of the hazards that currently exist on our highway system. However, state and local agencies should carefully review all types of highway hazards and make efforts to correct them in a systematic, organized manner.

2. Many highway agencies already treat perceived hazards at railroad crossings, and also make "yellow book-type" improvements to their Interstate system. However, more emphasis should be placed on the hazards on state and local routes, and on urban streets. There is a need for yellow book-type measures on local roads, and programs are needed to fund these improvements.

3. One of the obstacles to improving hazardous elements with hazard elimination program and other funds has been the requirement to show projected accident reductions and favorable benefit-cost ratios. However, accident savings may not be easily quantifiable for all elements. One method of realistically computing such benefits is to group all similar elements in a blanket improvement program. The total accident benefits for all elements and combined costs for improvements can then be used with expected accident reduction. A good example of this is the Kentucky "Interstate Safety Improvement Program," because it allowed for improvements to be compared in an economic analysis of blanket improvements of hazardous elements, as well as high-accident locations (*27*).

AGENCY PROBLEMS AND LIMITATIONS

Of nine basic problems relative to the identification and correction of hazardous highway elements, the most critical reported by agencies was lack of funding for making safety improvements and the second most critical was limited personnel. Inaccurate data collection was cited as the third biggest problem by state agencies, but was less of a problem (eighth in priority) for local agencies. The fourth most common problem cited by states was the difficulty in justifying the correction of highway elements unless accident experience is high. This was cited less often by local agencies, possibly because many local agencies emphasize the MUTCD-type (e.g., signing, striping, and signal projects) improvements with less emphasis on accidents, or because of limited personnel or the lack of high-quality accident data to perform accident-based analysis of roadway hazards.

Besides limited funds and personnel, the major problems facing responding local agencies were lack of computer capabilities and no clear direction and guidance for addressing highway hazards. These were of much lesser concern to state agencies. Other problems listed by state and local agencies include limited trained personnel, large highway systems (which hinder routine system-wide inspection and correction of hazards), and the lack of interest or support from top management.

Although no easy solutions exist for many of these problems, some suggestions that may be helpful include:

1. There should be an increased emphasis by state and local agencies on identification and treatment of obvious roadway hazards for which favorable accident benefits have been shown to result. In particular, many types of low-cost blanket improvements are highly desirable. Careful use of the funds should be emphasized to yield the greatest possible benefits.
2. High-quality training courses and programs related to highway safety are currently available and are highly recommended for engineering and technical staff. Also, many worthwhile training sessions are aimed at highway safety managers. In particular, the Federal Highway Administration, state highway departments, universities, and other organizations sponsor training courses related to administering highway safety programs, safety improvements, maintenance practices, correcting highway features, project and program evaluation, and other topics. Such courses can provide helpful guidance for handling highway safety hazards, and could generate interest and support from management personnel.
3. The recent developments with microcomputers have resulted in the availability of computers to many local agencies at minimal cost. Local agencies should seek information from state and FHWA personnel relative to funding sources for the purchase of suitable computer hardware and software for safety-analysis purposes. Numerous reference documents are also available on microcomputer applications to safety analysis, including the application to inventories of highway elements.
4. Justifying highway element improvements continues to be a problem for many agencies because of a lack of accident information at such sites. The grouping of elements into a "program" is one way of presenting a composite cost-effectiveness approach.
5. A funded program should be developed to address specific highway hazards without necessarily requiring formal economic analyses. Such a program could include system-wide improvements based on an analysis of accident severities and frequencies for particular types of elements.
6. The effects of treatments of hazardous elements should be routinely evaluated by states. Proper evaluation designs (i.e., with control or comparison sites) should be used instead of weak experimental designs (such as simple before-and-after studies). Program evaluations could be used to determine the overall effects of a group of similar projects (e.g., delineation improvements at 50 narrow bridges, skid surface treatments on 100 miles of roadway, etc.). The results of such project and program evaluations will provide valuable insights into which types of improvements are successful and which ones are ineffective. Such information is crucial to allow for better use of limited funding and increased highway safety in future years.

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APPENDIX A

SURVEY FORM

SURVEY FORM

"Methods for Identifying Hazardous Highway Elements"

Federal law (23 USC 152) requires states to identify hazardous locations, sections, and elements. Most of the efforts of highway agencies has been devoted to identifying high-accident locations, considering various measures of accident frequency, accident rate, and accident severity. While these are crucial to a highway safety program, another important aspect is identifying hazardous highway elements which may have the potential for high accident frequency or severity.

A highway element is any physical roadway feature, obstacle, device, or condition which can be measured or inventoried. Examples of highway features include bridges, railroad grade crossings, guardrail ends, roadside obstacles, traffic control devices, and many others. The following survey form was developed as part of a study by the Transportation Research Board entitled, "Methods for Identifying Hazardous Highway Elements". The results of this study will be summarized and published in an effort to assist state and local safety personnel and administrators in improving their highway safety efforts relative to highway elements. Your assistance in completing and sending back this survey form is greatly appreciated. Please send the completed form to:

Charles V. Zegeer
Goodell-Grivas, Inc.
17320 W. Eight Mile Rd.
Southfield, MI 48075

SURVEY FORM

METHODS FOR IDENTIFYING HAZARDOUS HIGHWAY ELEMENTS

1. Agency____

2. Name of Person Completing Survey________________________

   Title:______________________ Phone ( )______________

   Address:_______________________________________

3. Do you want a copy of the summary of results? _____Yes _____No

4. Mileage of streets and roads under agency control __________ miles

5. What does your agency consider to be hazardous highway elements? (Please give specific examples)__________________________

   ____

   ____

6. Several methods are available relative to identifying hazardous elements. Please check the one or more (A through E) that apply to your agency:

   A. Elements are not identified unless they experience high accident experience. (Check if this applies)______

   B. No routine procedure is used to identify hazardous elements. However, if obvious roadway deficiencies are seen in the field by a safety engineer, maintenance worker, policeman, etc., this is considered for improvement. (Check if this applies)_______

   C. Routine field inspections are made of the roadway system to identify deficient elements, although inspectors have no specific elements in mind prior to field inspections.
   (Check if this applies) _______

      If C is checked, list some of the roadway deficiencies which are typically found and corrected ________________________

      ____

   D. Routine field inspections are made of the roadway system. Specific pre-defined roadway elements are reviewed in these inspections.
   (Check if this applies)_______

      However, no formal inventory is taken of roadway elements, except those found to be deficient. (Check if this applies)_______

If D is checked, please list types of elements which are inspected routinely.

____

____

E. One or more types of roadway elements are routinely inventoried such as signs, roadside obstacles, signals, pavement markings, bridges, etc. (Check if this applies)_______

If E is checked, please complete parts a, b, c, and d below:

a. Please list all the types of elements in the inventory (or attach a copy of the field inventory forms)_______________

____

____

____

b. Are <u>all</u> types of deficient elements selected from this inventory for possible improvements: Yes_______ No_______

If no, which types of elements are considered for possible improvement? (Please list or attach a listing):____________

____

____

____

c. What methods are used to collect such roadway elements? (Check all that apply)

Manual field surveys ________
Photolog film ________
Videolog film ________
Electronic equipment ________
None ________

d. How are inventory data stored? (Check one or more)

Computer inventory file ________
File cabinets ________
Maps ________
Other (please state) ________

Please attach a sample of inventory on maps, computer printout of inventory (with coding instructions), forms used to summarize inventory data, etc.

7. The following is a list of roadway elements which may be considered by a highway agency for routine inspection when identifying hazardous elements for possible improvement. Please indicate the priority that is placed on each of these elements by your agency for possible improvements.

Element	Is an inventory kept by your agency? (check if yes)	Priority of element for identification purposes (check one that applies for each element) High	Medium	Low	Not at all
Narrow Bridges					
Bridge Rails					
Roadside Obstacles (trees, utility poles, etc.)					
Illumination					
Superelevation and Crown					
Number of Lanes					
Existence or Lack of Turn Lanes					
Shoulder Type and Curb					
Slippery Pavements					
Rough Pavements					
Railroad Grade Crossings					
Guardrail and Other Barriers					
Steep Roadside Slopes					
Narrow Lanes and Shoulders					
Shoulder Drop-Off					
Unprotected Overpasses					
Sharp Horizontal Alignment					
Steep Grades					
Gore Areas					
Drop Lanes and Roadway Discontinuities					
Pavement Markings and Delineation					
Roadway Signs and Supports					
Pedestrian and Bicycle Facilities					
Sight Distance Deficiencies					
Drainage Facilities					
Combinations of Elements					
Others: ________					
________					
________					

8. Are priorities placed on highway elements for possible improvements?
Yes________ No________

If yes, please describe how priorities are established.____________

____

____

____

9. After elements are identified as deficient, or in need of repair, must they compete with high-accident locations for improvement funding? Yes________ No________

10. Is an economic analysis conducted to justify making improvements to deficient highway elements? Yes________ No________ Sometimes________

    (please explain)____

    ____

    ____

11. What is the prevailing guidelines of your agency in terms of improving highway elements? (Please check all that apply)

    A. We spend money on improving highway elements only if the accidents exceed a certain level (i.e., We ca improve all of our high-accident locations, so why spend money on locations which haven't had accidents yet?) (Check if this agrees with your agency's philosophy)________

    B. We rarely make improvements, unless accident experience is high. (Check if this agrees with your agency's philosophy)________

    C. We try to be sensitive to deficient highway elements, as well as high accident locations and routinely improve a few of these elements each year. (Check if this applies to your agency)________

    D. We place a high priority on identifying and correcting highway elements for locations both with and without high accident experience. (Check if this applies to your agency)________

    E. Other (please specify)____

    ____

    ____

    ____

    ____(Check)______

12. Are highway elements routinely considered for improvement which are not high accident locations. Yes________ No________

    If yes, what are some of the possible reasons for considering them for improvement. (Check high, medium, low, or not at all for each item):

	High	Medium	Low	Not At All
a. They don't meet MUTCD guidelines or warrants	____	____	____	____
b. They don't meet Blue Book or other design standards	____	____	____	____
c. They are based on "political" pressure	____	____	____	____
d. They are based on citizen input or complaints	____	____	____	____
e. We fear possible problems with tort liability in case of an accident	____	____	____	____
f. They appear hazardous based on our past experience or judgement	____	____	____	____
g. They do not meet our current state or local guidelines or practices	____	____	____	____
h. To maintain consistancy in our roadway system	____	____	____	____
i. We have experienced accident problems at similar locations in the past	____	____	____	____
j. Based on findings from articles and past research on dangerous elements	____	____	____	____
k. It keeps our maintenance personnel busy during periods of low work loads	____	____	____	____
l. To improve our public image	____	____	____	____
m. Other (please state)____________________ ______________________________	____	____	____	____
n. Other (please state)____________________ ______________________________	____	____	____	____

13. What percent (approximate) of your safety improvement funding (23 USC 152 - Section 209) is spent on:

Citizen Complaints	________
High accident locations	________
Hazard highway elements (where accident data are not considered)	________
Other considerations (political, etc.)	________
Total	100%

14. What are common funding sources used to improve highway elements which are NOT identified from accident experience? (Please check frequent, sometimes, infrequent, or never for each funding source.)

	Frequent	Sometimes	Infrequent	Never
a. 3R (Resurfacing, Rehabilitation and Restoration) Projects				
b. Safety Improvement Funding				
c. Maintenance Program				
d. Construction Program				
e. No Fund				
f. Other (Please state)__________				
g. Other (Please state)__________				

15. What are some of the common limitations associated with identifying and improving highway elements? (Please check the degree of problem associated with each limitation).

