# NCHRP SYNTHESIS 321

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

# Roadway Safety Tools for Local Agencies

## *A Synthesis of Highway Practice*

TRANSPORTATION RESEARCH BOARD
*OF THE NATIONAL ACADEMIES*

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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## *A Synthesis of Highway Practice*


**CONSULTANT**
EUGENE M. WILSON, P.E., Ph.D., PTOE
Transportation Engineering Safety Consultant
Laramie, Wyoming


**TOPIC PANEL**
DONALD J. GALLOWAY, *Sarasota County Traffic Engineering and Operations*
ANTHONY R. GIANCOLA, *National Association of County Engineers*
JOHN N. IVAN, *Connecticut Transportation Institute*
JOSEPH J. LASEK, *Columbia, Maryland*
RICHARD F. PAIN, *Transportation Research Board*
STANLEY POLANIS, *City of Winston–Salem Department of Transportation*
BRAD SANT, *American Road & Transportation Builders Association*
A.D. WYATT, *North Carolina Department of Transportation*
KATHY HOFFMAN, *Federal Highway Administration (Liaison)*
JOHN MCFADDEN, *Federal Highway Administration (Liaison)*

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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

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## FOREWORD

*By Staff*
*Transportation Research Board*

Highway administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to highway administrators and engineers. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire highway community, the American Association of State Highway and Transportation Officials—through the mechanism of the National Cooperative Highway Research Program—authorized the Transportation Research Board to undertake a continuing study. This study, NCHRP Project 20-5, "Synthesis of Information Related to Highway Problems," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an NCHRP report series, *Synthesis of Highway Practice.*

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

## PREFACE

This synthesis will be of interest to local government agencies as they select tools and develop programs to implement road and street safety improvements. It recognizes the wide variation in the operations and responsibilities of local agencies and acknowledges that the level of expertise in transportation safety analysis also varies greatly. The guiding principle of this synthesis was to examine the tools and procedures that are practical, relatively easy to apply, and can be implemented by agencies with limited financial support and personnel.

This Transportation Research Board synthesis contains information collected from a series of surveys. State departments of transportation, Local Technical Assistance Program centers, local agencies, and professional organizations were contacted for information on the best safety practice ideas.

A panel of experts in the subject area guided the work of organizing and evaluating the collected data and reviewed the final synthesis report. A consultant was engaged to collect and synthesize the information and to write the report. Both the consultant and the members of the oversight panel are acknowledged on the title page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

# CONTENTS

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Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 Committee and the Synthesis staff.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

# ROADWAY SAFETY TOOLS FOR LOCAL AGENCIES


## SUMMARY

Local governments face significant challenges in implementing road and street safety improvements. They are responsible for local roadway networks, which can vary from a few city blocks to thousands of miles of paved, dirt, or gravel roads. Most local governments have substantial resource limitations in terms of financial support and personnel. As a result, many local agencies have not developed safety programs. This synthesis focuses on identifying safety tools that can be used by these agencies in formulating safety programs. It recognizes the wide variation in the parameters of operation and responsibilities of local agencies. Also, it acknowledges that expertise in transportation safety analysis varies widely among local agencies.

This synthesis was prepared for easy use by local agencies as they select their safety tools and develop safety programs. In the broad context of the synthesis, "tools" came to be defined as any ideas, practices, procedures, software, activities, or actions beneficial in aiding local agencies to improve the safety of their roadway network. However, these tools cannot reduce crashes if they are not applied. Anything and everything that works was considered for the synthesis. Therefore, a guiding principle of this synthesis was to examine the tools and procedures that are practical and relatively easy to apply.

The development of this synthesis was based in part on information collected in a series of surveys. State departments of transportation (DOTs), Local Technical Assistance Program centers, local agencies, and professional organizations were contacted and asked to provide information on best safety practice ideas. The safety tools were grouped into reactive and proactive safety tools, and basic and advanced analysis approaches were considered for each group. The individual tools were linked to a series of user-friendly appendixes that provide detailed information on the specific tool, its application, or references to additional documentation.

The best practices of reactive crash analysis of state DOTs using Highway Safety Improvement Programs (the front-end-loaded identification of safety needs for a given system) are presented. The emerging proactive safety tools of the Road Safety Audit and the Road Safety Audit Review, which assess the issues of safety using an independent team approach, are discussed as tools to structure many of the best practices. Most local agencies do not employ either of these proactive approaches, whereas state DOTs are just beginning to apply these concepts.

The overriding message of this synthesis is that *safety practices should be tailored to the problems and resources of an agency* and that there is no one-size-fits-all safety solution. Emphasis is placed on the use of tools that will give local agencies a practical and affordable toolbox, with a stronger safety program as the result.

Achieving buy-in and persuading local authorities to spend time and money directly on safety improvements were the objectives of this synthesis. Large financial commitments and complex analysis are not always necessary. Historically, liability issues have deterred local agencies from systematically identifying safety concerns, because they are fearful that they will be left vulnerable to tort liability simply by acknowledging that safety deficiencies exist on their local roadways. This synthesis emphasizes that the documentation of an agency's

safety agenda is a necessary defense against tort liability. It is important to note that many sound safety ideas are implemented at local levels without a specific acknowledgment of a safety program.

It is essential to recognize that improving the local crash picture will require an increased effort by both experienced and inexperienced professionals. Providing guidance for the local agency to become a more professional safety organization by applying the best and most appropriate tools to meet its needs is the key. Helping local agencies to implement safety improvement is the goal.

The conclusion of the synthesis is that a documented local roadway safety program is “the best safety tool.” Recognizing the need to implement even a rudimentary safety program is the first step. The selection of safety tools to meet the individual local agency’s needs comes next. Developing the selected tools into a continuing program and implementing safety improvements are identified as the keys to local roadway safety.

CHAPTER ONE

# INTRODUCTION

> Lesson: "Never neglect details. When everyone's mind is dulled or distracted the leader must be doubly vigilant."
>
> Strategy equals execution. All the great ideas and visions in the world are worthless if they can not be implemented rapidly and efficiently.
>
> From Colin Powell's
> *A Leadership Primer – Part II*

It is often said that all roads and streets are local. Certainly when a crash and a fatality occur, it is local. The human and economic costs are staggering. Each year, more than 40,000 traffic fatalities are reported. The 2000 economic cost of roadway related crashes was $230.6 billion (*1*).

