NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 132

# SYSTEM-WIDE SAFETY IMPROVEMENTS: AN APPROACH TO SAFETY CONSISTENCY

TRANSPORTATION RESEARCH BOARD
National Research Council

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **132**

# SYSTEM-WIDE SAFETY IMPROVEMENTS: AN APPROACH TO SAFETY CONSISTENCY

**BENJAMIN V. CHATFIELD**
**Chatfield Associates, Inc.**

*Topic Panel*

FORREST M. COUNCIL, *University of North Carolina*
RICHARD CUNARD, *Traffic Improvement Association of Oakland County*
LINDSAY GRIFFIN, *Texas A&M University*
DAVID L. HELMAN, *West Virginia Department of Highways*
JAMES K. WILLIAMS, *Transportation Research Board*
BRENDA C. KRAGH, *Federal Highway Administration* (Liaison)
RUDOLPH UMBS, *Federal Highway Administration* (Liaison)

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

**TRANSPORTATION RESEARCH BOARD**
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. SEPTEMBER 1987

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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

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

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the 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.

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

**NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.**

**NCHRP SYNTHESIS 132**

Project 20-5 FY 1985 (Topic 17-01)
ISSN 0547-5570
ISBN 0-309-04409-X
Library of Congress Catalog Card No. 87-50660

**Price: $6.80**

*Subject Area*
Transportation Safety

*Mode*
Highway Transportation

**NOTICE**

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

The Transportation Research Board evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

*Published reports of the*

**NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM**

*are available from:*

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America

## PREFACE

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

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

## FOREWORD

*By Staff*
*Transportation Research Board*

This synthesis will be of interest to safety engineers, highway planners, and others concerned with the procedures used by states to plan and program safety improvements. Information is presented on current practice of states in using system-wide improvements to provide safety consistency.

---

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.

The primary purpose of system-wide safety improvements is to increase safety by improving roadway consistency—to minimize violations of driver expectancy and to avoid or reduce injury and damage that occur when a vehicle leaves the roadway. This report of the Transportation Research Board describes the system-wide and spot approaches to safety improvement, explains strategies and programs for system-wide improvements, and gives general guidelines for a program of improving roadway consistency through system-wide safety improvements.

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

## ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Robert E. Skinner, Jr., Director for Special Projects. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. This synthesis was edited by Anne S. Brennan.

Special appreciation is expressed to Benjamin V. Chatfield, Chatfield Associates, Inc., who was responsible for the collection of the data and the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Forrest M. Council, Highway Safety Research Center, University of North Carolina; Richard Cunard, Traffic Improvement Association of Oakland County; Lindsay Griffin, Texas Transportation Institute, Texas A&M University; David L. Helman, West Virginia Department of Highways; and Liaison Members Brenda C. Kragh, Traffic Safety Research Division, and Rudolph Umbs, Office of Highway Safety, Federal Highway Administration.

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.

# SYSTEM-WIDE SAFETY IMPROVEMENTS: AN APPROACH TO SAFETY CONSISTENCY


## SUMMARY

For two decades the focus of the federal-aid highway safety-improvement program has been largely on spot improvements. Although a number of system-wide safety improvements (such as the installation of breakaway features on signs and luminaires and the improvement of connections between guardrail and bridges) have been widely applied during the same period, many highway engineers still think first—and sometimes exclusively—of spot improvements when highway safety improvements are mentioned. In jurisdictions where the benefits of system-wide safety improvements have been recognized, system-wide improvements are being used effectively along with spot improvements to make highways safer.

The primary purpose of system-wide safety improvements is to increase safety by improving roadway consistency. Roadway consistency may be defined as the degree to which highway systems are designed and constructed (a) to minimize violations of driver expectancy that may cause drivers to lose control and (b) to avoid or reduce the injury and damage that occur when out-of-control vehicles leave the roadway.

The aim of highway safety improvements is to correct hazards that may contribute to the occurrence or severity of accidents. Roadway sections or features are considered hazardous when they are associated with a level of accident risk that is, or is expected to be, unusually high for the particular highway system under consideration. This high risk often reflects problems with roadway consistency.

The system-wide approach to safety improvement, in contrast to the spot improvement approach, focuses on the roadway consistency of a substantial portion of the highways in a jurisdiction. "System-wide" may refer, for example, to all rural secondary roads in a county, to all divided highways in a state, or to other classes of roadway in any jurisdiction.

Three fundamental strategies for system-wide safety improvements are (a) the implementation of projects that focus exclusively on the correction of hazardous elements, (b) the inclusion of safety features in projects undertaken primarily for purposes other than safety, and (c) the treatment of side effects of alterations to adjacent or nearby highways. A program to install crossbucks at all unmarked railway-highway crossings in a state is an example of the first strategy. The second strategy is commonly used in the federal-aid 3-R and 4-R programs for resurfacing, restoration, rehabilitation, and reconstruction of existing roads. The least common of the three strategies—treatment of side effects—is usually practiced informally. It deals with problems such as those created when suitable transitions are not provided at the termini of newly constructed sections of highway.

A number of examples of system-wide safety improvements are described in this synthesis. Some of these improvements were made explicitly because they were considered to be the most effective way to avoid or reduce future tort liability claims.

Funding for system-wide safety improvements comes from a variety of sources. In addition to earmarked federal-aid highway funds, other federal, state, and local construction or maintenance funds, sometimes supplemented by private funds from railroad and utility companies, are being used to finance safety improvements. The improvement work is generally done on a contract basis but, in some cases, it can be done economically by highway agencies with their own forces during periods when other demands are low.

There is no simple prescription for improvement of roadway consistency. Highway agencies have unique road systems and unique sets of resources to use for improving their systems. General guidelines are:

1. Adopt standards for roadway consistency.
2. Conduct an inventory of existing facilities to identify substandard elements.
3. Determine the relationship of substandard elements to accident experience and to tort liability claim and award experience.
4. Estimate the expected future costs associated with substandard elements.
5. Consider alternatives for correcting substandard elements.
6. Compare the cost-effectiveness of proposed system-wide safety improvements with that of spot safety improvements.
7. Select and implement safety improvements.
8. Evaluate the costs and benefits of safety improvements to provide guidance for future work.

State and local highway agencies should consider increasing their emphasis on roadway consistency and system-wide safety improvements. It should be clearly understood that system-wide safety improvements and spot safety improvements complement each other and that both are needed in a balanced safety program.

Top administrators in highway agencies should make it clear to agency staff members that they consider safety to be as important as system preservation and level of service, and that roadway consistency and consideration of system-wide safety improvements have high priority. Without such leadership, it is difficult to sustain effective safety programs. Training and other guidance should be provided to ensure that agency staff members—at all levels—understand that highway safety must be taken into consideration in all phases of highway planning, design, construction, maintenance, and operations. Responsibility for highway safety can not be delegated to safety specialists who have little control over major agency programs.

CHAPTER ONE

# INTRODUCTION

## SAFETY IMPROVEMENTS

During the past 20 years a great deal has been written about hazardous locations on public highways and about the spot safety improvements made to correct problems at those locations. Relatively little consideration has been given in the technical literature to system-wide safety improvements, although the system-wide approach has been applied extensively with notable success. Examples of system-wide safety improvements that have been applied in many jurisdictions include installation of breakaway signposts and luminaires, improvement of guardrail ends, connection of guardrails to bridge parapets, installation of railroad crossing signs, pavement marking, replacement of wooden construction barriers with concrete barriers, and other accident countermeasures.

One major distinction between the spot approach and the system-wide approach to highway safety improvement is the degree of emphasis on roadway consistency. With spot improvements, the reduction of the number and severity of accidents on a small segment of highway is the first priority; consideration of the impact of the improvement beyond the project limits—or of overall roadway consistency—is secondary. With system-wide improvements the top priority is to increase safety by improving roadway consistency to (a) avoid violations of driver expectancy that may cause drivers to lose control of their vehicles and (b) eliminate or reduce the harmful consequences that may follow a driver's loss of control.

A second important difference between the spot and system-wide approaches to highway safety is implied by their names. System-wide approaches are applied on a system-wide basis; spot improvements are site-specific. "System-wide" in this context refers to a substantial share of the highways under the jurisdiction of an organization responsible for highway construction and maintenance. For example, "system-wide" may mean "all rural secondary roads" to a state engineer or, to a city or county engineer, "all local streets in residential areas."

A third distinction between spot and system-wide safety improvements relates to scheduling. A spot improvement is generally handled as an independent project (or part of a non-safety project) custom-designed to fit a specific site and constructed as a unit within a relatively short period of time. System-wide improvement work, on the other hand, may be handled in a variety of ways. The work could be a short-term project, with the improvement applied (independent of other work) to the whole system. Or system-wide work could be a long-term undertaking with safety improvements only implemented in conjunction with other construction or maintenance work.

Some types of safety improvement work fall rather naturally into either the spot improvement or system-wide improvement category. Improving a six-legged intersection and replacing obsolete signs throughout a jurisdiction would normally be treated, respectively, as spot and system-wide improvements. Flattening fill slopes on low embankments to eliminate the need for guardrail, on the other hand, could be handled easily under either the spot or system-wide approach. Such slope flattening could be an isolated countermeasure, and therefore a spot improvement, or part of a system-wide program. A countermeasure that would be regarded as a spot improvement if applied infrequently or at isolated sites would be considered to be part of a system-wide improvement if applied routinely at a large number of sites or over a substantial part of a highway system.

## HISTORY

It has been about 100 years since the development of the first automobile and 80 years since mass production of motor vehicles began in earnest (*1*, pp. 54–56). In the first quarter of the twentieth century the motor vehicle was transformed from a novelty to a major means of transportation in the United States. By the end of World War I there were five or six million vehicles on the roads and more than a million new vehicles were being produced each year. By 1925, more than 17 million registered motor vehicles were traveling more than 100 billion vehicle-miles each year in the United States (*2*).