	Major Problem	Problem	Minor Problem	No Problem
a. Lack of interest or support from top management				
b. Limited funds				
c. Limited manpower				
d. We cannot justify addressing highway elements unless accident experience is high				
e. Data collection accuracy is a problem				
f. Our highway system is too large				
g. No computer is available to process such data				
h. No clear direction or guideance exists on what elements or procedures should be used				
i. Finding or training good field people is a problem				
j. Other (state)__________				

16. If detailed information and recommendations could be provided to your agency on methods and benefits from identifying hazardous highway elements, this would probably cause (check one):

a. Little or no change in our procedure, since we already consider highway elements routinely ________

b. Possibly more emphasis on considering improvements to hazardous highway elements ________

c. We still would not be interested in identifying or correcting hazardous highway elements, unless an accident problem exists ________

17. What are your most critical needs desired improvements relative to the identification and elimination of hazardous highway elements?________

____

____

18. Other comments you wish to make regarding hazardous elements or safety programs____

____

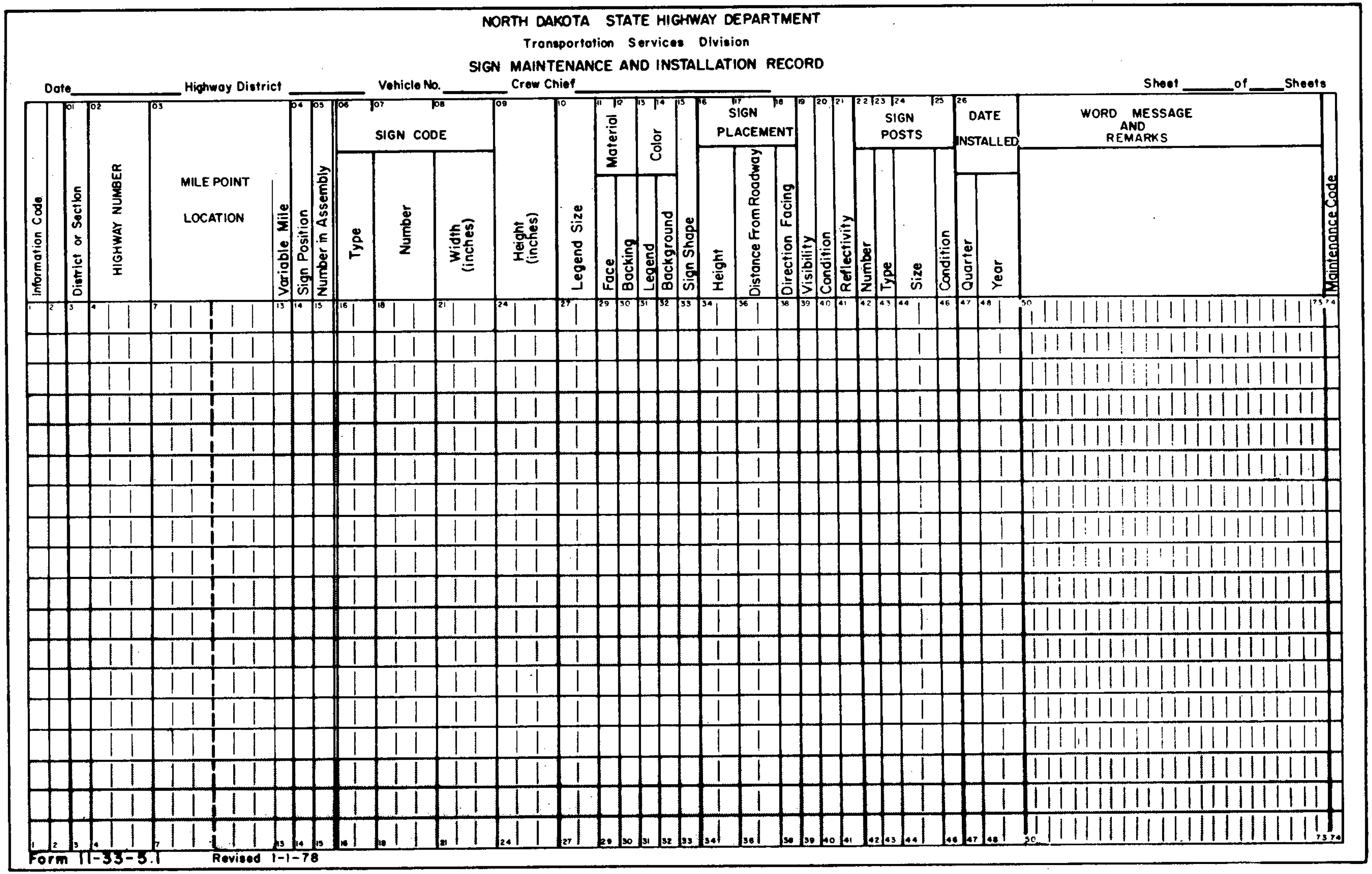
____

Please return this questionnaire to:

Charles V. Zegeer
Goodell-Grivas, Inc.
17320 W. Eight Mile Rd.
Southfield, MI 48075

APPENDIX B

INPUT AND OUTPUT FORMS FOR INVENTORY DATA


NORTH DAKOTA STATE HIGHWAY DEPARTMENT
Transportation Services Division
SIGN MAINTENANCE AND INSTALLATION RECORD

Date ______ Highway District ______ Vehicle No. ______ Crew Chief ______ Sheet ____ of ____ Sheets

Information Code		District or Section	HIGHWAY NUMBER	MILE POINT LOCATION	Variable Mile	Sign Position	Number in Assembly	SIGN CODE Type	SIGN CODE Number	Width (inches)	Height (inches)	Legend Size	Material Face	Material Backing	Color Legend	Color Background	Sign Shape	SIGN PLACEMENT Height	SIGN PLACEMENT Distance From Roadway	Direction Facing	Visibility	Condition	Reflectivity	SIGN POSTS Number	SIGN POSTS Type	SIGN POSTS Size	Condition	DATE INSTALLED Quarter	DATE INSTALLED Year	WORD MESSAGE AND REMARKS	Maintenance Code
1	2	3	4	7	13	14	15	16	18	21	24	27	29	30	31	32	33	34	36	38	39	40	41	42	43	44	46	47	48	50	73 74

Form 11-33-5.1 Revised 1-1-78

FIGURE B-1 Sample coding form for North Dakota sign inventory.

HW3-030-AA	03-09-84	NORTH DAKOTA STATE HIGHWAY DEPARTMENT TRAFFIC CONTROL SIGN INVENTORY	REQUEST NUMBER 219

HWY	LOCATE	POS	ASM NO.	SIGN CODE	WDTH	HT	LGND SIZE	MATERIAL	COLOR	SHAPE	PLACEMENT HT	OFF	DIR	VIS. OBST	COND	REFL	SIGN NO	TYPE	POST SIZ	COND	MAINT CODE	DATE INST	DATE POSTED
1-094	97.456	2	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			E	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	98.000	1		M 085 98	008	016	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	98.000	2		M 085 98	008	016	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	99.000	1		M 085 99	008	016	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	99.000	2		M 085 99	008	016	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	100.000	1		M 086 100	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	100.000	2		M 086 100	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	101.000	1		M 086 101	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	101.000	2		M 086 101	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	102.000	1	1	M 086	008	024	06	REFSS ALUM	RED GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD	5	1-68	06-10-82
1-094	102.000	2		M 086 102	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	102.606	1	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			W	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	102.774	2	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			E	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	103.000	1	1	M 086	008	024	06	REFSS ALUM	RED GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	BENT	5	1-68	06-10-82
1-094	103.000	2	1	M 086	008	024	06	REFSS ALUM	RED GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	BENT	5	1-68	06-10-82
1-094	104.000	1		M 086 104	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	104.000	2		M 086 104	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	105.000	1		M 086 105	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	105.000	2		M 086 105	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	106.000	1		M 086 106	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	106.000	2		M 086 106	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	107.000	1		M 086 107	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	107.000	2		M 086 107	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	108.000	1		M 086 108	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	108.000	2		M 086 108	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	08-05-71
1-094	108.209	1	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			W	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	108.510	2	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			E	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	109.000	1		M 086 109	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	109.000	2		M 086 109	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	110.000	1		M 086 110	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	110.000	2		M 086 110	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	110.154	1	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			W	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	110.556	2	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			E	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	111.000	1		M 086 111	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	111.000	2		M 086 111	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	112.000	1		M 086 112	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	112.000	2		M 086 112	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	113.000	1		M 086 113	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	113.000	2		M 086 113	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	113.240	1	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			W	GOOD	GOOD	GOOD						4-75	10-08-76
1-094	113.567	2	2	1M 084	072	060	12	HI-RS ALUM	WHT GRN	RECT			E	GOOD	GOOD	GOOD					7	4-75	10-21-82
1-094	114.000	1		M 086 114	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	114.000	2		M 086 114	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	115.000	1		M 086 115	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	W	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71
1-094	115.000	2		M 086 115	008	024	06	REFSS ALUM	WHT GRN	RECT	04	13	E	GOOD	GOOD	GOOD	1	ST.U	03	GOOD		1-68	03-10-71

FIGURE B-2 Sample output of North Dakota sign inventory.

ASSEMBLY NUM	MAIN STREET	SYS	SIGN LOCATION	REFERENCE CROSS STREET	SIDE OF STREET	DIR SIGN FACING	SIGN CODE	SIGN SIZE	DATE OF WORK	EXPECT LIFE	SIGN COND	VISIBILITY	SUPPORT TYPE	SUPPORT COND	STD/NSTD
14015517000100	MALIBU DR	C	35 1	HIGHLAKE DR	EAST	SOUTH	R1-1	30X30	02-01-84	10 YR	GOOD	GOOD	UPST	FAIR	STD
14015517000200	MALIBU DR	C	43 N	HIGHLAKE DR	EAST	SOUTH	W14-1	30X30	*05-03-79	0 YR	GOOD	GOOD	UPST	GOOD	NSF
14015517000300	MALIBU DR	C	95 1	DEAD END	OTHER	SOUTH	ER-1	24X24	02-01-84	7 YR	GOOD	GOOD	UPST	GOOD	STD
14015517000400	MALIBU DR	C	95 1	DEAD END	OTHER	SOUTH	ER-1	24X24	02-01-84	7 YR	GOOD	GOOD	UPST	GOOD	STD
14015517000500	MALIBU DR	C	95 1	DEAD END	OTHER	SOUTH	ER-1	24X24	02-01-84	7 YR	GOOD	GOOD	UPST	GOOD	STD
14015517000600	MALIBU DR	C	95 1	DEAD END	OTHER	SOUTH	ER-1	24X24	02-01-84	7 YR	GOOD	GOOD	UPST	GOOD	STD
14015517000700	MALIBU DR	C	95 1	DEAD END	OTHER	SOUTH	ER-1	24X24	02-01-84	7 YR	GOOD	GOOD	UPST	GOOD	STD
14015517000800	MALIBU DR	C	5 3	THE PLAZA	WEST	NORTH	R1-1	30X30	02-01-84	10 YR	GOOD	GOOD	WOOD	FAIR	STD
14015517000900	MALIBU DR	C	23 1	THE PLAZA	SOUTH	NORTH	D3-1	9X36	07-27-83	6 YR	GOOD	GOOD	MAST	GOOD	STD
15105519000100	MALLARD DR	C	35 W	ALMOND RD	SOUTH	WEST	D3-1	30X 6	05-27-79	5 YR	GOOD	GOOD	PIPE	GOOD	STD
15005519000200	MALLARD DR	C	389 S	SHADY LN	WEST	NORTH	W1-1L	30X30	*05-03-79	0 YR	GOOD	GOOD	WOOD	GOOD	STD
15005519000300	MALLARD DR	C	41 1	ALBEMARLE RD	WEST	NORTH	R1-1	30X30	10-20-83	10 YR	GOOD	GOOD	UPST	GOOD	STD
15005519000400	MALLARD DR	C	71 3	ALBEMARLE RD	WEST	NORTH	W14-1	30X30	10-20-83	7 YR	GOOD	GOOD	UPST	GOOD	STD
15005519000500	MALLARD DR	C	37 3	ALBEMARLE RD	EAST	SOUTH	R1-1	30X30	10-20-83	10 YR	GOOD	GOOD	UPST	GOOD	STD
15005519000600	MALLARD DR	C	30 4	ALBEMARLE RD	NORTH	WEST	D3-1	36X 9	08-09-82	5 YR	GOOD	GOOD	PIPE	GOOD	STD
15005519000700	MALLARD DR	C	95 S	RAINBOW DR	EAST	SOUTH	W1-1R	30X30	*05-03-79	0 YR	GOOD	GOOD	WOOD	GOOD	STD
15005519000800	MALLARD DR	C	32 S	SHADY LN	EAST	SOUTH	D3-1	30X 6	*05-03-79	0 YR	UNKN	POBS	PIPE	GOOD	STD
15005519000900	MALLARD DR	C	20 N	SHADY LN	EAST	SOUTH	ER-1	18X18	*05-03-79	0 YR	GOOD	GOOD	WOOD	GOOD	NSF
15015523000100	MALLEN DR	C	23 E	REDSTONES RD	WEST	EAST	D3-1	9X30	12-01-83	7 YR	GOOD	GOOD	PIPE	GOOD	STD
15015523000200	MALLEN DR	C	23 E	WINCHELSE DR	WEST	EAST	D3-1	9X30	12-01-83	7 YR	GOOD	GOOD	PIPE	GOOD	STD
12015528000100	MALLORY ST	C	302 S	DEAD END	EAST	SOUTH	R3-57	30X30	*07-11-79	0 YR	GOOD	GOOD	UPST	GOOD	NSF
12015528000200	MALLORY ST	C	302 S	DEAD END	EAST	SOUTH	W13-1	24X24	*07-11-79	0 YR	GOOD	GOOD	UPST	GOOD	NSF
12015528000300	MALLORY ST	C	48 S	DEAD END	EAST	SOUTH	OM-3R	12X36	*07-11-79	0 YR	REPL	FAIR	UPST	GOOD	STD
12015528000400	MALLORY ST	C	33 S	DEAD END	EAST	SOUTH	W1-6L	48X24	*07-11-79	0 YR	GOOD	GOOD	UPST	GOOD	STD
12015528000500	MALLORY ST	C	20 S	DEAD END	EAST	SOUTH	OM-3R	12X36	*07-11-79	0 YR	REPL	N/A	UPST	GOOD	STD