What can local agencies do to aid in reducing this tragedy? To achieve the stated U.S. goal of a 20% reduction in fatalities, or saving 8,000 lives annually, local agencies will need to help. Indeed, local agencies must take the lead if there is to be success. Helping these local agencies to achieve this success is the purpose of this synthesis.

Local roadway networks vary from a few city blocks to thousands of miles of paved, dirt, or gravel roads. Unfortunately, the local roadway network experiences the highest overall crash rates. Local agencies responsible for these roadways often have limited resources, staffs, and knowledge of safety tools. This situation is compounded because many local agencies do not have a safety program.

Local agency work forces vary widely according to the size of their jurisdictions and their financial resources. Local agencies' expertise in transportation also varies considerably. Many agencies have no full-time engineer, whereas others have large, trained professional staffs. In addition, these local agencies face the challenge of retaining qualified personnel with the ever-changing work force.

Under the best conditions, addressing safety issues on these extensive rural and urban local road networks is difficult, and the lack of resources further complicates the problem. Roadway safety is often subjugated to the maintenance function. Issues are also often ignored or not identified because these facilities carry very light traffic volumes. A brief discussion of local agency characteristics is presented here for interpreting and evaluating the tools presented in the following chapters.

## LOCAL AGENCY JURISDICTIONS

Local roads account for approximately 75% of the nationwide road and street network, or about 2.93 million miles. Responsibility for managing these roads is vested in more than 38,000 units of local government in the United States, which are generally classified as counties, townships, and cities. Counties manage about 1.74 million miles of road, and cities and townships manage the remaining. There are more than 231,000 bridges on county roads alone, and cities have as many or more. Many of these structures are deficient from a safety perspective and many are reaching the end of their functional life (*2*).

There is significant variation in work force size, responsibility, expertise, and resources. Many small cities/townships have limited budgets and employ only a clerk–treasurer as the full-time employee. Others can support full-time road crews with or without a full-time engineer. Some cities employ a public works director and traffic engineers, and they retain consulting firms to perform selected services. Many counties have a work force in which the road supervisor has many years of on-the-job experience, but little if any formal educational training, whereas others have full-time engineers and/or traffic engineers. The range of expertise and understanding of transportation safety issues varies as well.

Safety remains a problem for all local road and street agencies, and safety improvements are needed, because fatal crash rates are also the highest on local roadways.

The fear of tort liability is an important issue in some local agencies. There is frequently a concern that if safety issues are identified and then not corrected to the latest and highest standards, there will be a resulting liability if a crash occurs. There is also a belief that if a problem is fixed, but not fixed at all similar locations, the potential for liability exists. In general, the documentation of a needed safety improvement is often lacking unless the improvement is underway. Limited understanding of the legal aspects of safety and the prevalence of tort liability has negatively influenced the need for local roadway safety programs.

## SYNTHESIS OBJECTIVE

The objective of this synthesis is to provide a summary of practical safety tools for local agencies. However, these tools cannot reduce crashes if they are not applied. Meeting the safety needs of local agencies is a considerable challenge, given that these agencies operate in an environment of limited resources. Therefore, it is vital that this synthesis focus on tools and procedures that are practical and relatively easy to apply.

The development of this synthesis was based in part on information collected in a series of surveys. State departments of transportation (DOTs), Local Technical Assistance Programs (LTAP), local agencies, and professional organizations were contacted and asked to provide information on best safety practice ideas. The survey form is contained in Appendix A and the survey results are summarized in Appendix B. Responses were received from 24 DOTs, 36 local agencies, and 22 LTAP centers.

In the broad context of the synthesis, "tools" were defined as any ideas, practices, procedures, software, activities, or actions beneficial in aiding local agencies to improve the safety of their roadway network. Anything and everything that works to enhance safety was taken into consideration.

Included in the report are discussions of techniques that could be used by all local agencies, regardless of size. Although the professionally staffed agencies of larger population cities and counties generally do have safety analysis programs, these programs are often reactive crash analysis activities based on examining the locations identified as having the highest yearly crash rates. Larger agencies typically have full-time traffic engineering expertise and enough financial resources to establish a safety program. However, even these agencies will benefit from several relatively new techniques available to advance the practice.

The practices of reactive crash analysis of state DOT use of Highway Safety Improvement Programs (HSIP) are identified. The emerging proactive safety tools of the Road Safety Audit (RSA) and the Road Safety Audit Review (RSAR) are discussed as tools to structure many of the best practices. Most local agencies do not employ either of these proactive approaches, whereas state DOTs are just beginning to apply these concepts.

The overriding message of this synthesis is that safety practices should be tailored to the problems and resources of an agency and that there is no one-size-fits-all safety solution. A safety program is important no matter how small the agency. Emphasis is on the use of tools that will give local agencies a practical and affordable toolbox, with a stronger safety program as the result.

## SYNTHESIS STRUCTURE

The next four chapters discuss safety tools for local agency consideration. Chapter two addresses basic and advanced reactive safety tools. Basic and advanced proactive safety tools are outlined in chapter three. The fourth chapter discusses other basic safety tools for local road and street agencies. Developing a practical local safety improvement program is emphasized in chapter five. Each chapter includes both survey responses and literature summaries and is linked to an appendix, where appropriate. Also included are appropriate references in the literature, to provide users with a means to seek additional information if desired.

## CHALLENGES

Identifying safety tools for local agencies is challenging. Local agencies have a wide range of responsibilities and expertise and face a variety of problems. The intent of this synthesis is to provide local agencies with the tools necessary for initiating and maintaining a safety program without making the process unnecessarily complex.

The first challenge is to persuade local authorities to spend time and money directly on safety improvements. To accomplish this task, the safety awareness of local roadway agencies needs to be raised. If the significance of the local safety problem is recognized by local officials, then local agency managers can be persuaded that a local safety program is necessary. Safety training is an important step in achieving this goal (*3–8*).

A second challenge is that, historically, liability issues have deterred local agencies from systematically identifying safety concerns. Agencies are fearful that they will be susceptible to tort liability simply by acknowledging that safety deficiencies exist on their local roadways. However, this synthesis emphasizes that the documentation of an agency's safety agenda is actually a defense against tort liability.