The proliferation of motor vehicles brought a proliferation of traffic accidents. By 1925, the number of people killed each year in motor vehicle traffic accidents exceeded 20,000 (*3*). The traffic fatality rate in 1925 was more than 180 deaths per billion vehicle-miles.

Recognizing that highway safety had become a significant national problem, Secretary of Commerce Herbert Hoover in 1924 convened the First National Conference on Street and Highway Safety, the first major national meeting on this subject (*1*, pp. 127–128). The relationship between safety and consistency was recognized in a number of recommendations that were approved at the 1924 Conference. These recommendations included the adoption of minimum pavement and bridge widths, maximum grades and curvature, minimum sight distances, painted center lines to identify no-passing zones, and national standards for signs. These practices were designed to prevent accidents. The implementation of such practices, together with practices designed to reduce the severity of the accidents that do occur, has contributed substantially to the reduction in traffic fatality rates during the past 60 years.

Although the number of vehicle-miles driven each year in the United States has increased to about 1.8 trillion since 1925, the fatality rate has been following a downward trend, dropping more than 3 percent per year. By 1985, the fatality rate was close to 25 deaths per billion vehicle-miles, a sevenfold increase in traffic safety—as measured by the number of miles driven for each occurrence of a traffic death—over a period of six decades (*4*) (see Fig. 1).

Although highways in the United States are safer now than they have ever been, about 45,000 people die each year in traffic accidents. Continuing programs to make highways safer are necessary. As the more obvious safety problems are dealt with, and the remaining problems become harder to identify and cure, increasingly more sophisticated approaches must be used in administering these programs.

Safety had, for many years, been a major consideration for state and local agencies that design, construct, and maintain most highways in the United States. However, a sudden upturn in the number of traffic deaths per year in the early 1960s led to the creation of new federal-aid programs calling explicitly for highway safety improvements. These programs supplement (rather than replace) safety work included in the older federal-aid highway programs. In addition to expansion of federal highway safety efforts, the states and many local governments have increased funding for safety improvement programs of their own.

## ROADWAY CONSISTENCY

Roadway consistency, in the context of this report, is the degree to which highway systems are designed and constructed (a) to avoid violations of driver expectancies that may cause drivers to lose control of their vehicles and (b) to avoid or reduce injury and damage that occur when motor vehicles are out of control. The objectives of improving consistency are to help drivers keep their vehicles under control and, in situations when drivers do lose control, to prevent accidents or reduce their severity.

### Driver Expectancy

Driver expectancy has been described as the readiness of drivers to act in predictable and successful ways (*5*). When drivers are faced with unusual situations that require them to make decisions and act upon those decisions quickly, the results may be either unpredictable or unsuccessful. Unusual situations that have this effect are considered to be violations of driver expectancy. In some cases these violations will cause, or contribute to, the occurrence of accidents.

Driver expectancy can be violated by a patch of slippery pavement, a vehicle from a hidden driveway, a badly timed traffic signal, a sudden reduction in the number of lanes, an unusually sharp curve in a series of more moderate curves, a pedestrian or wrong-way vehicle on a freeway, or by many other exceptions to what drivers are used to encountering. Any of these violations may cause drivers to lose control of their vehicles. Improvement of roadway consistency is an effort to see that violations of driver expectancy occur less often.

Driver expectancies are either a priori, based on experience or training over a long period, or ad hoc, based on observations during a short period of time or on a single trip. The expectancy that stop signs will be red and octagonal is an a priori expectancy. If a driver in a shopping center, a park, or any other area where standard signs are not used, sees stop signs of some other color or shape, he or she may acquire an ad hoc expectancy that other stop signs in that area will be the same. With luck, the driver's first encounter with the strange stop sign will not be catastrophic. The introduction of a third type of stop sign may violate both a priori and ad hoc expectancies, making the likelihood of an accident even higher.

A priori driver expectancies are directly related to the expectation that roadway design and traffic control devices will be consistent. If a section of the roadway is substandard or under repair, drivers expect to be warned in time to take whatever action may be appropriate. The warning creates ad hoc expectancies that supersede the a priori expectancies for a short time. When drivers on a freeway pass a sign that says "Men Working" or "Road Construction Ahead" they normally acquire an ad hoc expectancy and become more alert. If they see no workers or signs of construction for two or three miles, they are likely to revert to the a priori expectancy that they will see none before they see warning signs. They may also acquire a new ad hoc expectancy that there will be no workers or construction even if there is another warning sign.

The expectancy concept was identified by psychologists a half century ago. It was first applied to highway traffic operations in the 1960s (*5*), many years after recognition of the advantages of consistency in roadway design and in traffic control devices and after achievement of a relatively high level of roadway consistency in the United States. The expectancy concept serves a useful purpose in explaining why consistency makes highways safer. This explanation supports the continuing effort to reduce the risks involved in highway travel.

### Forgiving Roadsides

Drivers will continue to lose control of their vehicles occasionally. Whether the loss of control results from highway design problems, excessive speed, driver fatigue, vehicle defects, or from other conditions, provision of "forgiving roadsides" and other measures can help drivers avoid accidents and can help reduce the severity of injuries and damage if an accident should occur. Provision of roadside clear zones, impact attenuators (crash cushions), ramps for runaway trucks, better guardrail, and many other safety measures contribute to roadway consistency and help cut the human and financial costs of traffic accidents. Examples of such safety measures may be found in *Highway Design and Operational Practices Related to Highway Safety* ("Yellow Book"), which was published by the American Association of State Highway Officials in 1967 (*6*). A second edition (also known as the Yellow Book) was published in 1974 by the same organization, which had then adopted its current name, American Association of State Highway and Transportation Officials (*7*).

Perhaps the best example of the benefit to be derived from roadway consistency is the reduction of fatality rates on segments of the Interstate system where "Yellow Book" improvements were implemented in the late 1960s. When Interstate segments that were opened or improved after 1966 were compared with those completed before the "Yellow Book" improvements were implemented, it was evident that the use of the new

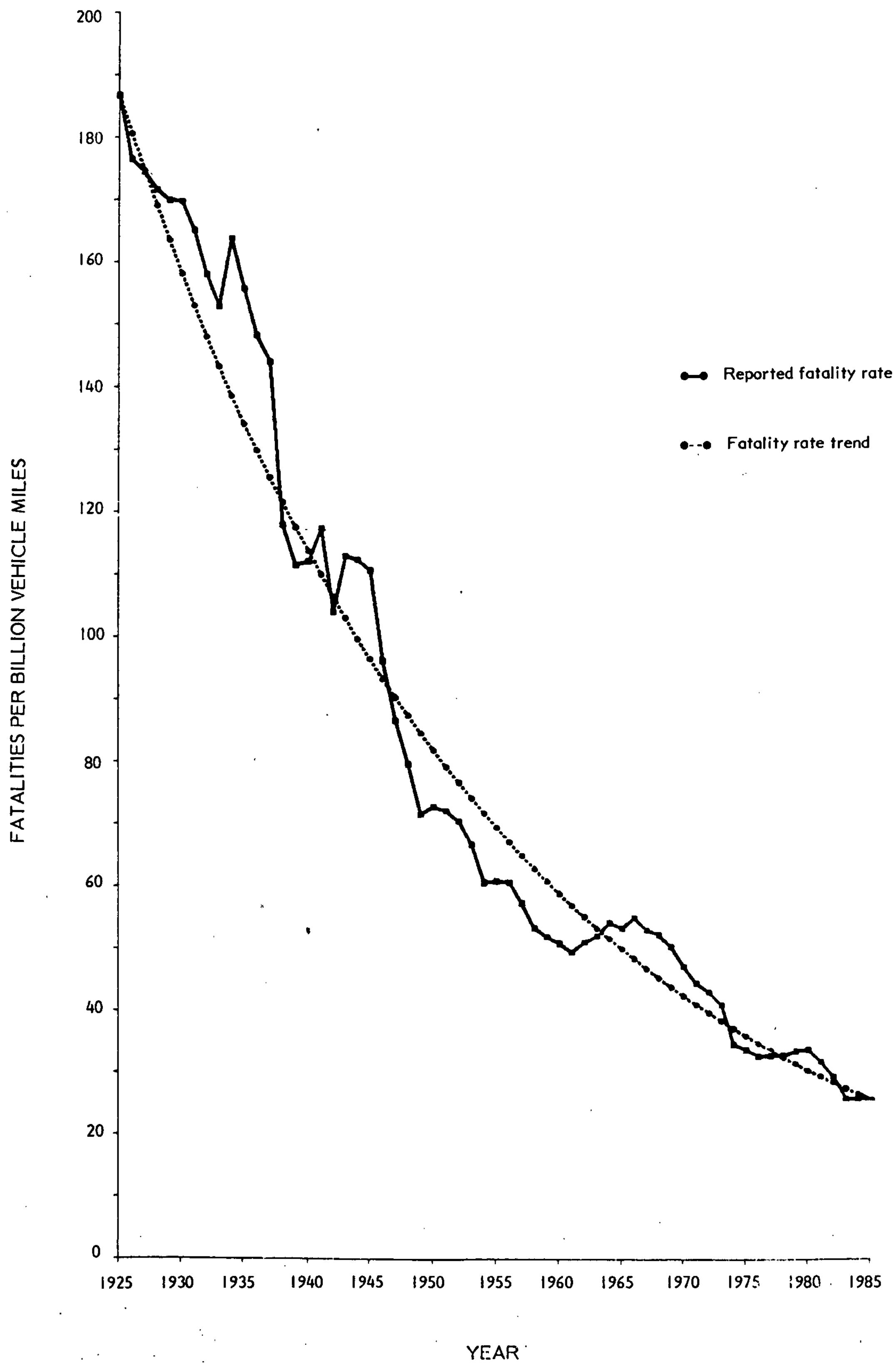


FIGURE 1 U.S. motor vehicle traffic fatality rates (1925–1985).

guidelines had reduced fatality rates by about 20 percent (*8*) (Fig. 2).