FIGURE B-3 Charlotte, North Carolina sign inventory output.

OAKLAND COUNTY OBSTACLE
DATA CODING FORM

District #__________ Street Type __________ D.O.T.__________ Viewer__________

Resolution__________ Date of Filming__________ Roll # __________ Page #__________

Main Street __________ Date Viewed__________

Cross Street	Obstacle Type	Frame ± Foot	Side of Street	Curb/ No Curb	Distance from Curb

FIGURE B-4 Obstacle coding form used by Oakland County, Michigan.

ROADSIDE OBSTACLE INVENTORY UPDATE FORM

Please Print

Complete Only Those Items Where a Change has Occurred

PROJECT PERMIT WORK ORDER (Circle One) No._________

CARD 1

Process Code A (Alter) I (Insert) D (Delete)	☐	1
Card Sequence	1	2
Beginning Line Number	☐☐☐☐☐☐☐☐	4 - 11
Ending Line Number	☐☐☐☐☐☐☐☐	13 –20
Main Street Name	☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	21 - 35
Cross Street Name	☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐	36–50
Distance from Cross Street	☐☐☐☐	51 - 54
Direction from Cross Street (N, S, E, W)	☐	55
Side of Street (N, S, E, W)	☐	56
Presence of Curbing (U, C)	☐	57
Obstacle Rigidity (Refer to Users Guide)	☐	58
Distance from Pavement (Feet)	☐☐☐	59 – 61
Road Type (Sub, Col, Loc, Pri)	☐☐☐	62 – 64

CARD 2

Process Code	☐	1
Card Sequence	2	2
Beginning Line Number	☐☐☐☐☐☐☐☐	4 – 11
Ending Line Number	☐☐☐☐☐☐☐☐	13 – 20
Obstacle Type (Refer to Users Guide)	☐☐☐☐☐☐☐☐☐☐	21 – 30
Speed Limit (P or U)	☐☐☐	31 – 33
Horizontal Geometrics (Refer to Users Guide)	☐☐☐☐☐☐☐☐☐☐☐☐	34 – 45
Verticle Geometrics (Refer to Users Guide)	☐☐☐☐	46 – 49
Passing Zone (Refer to Users Guide)	☐☐☐	50 – 52
Date of Initial Surfacing	☐☐	53 – 54
Traffic Volume (ADT)	☐☐☐☐☐	55 – 59
MALI PR Number	☐☐☐☐☐☐☐	60 – 66
MALI Milepoint	☐☐☐☐☐☐	67 – 72

FIGURE B-5 Obstacle update form used by Oakland County, Michigan.

DATE = 4/24/84

MICHIGAN DEPARTMENT OF TRANSPORTATION
GUARDRAIL GENERAL USE REPORT

PAGE 1

STATEWIDE ,RAIL TYPE = ,PURPOSE = ,APPROACH END = ,TRAIL END = ,HEIGHT = - ,RATING = - ,POST =
DISTRICT = 1

CONTROL SECTION	BEGIN MILE	END MILE	MAINT ROUTE	RUN NUM	LOCATION DESCRIPTION ---------	DIR	LOC	RAMP NUM	GR TYPE	APPROACH END TYPE	TRAIL END TYPE	GUARDRAIL PURPOSE	LENGTH	HEIGHT	POST TYPE	NUM POST	SECTION RATING
07011	00.01	00.24	US141	001	0.42 MI S OF RD W	N	R	00000	AA	BUFFER	BUFFER	SLOPE	1,212	25	PNT	100	
07011	00.03	00.24	US141	002	0.63 MI S OF RD W	S	R	00000	AA	BUFFER	BUFFER	SLOPE	1,112	26	PNT	92	
07011	00.46	00.59	US141	003	0.20 MI S OF RD W	S	R	00000	AA	BUFFER	BUFFER	SLOPE	700	26	PNT	59	
07011	01.62	01.63	US141	004	AT B-01 TRACY CR	N	R	00000	AA	BUFFER	CURVED END	BRIDGE	38	26	PNT	5	
07011	01.62	01.63	US141	005	AT B-01 TRACY CR	S	R	00000	AA	CURVED END	BUFFER	BRIDGE	38	26	PNT	5	
07011	01.63	01.64	US141	006	AT B-01 TRACY CR	N	R	00000	AA	CURVED END	BUFFER	BRIDGE	38	26	PNT	5	
07011	01.63	01.64	US141	007	AT B-01 TRACY CR	S	R	00000	AA	BUFFER	CURVED END	BRIDGE	38	26	PNT	5	
07011	04.66	04.80	US141	008	1.66 MI S OF RD W	S	R	00000	AA	BUFFER	BUFFER	SLOPE	738	26	PNT	62	
07011	04.82	04.86	US141	009	1.50 MI S OF RD W	S	R	00000	AA	BUFFER	BUFFER	SLOPE	250	26	PNT	23	
07011	06.50	06.64	US141	010	0.18 MI N OF RD W	N	R	00000	AA	BUFFER	BUFFER	SLOPE	750	22	PNT	63	
07011	06.50	06.69	US141	011	0.37 MI N OF RD W	S	R	00000	AA	BUFFER	BUFFER	SLOPE	988	24	PNT	82	
07011	07.95	08.18	US141	012	0.71 MI S OF MURPHY RD	S	R	00000	AA	BUFFER	BUFFER	SLOPE	212	26	PNT	100	
07011	09.34	09.43	US141	014	0.11 MI S OF M-28	S	R	00000	AA	BUFFER	BUFFER	SLOPE	437	26	PNT	38	
07011	09.34	09.43	US141	013	0.02 MI S OF M-28	N	R	00000	AA	BUFFER	BUFFER	SLOPE	437	26	PNT	38	
07012	00.72	00.87	M0028	002	1.29 MI S OF PARENT LAKE RD	S	R	00000	BB	BCT	BCT	SLOPE	900	28	WOOD	129	018
07012	00.76	00.86	M0028	001	1.15 MI S OF PARENT LAKE RD	N	R	00000	AA	BUFFER	BUFFER	SLOPE	562	20	WOOD	48	044
07012	01.93	01.94	M0028	003	0.08 MI S OF PARENT LAKE RD	S	R	00000	AA	BUFFER	BUFFER	CULVERT	12	28	WOOD	2	019
07012	01.96	01.97	M0028	004	0.04 MI S OF PARENT LAKE RD	N	R	00000	AA	BUFFER	BUFFER	CULVERT	12	30	WOOD	2	019
07012	02.56	02.69	M0028	005	0.68 MI N OF PARENT LAKE RD	S	R	00000	BB	BCT	BCT	SLOPE	600	23	WOOD	97	023
07012	04.96	04.98	US041	002	1.29 MI N OF US-141	S	R	00000	BB	BCT	BCT	SLOPE	100	26	WOOD	17	018
07012	04.97	05.00	US041	001	1.28 MI N OF US-141	N	R	00000	BB	BCT	BCT	CULVERT	100	27	WOOD	17	018
07012	05.23	05.27	US041	003	1.28 MI S OF B-02 STURGEON RIV	S	R	00000	BB	BCT	BCT	SLOPE	250	25	WOOD	41	005
07012	06.42	06.45	US041	004	0.09 MI S OF B-02 STURGEON RIV	S	R	00000	BB	TRANS	BCT	BRIDGE SLOPE	150	29	WOOD	24	020
07012	06.45	06.48	US041	005	0.03 MI S OF B-02 STURGEON RIV	N	R	00000	BB	BCT	TRANS	BRIDGE SLOPE	100	30	WOOD	16	018
07012	06.45	06.52	US041	007	0.01 MI N OF B-02 STURGEON RIV	S	R	00000	CC	TRANS	TRANS	BRIDGE SLOPE	355	32	WOOD	48	017
07012	06.48	06.54	US041	006	AT B-02 STURGEON RIV	N	R	00000	CC	TRANS	TRANS	BRIDGE	355	31	WOOD	48	017
07012	06.52	06.54	US041	009	0.03 MI N OF B-02 STURGEON RIV	S	R	00000	BB	BCT	TRANS	BRIDGE SLOPE	88	25	WOOD	14	022
07012	06.54	06.56	US041	008	0.03 MI N OF B-02 STURGEON RIV	N	R	00000	BB	TRANS	BCT	BRIDGE SLOPE	88	27	WOOD	14	008
07012	07.35	07.40	US041	011	0.47 MI S OF CO RD 345	S	R	00000	AA	BUFFER	BUFFER	SLOPE	275	29	WOOD	25	020
07012	07.37	07.42	US041	010	0.40 MI S OF CO RD 345	N	R	00000	AA	BUFFER	BUFFER	SLOPE	237	30	WOOD	22	011
07012	07.50	07.57	US041	013	0.32 MI S OF CO RD 345	S	R	00000	AA	BUFFER	BUFFER	SLOPE	337	30	WOOD	30	018
07012	07.52	07.59	US041	012	0.23 MI S OF CO RD 345	N	R	00000	BB	BCT	BUFFER	SLOPE	325	25	WOOD	53	015
07012	07.72	07.75	US041	015	0.10 MI S OF CO RD 345	S	R	00000	BB	BCT	BCT	SLOPE	137	30	WOOD	23	015
07012	07.74	07.78	US041	014	0.04 MI S OF CO RD 345	N	R	00000	BB	BCT	BCT	CULVERT	125	31	WOOD	21	010
07012	07.80	07.95	US041	017	0.13 MI N OF CO RD 345	S	R	00000	AA	BUFFER	BUFFER	SLOPE	500	29	WOOD	43	039
07012	07.87	07.97	US041	016	0.05 MI N OF CO RD 345	N	R	00000	BB	BCT	BCT	SLOPE	550	33	WOOD	89	009
07012	08.05	08.09	US041	018	0.27 MI N OF CO RD 345	S	R	00000	AA	BUFFER	BUFFER	SLOPE	225	21	WOOD	21	023
07012	08.10	08.11	US041	019	0.22 MI S OF BARAGA PLAINS RD	N	R	00000	AA	BUFFER	BUFFER	SLOPE	100	33	WOOD	11	020
07012	08.52	08.55	US041	020	0.19 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BCT	BCT	SLOPE	212	21	WOOD	35	013
07012	08.62	08.68	US041	022	0.32 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BUFFER	BUFFER	SLOPE	312	25	WOOD	51	008
07012	08.65	08.70	US041	021	0.29 MI N OF CO RD 345 OLD US-	N	R	00000	BB	BUFFER	BUFFER	SLOPE	275	28	WOOD	45	003
07012	09.05	09.19	US041	023	0.83 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BCT	BCT	SLOPE	750	26	WOOD	121	007
07012	09.83	09.89	US041	024	1.47 MI N OF CO RD 345 OLD US-	N	R	00000	BB	BCT	BCT	SLOPE	337	27	WOOD	55	002
07012	09.83	09.88	US041	025	1.52 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BCT	BCT	SLOPE	225	26	WOOD	37	000
07012	09.94	09.96	US041	027	1.60 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BCT	BCT	CULVERT	75	27	WOOD	13	019
07012	09.95	09.97	US041	026	1.59 MI N OF CO RD 345 OLD US-	N	R	00000	BB	BCT	BCT	SLOPE	75	30	WOOD	13	008
07012	09.98	10.01	US041	028	1.65 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BCT	BCT	SLOPE	175	26	WOOD	29	019
07012	10.02	10.04	US041	029	1.66 MI N OF CO RD 345 OLD US-	N	R	00000	BB	BCT	BCT	SLOPE	100	30	WOOD	17	001
07012	10.36	10.47	US041	031	2.01 MI S OF TAYLOR CR	S	R	00000	BB	BCT	BCT	SLOPE	587	28	WOOD	95	009
07012	10.38	10.53	US041	030	1.84 MI S OF TAYLOR CR	N	R	00000	BB	BCT	BCT	SLOPE	775	27	WOOD	125	016
07012	10.64	10.73	US041	033	1.73 MI S OF TAYLOR CR	S	R	00000	BB	BCT	BCT	SLOPE	487	28	WOOD	79	010
07012	10.65	10.75	US041	032	1.62 MI S OF TAYLOR CR	N	R	00000	BB	BCT	BCT	SLOPE	487	28	WOOD	79	001
07012	10.77	10.86	US041	034	1.51 MI S OF TAYLOR CR	N	R	00000	BB	BCT	BCT	SLOPE	437	25	WOOD	71	011
07012	10.77	10.84	US041	035	1.60 MI S OF TAYLOR CR	S	R	00000	BB	BCT	BCT	SLOPE	350	24	WOOD	57	008
07012	11.64	11.72	US041	036	0.65 MI S OF TAYLOR CR	N	R	00000	BB	BCT	BCT	SLOPE	412	27	WOOD	67	013
07012	11.64	11.68	US041	037	0.73 MI S OF TAYLOR CR	S	R	00000	BB	BCT	BCT	SLOPE	225	29	WOOD	37	004
07012	12.33	12.35	US041	040	0.02 MI N OF TAYLOR CR	S	R	00000	BB	TRANS	BCT	BRIDGE SLOPE	100	32	WOOD	16	016
07012	12.34	12.35	US041	038	0.02 MI S OF TAYLOR CR	N	R	00000	BB	BCT	TRANS	BRIDGE SLOPE	100	25	WOOD	16	009
07012	12.35	12.38	US041	041	0.01 MI N OF TAYLOR CR	S	R	00000	CC	TRANS	TRANS	BRIDGE SLOPE	175	33	WOOD	29	014
07012	12.35	12.39	US041	039	AT TAYLOR CR	N	R	00000	CC	TRANS	TRANS	BRIDGE	175	32	WOOD	29	013
07012	12.38	12.40	US041	043	0.03 MI N OF TAYLOR CR	S	R	00000	BB	BCT	TRANS	BRIDGE SLOPE	100	24	WOOD	16	003
07012	12.39	12.40	US041	042	0.02 MI N OF TAYLOR CR	N	R	00000	BB	TRANS	BCT	BRIDGE SLOPE	50	31	WOOD	8	012
07012	13.41	13.46	US041	045	0.08 MI N OF CO RD 345 OLD US-	S	R	00000	BB	BCT	BCT	CULVERT	125	25	WOOD	21	015
07012	13.42	13.45	US041	044	0.04 MI N OF CO RD 345 OLD US-	N	R	00000	BB	BCT	BCT	CULVERT	125	27	WOOD	21	017
07012	13.71	13.73	US041	047	0.06 MI S OF G-01 DSS&A RR	S	R	00000	BB	BCT	BCT	SLOPE	75	24	WOOD	13	018
07012	13.72	13.74	US041	046	0.03 MI S OF G-01 DSS&A RR	N	R	00000	BB	BCT	BCT	SLOPE	75	25	WOOD	13	017
07012	15.67	15.70	US041	048	AT DYNAMITE HILL RD	N	R	00000	BB	BCT	BCT	SLOPE	162	24	WOOD	27	017
07012	15.68	15.73	US041	049	0.02 MI S OF DYNAMITE HILL RD	S	R	00000	BB	BCT	BCT	SLOPE	287	27	WOOD	47	018
07012	16.37	16.39	US041	050	AT G-02 DSS&A RR	N	R	00000	AA	BUFFER	BUFFER	SLOPE	88	27	WOOD	10	023
07012	16.39	16.43	US041	051	AT G-02 DSS&A RR	S	R	00000	AA	TRANS	BUFFER	BRIDGE SLOPE	209	29	WOOD	23	035
07012	16.43	16.45	US041	052	AT B-04 FALLS RIV	N	R	00000	CC	BUFFER	BUFFER	BRIDGE SLOPE	87	32	WOOD	15	009
07012	16.43	16.44	US041	053	0.02 MI S OF B-04 FALLS RIV	S	R	00000	CC	BUFFER	TRANS	BRIDGE SLOPE	62	32	WOOD	11	007