Selling the need for a local roadway safety program will be difficult given the already overburdened time commitments and limited resources. It is therefore essential that sound, effective, and simple methods be available; if no existing local program exists, it is highly unlikely that one will be established if it is unduly complex. It is important to note that many sound safety ideas are implemented at local levels without specific acknowledgment of a safety program.

Unfortunately, many current safety tools used for the analysis of crash data are very complex. One method to overcoming this situation is to rely on national and/or state studies to help resolve concerns about implementing existing and emerging safety practices. Another method is to identify which tools are practical, given the resources and expertise of the agency. A third method is to hire the expertise, either permanently or through the use of consultants. These alternatives for before-and-after evaluations in highway safety are presented in *Traffic Safety Toolbox: A Primer on Traffic Safety* (*9*).

There are new tools that do not focus on crash analysis, but rather assess the issues of safety using an independent team approach. These are the RSA and the RSAR. Both of these practices are designed to focus entirely on safety in the assessment of a plan (RSA) or an existing road or street segment (RSAR). These safety tools, which are beginning to emerge in the United States, are based on international practice. They are presented as an alternative to the rigors of statistically based reactive crash analysis.

Given the magnitude of fatalities that occur on the local road network, it is essential to recognize that improving the local crash picture will require increased effort by both experienced and inexperienced professionals. Critical to this is the need to recognize and encourage all efforts. Criticizing safety improvement decisions because of the lack of statistical rigor will only exacerbate the problem. Providing guidance for the local agency to become a more professional safety organization by applying the best and most appropriate tools to meet their needs and implement safety improvements is the goal. This effort requires user-friendly tools, positive advice, and the advancement of practical and affordable concepts.

In 1969, the passage of the National Environmental Policy Act prompted national attention on environmental issues. The act has continually enhanced the recognition of environmental issues through new legislation and environmental assessment. Safety has not had the advantage of such a tool.

Given the absence of similar requirements in assessing safety, the following chapters provide an overview of reactive tools, proactive tools, and practical tips for local agencies to interact with the public on safety issues. The appendixes provide opportunities for advancing agencies' understanding of these tools. Computer-based software, successful examples, focused safety briefs, and annotated safety references are summarized in the appendixes as well. Reactive safety tools begin the assessment.

## USING THIS SYNTHESIS

The goal of this synthesis is to assist local agencies in implementing safety improvements by providing a practical and easy to use summary of safety tools. There are many safety tools that are adaptable for local agencies. This document provides an overview of safety tools ranging from rigorous analysis to applying partner concepts. Throughout the text, references, and appendixes, the emphasis is on practical resource tools.

A quick reference guide to these tools is provided in Table 1. This table links the synthesis text and appendixes for each of these tools.

TABLE 1
SUMMARY OF SAFETY TOOLS

| Tools | Synthesis Chapter | Primary Annotated References | Secondary Annotated References | Appendix |
|---|---|---|---|---|
| Reactive Safety Tools | | | | |
| Basic—high crash locations | 2 | *10–13* | *14–16* | H |
| Advanced—statistical analysis | 2 | *17,18* | *19* | |
| Proactive Safety Tools | | | | |
| Basic—RSAR | 3 | *20* | | I |
| Advanced—RSA | 3 | *20* | | J |
| Other Safety Tools | | | | |
| Safety study data | 4 | *21* | *22,23* | C |
| Local partners | 4 | NA | *3,24* | F, G, L, M |
| Professional organizations | 4 | NA | | D, L, M |
| Computer-based software | 4 | NA | | E |
| World Wide Web | 4 | NA | | C |
| Safety references | 4 | *25,26* | *15,27* | C |
| Work zone safety | 4 | *28,29* | | |
| Economic analysis and priority improvement tools | 4 | *11,21* | *15,16* | |
| Known safety improvements | 4 | *12,28,30,31,35–37* | *24,27,32–34,38–41* | |
| Emerging Research and Gaps in Knowledge | 4 | | | K |
| Local Safety Improvement Program | 5 | *12,42* | *4,15,16,24,39,41* | M |

Notes: NA = not available.

Numerous references have also been provided. The primary safety references have been annotated and are presented in Appendix C. It is important to ensure that the latest editions of these publications are used. Using the World Wide Web and LTAP centers is an easy way to stay current (see Appendixes C and M).

Emphasis has been given to developing a local safety improvement program that is tailored to fit agency needs and available resources. Users should select safety tools, document the safety program, and use the program to enhance safety on the roadway networks within their jurisdictions.

CHAPTER TWO

# REACTIVE SAFETY TOOLS

Ultimately, any significant reductions in roadway fatalities and crashes will require the mitigation of safety concerns along roadways under the jurisdiction of local government entities (e.g., cities, towns, counties, and villages). Effective local road safety training, technology transfer, and the resources necessary to complete these safety improvements are essential. To properly implement improvements to reduce roadway fatalities and injuries, local roadway managers and staff need to be able to

- Evaluate the safety performance of their transportation network,
- Identify the key locations of safety concern,
- Compare the effectiveness of possible solutions,
- Plan and design a chosen improvement,
- Obtain appropriate funding,
- Implement the safety improvement, and
- Evaluate the improvement.

One such mitigation approach is to evaluate crash data on the local network. This approach is reactive in that safety decisions emanate from a review of crash histories. To evaluate if safety improvements are needed, decisions are made based on evaluating locations where a high crash situation exists. The analysis of crash data is considered at two levels, basic and advanced. The difference between the two lies in the sophistication of the application of statistical analysis.

## BASIC REACTIVE ANALYSIS TOOLS

Crash analysis forms the basis of this reactive approach. Essential elements for a crash analysis program begin with decisions on the types of crashes—property damage only (PDO), personal injury, and fatal, including a means of locating where crashes occur. After these decisions have been made, the locations for a more detailed analysis are identified.

The initial decision is to determine the types of crashes to include in the analysis, specifically if PDO crashes should be included. Often there is a threshold value (dollars) before a PDO crash is even reported as an accident (crash) in state records. It is suggested that the policies of the state be used to help make this decision. States typically have their own reporting forms that are used when a crash occurs. The use of the term "accident" has been replaced with the term "crash," because there are causes associated with a crash, whereas the perception of an accident is that it is a random event without a cause. These crash forms are filled out by the police responding to the scene, in addition to the forms filled out by driver(s) and others involved.