## Hazards

The aim of highway safety improvement programs is the correction of hazards that may contribute to the occurrence or severity of accidents. A hazard, in the context of this report, is a section of roadway or a roadway feature associated with a level of accident risk that is expected to be unusually high for the particular highway system under consideration. High risk often reflects problems with roadway consistency—either violations of driver expectancy or the lack of forgiving roadsides, or both.

Recent increases in tort liability claims and awards resulting from traffic accidents have created considerable pressure to avoid the term "hazard." Terms such as "potential safety improvement" and "correctable location" or "correctable element" have been suggested as substitutes for "hazardous location" or "hazardous element." Signs that warn of roadside safety problems, formerly called "hazard markers," are now called "object markers" in the *Manual on Uniform Traffic Control Devices* (MUTCD) (*9*). This careful use of terminology is not unreasonable, particularly where risks associated with hazards are only slightly greater than normal risks. The technical definition of "hazard" used by engineers to distinguish between things that are hazardous and things that are not is not the same as the definition used by a layman. Thus the public may be misled by highway agency statements about hazards and assume that the term indicates a much higher level of risk than it actually does. Journalists, as well as judges and juries in liability cases, may also be misled if they give undue weight to the term. Despite recognition of this danger, the terms "hazard" and "hazardous" are widely used within the traffic safety community and are used, with reservations, in this synthesis.

It is not unusual for highway and traffic engineers to distinguish between highway locations or elements that have been involved in accidents and those that have not, but are expected to be, by referring to the latter as "potential hazards." This terminology is *not* used in this report. Instead, the use of the term "hazard" generally is based on expected future risks. It is immaterial whether that expectation is based on observation of the specific roadway section or specific feature classified as a hazard, on observation of similar roadway sections or features, on research findings, or on other information. If, for example, a utility pole is installed near the edge of pavement on a busy suburban street and is hit three times by motor vehicles within the next year, it is a hazard. If another pole is installed in a similar position, it is not necessary to wait until an accident has occurred to identify the second pole as a hazard.

The precise distinction between what is labelled as a hazard and what is not is necessarily somewhat arbitrary. A large tree that encroaches on the outer edge of a 40-ft wide clear zone on a rural Interstate highway may be considered a hazard, whereas another tree a few inches farther from traffic would not be classified as a hazard because it is outside the clear zone. Yet the risk of hitting one of the trees differs very little from the risk of hitting the other. As a group, highway sections or features that have been classified as hazards are more dangerous than those that have not been so classified, but it should not be assumed that, for every pair of highway sections or elements, if one is called a hazard, it is more dangerous than the other.

In the identification of hazards, statistical methods are sometimes designed to select only a limited number of highway sections or features with the highest risk. The rationale for this is

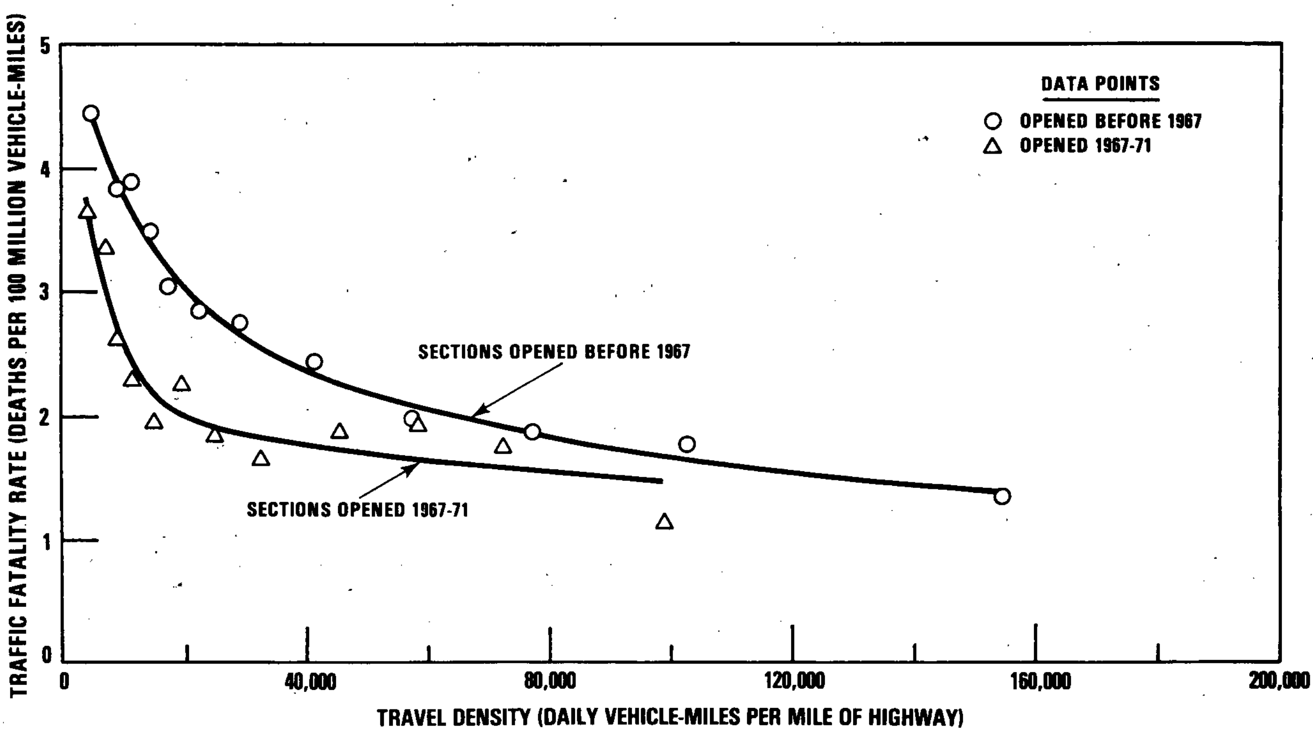


FIGURE 2 1969–1972 fatality experience on Interstate highways (*8*).

that there is little point in identifying 100 or more hazards if there is only enough staff to study 20 and only enough money to correct 5 of them. Using such an approach, new hazards are identified to replace those that are corrected. Thus, the number of hazards on a highway system might remain about the same over a period of years even though all major safety problems had been resolved and the safety of the highway system had been improved substantially. This approach is much the same as the common journalistic practice of focusing on the ten most dangerous intersections in a city or the FBI's ten most-wanted list. In each case, the number of problems is unrelated to their severity, and there is no expectation that there will be no more problems when those on the list have been taken care of.

The objective in identifying hazards is to find those that can be eliminated most cost-effectively. Elimination of a hazard is accomplished by modifying the physical highway facility or its environment in a manner that reduces or eliminates accident risks.

### Hazardous Locations

Hazardous locations are segments of highway or intersections that have been identified as hazards. Short highway segments, usually less than a half-mile long, are commonly called "spots." The wide use of the term "hazardous location" began in the mid-1960s and is related to the Highway Safety Act of 1966 and subsequent federal legislation. The 1966 Act established a requirement that states adopt safety standards, including one that called for surveillance of traffic for the detection and correction of high-accident locations. Procedures developed for the implementation of the Act included rules for identifying "hazardous locations" (*10, 11*). In the Highway Safety Act of 1973, Congress authorized the expenditure of $200 million from the Highway Trust Fund for correction of "high-hazard locations" in the 1974 through 1976 fiscal years. Federal funding has continued since that time. As a result, all states have had programs for the improvement of safety at hazardous locations. In Section 168 of the 1978 Surface Transportation Assistance Act, Congress modified the wording of Section 152 of Title 23, United States Code (23 USC 152), to provide for a program that included, among other things, the correction of "hazardous locations." This program was still in effect at the end of 1986.

### Hazardous Elements

In 1973, Congress authorized the expenditure of $200 million for the correction of high-hazard locations and also authorized the expenditure of $175 million over a three-year period for the elimination of "roadside obstacles which may constitute a hazard to vehicles and to pedestrians" (23 USC 153; PL 93-87, Section 210). In 1978, Congress combined this program with the program for the correction of hazardous locations by adding the correction of "hazardous . . . elements, including roadside obstacles," to 23 USC 152.

Hazardous elements are hazards distinguished from hazardous locations by characteristics other than their inclusion within a specific segment of a highway system. Hazardous elements fall in two general classes, those that contribute to the loss of control of highway vehicles (generally by violating driver expectancies) and those that contribute to the occurrence or severity of accidents that occur when control is lost.

Examples of hazardous elements that contribute to loss of control include:

- Abrupt reductions in design speed
- Unexpected combinations of sharp curvature with steep grades
- Reduction of lane width or the number of lanes without adequate warning
- Slippery pavement
- Poor drainage of through-traffic lanes
- Curbs near through-traffic lanes on high-speed highways
- Unmarked rail-highway grade crossings

Examples of hazardous elements that contribute to accident occurrence or severity when control is lost are:

- Large trees close to through-traffic lanes
- Non-breakaway sign posts near the edge of rural roads
- Steep fill slopes without guardrails
- Concrete luminaire bases extending several inches above ground level
- Culvert ends or headwalls protruding from fill slopes
- Lack of connections between guardrails and bridge parapets
- Blunt non-breakaway guardrail ends
- Narrow bridges
- Deep ditches
- Mailboxes

## APPROACHES TO SAFETY IMPROVEMENT

State and local organizations responsible for the construction and maintenance of highways generally use both a spot improvement approach and a system-wide improvement approach.