FIGURE B-6 Sample output from Michigan's guardrail inventory.

TABLE B-1

SUMMARY OF GUARDRAIL TYPES AND END TREATMENTS IN MICHIGAN GUARDRAIL INVENTORY

MICHIGAN DEPARTMENT OF TRANSPORTATION
GUARDRAIL GENERAL USE REPORT

DATE = 4/24/84

STATEWIDE ,RAIL TYPE = ,PURPOSE = ,APPROACH END = ,TRAIL END = ,HEIGHT = - ,RATING = - ,POST =

STATEWIDE

ENDING TYPE	--- A --	-- AD --	--- B --	-- BD --	--- C --	-- CD --	CABLE	OTHER	TOTAL
	GUARDRAIL TYPES								
BCT	394	0	6693	3	2216	10	3	3	9322
BUFFER	5987	70	2022	8	677	19	20	2	8805
CURVED END	5404	6	1007	5	407	44	1	10	6884
TURN DOWN	60	0	92	0	20	0	0	3	175
TEXAS TWIST	793	5	1954	19	780	63	2	8	3624
ANCHORED	798	0	3810	11	2818	158	0	7	7602
EXP END	345	1	27	0	42	2	0	0	417
TRANS	400	9	587	14	506	33	11	44	1604
INTER RAD	657	0	381	0	13	0	8	0	1059
MBN	11	0	111	0	42	0	0	0	164
ATTENUATOR	2	0	2	0	13	2	0	3	22
TERMINAL	161	7	395	2	358	1	0	6	930
UNKNOWN	2	0	17	0	0	0	1663	0	1682
POST TYPES									
WOOD	96645	622	426675	5729	220183	51238	28068	1463	830623
GALV STEEL	27387	540	45491	279	93	717	80	1280	75867
PAINTED ST	56257	1347	647	0	58	0	0	131	58440
OTHER	10566	0	51	0	50	0	0	9444	20111
GR LENGTH	2072214	28909	2883709	36828	1346080	321908	298035	15571	7003254

BRIDGE NO.	COUNTY	FEATURES INTERSECTED	LOCATION	TYPE	CULV. DESCR.	SP-ANS	LENGTH	RDWAY WIDTH	VERT. CLEAR	YEAR BUILT	INV LOAD	SUFF RATE	MAJ MIN
021-101.944	GRANT	CREEK	1.6 M W SH 31	CULV	2X9X11	2	19	.0		54/00	H20		MI
021-103.489	COUNTY LINE - MORTON												
021-103.489	INTERSECTION WITH N.D. 31 MILEPOINT 35.257												
021-106.109	MORTON	LOUSE CREEK	1.2 W FLASHER	SMS C		2	120	28.0		54/00	H21	080.1	MJ
021-106.603	BEGIN CORPORATE LIMITS OF FLASHER												
021-107.428	END CORPORATE LIMITS OF FLASHER												
021-109.720	MORTON	BR-CHANTA PETA	2.5 E FLASHER	CULV	2X10X8	2	21	.0		66/00	H20	063.5	MJ
021-110.060	MORTON	B N R R SEP OH	3 M E FLASHER	SMS		3	190	30.0		67/00	H35	085.5	MJ
021-110.468	MORTON	CHANTA PETA CR	3.4 E FLASHER	SMS C		2	100	28.0		54/00	H20	079.4	MJ
021-116.858	MORTON	E BR-CHANTA P	5.5 M W SH 6	TS C		1	38	32.0		31/54	H12	054.2	MJ
021-117.460	MORTON	E BR-CHANTA P	4.9 M W SH 6	CULV	3X9X10	3	28	.0		54/00	H20	082.3	MJ
021-118.908	MORTON	E BR-CHANTA P	3.5 M W SH 6	TS C		1	31	32.0		31/54	H14	065.2	MJ
021-119.357	MORTON	E BR-CHANTA P	3 M W SH 6	TS C		1	31	32.0		31/54	H14	065.2	MJ
021-122.384	INTERSECTION WITH N.D. 6 MILEPOINT 42.149												
024-000.000	COUNTY LINE - SIOUX												
024-000.000	INTERSECTION WITH N.D. 6 MILEPOINT 6.104												
024-000.320	SIOUX	FOUR MILE CR	0.32 E SH 6S	SMS		1	53	34.0		30/63	H15	079.0	MJ
024-001.791	SIOUX	CREEK	1.8 E SH 6S	CULV	1X10X6	1	10	.0		30/63	H20		MI
024-007.873	SIOUX	CREEK	7.9 NE SH 6S	CULV	2X8X10	2	17	.0		62/75	H20		MI
024-011.577	SIOUX	CREEK	11.5 NE SH 6S	CULV	1X8.5	1	9	.0		62/00	H20		MI
024-015.004	SIOUX	PORCUPINE CR	15 NE SH 6S	P/CB C		3	200	30.0		63/00	H14	062.8	MJ
024-018.647	SIOUX	BATTLE CREEK	11.3 S SH 1806	CULV	3X8X10	3	25	.0		65/00	H20	093.6	MJ
024-020.413	SIOUX	CREEK	9.5 S SH 1806	CULV	8+X5+	1	8	.0		65/00	H20		MI
024-021.401	SIOUX	CREEK	8.5 S SH 1806	CULV	1X6X6	1	6	.0		65/00	H20		MI
024-023.554	SIOUX	COAL MINE CR	6.4 S SH 1806	CULV	1X10X6	1	10	.0		65/00	H20		MI
024-025.856	SIOUX	CREEK	4.1 S SH 1806	CULV	2X12.5	2	25	.0		65/00	H20	095.1	MJ
024-029.914	INTERSECTION WITH N.D. 806 MILEPOINT 31.190												
024-032.443	SIOUX	CREEK	2.5 W SH 1806	CULV	2X7X9	2	15	.0		69/00	H20		MI
024-034.222	SIOUX	CREEK	4.3 W SH 1806	CULV	2X7X9	2	15	.0		69/00	H20		MI
024-035.232	SIOUX	CREEK	5.3 W SH 1806	CULV	2X7X9	2	15	.0		69/00	H20		MI
024-037.779	BEGIN CORPORATE LIMITS OF SOLON												
024-037.824	SIOUX	CREEK	7.9 W SH 1806	CULV	1X11X13	1	11	.0		69/00	H20		MI
024-038.133	END CORPORATE LIMITS OF SOLON												
024-040.376	SIOUX	CREEK	4.7 E SH 6N	CULV	3X7X5 R	3	22	.0		48/69	H20	094.8	MJ
024-042.987	SIOUX	CREEK	2.1 E SH 6N	CULV	2X8X8	2	17	.0		48/69	H20		MI
024-045.046	INTERSECTION WITH N.D. 6 MILEPOINT 34.894												

FIGURE B-7 Bridge output from North Dakota.