The crash forms contain location information, date on the type of crash, contributing factors, and other parameters of involvement, and should provide the basis for accurately locating the crash. Accurately locating crashes is crucial to these records. When working with these data it is often necessary to ensure that the crash record applies to the spot or section being analyzed. The emerging use of geographic information system (GIS) and Global Positioning System (GPS) technology is helping to overcome this problem. If a local agency is considering such a system, a review of "GIS-Based Crash Referencing and Analysis System" could be of assistance in making the decision (*39*).

There are a number of different techniques for locating crash sites, beginning with a simple map of the area and the placement of a pin where the crash occurred. The greater the number of pins placed in one location, the greater the frequency and hence the greater the potential for the location to be classified as a high crash location. The missing information in these data is a reflection of traffic volumes—not just total volumes, but also conflicting volumes, at locations such as intersections and driveways. Typically, one would expect locations where there are higher volumes and more conflicts to have a higher potential for crashes. The consideration of the influence of volume impacts is often factored into methods of identifying high crash locations. Depending on the level of analysis sophistication, there are ways to evaluate one location relative to similar traffic volume locations to determine if the location is a high crash location. Factoring in traffic data provides a greater degree of predictability.

The value in a basic reactive analysis technique is to determine if there are clusters of like crashes. For example, there is generally a limited ability to look at all crashes on the network and to conduct a detailed survey of all crash location sites. Therefore, a reactive program, based on a degree of certainty that problem locations are being identified and treated, is important. It is also important to state that just beginning a reactive crash analysis program will provide benefit. If any location is improved by evaluating crashes, then there is a good chance that crash reductions will occur. In essence, the message is to *just do it*. Concern about the details should not matter.

There are several important publications that provide more information on the reactive approach (*9,43–46*). Key points identified in these references include the following:

- Cluster analysis requires subjective judgment. Because the analysis depends on the knowledge and judgment of the individual conducting the analysis, individuals using the same data may reach different conclusions. To overcome this difficulty, agencies often identify threshold numbers of crashes to aid in determining if the reflected location is a high crash location.
- Is there a pattern of like crashes? Are these types of crashes the types expected with the type of traffic control provided at the intersection? For example, one would expect a signalized intersection to be more likely to have a higher incidence of rear-end vehicle crashes and a lower number of right-angle crashes than other locations. Even with this knowledge, are there other factors that may contribute to this statistic? For the previous example, is the clearance interval of the signal cycle too short?
- Implied in the first two points is that the crash spot (intersection) has been correctly identified. Checking the actual crash records is generally necessary when conducting an in-depth analysis of a high crash location. Statements made by the police and others involved become helpful in understanding factors that contributed to the crashes and what types of safety actions may reduce the incidence of these types of crashes.
- A threshold number of crashes may also be used to establish a decision starting point. This number helps in deciding if a more detailed analysis is justified. These threshold numbers generally depend on the crashes associated with the different types of areas and also the different types of facilities. The city or size of the local area plays a major role in reaching a decision.
- In many situations, crashes are not reported unless there is an injury, fatality, or major property damage. Local road users can often provide good information on unreported crashes, other factors, and special conditions that may have existed at the time of the crash. These data should not be overlooked in the analysis.
- There are similar approaches employed for linear or roadway segments, although crash clusters most often occur at intersection locations. If road segments are used in the analysis, it is generally a good idea to normalize the effect of length and also traffic volume.
- A cluster of crashes involving like occurrences may or may not be abnormal depending on factors such as intersection geometry, environmental conditions, and special events. Learning the details associated with the crashes and crash patterns helps to isolate these factors.
- The experience of the individual conducting the analysis, the consistency of decisions, and continued evaluation of the effects of the improvements makes reactive analysis a potentially valuable tool. The tables contained in Appendix H have been provided to aid in decisions regarding the potential countermeasures and the issues associated with the clusters of crashes that may occur.
- In the investigation of intersection crashes, approach speeds, vehicle types (trucks, passenger cars, etc.), and prevailing sight distances at the corners of the intersections are important factors to be considered. At rural intersections, a lack of recognition that the vehicle is approaching an intersection may be a factor. This may be particularly true during certain times of the year when crops, trees, or other vegetation obscure the definition of a crossroad or other junction, such as a railroad crossing. Well-maintained advanced warning signs are essential to prevent rural crashes in these locations. Morning or evening sun glare also may be a significant contributing factor.
- Maintenance factors such as adverse pavement conditions may also be identified through crash analysis. These situations may result in clusters of incidents during certain times of the year.
- Many of these safety issues will be identified in the specific analysis of a location, whether or not it is a high crash location. Even if a lower incident location were selected, the decisions and implementation of the improvements may reduce crash potential.

These factors have not taken into consideration the number of years of crash data that should be used in the analysis. That is because an in-depth analysis takes time and resources, and that concentrating on the worst locations will potentially provide the greatest safety benefit. How many years of data are needed to normalize trends? Is 1 year's worth of crash data adequate? What is the ideal number of years of data? To answer these questions, the location must also be carefully evaluated for changing conditions that may affect the magnitude of the crash picture. In most cases, a 1- to 3-year period is considered adequate. If there is a major change in the network or the traffic volume, or the facility in question has been under construction, then a briefer period may be appropriate. It is generally accepted that a 3-year period of crash data is ideal for a before evaluation of crash clusters.

Once a change or improvement has been implemented, then the question to ask is, "How effective is the change?" Evaluating the effectiveness of a change is based on a before-and-after statistical methodology. If the change produces the desired result, then implementing these changes at similar locations would be warranted. The after evaluations and before-and-after analysis decisions need to reflect the following:

- How much time is needed after the change has been made before beginning the after period of time? In essence, an initial benefit may appear to occur, but the effect diminishes with time as the traffic picture changes. A brief period of time is often used (1 to 3 months) and these immediate effects are not included in the analysis.

- What changes have occurred in the area and/or adjacent to the facility that may have affected the results?
- What may have introduced other bias into the analysis results?
- An analysis of the crash history at similar locations is often used to address such questions. This analysis involves locations where no change was made. Adding these sites provides a greater degree of certainty when evaluating the effectiveness of the improvement.