### Spot Improvement Approach

When the spot improvement approach is used, the focus is on hazardous locations—small segments of a highway system on which future accident frequency or severity is expected to be unusually high. Spot improvement projects often include a number of accident countermeasures such as revising grade and alignment, widening pavement, installing signs or signals, marking pavement, flattening fill slopes, removing guardrail, reconstructing drainage inlets and outlets, removing trees, and moving utility poles. The scope of a single spot improvement could range from replacement of a single sign to complete reconstruction of a few miles of highway. In either case, the objective of a spot improvement project is to correct a unique site-specific safety problem. Little or no consideration may be given to the effect of the project on the safety of adjacent roads.

Spot safety improvements often improve roadway consistency by eliminating local inconsistencies, but they do not necessarily do so.

### System-wide Improvement Approach

The system-wide improvement approach, in contrast to the spot improvement approach, focuses on the roadway consistency of a substantial portion of the highways in a jurisdiction. "System-wide" may, for example, refer to all rural secondary roads in a county, all divided highways in a state, all highways within the jurisdiction of an agency, or to other classes of highway with similar administrative or physical characteristics.

System-wide improvement projects may be undertaken as part of either a construction or maintenance program. Examples of system-wide improvements include:

- Installation of crossbucks at all unmarked rail-highway crossings in a state,
- Connection of guardrail to bridge parapets on all roads with more than 100 vehicles per day in a county,
- Upgrading all guardrail ends on a state primary system,
- Installation of breakaway bases on all luminaires located in medians in a city,
- Painting edge lines on all paved rural roads in a county,
- Upgrading all yield signs in a city to current standards,
- Flattening all fill slopes steeper than 3:1 on fills of less than 10 ft on rural state primary highways,
- Elimination of curves on which safe speeds are more than 15 mph below posted speeds on county roads with ADT > 1,000,
- Installation of no-passing pennants, and
- Selective tree removal.

System-wide improvements may be made in intensive programs that are completed within a short period, or they may be combined with other construction or maintenance projects and implemented on a staggered basis when workers and equipment are available nearby, over a period of years.

## STRATEGIES FOR SYSTEM-WIDE SAFETY IMPROVEMENTS

### Implementation of Safety Projects

The first of three fundamental strategies used in operating system-wide safety improvement programs is to focus exclusively on the correction of hazardous elements. Procedures for implementation of this strategy are parallel to procedures normally used in spot improvement programs to correct hazardous locations. When a hazardous element has been identified, safety projects are programmed to correct that hazard throughout the appropriate highway system or subsystem. Little or no work other than correction of the specified hazardous element is included in these projects. This strategy is most commonly used with low-cost countermeasures.

### Inclusion of Safety Features in Construction and Maintenance Projects

The second fundamental strategy for achieving roadway consistency through system-wide safety improvements is the inclusion of safety measures in construction or maintenance projects undertaken for purposes other than safety. These projects include ordinary federal-aid work, 4-R work (resurfacing, restoration, rehabilitation, and reconstruction) on the Interstate System, 3-R work (resurfacing, restoration, and rehabilitation) on other federal-aid systems, bridge replacement and rehabilitation, and many other state and local programs funded primarily to improve mobility or to counter deterioration of the highway system. This strategy is most often used when the cost of countermeasures can be reduced by combining them with other work.

### Treatment of Side Effects

The third fundamental strategy for achieving system-wide roadway consistency is treatment of side effects—the routine or systematic identification and prevention or correction of safety problems that may arise as side effects of alterations to adjacent or nearby highways. One aspect of this strategy is anticipation of problems that might be created at the termini of construction projects if suitable transitions between new and old sections of the highway are not provided. "Inconsistency of design was a major contributor to accident experience at many sites reviewed," according to a Federal Highway Administration safety review task force that looked at transition problems in 1978 (*12*). Another aspect is the avoidance of safety problem transfers from one section of the road to another. If, for example, many accidents have been occurring when vehicles come to the first of two sharp curves on a two-lane rural road, flattening the first curve may increase accidents at the second. The third and last aspect of treatment of side effects, which arise when traffic is diverted to or from other roads as a result of new construction or modifications, is correction of safety problems that may be caused by the changes in traffic patterns or volumes.

Of the three strategies for system-wide safety improvements, treatment of side effects is least common. Where it is practiced at all it tends to be practiced informally. Engineers reviewing plans before or during construction may identify adverse side effects, or side effects may be observed in a post-construction check. No formal requirements for a comprehensive search for undesirable safety side effects were discovered during the preparation of this synthesis.

CHAPTER TWO

# CURRENT PRACTICE

It is impossible to categorize current state and local practices neatly with respect to system-wide safety improvements and roadway consistency. Practices reflect a wide range of influences including:

- top management support for safety improvement work;
- middle management attitudes toward safety in design, construction, and maintenance;
- attitudes of those who supervise and perform design, construction, and maintenance work;
- formalization of safety improvement policies;
- tort liability claim experience;
- opportunities to combine safety improvements with other work;
- availability of funds for safety improvements, including funds not allocated primarily or exclusively for safety projects;
- access to data systems that support safety problem identification and safety program development, management, and evaluation; and
- public interest and action.

These influences are not mutually exclusive. Losses in tort liability suits, for example, are very effective in getting management attention and support. The availability of funds is affected by public interest and action. And opportunities to combine safety improvements with other work is closely tied to the availability of funds that can be used to pay for such work.

Management attitudes have much to do with the effectiveness of safety programs. In an agency where the management reaction to tort liability losses is an attempt to avoid responsibility, rather than to deal with the safety problems that led to the losses, it is unlikely that employees at lower levels will give much weight to safety considerations. In 1983 the AASHTO Standing Committee on Highway Traffic Safety advised administrators to "establish highway safety as a goal of the highway agency at the highest policy level, as an equal to system capacity and level-of-service preservation, and system improvements" and to "recognize that safety decisions affect tort liability" (*13*).

Where support for roadway consistency is strong, managers can usually find a variety of opportunities to achieve desired goals. It is not unusual for an organization to draw upon a number of funding sources for a single type of safety improvement.

Highway agencies approach system-wide safety improvements in various ways. A number of examples of current practice are described below. These examples were selected from a few states to illustrate the variety of work being done by many highway agencies. Accident data are given where available.

## SYSTEM-WIDE SAFETY IMPROVEMENTS IN IOWA

In Iowa, traffic safety considerations are taken into account throughout highway design, construction, and maintenance. Investment in safety has been substantially greater than that required to qualify for federal-aid safety funds under the hazard elimination and rail-highway crossing programs.

Under Iowa procedures for administration of secondary roads under county jurisdiction, when safety standards are adopted for roads on the state primary system, similar standards are applied to the county-administered secondary roads. As a result, roadway consistency improves at a more rapid rate than would otherwise be the case.

In mid-1985 a Bureau of Transportation Safety was created in the Iowa DOT in recognition of the growing importance of safety work—work formerly performed in other offices. Roughly half of the work of the new Bureau is accident analysis, transportation engineering, and other activity in support of a program to improve the safety of the highway environment. The other half is devoted to risk management and support of the legal staff defending the state against tort claims. Risk management is an effort to avoid future claims. About $80 million of claims related to traffic safety were pending against the State of Iowa in late 1985.

The Bureau of Transportation Safety ensures consideration of safety in all Iowa DOT construction by reviewing project concept statements before design begins and by reviewing construction plans before construction work starts. In addition, it develops procedures or policies for post-construction field reviews.

Pre-design field reviews are conducted routinely by design, materials, and maintenance engineers for construction projects, including all projects funded as federal-aid 3-R or 4-R projects. These field reviews include consideration of a variety of safety improvements. On 3-R resurfacing projects on the Iowa primary highway system, the Office of Road Design typically expects that the cost of safety features will be 20 to 30 percent of the resurfacing cost.

Preliminary engineering for 3-R projects includes the following safety items:

- Accident history, to identify safety deficiencies
- Guardrail presence, and connections at bridge parapets
- Upgrading of structurally inadequate bridge railing
- Signing and marking of no-passing zones
- Additional signs and markings where narrow bridges remain in place
- Revision of horizontal and vertical alignment, or additional

signs and markings, when advisory speeds are 15 mph or more below posted speeds

- Signing all curves where recommended speeds are lower than posted speeds
- Removal or shielding of obstructions within clear zones 30 ft or more wide on roads with average daily traffic (ADT) above 750 vehicles and 10 ft or more elsewhere
- Flattening foreslopes (fill slopes) steeper than 3:1

A number of system-wide safety improvements have been or are being made in Iowa. The following examples illustrate a variety of improvements and approaches. Because all of the federal-aid funds made available to Iowa for safety improvements under 23 USC 152 are currently being used for improvement of high-accident locations, most of these system-wide safety improvements (other than those at railroad-highway crossings) are financed with funds that have not been set aside exclusively for safety work. All of the improvements listed below contribute to roadway consistency.

#### Railroad-Highway Crossings—Passive Sign Project

In 1982 a project was initiated to replace or improve crossbucks and advance warning signs where these were missing or deficient. The 8,000 public crossings in Iowa were surveyed by temporary employees in the summer of 1983. During 1984 and 1985, using materials supplied by the Iowa Department of Transportation, the railroads replaced or repaired about 10,000 crossbucks, and local highway jurisdictions did the same for about 10,000 advance warning signs. The railroads and local highway jurisdictions paid 10 percent of the cost of materials and installation. The balance of the work was funded with federal-aid funds provided under section 203 of the 1973 Highway Safety Act (as amended). (See Appendix for a more complete description.)

#### Abandoned Railroad-Highway Crossings—Removal of Rail

In cooperation with railroads that have abandoned sections of their systems, the Iowa DOT has arranged for the removal of rails and replacement of roadway at abandoned crossings. One set of projects extending over six DOT districts includes rail removal and roadway replacement at more than 110 crossings throughout the state. Roadway replacement required more than 8,000 square yards of asphalt or portland cement concrete patches. Where signals were in place—at about a dozen crossings—they were removed. Restoration of the highway at these abandoned crossings eliminated hazardous conditions caused by interruption of the normal traffic flow when vehicles slowed or stopped unnecessarily.