STRUCTURE INVENTORY AND APPRAISAL

MDOT 1717A (12/80)

DIST=4 DATE LAST REVISED 02/13/84 PRINTED 05/24/84

IDENTIFICATION — STRUCTURE IDENTIFICATION

CO	4 CITY CODE	8 TGL	PROJECT ID	STR NUM	DIR
16		1	1602200050000	B01	

Card 1 — IDENTIFICATION

5 ROUTE OVER: LVL	KND	DES	ROUTE NUMBER	DIR	6 FEATURES INTERSECTED	7 FACILITY CARRIED
1	3	1	000068	0	PIGEON R	M-68

Card 2 — LOCATION / DEFENSE STRUCTURES AND TEMPORARY REPAIRS

9 LOCATION	11 MILEPOINT	12 ROAD SECTION NO	13 BRIDGE DESC	14 MILEPOINT	15 SECTION LENGTH	16 LATITUDE	17 LONGITUDE	18 VUI	19 DETOUR LENGTH
1.0 MI W OF AFTON	00520	0140		0560	190	45224	08430	8 3	15

Card 3 — IDENTIFICATION / CLASS / STRUCTURE DATA

20 TOLL	21 CST	22 OWN	23 FEDERAL AID PROJECT NUMBER	24 FA SYS	25 AD-MIN	26 FUNC CLASS	27 YEAR BUILT	RECON	28 LANES ON	LANES UNDER	29 AVERAGE DAILY TRAFFIC	30 YEAR OF A.D.T	31	32 APP. ROADWAY WIDTH	32B APP. PAVEMENT WIDTH	33 MD	34 SKEW	35 STR FLAR	38 NAV CON	39 NAVIG. VERTICAL CLEARANCE	40 NAVIGATION HORIZONTAL CLEARANCE
3	1	1	F225D(11)	03	1	03	939	00	02	00	002000	82	4	042	424	0	00	0	0	000	0000

Card 4 — STRUCTURE DATA

42 SER TYPE ON	UND	43 MAIN STRUCTURE TYPE	44 APPROACH STRUCTURE TYPE	45 SPANS MAIN	46 SPANS APPROACH	48 MAXIMUM SPAN LENGTH	49 STRUCTURE LENGTH	50 SIDEWALK WIDTHS LT	RT	50A RL	51 CURB-TO-CURB BRIDGE WIDTH	52 DECK WIDTH	47 TOTAL HORIZONTAL CLEARANCE LT	RT	53 VERTICAL CLEARANCE OVER DECK	54 MINIMUM VERTICAL UNDERCLEAR LT	54 MINIMUM VERTICAL UNDERCLEAR RT	50B
1	5	302	000	001	0000	0050	000050	015	015	8	0330	0389	000	360	9999	0000	0000	4

Card 5 — STRUCTURE DATA / CONDITION / APPRAISAL

10 VERTICAL CLEARANCE ROUTE OVER-BEST 10 FT LT	RT	55 LAT. CLEAR BENEATH RIGHT	56 LAT. CLEAR BENEATH LEFT	57 SUR	58 DCK	59 SUP STR	59A PNT	60 SUB STR	61 CHA	62 CLV	63 EST REM. LIFE	64 OPERATING RATING	65 APP ALG	66 INVENTORY RATING	67 STR CND	68 DCK GEO	69 UND CLR	70 LD CAP	71 WTR ADE	72 APP ALG	41 O/C	36 TRAF SAF.FET. RL	TR	AP	TM	92 SCHEDULED LETTING DATE	108 CGL	OTHER PROJECT ID
0000	9999	999		8	6	8	7	7	6	N	16	9090	6	124	5	8	N	6	6	6	A	1	0	0	1			

Card 6 — PROPOSED IMPROVEMENTS / IMPROVEMENT COSTS

73 YEAR NEEDED	74	75 WORK TYPE	76 IMPROVEMENT LENGTH	77 LD	78 ROADWAY WIDTH	79 NUM OF LANES	80 AVERAGE DAILY TRAFFIC	81 YEAR OF A.D.T	82 RDWY IMP YEAR	83 TYP	84 IMPROVEMENT COST	85 P.E COST	86 DEM COST	87 SUBSTRUCTURE COST	88 SUPERSTRUCTURE COST	100 DATE LAST INSPECTED MO	DA	YR	91 STL
84	1	351	000050	4	0033	02	002600	03	00	0	00113	000	000	00001	00012	06	13	83	1

Card 7 — DEFENSE STRUCTURES AND TEMPORARY REPAIRS / CLASS / ROUTE UNDER STRUCTURE DATA

102 RTE UND	105 ROUTE UNDER: LVL	KND	DES	ROUTE NUMBER	DIR	111 MILEPOINT	112 ROAD SECTION NO.	113 DESC.	114 MILEPOINT	115 SECT. LENGTH	119 DETOUR LENGTH	124 F.A SYS.	125 AD-MIN	126 FUNC CLASS.	129 AVERAGE DAILY TRAFFIC	130 YEAR OF ADT	147 TOTAL HORIZONTAL CLEARANCE LT	RT	110 VERTICAL CLEARANCE ROUTE UNDER-BEST 10 FT LT	RT
0																				

CDC # =4082 OVER LOAD=B

FIGURE B-8 Michigan structure inventory and appraisal form.

03/29/83

TOTAL SIGNAL INVENTORY
DISTRICT 1

COUNTY	ROUTE	LOG	CITY	CROSS STREET	SIGNAL INSTALLATION PROJECT NUMBER	CONTROLLER INSTALLED PRESENT	PRIOR	NO CTL	CTL BRND	CNTRLR MODEL	MONITOR	INRCON	COMMO	TYPE	PHASES	DETECT AND ACTIVA	PP EH DA S E S	INSTLN	OP COST BY	CLASS	APPROACHES WHERE RTOR RESTRICTED NB	SB	EB	WB	O
BUCHANA	6 C	0.35	ST JOSEPH	WOODBINE RD	MF	081682		1	ECCN	F	N			X	2	2L		4	SHD	T					
BUCHANA	6 C	0.46	ST JOSEPH	I 29	1-U-6-17 CAB AT 0.56	06 75	72	1	AUTO	MF10	Y		M	F	3	5L		D	SHD	P					
BUCHANA	6 C	0.56	ST JOSEPH	I 29	1-U-6-17	06 75	72	1	AUTO	MF10	Y		M	F	3	6L		D	SHD	P					
BUCHANA	36 B	0.22	ST JOSEPH	RAMP TO 759	I-IG-229-2(81 TEMP SPAN WIRE	12 79		1	EAGL	EF70	N			P	3			T	SHD	T					
BUCHANA	169 B	1.94	ST JOSEPH	KARNES RD	MF			1	ECCN	F	N			X	2	2L		4	SHD	T					
BUCHANA	169 B	2.47	ST JOSEPH	GENE FIELD	MF TEMP SPAN WIRE	72		1	ECCN	F	N			X	4	2L		4	SHD	T					
BUCHANA	169 B	3.62	ST JOSEPH	MO 6	11(4)U	09 74	66	1	ECCN	8800	Y			F	8	8L		4	SHD	P					
BUCHANA	169 B	4.17	ST JOSEPH	FARON	1-U-169-1	121377	75	1	KENT	KST-S	N	L	T	P	2			4	SHD	P					
BUCHANA	169 B	4.61	ST JOSEPH	MESSANIE	1-U-169-1	121377	69	1	KENT	KST-S	N	L	T	P	3			4	SHD	P					
BUCHANA	169 B	5.12	ST JOSEPH	RT YY	1-U-169-1	121377	52	1	KENT	KST-M	N	M	T	P	4			4	SHD	P					
BUCHANA	169 B	6.15	ST JOSEPH	PICKETT ROAD	HES-169-1(18) TEMP SPAN WIRE	010683	69	1	ECCN	F	N			X	3	2L		4	SHD	P					
BUCHANA	169 B	6.64	ST JOSEPH	29 LOOP (PEAR)	MF TEMP SPAN WIRE	74	52	1	CH	PCE3000	N			P	3			4	SHD	T					
BUCHANA	229 A	4.21	ST JOSEPH	EDMOND-CHARLES	IDG-229-2(82))	12 81		1	EAGL	EF70	N	L	W	P	2			4	SHD	P					
BUCHANA	229 A	5.21	ST JOSEPH	US 36	I-IG-229-2(65	113081		1	EAGL	EF70	N			P	3			4	SHD	P					
BUCHANA	229 A	5.68	ST JOSEPH	6TH ST	IDG-229-2(83)	113081		1	EAGL	EF70	N			P	3			4	SHD	P					
BUCHANA	752 C	0.60	ST JOSEPH	KING HILL AVE	C011-752(1)U EF10 PIGGYBACK	71		1	GFS		N			F	2	8L		4	SHD	P					
BUCHANA	759 C	0.18	ST JOSEPH	RAMP TO 36	I-IG-229-2(81) PERM AND TEMP SPAN WIRE	12 79		1	EAGL	EF70	N			P	3			T	SHD	P		4			

FIGURE B-9 Sample of Missouri signal inventory.

OMB-004-R4039

III-28

U.S. DOT – AAR CROSSING INVENTORY FORM

A. INITIATING AGENCY ☐ RAILROAD ☐ STATE

B. CROSSING NUMBER

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

D. EFFECTIVE DATE M D Y

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

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

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

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

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

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

COMPLETE REMAINDER OF FORM ONLY FOR PUBLIC VEHICLE CROSSINGS AT GRADE

Part II Detailed Information for Public Vehicular at Grade Crossing

1A. Typical Number of Daily Train Movements

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

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

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

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

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

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

6. Type of Warning Device at Crossing

A. Signs

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

B. Train Activated Devices

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

C. Specify Special Warning Device not Train Activated 19

D. No Signs or Signals ☐ 20

7. Is Commercial Power Available? ☐ Yes ☐ No

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

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

Part III Physical Data

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

Part IV Highway Department Information

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

I. D. Number

FIGURE B-10 U.S. DOT-AAR crossing inventory form.

RAILROAD CROSSING INVENTORY
SURFACE CONDITION RATING FORM

Street ______________________
R.R. Co ______________________
Name ______________________
Speed Limit ________ DOT No. ________ Date ________
ADT ________ M.P. ________ Agency ________

Type Xing:	Overall Rideability Of Crossing	Check One
☐ Unconsolidated	Good, relatively smooth no repairs needed	☐
☐ Asphalt	Fair, adequate but some minor work required	☐
☐ Asphalt With Header	Poor, noticeable roughness more extensive work required	☐
☐ Inner Guardrail & Asphalt	Bad, very rough complete reconditioning needed	☐
☐ Full Width Plank		
☐ Timber Header	General condition graded from 0 to 10 (0 is excellent 10 is worst extreme)	____
☐ Prefabricated		
☐ Concrete	Note Rate Multiple Track Crossings Individually, in part or whole.	