Given the discussion of reactive analysis issues and the potential analysis pitfalls in drawing the wrong conclusions, is this an effective safety tool for local agencies? Is there a good way for local agencies with limited expertise and practice in reactive analysis to employ the crash analysis reactive safety tool? How can local agencies achieve the greatest benefit from reactive analysis? The following guidance is provided for the use of reactive tools.

#### SUGGESTIONS FOR LOCAL AGENCIES TO CONSIDER IN APPLYING BASIC REACTIVE SAFETY TOOLS

The suggestions that follow are provided to aid local jurisdictions in maximizing the benefits of including reactive analysis in an affordable approach to improving their safety programs (*9,43,45,47*).

1. Knowing and identifying local crashes is important to improving local road safety. Care needs to be taken to ensure that crash reports reflect the location being studied. Consider using the tools of GIS and GPS to locate crashes and to ensure that these data are accurate (*39*).
2. Contact your state DOT to see if your local jurisdiction can receive a yearly summary of crashes. If the answer is yes, then request a map display of the crashes by location and type of crash and proceed to Step 7. Again, the use of GPS and GIS technology is valuable to location accuracy. Post a map of the network of roads and streets in your local jurisdiction.
3. Contact all law enforcement jurisdictions that may investigate crashes on this local network and request that crash reports be sent to you.
4. On a map, plot each crash by type of crash by using different colored pins to reflect the different types of crashes.
5. Follow your state's reporting requirements for PDO crashes. [See the primary annotated references (Appendix C) for different ways to plot crashes and examples of different types of these pin maps.]
6. Identify the locations with the highest number of crashes. (See Appendix H for examples of crash maps, as well as collision and condition diagrams.)
7. Determine if there is a pattern of crashes. Appendix H contains an example of a collision diagram and a condition diagram that are used to evaluate the patterns of crashes and also link the patterns to the conditions at the site. These diagrams are easily developed by using aerial photographs or plan maps or by visiting the site being evaluated. Check to see if your state DOT will provide computer-generated spot maps and collision diagrams and their review of high crash locations. This service was indicated as being available in some states, although often only for cities with larger populations.
8. Identify possible issues associated with the crash location. Determine if there are site-related factors that cause crashes to occur there. This step may require an on-site visit or the evaluation of aerial photographs of the location.
9. Consult referenced listings of crash types and possible countermeasures, which are also contained in Appendix H.
10. Implement the selected decision. Even though it may not be the ideal implementation decision, identify what was done, when it was done, and what other improvements were considered.
11. Document the agency's use of a reactive safety program tool, the immediate implementation decisions, and the actions that are desired when additional resources become available.

The listings of alternative treatments contained in Appendix H are based on analysis of before-and-after crash data conducted in a number of different locations. These nationally recognized successful alternatives provide a simple decision process. Using crash data may also be undertaken with a more rigorous analysis.

#### ADVANCED REACTIVE ANALYSIS TOOLS

This section presents statistical analysis options for reactive analysis beyond that of relying on nationally established improvement alternatives. The issue for local agencies to consider is the added benefit gained from methodologies that focus on a more in-depth analysis of local data. Many larger jurisdictions with adequate staffs and larger volumes of crashes may benefit from an approach based on using their local crash data. Many of the issues presented in the basic section for reactive tools also apply to advanced methods of analysis. It should be noted that good statistical analyses require high-quality input data. Again, state DOTs are the best initial source for data. Several states provide yearly summary reports and special location analysis upon request from a local agency. Those documents enable the development of high-quality input for analysis. They also provide excellent starting points for reviewing crash histories within the community. The analyses are also made with or without control sites. It has been generally accepted that the inclusion of control sites with similar characteristics benefits the reliability of the analysis by normalizing changing conditions such as traffic growth and weather effects.

It is important to recognize that significant expertise is required to conduct sound before-and-after safety analyses. As indicated by Mike Griffith of the FHWA, nationally, analyses of crash data provide local agencies with excellent links to crash causation and probable crash reduction techniques for patterns of crashes (*9*). In 1999, the Institute of Transportation Engineers (ITE) produced a report, *Statistical Evaluation in Traffic Safety Studies* (*48*), which also provides an excellent background for local agencies in making the decision on conducting their own local advanced reactive analysis. In assessing the benefits of conducting advanced analyses, it is recommended that local jurisdictions look closely at the established relationships between crash data and possible treatments based on rigorous analyses that have been conducted nationwide (use the experience- and knowledge-based solutions that are presented in Appendix H).

Another excellent source for more advanced reactive safety analysis is *NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highways* (*43*). Although this report focuses on rural two-lane highways, the recommended approach is applicable for any road or street network and is also complete in describing a crash mitigation process. The following six specific steps are identified in the report:

1. Identify sites with potential safety problems,
2. Characterize crash experience,
3. Characterize field conditions,
4. Identify contributing factors and appropriate countermeasures and select the most appropriate,
5. Implement the most appropriate countermeasure, and
6. Evaluate the effectiveness.

The higher level of statistical reactive analysis compares and evaluates the effectiveness of different countermeasures. Documentation is an essential component of this process. Measuring whether or not the countermeasure was effective is also essential to the process. Although, as mentioned, the focus is on two-lane rural roads, the examples provided are often urban situations, consistent with the concept that most crashes are related to intersection conflicts.

The following two lists derived from Tables 2 and 3 of *NCHRP Report 440* were modified to reflect crash terminology and are provided for consideration of the concepts associated with the different ways in which a high crash location may be determined.

> The focus becomes identifying sites which are likely candidates for crash countermeasures as opposed to identifying high-crash locations. In some respects the concept reflects a shift to using crash data in a more proactive manner. The conventional methods require a large set of data, expensive to perform every year, subject to regression to the mean biases, and likely to identify sites with no obvious cost-effective remedy (*43*).

### Crash Evaluation Methods

**Number of crashes**—the number of crashes at a location. Locations with more than a predetermined number of crashes are classified as high crash locations.

**Crash density—**the number of crashes per unit length for a section of highway. Sections with more than a predetermined number of crashes are classified as high crash locations.

**Crash rate—**crash numbers divided by vehicle exposure to provide rates such as crashes per million entering vehicles per spot location and crashes per million vehicle-miles for sections of highways. Locations with higher than a predetermined rate are classified as high crash locations.

**Number rate—**a combination of number of crashes and crash rate. Locations with more than the prescribed minimum number of crashes and higher than the minimum crash rate are classified as high crash locations.