#### Railroad-Highway Crossings—Line-Segment Reviews

For management purposes, the Iowa DOT has divided railroads in the state into 164 "line segments" ranging in length from 50 or more miles to short spurs and connectors. A line-segment review (an on-site evaluation of all at-grade crossings on a specific line segment) may be initiated by a railroad company and is conducted by the railroad in cooperation with the DOT and local engineering and law enforcement officials. The incentive for the railroad company is the availability of federal-aid and other public funds for crossing improvements.

Teams conducting line-segment reviews visit about a dozen crossings each day. Schedules are provided beforehand to local officials who are invited to participate. At each crossing the team considers physical characteristics, accident history, highway and railroad traffic, and any additional information provided by local officials. Railroad and DOT representatives determine what safety improvements should be made at each crossing.

The line-segment review procedure is a system-wide approach that enhances roadway consistency by applying similar problem identification criteria and similar accident countermeasures to groups of crossings.

#### Drainage Structures—Headwall Removal

The Office of Maintenance initiated a program in 1983 to remove headwalls on culverts adjacent to the traveled way, where driving into the drainage channel would be less hazardous than hitting the headwall. Appropriate delineators or object markers were installed to reduce the risk of accidents after headwall removal. Counties were encouraged to initiate similar programs (*14*).

#### Drainage Structures—Removal of Lip Curbs

Many miles of Iowa highways that were paved with portland cement concrete before World War II included lip curbs to prevent shoulder erosion. Concrete flumes were used to drain away accumulated water without eroding fill slopes. Lip curbs on major two-lane roads were removed more than 20 years ago when the pavement was widened, but many miles of lip curbs remained on low-volume roads.

As a result of accidents and near-accidents resulting when drivers lost control of their vehicles after hitting lip curbs on low-volume primary roads, the DOT conducted a program to remove the remaining lip curbs and flumes. This work was funded by the state without federal aid. Lip curbs were removed from approximately 1,300 miles of low-volume primary roads.

One benefit of the state decision to deal with the lip-curb problem on a system-wide basis was a reduction in unit cost. Because of the volume of work, it was profitable for construction equipment manufacturers in Iowa to develop special equipment that removed the curb more efficiently than could be done with standard tools.

#### Drainage Structures—Traversable Culvert Grates

At box culvert and large pipe culvert ends within the clear zone on Interstate or other primary highways, Iowa has been installing traversable bar or pipe grates instead of shielding the ends with guardrail. Grates are used on longitudinal culverts in medians as well as on transverse culverts. For traversability, bars are installed horizontally on longitudinal culverts and vertically on culverts extending through side slopes. The bar grates are placed flush with the surface to eliminate collisions with fixed obstacles and reduce the likelihood that out-of-control vehicles will be brought to a sudden stop or overturn in drainage channels.

Bar grates have generally been installed as an added safety feature on projects programmed for other purposes. Guardrail is used to shield box culverts larger than 8 ft by 5 ft only where it is impractical to use grates or extend the culvert beyond the clear zone.

#### T Intersections—Double-Arrow Signs

During fiscal year 1984, double-arrow signs were erected at approximately 3,200 T intersections—all T intersections on the 10,000-mile Iowa primary highway system that were not so marked. This work, which was done in part because of feedback from tort liability suits filed after accidents at T intersections, was performed as a maintenance project.

#### T Intersections—Escape Ramps

Occasionally, when drivers approaching T intersections on the main leg (stem) of the T are not alert, they are moving too fast to stop when they reach the crossroad. As a result of a number of cases in which the out-of-control vehicle crossed the intersection and collided with a fixed object or encountered some other nontraversable hazard, and as a result of consequent tort liability suits, Iowa has constructed escape or safety ramps wherever possible at T intersections on rural primary highways. This work is normally done by maintenance crews, using material obtained by cleaning ditches.

#### Y Intersections—Conversion to T Intersections

Because sight restrictions and driver confusion appeared to be contributing to accidents at Y intersections, the Iowa DOT has converted many of these to T intersections. Where they were warranted, left-turn and right-turn lanes were added and turning radii were improved. Reconstruction of Y intersections has been funded under the federal-aid hazard elimination program and as regular construction projects.

A study of nine of the Iowa Y intersections that were reconstructed indicates substantial safety benefit. Total accidents were cut 39 percent (to 30 accidents), injury accidents went down 50 percent (to 6), and property damage accidents went down 39 percent (to 23). Although fatal accidents also decreased, the numbers were not statistically significant (*15*).

#### Pavement Friction Evaluation Program

In 1972, Iowa established a "program for conducting friction tests on the Interstate and primary road systems, [to] isolate potential wet weather accident sites, evaluate pavement materials, test construction processes, and determine the effectiveness of maintenance practices designed to increase the frictional coefficient of the pavement surface" (*15*) (Fig. 3). Each year, friction tests are conducted over the entire length of the Interstate system and on about one-third of the primary system. Secondary roads are also tested when requested by the counties.

During the 1985 fiscal year projects to increase pavement friction numbers, eliminate rutting or oil bleeding, and improve other pavement surface conditions were completed on about 70 miles of Interstate and primary highways. This total does not include corrective actions, such as pavement burning, spot sealing, strip sealing, slurry sealing, and rolling chips, which were done at numerous locations throughout the state at the discretion of the District Engineers (*15*).

#### Bridge Rail and Approach Guardrail

When bridge decks are repaired in Iowa, bridge rail and approach guardrail deficiencies are corrected. Such corrections were necessary on more than half of the 107 bridge deck repair projects in fiscal year 1985 (*15*).

On the secondary (farm-to-market) system, county engineers rate bridge rails according to a five-factor system to determine the level of upgrading. The five factors are accident experience, traffic volume, type of rail, bridge width, and bridge length. Upgrading may involve installation of delineators or blocked-out W-beam guardrail, or retrofitting the bridge rail. Guardrails are connected at all four corners of each bridge except on some low-speed roads where approach guardrail is only installed on the right side of the road. On short bridges or bridges without end posts, guardrail is sometimes extended across the bridge. This type of work is commonly done as part of the 3-R program (*16*).

#### Removal of Guardrail

According to the 1977 AASHTO Guide for Selecting, Locating, and Designing Traffic Barriers (*17*), guardrail is not warranted on fills with 3:1 or flatter slopes except where shielding of roadside objects is necessary. In general, traversable slopes are less hazardous than guardrail. Where Iowa had installed guardrail on 3:1 or flatter slopes in the past, or where steeper slopes can be economically flattened, guardrail is being removed in conjunction with 3-R and 4-R work administered by the state and the counties.

#### Guardrail Repair Team

In 1984 a guardrail repair team was organized within the Office of Maintenance to demonstrate current standards for guardrail repair to maintenance personnel throughout Iowa. The team has been effective in achieving a higher level of roadway consistency in this specialized activity. In addition to its training function, the team has the expertise to deal with unusual guardrail repair problems.

#### Utility Poles

Current policy for placement of utility poles requires that, for curbed sections of road in urban areas, utility poles should be as far as possible from the traveled way. Poles should be placed at the right-of-way line or far enough from the traveled way to provide a clear zone at least 10 ft wide.

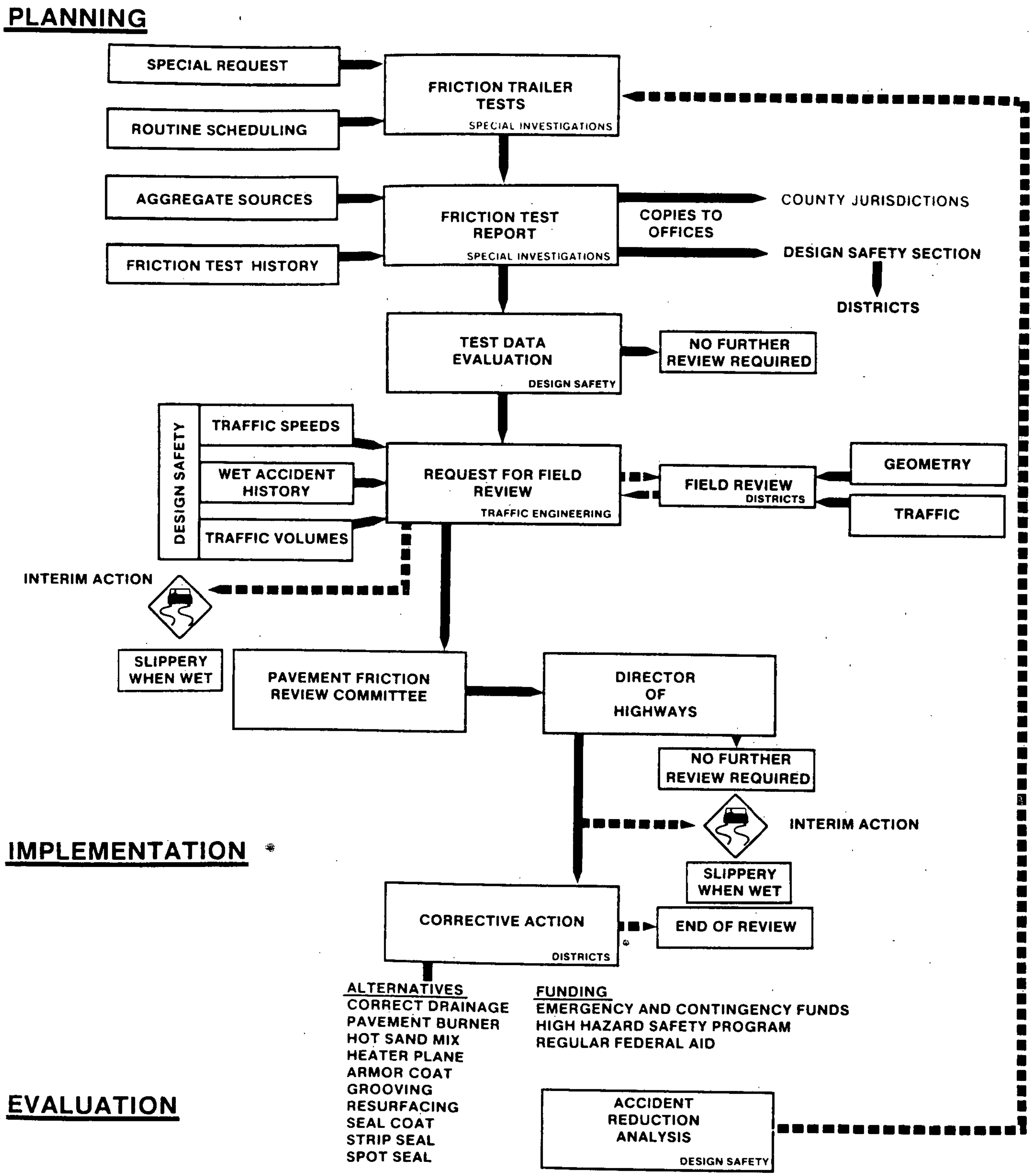


FIGURE 3 Pavement friction evaluation program.