Crossing Surface Between Rails

Rough uneven surface between rails, settlement or sagging condition	0–5	____
Broken, splintered, missing, or loose planking, or panels	0–5	____
Bent or missing spikes, lag screws, tie plates, fasteners, etc.	0–5	____
Pot holes or broken sections of asphalt	0–5	____
Corrugations; ridging, or shoving of asphalt, flangeway restriction	0–5	____
Protruding surface above top of rail (aggregate, plank, track hardware, etc.)	0–5	____

Track Substructure

Poor tie condition (broken, split, skewed, etc.) within or adjacent to xing surface	0–5	____
Ballast condition (good, fouled, non existent, etc)	0–5	____
Rail condition – defective rail, and joint mismatch, missing hardware, loose connections, etc.	0–5	____
Evidence of poor drainage or pumping action, erosion	0–5	____
Vegetation – heavy growth, slope condition	0–5	____
Switches, or crossovers within vicinity of xing & general condition	0–5	____

Roadway Approaches

General condition of asphalt for 150' ± on each side of xing. Note & circle the following conditions if present.

Corrugations, Rutting, Shoving, Cracking, Raveling, Etc.	0–5	____
Steep grade (%), or inadequate approach platform	0–5	____
Narrow roadway, single lane approach, inadequate shoulders	0–5	____
Unpaved roadway (general condition well maintained, graded & graveled, unimproved)	0–5	____
Drainage problems, settlement, steep embankment, structures	0–5	____
Passive warning devices (presence & condition of AWS, pavement marking, striping)	0–5	____

Complete computations in office.

Total points allowed 100
minus sum of defects - ____
Total points this xing ____
____ + ____ = Average Rating ☐

Additional Comments:
____
____
____
____

Note specific condition of any rating of five or greater.

FIGURE B-11 Nevada surface condition rating form for railroad crossings.

PUBLIC RAIL-HIGHWAY CROSSINGS IN MARYLAND
RANKED BY PREDICTED ACCIDENTS PER YEAR
INVENTORY DATE: APRIL 1983

RANK	PREDICTED ACCIDENTS	CROSSING ID #	STATE	RAIL ROAD	# OF ACCIDENTS 78	79	80	81	82	DATE OF CHANGE	WARNING DEVICE CLASS	TRAINS PER DAY	DAY THRU TRAINS	# OF MAIN TRACKS	TIME TABLE SPEED	IS HWY. PAVED	# OF TRAFFIC LANES	FUNC. CLASS	AADT
1	2.2479	140329W	MD	BO	5	4	2	3	3		4	12	6	1	15	YES	2	16	8100
2	1.3100	140696N	MD	BO	0	0	3	2	4		7	18	8	2	70	YES	2	14	8950
3	0.6934	831614E	MD	WM	0	1	1	1	1		7	10	4	2	25	YES	4	14	15600
4	0.6399	140330R	MD	BO	1	1	1	1	0		5	14	2	1	15	YES	2	19	18443
5	0.6254	529617W	MD	ATK	1	1	1	1	0		8	76	50	4	80	YES	2	19	3400
6	0.6236	140899J	MD	BO	0	3	0	0	1		7	18	8	2	70	YES	2	17	6160
7	0.5521	140356T	MD	BO	0	0	2	2	0		5	3	2	1	15	YES	3	16	13000
8	0.5433	530693L	MD	ATK	0	0	2	1	0		8	108	86	3	80	YES	4	16	7775
9	0.4797	140362W	MD	BO	1	0	0	0	2		5	3	2	1	15	YES	4	14	18925
10	0.4758	140327H	MD	BO	1	2	0	0	0		4	12	6	1	15	YES	2	19	12500
11	0.4721	529571K	MD	CR	1	0	2	0	0		7	4	3	1	30	YES	4	06	11500
12	0.4079	532250G	MD	CR	0	2	0	1	0		7	3	3	1	30	YES	1	07	17200
13	0.3987	140411R	MD	BO	2	0	1	0	0		7	10	5	1	45	YES	2	07	2460
14	0.3789	140381B	MD	BO	1	0	1	0	0		7	10	5	1	15	YES	3	14	14800
15	0.3592	532295N	MD	CR	0	0	0	0	3		4	3	3	1	30	YES	2	07	3060
16	0.3248	532259T	MD	CR	1	0	1	0	0		4	3	3	1	30	YES	1	06	10000
17	0.3090	529608X	MD	ATK	0	0	0	0	2		8	76	50	3	80	YES	2	19	2000
18	0.2828	140908F	MD	BO	0	1	0	0	1		8	20	10	2	70	YES	2	16	5950
19	0.2789	140313A	MD	BO	0	1	1	0	0		4	12	6	1	15	YES	2	19	2250
20	0.2784	532265W	MD	CR	1	0	0	0	2		4	3	3	1	30	YES	1	08	725
21	0.2727	140869S	MD	BO	0	0	1	1	0		8	25	15	2	50	YES	2	16	6100
22	0.2632	140863B	MD	BO	1	0	0	0	1		8	31	15	3	25	YES	2	19	1500
23	0.2629	530669K	MD	CR	0	1	0	0	0		4	15	0	2	15	YES	4	14	26000
24	0.2598	140905K	MD	BO	0	1	1	0	0		8	18	8	2	70	YES	2	19	6000
25	0.2576	529956B	MD	MDDE	0	1	0	0	0	10/81	4	2	0	1	15	YES	2	07	7300
26	0.2497	140364W	MD	BO	0	0	0	0	1		6	10	5	1	15	YES	4	16	10340
27	0.2495	532256X	MD	CR	1	3	0	0	0		4	3	3	1	30	NO	2	09	375
28	0.2481	139521E	MD	BO	0	0	0	0	1		7	2	2	1	15	YES	5	14	34850
29	0.2446	144684Y	MD	BO	1	0	0	0	0		5	20	7	2	25	YES	2	14	7100
30	0.2436	469321F	MD	NW	0	2	0	0	0		7	5	2	1	50	YES	2	07	1400
31	0.2392	832376S	MD	WM	0	0	0	1	0		5	6	0	0	4	YES	4	14	28000
32	0.2363	831844F	MD	WM	0	0	1	0	0		7	10	5	2	12	YES	2	14	10900
33	0.2353	140393V	MD	BO	0	2	0	0	0		5	20	0	2	15	YES	2	19	275
34	0.2347	532044U	MD	MDDE	0	0	0	0	0	10/81	4	4	0	1	30	YES	2	07	2400
35	0.2346	144851V	MD	BO	1	0	0	0	1		8	16	7	2	30	YES	2	09	3300
36	0.2343	529593S	MD	ATK	0	0	0	1	0		8	76	50	3	80	YES	2	19	7200
37	0.2319	529573Y	MD	CR	0	0	3	0	0		4	4	3	1	30	YES	2	19	200
38	0.2221	831819X	MD	WM	0	0	0	2	0		4	11	3	1	35	YES	2	09	450
39	0.2153	140396R	MD	BO	0	0	0	1	0	12/80	8	10	0	1	15	YES	4	14	14500
40	0.2128	140465W	MD	BO	1	0	0	0	1		4	2	1	1	15	YES	2	14	1800
41	0.2111	831657X	MD	WM	0	0	0	1	0		6	2	0	0	4	YES	4	14	29050
42	0.2025	140450G	MD	BO	0	0	1	0	0		7	10	5	1	45	YES	2	07	4400
43	0.2017	140608S	MD	BO	0	0	1	0	1	9/81	8	57	12	2	50	YES	2	09	900
44	0.1959	848094Y	MD	CTN	1	0	0	0	0		4	7	1	1	3	YES	2	19	18443
45	0.1952	832025T	MD	WM	1	0	0	0	0		7	5	0	1	45	YES	2	08	11200
46	0.1933	832018H	MD	WM	0	1	0	0	0		7	5	0	1	45	YES	2	07	10300
47	0.1897	140340W	MD	BO	0	0	0	0	1		7	5	3	2	15	YES	2	16	4030
48	0.1837	831699J	MD	WM	0	0	0	1	0		4	12	2	1	35	YES	2	19	2650
49	0.1830	532283U	MD	CR	1	0	0	0	1		4	1	0	1	30	YES	2	07	2630
50	0.1817	140438A	MD	BO	1	0	0	0	0		6	10	5	1	45	YES	1	09	3150

FIGURE B-12 Maryland ranking of rail-highway crossings.

RAIL-HIGHWAY CROSSING INSPECTION SHEET

Date: ____________________

Town: ____________________

District: ____________________

Railroad: ____________________

DOT No. ____________________

RR Milepost: ____________________

Route: ____________________

Highway System: ____________________

Hazard Index ________ Priority ________

EXISTING HIGHWAY

1. Route Log Station ____________________
2. Location - Rural ☐ Urban ☐
3. Surface Type ________________ Width ________ ft.
4. Vertical Alignment:

   Approach Grade
   - 0% - 3% ☐
   - 3% - 5% ☐
   - 5% - 10% ☐
   - 10%+ ☐

5. Horizontal Alignment:

   Skew
   - 0° - 20° ☐
   - 20° - 40° ☐
   - 40° - 60° ☐
   - 60° - 75° ☐
   - 75° - 90° ☐

6. Sight Distance:

   Substandard in quadrant(s) ________________.

   Along Track(s)
   - 0 - 100' ☐
   - 100 - 200' ☐
   - 200 - 500' ☐
   - 500 - 1000' ☐
   - 1000'+ ☐

   Crest
   - Adequate ☐
   - Inadequate ☐

7. 5-year accident record ____________________
8. Protection (Check ea. dir.)

Crossbucks	☐☐	Advance Sign	☐☐
Refl. X-bucks	☐☐	Stop Sign	☐☐
Flashing Lts.	☐☐	Flagman	☐☐
Gates	☐☐	Other	☐☐
Wig Wag	☐☐	None	☐☐

9. AADT ____________________.
10. Posted Speed ____________ mph.
11. School bus route ______ Buses/day ______.
12. Hazardous mat'l. ________________.
13. Comm. bus rte. ________________.

EXISTING RAILROAD

1. Track condition:
   - Poor ☐
   - Fair ☐
   - Good ☐
2. Mudrail - mudrail length ________ ft.
3. No. tracks ________
4. Trains/day ________
5. Whistle sounded ________
6. Amtrk rte. ________
7. Other pass. rte. ________

Comments: ____________________

____

____

____

____

____

____

____

____

____

____

14. Pedestrians ________________.
15. Rideability (X ing)
    - Severe ☐
    - Poor ☐
    - Fair ☐
    - Good ☐
16. Crossing Surface ____________ Width ________ ft.

N

SKETCH

Inspected by: ____________________

____

____

FIGURE B-13 Vermont rail-highway crossing inspection form.