**Number quality control—**locations with the number of crashes that is greater or significantly greater than the average number of crashes for the state or a similar region.

**Rate quality control—**locations with a crash rate that is greater or significantly greater than the average crash rate for the state or a similar region.

**Crash severity—**the number of fatal and/or injury crashes at a location or per unit length for a section of highway.

**Severity index—**the number of fatal and/or injury crashes at a location or section of highway being given a greater weight than PDO crashes.

**Crash index—**combining some of the aforementioned methods to determine a single index value for a group of sites.

### Crash Rate Method

This method is practiced through these steps:

1. Locate all crashes in accordance with accepted coding practices.
2. Identify the number of crashes in each established section and at individual intersections and spots.
3. Calculate the actual crash rate for each established section during the study period.

$$\text{Rate/MVM} = \frac{(\text{no. of crashes on section})\ (10^6)}{(\text{ADT})\ (\text{no. of days})\ (\text{section length})}$$

where MVM = million vehicle-miles, and
ADT = average daily traffic.

4. Calculate the actual crash rate for each intersection or spot during the study period.

$$\text{Rate/MV} = \frac{(\text{no. of crashes at intersection or spot})\ (10^6)}{(\text{ADT at location})\ \ (\text{no. of days})}$$

where MV = million vehicles, and
ADT = average daily traffic.
(ADT at location represents the sum of all vehicles entering the intersection.)

5. For the same period, calculate the systemwide average crash rates for sections, intersections, and spots, using the formulas in steps 3 and 4 and the summation of total crashes, total vehicle-miles, and total vehicles, respectively, for each category of location.
6. Select crash rate cutoff values as criteria for identifying high crash locations. A value approximately twice the systemwide rate usually is realistic and practical.
7. If actual rates exceed the minimum established criteria, the location is identified as a high crash location and placed on the list for investigation and analysis.

Selection of the cutoff value (Step 6) is not as critical as it might appear. The principal purpose is to control the size of the list of locations to be investigated—a shorter list with high values or a longer list with low values. Experience will indicate the appropriate level for a particular agency.

Another excellent informational table in *NCHRP Report 440* is Table 10, which identifies basic field observations used to study problem locations. These include exercising good judgment while simply driving through the location. Also, considering the issues associated with the site, such as the conditions at nighttime and at nighttime with opposing traffic, is an important step toward ensuring a thorough evaluation. An on-site observation report form is also included in this study. [Table 10 and the on-site report (Figure 3) from *NCHRP Report 440* are contained in Appendix H of this synthesis.]

Table 11 in *NCHRP Report 440* points out other supplemental studies that may provide more detailed information to assess the relationship of the crash data and the conditions that may indicate the need for a particular type of study. The final series of informational tables in the report are the listing of contributing factors for crashes and the potential countermeasures. (These are contained in Tables 14 and 15 and also provided in Appendix H of this synthesis.)

Reactive crash analysis provides an excellent basis for a safety program, whether conducted at the simplest or most complex stages. The improvement alternatives that have been developed when applying the reactive safety tool also result in excellent implementation decision aids for the proactive tools discussed in the next chapter.

CHAPTER THREE

# PROACTIVE SAFETY TOOLS

This chapter provides an overview of two primary proactive safety tools available to local agencies. The first is proactive analysis using the concept of a RSAR. The advanced proactive analysis safety tool for local agencies is the RSA (*22,49,50*).

## BASIC PROACTIVE SAFETY—THE RSAR

Local agencies are continuously faced with the need to consider how the safety of an existing road or street may be enhanced. Because the uses of a roadway change over time, roads that fully complied with all safety standards at the time they were built may no longer provide a high degree of safety for the traveling public.

The use of reactive crash data to help identify local sites or sections of roadway in need of safety improvements is often difficult. This is primarily due to two factors. First, although crash rates are often the highest for local facilities based on functional classification, the low volume on many local roads and the random nature of crashes often will not result in a large number of crashes at a particular location. Second, many local crashes go unreported unless there are major damages. This is particularly true in low-volume rural areas. Frequent clusters of crashes may, however, become readily apparent at higher-volume intersections. Given these observations, an analysis emphasizing the safety improvement issues is often more appropriate.

Also important in the low-volume rural road environment is that improving so many miles of roadway to current standards would be neither economical nor practical. For these rural local governments, a proactive program involving a functional classification of their rural roadway system and the use of an independent peer group of auditors is proposed.

The concept of an RSAR is based on an analysis technique that formalizes an approach to documenting safety issues. Proactively considering safety is the value of the RSAR tool (*51*).

An RSAR is an examination of an existing roadway in which an independent, qualified team of auditors reports entirely on safety issues. The RSAR concept is just beginning to be applied in the United States. Synthesis surveys identified the use of the RSAR by rural local agencies in Arizona, South Dakota, and Wyoming. Depending on local resources, there are a number of different ways to use the RSAR to develop a local safety program. Outlined in Table 2 is a proposed approach for local rural transportation agencies. This methodology has been applied successfully by rural counties in several states. Although the approach has not been applied to urban areas, a similar approach pertaining to intersections is suggested (see Appendix I).

The suggested approach has several essential components. First is the need to classify the local rural road network. Improving safety ideally would not require this step if there were unlimited resources. However, the real local world of funding and safety enhancements should recognize that a program to improve safety needs to be practical. A classification system helps to guide the improvements of the identified safety issues into a series of improvement alternatives by considering the use of the roadway section being evaluated and the ability to apply the improvements incrementally. Decisions are made by considering the classification and the safety issue involved, and by applying a value judgment to the urgency of the improvement and the resources needed. In essence, an incremental approach to safety enhancements forms the backbone of the enhancements. Recommendations are made by an independent audit team. Another essential component is to document the audit findings and address the issues identified. The philosophy of the RSAR local approach is for a county to try out the process and then to assess its value. If there is positive acceptance, then the local agency needs to develop a program to conduct RSARs for their road network over a reasonable period of time.

The steps in planning an RSAR program are described here.