### Stop-Sign Placement

At some intersections in Iowa, placement of stop signs was not within the area prescribed by current MUTCD standards (*9*). Because of liability considerations, the Office of Maintenance arranged for a survey of the locations of all stop signs on side roads approaching highways on the 10,000-mile state primary system for conformity with placement standards. The survey was conducted during 1984 and 1985. Distance from the traveled way, distance from the intersection, and the height of the sign were measured. Although no precise records were kept, it is estimated that an average of about 5 nonconforming stop signs were corrected in each of the 99 Iowa counties as a result of the location check.

This is a good example of a low-budget project that raised the system-wide level of consistency.

### Chevrons and No-Passing Pennants

In 1978, no-passing pennants were installed on all county roads in 40 of the 99 counties in Iowa. About 13,600 signs were erected in 5,500 miles of no-passing zones. Edge lines and center lines on the pavement were painted or repainted in conjunction with the pennant installation.

During 1980 and 1981, 70 Iowa counties participated in a program to install chevron signs on sharp curves. About 6,100 signs were installed on 1,500 curves.

Both the pennant and the chevron project were financed with federal-aid pavement marking demonstration funds and local matching funds. The work was done as county force account projects.

## MICHIGAN SYSTEM-WIDE SAFETY IMPROVEMENTS

The initial implementation of "Yellow Book" safety improvements in Michigan began in 1969 (*18*). The improvements were incorporated in new freeways built during the 1970s and, concurrently, the roadside environment of older freeways was upgraded. A systematic program for improving roadside safety on Michigan freeways was initiated in 1971. By 1975, maintenance forces had improved 42 percent of the Interstate system in accordance with Yellow Book recommendations. Guardrail improvements were the top priority during this period, with lower priorities for slope flattening, filling of gore areas, and modifying culvert end sections. After 1975, the remaining work was done by competitively bid contracts. Almost all of the Interstate system had been upgraded to more forgiving roadsides by 1982, but further improvement continues. Although the system-wide safety improvements on Michigan's Interstate highways appear to have reduced deaths and serious injuries significantly, concurrent effects of the 55-mph national maximum speed limit make it difficult to quantify benefits.

A more recent system-wide approach to safety improvement in Michigan is the establishment of a guardrail inventory file. This file was created after Michigan was found liable for more than a million dollars in a claim resulting from a rotted wooden guardrail post. Initial inventory data, taken from photologs and supplemented with field data collected by state construction employees in the off-season, include descriptive data on location, type, and condition of rails and posts. Measurements of penetration of wooden posts with manual probes at ground level are included. The file has been used to plan upgrading of guardrail ends and should be extremely useful in planning other system-wide guardrail projects. Inventory data have also been used in studies of high-accident locations and, by maintenance managers, in planning herbicide programs. Programs have been written to permit the field offices to update the guardrail file to reflect any changes resulting from construction or maintenance activity.

The Michigan Department of Transportation approved and issued "Revised Resurfacing, Restoration and Rehabilitation (RRR) Guidelines" in 1985 to assist "in promoting uniform safety practices throughout the state" (*19*). This action improves roadway consistency by applying the following system-wide safety improvements:

- Upgrading horizontal and vertical curves;
- Upgrading sign reflectivity, supports, and locations;
- Selective tree removal;
- Removal, relocation, redesign, or shielding of such obstacles as culvert headwalls or ends, utility poles, and bridge supports within the clear zone; and
- As part of bridge improvements, upgrading approach guardrail, guardrail connections, and bridge rail.

## SYSTEM-WIDE IMPROVEMENTS IN OAKLAND COUNTY, MICHIGAN

The Oakland County Road Commission, in cooperation with the Traffic Improvement Association of Oakland County, Michigan, has developed a roadside hazard inventory for major county roadways. It is used for identifying hazardous elements for correction (*20*). The data base was compiled largely by examining existing photologs. Lateral distances were estimated by using a grid overlay with the photolog viewer. Information about road grades, traffic volumes and speed limits were obtained from other sources. Priority factors used to rate the relative hazard of fixed roadside objects include presence of curbs, horizontal and vertical alignment, traffic volume, speed limit, roadway type, distance of the object from the pavement edge, and a severity factor. Severity factors range from 5 for bridge abutments or large trees to 1 for small wooden posts or breakaway supports.

The hazard inventory permits planning of system-wide safety improvements on a highly selective basis. For example, one Oakland County Road Commission project covered removal of rocks over 3 ft in diameter from within 10 ft of the pavement on roads where the average daily traffic was more than 8,000 vehicles. In this project, property owners—many of whom had placed the rocks near the road to keep vehicles off of their property—were asked to remove these hazards.

By merging the hazard inventory with the accident file, the Oakland County Road Commission can identify guardrails that may have been struck in accidents. With this information, arrangements are made for inspection of the guardrails to determine whether repairs have been completed or are needed.

Priority factors for each element in the hazard inventory permit identification and treatment of the most hazardous elements in the system first, improving roadway consistency.

As a result of a tort liability case, the relationship of traffic accidents to flashing signal operation at night in Oakland County was studied. It was found that the conversion of traffic signals from stop-go operation to flashing operation at night was associated with significant increases in accidents at four-legged intersections (*21*). In 1984, changes in signal timing to eliminate flashing operation at night were authorized for all signals under the control of the Oakland County Road Commission.

Tort liability became a serious problem for the Oakland County Road Commission during the 1970s. By 1978, liability claims in lawsuits filed against the Road Commission were three times as much as its annual revenues. This led the Road Commission to adopt a "risk management" approach to identify safety problems (preferably before accidents occur) and treat the problems promptly. Many agencies are reluctant to acknowledge safety problems, hoping that pleas of ignorance will be an adequate defense in court. The Oakland County Road Commission has rejected this approach, recognizing that it will not work if the problem is something the Commission should have known about (*22*).

## WASHINGTON STATE'S LEVEL OF DEVELOPMENT PLAN

The Washington State Department of Transportation, recognizing that funds are not available to improve the entire state highway system to current design standards, has adopted a Level of Development Plan to ensure that available funds are spent where they are most needed (*23*). All state highways have been assigned to one of the following development categories:

1. Design Standards
2. 3-R Standards
3. Maintain Structural Integrity and Operational Safety

Highways in the Design Standards Level include Interstate highways and other principal arterials that serve interregional and interstate transportation of people and goods. Long-range planning for these roads includes major construction, reconstruction, or relocation needed to bring them up to appropriate design standards. Interim construction or operational improvements are contemplated in the short range.

Highways in the 3-R Standards Level are primarily minor arterials or principal arterials serving local needs. Future plans for these roads include minor improvements, such as additional structural integrity, intersection improvements, truck climbing lanes, and isolated corrections of horizontal or vertical alignment to improve safety.

Roads not assigned to the two higher levels are included in the Maintain Structural Integrity and Operational Safety Level. As implied by its name, planning for this level contemplates preservation of these roads in safe operating condition without major improvement. Exceptions may be made to correct serious structural or safety deficiencies.

The Level of Development Plan should contribute significantly to traffic safety in Washington by its system-wide approach. The Plan puts the greatest emphasis on roadway consistency and system-wide safety improvement on the principal arterials at the Design Standards Level, the most heavily traveled quarter of the 7,000-mile state highway system. The ratio of spot safety improvements to system-wide safety improvements is somewhat higher on roads in the middle category, the 3-R Design Level. The type of system-wide safety improvements being made at the 3-R Level are described below. On the least heavily traveled quarter of the state system, safety problems are addressed primarily by spot improvements.

## SYSTEM-WIDE 3-R SAFETY IMPROVEMENTS IN WASHINGTON STATE

Washington State Department of Transportation analyses have indicated that low-cost accident countermeasures related to elements of high-accident severity are cost-effective for the majority of 3-R projects. For consistency, WSDOT requires specific safety enhancements on all 3-R projects administered by the state or by local agencies operating under certification acceptance procedures (*24, 25*). These enhancements are:

1. Guardrail end treatments upgraded to current standards.
2. Appropriate transition and connection of approach rail to bridge rail.
3. Mitered end sections for both parallel and cross-drain structures located in the "clear zone," i.e., within right-of-way limits.
4. Relocating, protecting, or providing breakaway features for sign supports and luminaires.
5. Protection for exposed bridge piers and abutments.
6. Modification of raised drop inlets that present a hazard in the clear zone.