R43010 RUN 01/05/84 RURAL-URBAN INVENTORY WORK LISTING REVISED 01/01/84 PAGE 0706

DISTRICT 1 PLN SEQ 015 STATE ROUTE 202 FUNCT CLASS 2 CON SEC 1774 C.S. SEQ 015

CS MP	SR MP	DESCRIPTION	JCT	IN CT	APPROACHES -NEAR-**FAR*	IN BR	RR XG	W S T	RURL URBN	LN	TRN	DIV-MULTI-LANE 2 LANE MEDIN*UNDIVID*	TYP	CLMB LANE	CITY NO	PRK	F.A. NO	FP AR CG	CROSS ROAD ADT
0000	00822	JCT E LAKE SAMMAMISH PARKWAY	R	N					UU4R	11		06G22A06G			1065	B	202	2	000000
0043	00865	JCT 185TH AVE NE	L	N					UU4R	11		04G22A04G			1065	B	202	2	000000
0075	00897	SR MP 9																	
0082	00904	JCT 187TH AVE NE	R	N					UU4R	11		06G22A08G			1065	B	202	2	000000
0083	00905	REDMOND ECL							U R	11		08G22A08G					202	2	
0097	00919	JCT 192ND PL NE	R	N															000000
0122	00944	MARTIN CREEK BR WPS 202/46				0			U R	11		C24A C					202	2	
0123	00945	MARTIN CREEK BR EPS 202/46							U R	11		08G22A08G					202	2	
0127	00949	JCT 196TH AVE NE/URB AREA BDRY	B	N					R R	11		08G22A08G					202	2	000000
0143	00965	JCT NE 55TH PLACE	L	N															000000
0165	00987	JCT 204TH PLACE NE	L	N					R R	11		04A22A04A					202	2	000000
0185	01007	SR MP 10																	
0192	01014	MARTIN CREEK BR WPS 202/47				0			R R	11		C24A C					202	2	
0193	01015	MARTIN CREEK BR EPS 202/47							R R	11		04A23A04A					202	2	
0205	01027	JCT SAHALEE WAY NE	R	N															000000
0233	01055	BRIDGE NO 522/48.25 WPS				0			R R	11		C24A C					202	2	
0234	01056	BRIDGE NO 522/48.25 EPS							R R	11		04A23A04A					202	2	
0269	01091	JCT NE 50TH STREET	R	N															000000
0272	01094	JCT COUNTY ROAD	L	N															000000
0278	01100	SR MP 11																	
0326	01148	JCT 224TH AVE NE	R	N															000000
0353	01175	JCT 228TH AVE	L	N															000000
0376	01198	SR MP 12																	
0404	01226	JCT 236TH AVE NE	L	N															000000
0477	01299	SR MP 13																	
0478	01300	JCT 244TH AVE NE	R	N															000000
0547	01369	JCT NE AMES LAKE ROAD	L	N					R R	11		05A23A05A					202	2	000000
0566	01388	JCT NE AMES LAKE ROAD WYE CONN	L	N															000000
0577	01399	SR MP 14																	
0623	01445	JCT 264TH AVE NE	R	N															000000
0677	01499	SR MP 15																	
0728	01550	JCT NE TOLT HILL ROAD	L	N															000000
0738	01560	JCT NE TOLT HILL RD WYE CONN	L	N															000000
0779	01601	SR MP 16																	
0878	01700	SR MP 17																	
0899	01721	JCT COUNTY ROAD	L	N															000000
0975	01797	SR MP 18																	
1003	01825	JCT 292ND AVE SE	R	N															000000
1067	01889	JCT 300TH AVE SE	R	N															000000
1077	01899	SR MP 19																	
1084	01906	JCT SE 31ST STREET	L	N															000000
1101	01923	PATTERSON CREEK BR WPS 202/54				0			R R	11		C27A C					202	2	
1102	01924	PATTERSON CREEK BR EPS 202/54							R R	11		05A23A05A					202	2	
1123	01945	JCT 308TH AVE SE	B	N															000000
1178	02000	SR MP 20																	
1227	02049	JCT SE 40TH STREET	R	N															000000
1236	02058	JCT 323TH AVENUE SE	R	N															000000
1242	02064	JCT 324TH AVE SE	B	N															000000

FIGURE B-14 Washington State roadway inventory output.

C 430570 HORIZONTAL ALIGNMENT 01/09/7[illegible]

D P	SR	F C	CONT SECT	CSS	CARD SEQ	EC NO	MILE POSTS: TS OR BACK	MILE POSTS: SC OR PC	MILE POSTS: CS OR PT	MILE POSTS: ST OR AHEAD	CURVE RADIUS	CENTRAL ANGLE	DIR	I A	STATIONS: TS OR BACK	STATIONS: SC OR PC	STATIONS: CS OR PT	STATIONS: ST OR AHEAD
5	010	3	1923	120	0010					00.000								000950
5	010	3	1923	120	0020			00.022	00.066		00240	055*10.3'	L			100832	000600	
5	010	3	1923	120	0030	01	00.085			00.085					000500			001524
5	010	3	1923	120	0040	02	01.048			01.048					006606			006609
5	010	3	1923	120	0050	03	01.080			01.080					006779			006776
5	010	3	1923	120	0060	04	01.252			01.252					007684			007689
5	010	3	1923	120	0070			01.252	01.446		05730	010*16.0'	L			007689	008716	
5	010	3	1923	120	0080			01.570	01.601		05730	001*37.0'	L			009370	009532	
5	010	3	1923	120	0090			01.773	01.824		04584	003*24.0'	L			010140	010712	
5	010	3	1923	120	0100	05	01.824			01.824					010712			010719
5	010	3	1923	120	0110	06	01.906			01.906					011148			011149
5	010	3	1923	120	0115	07	02.064			02.064					011986			011987
5	010	3	1923	120	0120			02.064	02.239		01042	050*52.0'	R			011987	012911	
5	010	3	1923	120	0130			02.522	02.627		00955	033*08.0'	R			014406	014958	
5	010	3	1923	120	0140			02.724	02.952		02865	024*05.0'	L			015470	016674	
5	010	3	1923	120	0150	08	03.102			03.102					017467			017482
5	010	3	1923	120	0160			03.102	03.213		02865	011*45.0'	L			017482	018069	
5	010	3	1923	120	0170	09	04.392			04.392					024293			024294
5	010	3	1923	120	0180			04.392	04.456		01910	010*12.0'	L			024294	024634	
5	010	3	1923	120	0190			04.703	05.018		02865	033*12.0'	L			025938	027599	
5	010	3	1923	120	0200			05.294	05.419		02865	012*16.0'	L			029057	029670	
5	010	3	1923	120	0210	10	05.410			05.410					029670			[illegible]

430570 VERTICAL ALIGNMENT 01/09/[illegible]

D P	SR	F C	CS	CSS	CARD SEQ	EQ	BEGIN CSMP	PI CSMP	END CSMP	GRADE BACK	GRADE AHEAD	A E	PI STA	CURVE LGT	ELEV	BACK STA	AHEAD STA
1	002	1	3108	030	0010		00.000		00.000		03.121		081107	0000	89.70		
1	002	1	3108	030	0020		00.112	00.245	00.377	-03.121	-04.764		082400	1400	130.06		
1	002	1	3108	030	0030		00.387	00.453	00.520	04.764	00.071		083500	0700	77.66		
1	002	1	3108	030	0040		01.476	01.495	01.514	-00.071	00.411		089000	0200	81.57		
1	002	1	3108	030	0050		02.044	02.063	02.082	-00.411	00.252		092000	0200	93.90		
1	002	1	3108	030	0060		02.499	02.537	02.574	-00.252	02.440		094000	2400	130.19		
1	002	1	3108	030	0070		02.830	02.972	03.114	-02.440	-03.109		096800	1500	156.31		
1	002	1	3108	030	0080		03.256	03.313	03.370	03.109	00.102		098500	0600	100.34		
1	002	1	3108	030	0090		04.582	04.601	04.620	-00.102	02.700		105400	0200	107.30		
1	002	1	3108	030	0100	01	04.772		04.772							106003	[illegible]
1	002	1	3108	030	0110		04.823	04.946	05.070	-02.700	-01.567		107250	1300	156.55		
1	002	1	3108	030	0120	02	05.079		05.078							107940	107940
1	002	1	3108	030	0130		05.240	05.278	05.316	01.567	00.000		109000	0400	129.12		
1	002	1	3108	030	0140			05.467		00.000	00.220		110000	0000	129.12		
1	002	1	3108	030	0150		05.665	05.695	05.704	-00.220	-00.335		111200	0100	131.76		
1	002	1	3108	030	0160		05.845	05.856	05.865	00.335	00.428		112050	0100	128.91		
1	002	1	3108	030	0170			06.187		-00.428	-00.200		113800	0000	130.40		
1	002	1	3108	030	0180			06.547		00.200	-00.102		115700	0000	132.60		
1	002	1	3108	030	0190			06.642		00.102	-00.200		116200	0000	132.09		
1	002	1	3108	030	0200		06.736	06.793	06.850	00.200	-00.130		117[illegible]00	0000	130.45		
1	002	1	3108	030	0210			07.409		00.130	-00.039		120750	0000	127.25		
1	002	1	3108	030	0220			07.466		00.039			120554	0000	127.13		
1	002	1	3108	030	0230	03	07.466		07.466							120554	120547
1	002	1	3108	030	0240			07.466			00.000		120547	0000	127.40		
ELEVATION EQUATION																	
1	002	1	3108	030	0250		07.467	07.505	07.543	00.000	04.000		120750	0400	127.40		

FIGURE B-15 Output on horizontal and vertical curvature data form Washington State.

```
                                MICHIGAN DEPARTMENT OF TRANSPORTATION
                                    TRAFFIC AND SAFETY DIVISION
05/16/84                 MICHIGAN DIMENSIONAL ACCIDENT SURVEILLANCE SYSTEM (MIDAS)

                                       S E G M E N T   F I L E

DISTRICT 6   CS 25011   ROUTE M-13,M-21   GENESEE COUNTY
------------------------------------------------------------------------------------------------------------
0.00- 0.54   4 LANE DVDED   10ft LANE 12 SHLDER   BEARING N  3:42 E      RURAL    PASSING      55   N   S
        0.12  M13   /W I69         CLAYTON TWP.   NO SIGNAL    OTHER      3 LEGS   INFLUENCE ZONE =  0.00 -  0.15
        0.17  MALI UNKNOWN         CLAYTON TWP.   NO SIGNAL    OTHER      3 LEGS   INFLUENCE ZONE =  0.15 -  0.30
        0.42  BROOKS ROAD          CLAYTON TWP.   NO SIGNAL    TEE        3 LEGS   INFLUENCE ZONE =  0.30 -  0.47
        0.52  BRISTOL ROAD         CLAYTON TWP.   NO SIGNAL    TEE        3 LEGS   INFLUENCE ZONE =  0.47 -  0.58

0.54- 1.27   4 LANE DVDED   12ft LANE  8 SHLDER   BEARING N  3:42 E      RURAL    PASSING      55   N   S
        0.63  GANSSLEY ROAD        CLAYTON TWP.   NO SIGNAL    TEE        3 LEGS   INFLUENCE ZONE =  0.58 -  0.99

1.27- 1.35   4 LANE DVDED   12ft LANE  8 SHLDER   BEARING N  3:42 E      URBAN    NO PASSING   55   N   S

1.35- 1.37   4 LANE DVDED   12ft LANE  8 SHLDER   CURVE L  O DEG  4 MIN  URBAN    NO PASSING   55   N   S
        1.35  SOUTH ST             LENNON CITY    NO SIGNAL    CROSS      4 LEGS   INFLUENCE ZONE =  0.99 -  1.38

1.37- 1.40   4 LANE DVDED   12ft LANE  8 SHLDER   CURVE L  O DEG  4 MIN  URBAN    PASSING      55   N   S

1.40- 1.42   4 LANE DVDED   12ft LANE  8 SHLDER   CURVE L  O DEG  4 MIN  URBAN    PASSING      35   N   S
        1.41  ORCHARD ST           LENNON CITY    NO SIGNAL    TEE        3 LEGS   INFLUENCE ZONE =  1.38 -  1.46

1.42- 1.44   4 LANE DVDED   12ft LANE  8 SHLDER   CURVE L  O DEG  4 MIN  URBAN    NO PASSING   35   N   S

1.44- 1.71   4 LANE DVDED   12ft LANE  8 SHLDER   BEARING N  3:18 E      URBAN    NO PASSING   35   N   S
        1.50  MAIN ST              LENNON CITY    SIGNAL       CROSS      4 LEGS   INFLUENCE ZONE =  1.46 -  1.58
        1.65  PARK DR              LENNON CITY    NO SIGNAL    TEE        3 LEGS   INFLUENCE ZONE =  1.58 -  2.04

1.71- 1.72   4 LANE DVDED   12ft LANE  8 SHLDER   BEARING N  3:18 E      URBAN    NO PASSING   55   N   S
```