1. Classify the local roadway system functionally.
    - Identify several sections of roadways in each functional classification for an RSAR trial. Chapter five provides several alternative functional classifications. The local agency may wish to design its own to better fit the local situation. The key to using this system is that it provides a rational basis to begin auditing the system for safety issues.
2. Begin a trial RSAR program.
    - Solicit reviewers from adjacent local county engineers and road supervisors (three or four). Follow the procedures developed for the RSAR, which are detailed in Appendix I.
    - Provide the RSAR team review for the selected roadways. The team should be small (three to five members) and not from the local agency where the roads are being audited. Such independence provides a fresh eyes assessment of the safety issues and recommended actions. Consider contacting personnel from adjacent

TABLE 2
FUNCTIONAL CLASSIFICATIONS OF LOCAL RURAL ROADS

| Rural Major High Speed | Rural Minor | Rural Local | Rural Major Medium Speed | Rural Low-Volume Local |
|---|---|---|---|---|
| Serves larger towns and other traffic generators not served by higher functional classification systems and serves more important intracounty travel corridors.<br><br>Typically<br>• Paved surfaces<br>• Traffic volumes up to 400 vpd<br>• Operating speed 40–65 mph<br>• Limited intersections and accesses | Accumulates traffic from local roads, brings all developed areas within reasonable distances of collector roads, provides service to the remaining smaller communities, and links the locally important traffic generators within their rural region.<br><br>Typically<br>• Unpaved surfaces but some may be paved<br>• Traffic volumes 250–400 vpd<br>• Operating speed 30–60 mph | Provides access to land adjacent to the higher functional classification network and serves travel into isolated areas over relatively short distances.<br><br>Typically<br>• Unpaved surfaces<br>• Traffic volumes 100–250 vpd<br>• Operating speed 20–45 mph | Serves smaller towns and other traffic generators not served by higher functional classification systems, links these places with nearby cities and larger towns or with higher systems, and serves more important intracounty travel corridors. Links to rural major and collector classifications.<br><br>Typically<br>• Paved surfaces but some may be unpaved<br>• Traffic volumes up to 400 vpd<br>• Operating speed 30–45 mph<br>• Frequent accesses | Provides access to adjacent land and serves travel over relatively short distances.<br><br>Typically<br>• Unimproved surfaces and some may be considered improved, but unpaved<br>• Traffic volumes 0–100 vpd<br>• Operating speed variable |

Notes: vpd = vehicles per day. [*Source*: Local RSAR training materials developed by Eugene M. Wilson, 2001 (see Appendix I).]

agencies, LTAP centers, and state DOTs or FHWA division to provide possible team members.

3. Prepare a brief statement of your findings.
   - Briefly summarize the safety issues,
   - Prioritize the issues identified,
   - Recommend actions to be taken,
   - Provide an overall evaluation of the road section, and
   - Discuss the findings with each county.
4. Seek special funding as needed.
   - Consider applying for safety funding. Contact your governor's office of highway safety. These contacts can be accessed by linking to the FHWA website at www.fhwa.dot.gov.
5. Implement and evaluate the RSAR program.
   - Implement improvements,
   - Evaluate the RSAR concept, and
   - Evaluate the effectiveness of the improvements.
6. Make the decision on beginning an RSAR trial program.
   - Begin an RSAR program by developing a 4- or 5-year plan to study all roadways and
   - Consider auditing the design of a major project, from a safety viewpoint, for all road users.
7. Promote the proactive RSA/RSAR program.

Because there are several critical components in the RSAR that provide value beyond an unstructured safety review, locally needed modifications to the concept are encouraged. The RSAR results in a formal written report, but the report should be brief, simple, and proactive. Oral communication of the report is also important, as is a formal written response to the report by the local agency. These actions imply that the RSAR is *not* performed by the agency's local staff. This independence is also vital to the RSAR. The local agency becomes the client for the RSAR report and provides the review team with the roads and streets to be audited, as well as information on their functional classification information.

The review team has a variety of expertise. Core knowledge is generally considered to be the knowledge of local road safety and maintenance issues. Other skills of the team members may vary depending on the issues associated with the road users and issues associated with the complexity of the environment of the facility. Potential skills of review team members should include traffic engineering, human factors, construction, design, and operations. Knowledge concerning bicycles, trucks, or pedestrians is also desirable. The need for these skills may vary from audit to audit.

Appendix I contains a sample RSAR report. As this report shows, an RSAR can be quite simple. This appendix also contains a sample process that was developed to aid local agencies in performing an RSAR. The examples show that there are a number of different ways to undertake an audit and to develop a team. One suggested methodology has one county auditing another county's network. A system to classify existing roads, examine their current usage, identify deficiencies, and prioritize needed safety improvements is the goal of a local government RSAR program. The premise is that local agencies can best achieve needed safety improvements by prioritizing and chipping away as resources allow. A functional classification is used to present the concept of adapting safety issues to fit the profile of the road section. Chapter five provides an expanded discussion of the RSAR as the best safety tool.

## ADVANCED PROACTIVE SAFETY—AN RSA

An RSA is an advanced proactive tool for improving transportation safety. An RSA is an examination of a future roadway project plan by an independent, qualified audit team that then reports on safety issues raised during the examination. The step-by-step procedure of an RSA can be performed during any stage or all stages of a project, including planning, preliminary design, and detailed design, as well as construction traffic control planning and construction. Generally, the RSA is most likely to be a local agency tool for evaluating a complex situation. That statement is not intended to limit the use of the tool, but rather reflects the local situation and expresses a view similar to that used in applying advanced reactive safety analysis. The personnel at most local agencies in the United States have not received the training nor do the agencies have the resources to apply the tool except on a limited basis. It is, however, an excellent and proven safety tool with widely accepted application internationally (*22,49*).

An RSA is a systematic process that can be tailored according to an agency's specific organizational culture and safety issues. Generally, an audit involves the following steps:

- Select the road safety audit team.
- Provide the relevant data and documentation.
- Hold a kickoff meeting.
- Assess the data and documents.
- Inspect the site.
- Discuss audit safety issues with the designer or internal client.
- Write the RSA report.
- Hold a completion meeting.
- Respond to the report.
- Implement agreed-on changes.
- Share lessons learned.