The WSDOT Design Manual was revised in 1984 to increase emphasis on safety considerations for 3-R projects (*25*). The new provisions require analysis of each project before the design is approved. The analysis includes examination of:

- Horizontal and vertical alignment
- Cross-sectional geometrics
- Traffic control
- Access
- Railroad crossings
- Pedestrian facilities
- Bridges that remain in place
- Illumination
- Signing
- Channelization

In addition, if operating speeds are expected to increase as a result of improvements, geometrics should be modified to maintain an acceptable level of operating safety.

The roadside recovery area, or clear zone, is given particular attention. Obstacles in the clear zone are inventoried and the consistency of the clear zone throughout the project length is evaluated. Cost analyses are used as the basis for selection of appropriate remedial action (*25*).

CHAPTER THREE

# GUIDELINES FOR ROADWAY CONSISTENCY

There is no simple prescription for improvement of roadway consistency. Every state and local highway agency has a unique highway system and a unique set of resources to use for improving its system. In addition, every state and local highway agency serves a unique constituency. Those who use the highway system and those who pay taxes to support it have very definite opinions about how it is modified. And to add to the complexity of the situation, every agency faces a unique set of legal constraints and challenges. One of the major factors that influences safety planning today is the threat of tort liability claims.

In *A Policy on Geometric Design of Highways and Streets* (the "Green Book") issued in 1984 by the American Association of State Highway and Transportation Officials (*26*, p. 131), the following policy on safety improvements is set forth:

> A viable safety evaluation and improvement program, as part of the overall highway improvement program, is a necessity. The identification of safety hazards, the evaluation of the effectiveness of alternative solutions, and the programming of available funds to the most effective uses are of primary importance. The safety of the traveling public must be reflected throughout the highway program: in the spot safety projects, in the rehabilitation projects, in the construction of new highways, and elsewhere.

It is clear from the above statement that although AASHTO regards spot safety improvements as an important part of state safety programs, much broader attention to safety is necessary. Emphasis on roadway consistency and system-wide safety improvements addresses aspects of safety that are not covered adequately by a spot improvement program.

A set of general guidelines for improvement of roadway consistency is listed below. It is neither expected nor intended that these guidelines be followed blindly; but they may be useful to agencies that are increasing emphasis on roadway consistency and are developing procedures to support this objective.

1. For each functional class, or for other categories of highways under its jurisdiction, a highway agency should adopt a comprehensive set of roadway consistency standards. In many agencies, these will simply be an extension of design standards that are already in use. These standards should include design speeds and should provide that design features are compatible with a high level of operational safety at the prescribed speeds under expected operating conditions. In addition to the roadway consistency standards for the roadway itself, standards should be included for the roadside—specifying desired minimum widths for clear zones as well as standards for slopes, warrants for installation of guardrail or other barriers, and design criteria for sign posts, culvert ends, and other potentially hazardous features that often remain within clear zones. Standards should not be set so high that their implementation will seldom be cost-effective.

The agency should designate clearly which standards apply to each section of highway in its system. Care should be taken to ensure that drivers will not encounter frequent or sudden changes in the standards unexpectedly as they drive from one section of the system to another.

2. Having established standards, the agency would presumably incorporate them in any new construction. In addition, it should proceed with plans to apply the roadway consistency standards to facilities already in place. An inventory of the highway system should be conducted to identify substandard features. This process is obviously easier for an agency that has already established computerized inventories of various features of its highway systems (*27*), or for one that can refer to its photolog, but even a small highway agency can inventory exceptions to its standards with a moderate amount of effort if its standards have been set at a reasonable level.

Methods being used by highway agencies to collect inventory data and to identify substandard elements are given in NCHRP Synthesis 128 (*28*). Public complaints and maintenance experience can also be used to help identify substandard elements.

Some states and local agencies use their full-time construction or maintenance personnel to inventory substandard features during periods of the year when they might otherwise be idle. In some cases, it may be useful to establish a permanent inventory that can be updated either at regular intervals or as improvements are completed by construction or by maintenance forces.

The conduct of these inventories should be supplemented by pre-design and post-construction inspections. These inspections allow better definition of the project scope, review of accident locations, and detection of side effects of construction projects that might violate the standards or create other foreseeable safety problems.

Design features to be examined during these inventories may include items such as:

- horizontal alignment
- vertical alignment
- sight distance
- lane width
- shoulder width
- median width
- curb location and dimensions
- guardrail location, type, and height
- side slopes
- drainage ditch location and dimensions
- features within clear zones
  - trees

utility poles
mailboxes
rocks
culvert headwalls
unbeveled culvert ends
culvert ends without protective grates
sign posts
luminaires
unnecessary guardrail

signs and signals
pavement markings
structures
rail-highway crossings

3. After identification of substandard elements, determine the relationship of these elements to accident experience and to tort liability claim and award experience. This step is an important part of a system-wide improvement program and may be quite difficult, time-consuming, and costly. However, it is necessary before accident costs can be estimated.

4. Estimate the expected future costs of accidents involving each type of substandard element—assuming no remedial action is taken—in terms of fatalities, injuries, and dollar value of property damage and other losses. The time period used for this estimate may vary from the normal life expectancy of customary countermeasures to as much as 20 years.

5. For each type of substandard feature, consider alternative countermeasures. For example, AASHTO recommends the following treatments for roadside obstacles, in priority order (*26*, p. 129):

1. Elimination of the hazard.
2. Relocation of the hazard to a point where it is less likely to be struck.
3. Use of breakaway devices to reduce the hazard.
4. Selection of a cost-effective traffic barrier (longitudinal barrier or crash cushion) to reduce accident severity.

Similar priorities may be used for other substandard features to provide uniform criteria.

Evaluation of alternatives should take into account available strategies for accomplishing the work. Should it be handled as construction or maintenance? Should the implementation strategy be to apply the improvement on a system-wide basis as a short-term independent project, or should it be to incorporate the improvement in other projects as they are scheduled over a longer period?

6. Compare the cost-effectiveness of proposed system-wide safety improvements with the cost-effectiveness of proposed spot safety improvements. A well-designed agency safety program will usually include some of each. In some cases, differences in administrative costs could be the deciding factor in a choice between the two.

7. Select and implement system-wide improvements and spot safety improvements, including establishment of priorities and schedules.

8. Evaluate the costs and benefits of each improvement, documenting the evaluation carefully for use in developing future safety programs and in supporting future safety improvement budgets.

CHAPTER FOUR

# FINDINGS AND RECOMMENDATIONS

## FINDINGS

Although the concept of roadway consistency has not received a great deal of attention among engineers and others concerned with highway traffic safety, substantial contributions to roadway consistency have been made by highway designers and builders over the last 60 years. Currently, there is increasing emphasis on design consistency—a concept closely related to roadway consistency but less sharply focused. The need for consistency has been addressed explicitly in NCHRP Synthesis 106 (*29*) and by Oglesby (*30*), who suggests that consistency in design be defined to include both geometry and positive guidance.

In state and local agencies responsible for administration of highway programs, there is a lingering tendency to think first of spot improvements—and sometimes only of spot improvements—when safety improvements are mentioned. On the other hand, highway leaders have been stating for many years that safety should be a major consideration in all phases of highway development. Spot improvements are useful but they are not enough by themselves. It is necessary to take a broader look. More initiative is needed at the state and local level to identify hazardous elements and to develop system-wide improvement programs to correct them.

One example of a state action that fosters roadway consistency is the Level of Development Plan adopted in the State of Washington. This plan helps to ensure that driver expectancy will not be violated on the state highway system and that investments in safety will be made where they will do the most good. Some other state and local agencies have similar plans but they are rarely defined as clearly and as widely accepted as in Washington State.

Attitudes toward safety vary considerably in highway agencies. In some, where there is strong safety leadership, the high priority given to highway safety considerations is clearly evident at all levels.

State and local agencies are using a wide variety of approaches to safety improvement. These approaches are influenced by funding constraints, court decisions in tort cases, staff skills and preferences, and many other factors. The federal-aid 3-R program is having a major impact on roadway consistency as system-wide safety improvements are incorporated routinely in 3-R projects. In some states, safety standards required for federal-aid projects are being used for state-funded projects as well.

Evaluation of system-wide safety improvements is particularly difficult. Benefits are spread over long distances and are hard to distinguish from the effects of other changes. A study of system-wide safety improvements on the Interstate system, based on unusually complete data, indicated that fatalities fell about 20 percent as a result of "Yellow Book" improvements.

Some spot improvements may have higher payoffs than system-wide improvements, but as the worst spots are treated, system-wide improvements become more attractive. Court awards in tort cases may also make system-wide safety improvements attractive if they clearly demonstrate the cost of failure to treat specific hazards.

## RECOMMENDATIONS

State and local highway agencies should increase their emphasis on roadway consistency and system-wide safety improvements. Initial steps are the adoption of roadway consistency standards for the entire system under each agency's jurisdiction and the adoption of guidelines for system-wide safety improvements. It should be clearly understood at all levels of management that system-wide safety improvements and spot safety improvements complement each other, and that both are needed in a balanced safety program.

Top administrators in highway agencies should make it clear that safety is as important as system preservation and level of service, and that roadway consistency and consideration of system-wide safety improvements have high priority. Because safety is involved in so many activities of a highway agency, responsibility for ensuring that safety receives appropriate weight in management decisions should be formally assigned.

The costs and benefits of system-wide safety improvements should be evaluated and thoroughly documented. This information is needed to support development of future budgets and safety improvement programs and to counter tort liability suits. Agencies should be able to explain the effect of underfunding safety improvements to the public and to legislative bodies.

Procedures should be established for identifying and correcting side effects of construction projects that adversely affect traffic safety. These should include explicit consideration of side effects in both preconstruction and post-construction project reviews.

Training or other guidance is needed to make sure that highway agency staff members (at all levels) understand that traffic safety must be taken into consideration at all phases of highway planning, design, construction, maintenance, and operations. Transportation systems must be made safer as well as more efficient. Safety is a responsibility of all staff members, not only of safety specialists.