FIGURE B-16 Output from Michigan's MIDAS inventory.

```
                      FIVE YEAR ROAD FEATURES INVENTORY SHEET
STATE OF NEBRASKA                                          DEPARTMENT OF ROADS
******************************************************************************
* HWY  REF     SUP REC  REF POST COUNTY  RUI   MAJOR   OVERLAP   OVERLAP*
* NO   POST        CODE LENGTH                 HWY NO  REF POST  LENGTH *
* 1-4  5-9     10-14                                                    *
*                                                                       *
* ___  ___.__  ___ __   __.___    __     _    _____   ____.___   __.___ *
*                                                                       *
******************************************************************************
*                                                                       *
*    PROFILE MILES BY SURFACE TYPE (CODE TO TENTHS OF A MILE)           *
*                         BITUMINOUS  CONCRETE  GRAVEL  OTHER           *
*      2 LANE             _._         _._       _._     _._  (15-22)    *
*      4 LANE DIVIDED     _._         _._       _._     _._  (23-30)    *
*      4 LANE UNDIVIDED   _._         _._       _._     _._  (31-38)    *
*      6 LANE             _._         _._       _._     _._  (39-46)    *
*                                                                       *
*     SHOULDER MILES     SPECIAL                                        *
*     SOD  PAVED 36"    LANE MILES                                      *
*       (47-55)           (56-58)                                       *
*                                                                       *
*     _.__ __.__ _.__      _.__                                         *
*                                                                       *
* **ROADWAY FEATURES**          **TALLY AREA**              TOTAL       *
* ----------------------------------------------------------------------*
*     STRUCTURES < 20                                    = ___  (59-61)*
*     ------------------------------------------------------------------*
*     OTHER STRUCTURES                                   = ___  (62-64)*
*     ------------------------------------------------------------------*
*     SMALL SIGNS                                        = ___  (65-67)*
*     ------------------------------------------------------------------*
*     OVERHEAD SIGNS                                     = ___  (68-70)*
*     ------------------------------------------------------------------*
*     DELINEATORS                                        = ___  (71-73)*
*     ------------------------------------------------------------------*
*     FEET OF GUARDRAIL                                  = _____ (74-78)*
*     ------------------------------------------------------------------*
*     ROW MOW ACRES                                      = __._ (79-81)*
*     ------------------------------------------------------------------*
*     FEET OF FENCE                                      = _____ (82-86)*
*     ------------------------------------------------------------------*
*     LIGHT POLES                                        = __   (87-88)*
*     ------------------------------------------------------------------*
*     CRASH BARRIERS                                     = __   (89-90)*
*     ------------------------------------------------------------------*
*     TRAFFIC SIGNALS                                    = __   (91-92)*
*     ------------------------------------------------------------------*
*     BRIDGES                                            = __   (93-94)*
*     ------------------------------------------------------------------*
*                                                                       *
*         YARD   PREMIX  AGREEMENT                                      *
*         NO.     SITE     CODE                                         *
*       (95-99) (100-102) (103)                                         *
*                                                                       *
*       _____    ___       _                                            *
*                                                                       *
*                                                                       *
*   SUPERVISOR ________________________  DATE ____________________      *
*                                                                       *
******************************************************************************
```

FIGURE B-17 Nebraska inventory coding form for road features.

MAINTENANCE MANAGEMENT SYSTEM
INVENTORY SUMMARY FOR SUPERINTENDENT BY SUPERVISOR
REPORT NO. MMS 552-2

RUN DATE 05/29/84

MAINTENANCE ITEMS	SUPERVISOR 111	112	113	114	116	SUPERINTENDENT
ROAD MILES BY SURFACE TYPE						
BITUMINOUS	20.5	94.0	100.6	9.0	67.2	291.3
PORTLAND CEMENT CONCRETE	37.4	36.1	21.1	21.1	17.8	133.5
GRAVEL		5.6				5.6
OTHER						
ROAD MILES BY PROFILE TYPE						
2 LANE	21.2	117.7	121.3	12.8	85.0	358.0
4 LANE DIVIDED	36.1	18.0		17.3		71.4
4 LANE UNDIVIDED	.6		.4			1.0
OTHER						
SHOULDER MILES BY TYPE						
SOD	27.8	167.8	202.7	25.6	136.4	560.3
PAVED	86.1	84.8	32.0	34.6	32.2	269.7
36" PAVED APRON	66.3	34.0		34.6		134.9
SPECIAL LANE MILES	15.9	11.3	6.8	2.6	5.3	41.9
STRUCTURES, SIGNS & MISC						
STRUCTURES LESS THAN 20 FT	509.0	456.0	1060.0	252.0	225.0	2502.0
OTHER STRUCTURES	323.0	1048.0	7.0	183.0	663.0	2224.0
SMALL SIGNS	998.0	1818.0	1407.0	562.0	1151.0	5936.0
OVERHEAD SIGNS	46.0			2.0	2.0	50.0
DELINEATORS	7852.0	5177.0	1180.0	2438.0	1855.0	18502.0
GUARDRAIL (FEET)	103927.0	58880.0	20534.0	38992.0	12218.0	234551.0
MOWABLE R.O.W. ACRES	549.0	568.3	405.0	254.5	281.4	2058.2
FENCE (FEET)	381419.0	204308.0		184051.0		769778.0
LIGHT POLES	197.0	4.0		52.0	30.0	283.0
CRASH BARRIERS						
TRAFFIC SIGNALS		5.0				5.0
BRIDGES	81.0	55.0	32.0	38.0	31.0	237.0
PREMIX SITES		1.0	2.0		1.0	4.0

FIGURE B-18 Sample output from Nebraska maintenance management system.

CITY OF CHARLOTTE, N.C.

TRANSVERSE PAVEMENT MARKING ACTIVITY REPORT

TRAFFIC ENGINEERING DEPT.

RQS NUMBER: 1 ☐☐☐☐☐ 5

STREET TYPE ☐ 6

DISTRICT NUMBER ☐ 7

DIRECTION OF TRAVEL [N=1, E=2, S=3, W=4] ☐ 9

11 ☐☐☐☐☐ 15 MAIN ST. NUMBER

17 ☐☐☐☐☐☐☐ 23 LINE NUMBER

CREW NUMBER 25 ☐☐☐ 27

LOCATED ON: 29 ☐ 30 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 50 NAME OF STREET 51 ☐☐☐☐ 54 55 ☐ 57 ☐☐☐☐☐ 61 DISTANCE FEET

[N=1, E=2, S=3, W=4] 63 ☐ OF: 65 ☐ 66 ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐ 86 NEAREST INTERSECTING STREET 87 ☐☐☐☐ 90 91 ☐ 93 ☐☐☐☐☐ 97 CROSS ST. NUMBER

[N=1, E=2, S=3, W=4] 99 ☐ SIDE OF STREET

WORK REQUIRED: NEW MARKING (1); REPAINT (2); REVISION (3); REMOVAL (4) 101 ☐

WORK TO BE PERFORMED: ______________________ GENERAL DESCRIPTION

MARKING CODE: 103 ☐☐☐☐☐☐☐☐☐☐☐☐ 114

LEGEND: 116 ☐☐☐☐☐☐☐☐☐☐☐☐ 127

CONDITION: 129 ☐☐☐☐☐ 133

WIDTH 135 ☐☐☐ 137 ACROSS FEET

MATERIAL: 139 ☐☐☐ 141

COLOR: 143 ☐☐☐☐☐ 147

AMOUNT OF MATERIAL 149 ☐☐☐ 151

TOTAL LINEAL FEET: 153 ☐☐☐☐☐ 155

WORK PERFORMED BY: 157 ☐☐☐ ☐☐☐ ☐☐☐ ☐☐☐ 168

DATE COMPLETED: 169 ☐☐ - ☐☐ - ☐☐ 174
MONTH DAY YEAR

TEO 86 (3/80)

FIGURE B-19 Pavement marking coding form from Charlotte, North Carolina.

CITY OF CHARLOTTE, N.C.
PAVEMENT MARKING INVENTORY REPORT (TRANSVERSE TYPE DATA)

DATE 01-19-84

MAIN STREET NAME - E INDEPENDEN   STREET TYPE - PRI   DISTRICT 2

DIR OF TRAVEL	LINE NUMBER	DIST & DIR	REFFRENCE CROSS STREET	SIDE OF STR	TYPE OF MARKING	LEGEND	CON- DITION	LEN	MATER- IAL	COLOR	AMOUNT PAINT	LAST STRIPE	NEXT STRIPE	S N
EAST	003636940	2232 W	IDLEWILD RD	NORTH	ARROW	LA	GOOD		PLS	WHITE		08 01 83		S
EAST	003636950	2172 W	IDLEWILD RD	NORTH	ARROW	LA	GOOD		PLS	WHITE		08 01 83		S
EAST	003636960	2112 W	IDLEWILD RD	NORTH	ARROW	LA	GOOD		PLS	WHITE		08 01 83		S
EAST	003636970	1176 W	IDLEWILD RD	NORTH	ARROW	LA	GOOD		PLS	WHITE		08 02 83		S
EAST	003636980	1116 W	IDLEWILD RD	NORTH	ARROW	LA	GOOD		PLS	WHITE		08 02 83		S
EAST	003636990	1056 W	IDLEWILD RD	NORTH	ARROW	LA	GOOD		PLS	WHITE		08 02 83		S

FIGURE B-20 Sample computer output from Charlotte, North Carolina pavement marking inventory.

IMPACT ATTENUATOR REPLACEMENT PROGRAM INVENTORY

ATTEN. NO.	LOCATION	STREET CLASS / SPEED LIMIT	ADT (1000) / % DISTR.	TYPE	INSTALL DATE	INSTALL COST	LAYOUT PATTERN
1	SOUTHWEST FREEWAY. S.W. E/B. AT EXIT RAMP TO U.S. CAPITOL	02 (35)	108. 60%	SAND BARRELS (16)	OCT. 1969	$ 11900.	<-- a c e g i k m o p b d f h j l n <--
2	SOUTHEAST FREEWAY. S.E. W/B. AT EXIT RAMP "E" TO U. S. CAPITOL	02 (40)	108. 60%	SAND BARRELS (17)	OCT. 1969	$ 11900.	a b c d e f g h i j k l m n o p q
3	SOUTHWEST FREEWAY. S.W. E/B. AT EXIT RAMP "E" TO U. S. CAPITOL	02 (35)	98.4. 60%	SAND BARRELS (26)	1969	$ 7000.	a b c d e f g h i j k l m n o p q r s t u v w x y z

DATE INSPECTED/DAMAGED PARTS/REPAIR COST & DATE

11/01/83	12/13/83	01/26/84	02/21/84	04/02/84	05/09/84
NO DAMAGE NEEDS PAVEMENT MARKING	# e DAMAGED	# d DAMAGED	HAS BEEN HIT # d DAMAGED	HAS BEEN REPAIRED NO DAMAGED	# n DAMAGED
# n BARREL NEEDS LID 1 BRIDGE RAIL MISSING	NO DAMAGE	NO DAMAGE	NO DAMAGE	NO DAMAGE	NO DAMAGE
NO DAMAGE NEEDS REPOSITION NEEDS FIX THE FENDERS NEEDS OBJECT MARKING SIGN	NO DAMAGE	NEED NUMBER ON RAMP	NO DAMAGE NEEDS NUMBER ON RAMP	NO DAMAGE	MINOR HIT

FIGURE B-21 Washington, D. C. inventory of impact alternatives.

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