Highway agencies should not wait for the courts to tell them what to do about safety, but should recognize that the cost of doing nothing to correct a problem identified in court may be very high.

# REFERENCES


1. FHWA, *America's Highways, 1776–1976: A History of the Federal-Aid Program,* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. (1977) pp. 54–56.
2. FHWA, *Highway Statistics Summary to 1975,* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. (1977) p. 45.
3. *Accident Facts,* 1937 Ed., National Safety Council, Inc., Washington, D.C. (1937) p. 77.
4. FHWA, *Highway Safety Performance—1984: Fatal and Injury Accident Rates on Public Roads in the United States,* Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. (January 1986) p. 8 (1985 data added).
5. Alexander, G. J. and H. Lunenfeld, "Driver Expectancy in Highway Design and Traffic Operations," Report No.FHWA-TO-86-1, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. (April 1986) p. 18.
6. AASHTO, *Highway Design and Operational Practices Related to Highway Safety,* American Association of State Highway Officials, Washington, D.C. (1967).
7. AASHTO, *Highway Design and Operational Practices Related to Highway Safety,* 2nd Ed., American Association of State Highway and Transportation Officials, Washington, D.C. (1974).
8. FHWA, "Relationship of Interstate Highway System Fatality Rates to Date of Highway Construction," unpublished report, Office of Traffic Operations, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. (March 10, 1975).
9. FHWA, *Manual on Uniform Traffic Control Devices for Streets and Highways,* (ANSI D6.1), Federal Highway Administration, U.S.Department of Transportation, Washington, D.C. (1971) p. 209.
10. Roy Jorgensen and Associates and Westat Research Analysts, Inc., "Evaluation of Criteria for Safety Improvements on the Highways," a report to the United States Department of Commerce, Bureau of Public Roads, Office of Highway Safety, Washington, D.C. (1966).
11. FHWA, "Identification and Surveillance of Accident Locations," Vol. 9, *Highway Program Safety Manual,* National Highway Safety Bureau, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. (January 1969).
12. FHWA, "Highway Safety Review: Report of the Safety Review Task Force to the Federal Highway Administrator," Federal Highway Administration, U. S. Department of Transportation, Washington, D.C. (December 1978) p. 50 ff.
13. AASHTO, "A Guide for Enhancement of Highway Safety Directed to Agencies, Programs and Standards," Standing Committee on Highway Traffic Safety, American Association of State Highway and Transportation Officials, Washington, D.C. (1983) Goals I-1 and I-7.
14. "Annual Report for Special Highway Safety Improvement Programs, FY 1983," Office of Road Design, Iowa Department of Transportation, Ames, Iowa (August 1983) p. 2.
15. "Annual Report for Special Highway Safety Improvement Projects, FY 1985," Transportation Safety Bureau, Iowa Department of Transportation, Ames, Iowa (August 1985).
16. "Instructional Memorandums to County Engineers, Traffic Barriers (Guardrail and Bridge Rail)," IM No. 3.213, Office of Local Systems, Iowa Department of Transportation, Ames, Iowa (October 15, 1985).
17. AASHTO, "Guide for Selecting, Locating, and Designing Traffic Barriers," American Association of State Highway and Transportation Officials, Washington, D.C. (1977).
18. Lebel, W. T., "Evaluating Roadside Safety Improvements in Michigan," *Public Works* (December 1984) pp. 52–53.
19. Roberts, C., "Revised Resurfacing, Restoration, and Rehabilitation (RRR) Guidelines," Memorandum to Division and District Engineers, Michigan Department of Transportation, Lansing, Mich. (October 16, 1985).
20. Labadie, M. J. and J. C. Barbaresso," Development of Priority Program for Roadside Hazard Abatement," in *Transportation Research Record 867: Transportation Programming Process,* Transportation Research Board, National Research Council, Washington, D.C. (1982) pp. 6–11.
21. Barbaresso, J. C., "Flashing Signal Accident Investigation (Abridgment)," in *Transportation Research Record 956: Traffic Control Devices and Grade Crossings,* Transportation Research Board, National Research Council, Washington, D.C. (1984) pp. 25–32.
22. Bair, B. O., W. J. Fognini, and J. L. Grubba, "Highway Risk Management: A Case Study," in *Transportation Research Record 742: Program Planning, Finance, and Preconstruction Management,* Transportation Research Board, National Research Council, Washington, D.C. (1980) pp. 8–11.
23. "State Highways System Level of Development Plan," Washington State Department of Transportation, Olympia, Wash. (June 1984).
24. Eggen, K., "3R Projects Safety Enhancement," Memorandum to All Certification Acceptance Agencies, Washington State Department of Transportation, Olympia, Wash. (January 31, 1985).
25. "3-R Projects," Instructional Letter 22-01.4, Washington State Department of Transportation, Olympia, Wash. (September 6, 1984) section 315.06(6).
26. AASHTO, *A Policy on Geometric Design of Highways and Streets,* American Association of State Highway and Transportation Officials, Washington, D.C. (1984) p. 131.
27. Briggs, D. W. and B. V. Chatfield, *NCHRP Synthesis of Highway Practice 133: Integrated Highway Information Systems,* Transportation Research Board, National Research Council, Washington, D.C. (1987).
28. Zegeer, C. V., *NCHRP Synthesis of Highway Practice 128: Methods for Identifying Hazardous Highway Elements,* Transportation Research Board, National Research Council, Washington, D.C. (November 1986) 80 pp.
29. Lewis, R. M., *NCHRP Synthesis of Highway Practice 106:*

*Practical Guidelines for Minimizing Tort Liability,* Transportation Research Board, National Research Council, Washington, D.C. (1983) p. 16.

30. Oglesby, C. H., "Consistency in Design for Low-Volume Rural Roads," *Journal of Transportation Engineering,* American Society of Civil Engineers, Vol. 111, No. 5, (September 1985) pp. 510–519.

# APPENDIX

## IOWA PASSIVE SIGN PROJECT

In the early 1970s, national concern about accidents at railroad-highway grade crossings led to establishment of an inventory of crossings and a program to provide signs, at a minimum, at all railroad-highway grade crossings (Highway Safety Act of 1973, Section 203). The states and railroads, in cooperation with the American Association of Railroads (AAR), the Federal Highway Administration, and the Federal Railroad Administration, performed the inventory, which included the numbering of all public crossings.

In Iowa, all 8,000 public railroad-highway grade crossings were marked in 1974 with temporary paper tags when the crossing inventory was performed. On the basis of the inventory, the Iowa Department of Transportation arranged with the railroads and local highway jurisdictions for the replacement of missing crossbucks and advance warning signs. Replacements were installed in 1977.

By 1982 it was evident that further work was needed. Many crossbucks and advance warning signs were damaged or missing as a result of accidents, vandalism, and theft. Most crossbucks were not reflectorized, front and back, as required by current Iowa standards. In addition, the temporary paper tags with crossing identification numbers had deteriorated or disappeared and much of the information in the 1974 inventory was no longer valid. For these reasons, a Passive Sign Project was developed with the following goals:

1. To replace all crossbucks that do not have high-intensity reflective sheeting on the front and a 5-in. strip of the same material on the back.
2. To replace all metal, concrete, or broken wood crossbuck posts with wooden posts of sufficient height.
3. To replace advance warning signs in highway jurisdictions where they are missing or damaged.
4. To install permanent aluminum AAR-DOT identification tags at each public crossing in Iowa.
5. To update the National Grade Crossing Inventory to reflect accurate statistics about each crossing.

To start the project, the Iowa DOT hired summer workers in 1983 to inspect all public grade crossings in Iowa, install permanent crossing identification tags, update the crossing inventory, and compile a list of missing or deficient crossbucks and advance warning signs. The cost of this preliminary engineering work was largely covered by the 90 percent federal-aid share available to carry out the provisions of Section 203 of the 1973 Highway Safety Act (as amended).

In 1984 and 1985 the railroads installed or improved the crossbucks while the local highway jurisdictions took care of the advance warning signs. The Passive Sign Project included installation of about 10,000 crossbucks and 10,000 advance warning signs. Railroads and local highway jurisdictions paid 10 percent of the costs for materials and installation and the balance was paid from federal-aid funds under Section 203. In most cases, materials were purchased by the Iowa DOT and delivered to designated locations. Railroads and local highway jurisdictions were responsible for any lost, damaged, or unused material and were paid for their work after the signs had been installed or improved and the work had been inspected. Replacement and improvement of the missing or deficient crossbucks was estimated to cost about $1.5 million.

This system-wide project, completed in a period of three years, vastly improved the roadway consistency at Iowa's 8,000 public railroad-highway crossings. In addition, it provided an up-to-date inventory that is being used to identify crossings where more extensive spot safety improvements may be warranted. Both the system-wide and spot improvements should help to reduce crossing accidents and the resultant deaths, injuries, and property damage.

### SOURCES

"Iowa Passive Sign Project, 1983–1984," unpublished report, Railroad Division, Iowa Department of Transportation, Ames, Iowa (March 5, 1983).

"Iowa Passive Sign Project," unpublished report, Railroad Division, Iowa Department of Transportation, Ames, Iowa (November 15, 1982).

"Annual Report for Special Highway Safety Improvement Programs, FY 1985, "Transportation Safety Bureau, Iowa Department of Transportation, Ames, Iowa (August 1985) pp. 12, 14.

**THE TRANSPORTATION RESEARCH BOARD** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Frank Press is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Samuel O. Thier is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Frank Press and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.

TRANSPORTATION RESEARCH BOARD
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
WASHINGTON, D.C.
PERMIT NO. 8970

000015M001
JAMES W HILL
RESEARCH SUPERVISOR

IDAHO TRANS DEPT DIV OF HWYS
P O BOX 7129 3311 W STATE ST
BOISE ID 83707