The RSA has the same attributes as an RSAR, except that the safety evaluation is made on a project plan and not on an existing roadway. One approach to modify the traditional RSA and RSAR that is being applied by the New York State DOT is to use the agency's in-house safety audit team to integrate safety improvements into the pavement management program. This audit team consists of staff from design, traffic, and maintenance. Team members use crash data to assist in the enhancement of safety when the roadway sections are resurfaced. Complete discretion is vested in the agency's regional audit teams to decide jointly what actions should be taken, and there is no mandate that the team's recommendations be implemented. Each of the regional offices decides how much work it can afford to undertake within the context of a balanced program and limited resources. The program has been highly successful in proactively advancing safety. Locally, this program is known by its acronym SAFETAP—that is, the Safety Appurtenance Program.

Several state DOTs in the United States are beginning to advance the application of the RSA, prompted by the training that has been presented since 1998 and the development of that training into a National Highway Institute (NHI) course. That NHI course features a reference manual that was developed by Global Learning Systems (*50*). The NHI manual provides a discussion of the details and the considerations that need to be made. A local agency considering an RSA should consult this reference.

A key to the RSA is that the evaluation be a formal document reporting solely on safety issues. An RSA is a proactive tool designed to ensure that safety considerations and the concerns of all users have been addressed before the project is constructed. The RSA report is presented to the local agency, which then uses it to direct additional safety considerations, if needed. The costs of conducting an RSA have been most often stated as minimal, given the added value of increasing the safety of a project. The cost will vary depending on the project scope, stage of the audit, and size and makeup of the audit team. An RSA is not a check to ensure that standards and guidelines have been met. An upcoming NCHRP synthesis will report in more detail on the use of RSARs and RSAs. That synthesis will focus on the use of these proactive tools in the United States and will provide an update on global applications.

CHAPTER FOUR

# OTHER SAFETY TOOLS

## SAFETY STUDY DATA—EFFECTIVE SAFETY TOOLS

There is often a need to supplement crash data with other factual traffic and user information. Outlined here are these types of safety data and the value added to the analysis to improve safety. A more detailed discussion of these data types and methods can be found in the references, particularly the ITE *Manual of Transportation Engineering Studies* (*45*) and the *Fundamentals of Traffic Engineering* (*47*), which provide details and sample data collection forms. In addition, these references provide other types of study concepts and useful survey forms, experimental design concepts, survey design concepts, statistical analysis tools, and ways to present the results of these studies, both in written and presentation formats. Special concern for the safety of personnel during data collection for all studies should be considered. The wearing of safety vests, parking of work vehicles to minimize the impact on traffic, and use of traffic control devices and enforcement personnel are important considerations.

Specific data collection concepts helpful in evaluating safety issues are associated with traffic volumes, speeds, travel time and delay, intersections and driveways, inventories, traffic access and impacts, traffic conflicts, pedestrians, and compliance with traffic control devices (*9,45,47*). The utility of these study data and the value of these different types of safety data are presented in the following section.

- Traffic volume studies—This is a basic and widely used type of data, which has many different forms and collection techniques. In reactive analysis, the use of these data helps to identify crash differences owing to the influence of different traffic volumes. In the case of the RSAR, volume data are useful in aiding the classification of the local facilities. In most cases, the volume data that are collected will need to be viewed as a representative sample.
- Speed studies—There are a number of different types of speed data. For local safety, the issues generally pertain to spot speed, travel speed, and posted speed. Spot speed data reflect the instantaneous speed at a given point. Analyzing a sample set of data provides average values. These data also provide information concerning the variation of speeds. The range of speeds can be used to identify safety issues and to aid in evaluating safety decisions. For a neighborhood where complaints of higher than desired speeds are reported or where there may be a large number of crashes, spot speed studies are often used. If a safety improvement was made, then the effectiveness of the change in reducing the speed is evaluated by using a before-and-after spot speed study, for example, in identifying the effectiveness of a speed hump in reducing traffic speeds. The use of instantaneous speeds, coupled with information on the classification and/or location of the facility, is also helpful in establishing the posted speed limit. Generally, there is a need to lower or raise vehicle speeds by the posting of limits. The ideal result is all vehicles traveling at or near the same speed, to provide the safest environment. Locally, there is often a need to evaluate locations where there is a concern for providing vehicle speed guidance, such as posting an advisory curve speed. A device referred to as a ball bank indicator is an inexpensive tool for this purpose.
- Travel time and delay studies—These studies provide measures of a facility's ability to accommodate traffic flow. The longer the travel time and the more the delay, the greater the potential for safety problems to occur because of driver frustration. For a specific facility, identifying the sources and amounts of delay is useful in providing potential corrective countermeasures.
- Intersection and driveways studies—A number of special studies associated with these locations are typically collected during safety investigations. The key to enhancing safety is how to apply the data correctly to identify specific safety issues at the locations. One primary use is to determine the adequacy of intersection sight distance for a vehicle or a pedestrian to make a crossing or turning movement. In applying these study results, it is essential to ensure that adequate sight triangles at the corners of the intersection are maintained. As a vehicle approaches an intersection, a clear sight triangle is needed for all different types of vehicles using the intersection. This generally requires 3 to 8 vertical ft for clear lines of sight, for both passenger cars and truck drivers. The size of the sight triangle is a function of the vehicular approach speeds. AASHTO provides recommendations for sight distances at intersections, which consider the type of traffic control at the intersection (*20*). If the measured sight distances are not available, then removing the sight obstruction should be considered; if that is not possible, then the intersection approach speeds should be reduced or the type of intersection traffic control changed to reflect the available sight distances. It is equally important that the intersection itself be visible and clearly identified. It is also important to recognize that when vehicles are delayed for a long period of time because of inadequate gaps that prevent a safe turn or cross, driver frustration often results. This situation may lead to crashes, near misses, and a potential to ignore

changing traffic control, resulting in behavior such as red light running.

- Inventories—Basic record keeping, an inventory of existing conditions, improvement activities, and crashes, is essential to improving local safety. Such efforts complement the functional classification of the local network. Knowing the types, locations, and conditions of different traffic control devices; knowing the condition of the road surface (both roughness and skid resistance); and providing a historical log of actions taken will enable local agency officials to make better informed safety decisions and help maintain a safer roadway network.
- Traffic access studies—A proactive tool for safety is the traffic access study. As new development is proposed, the consideration of access, both ingress and egress to the new development, is the best time to ensure safety for the new intersections and driveways that may be created. It is also an optimum time to evaluate internal safety considerations for larger developments in which both pedestrian travel and internal vehicle travel become a greater concern. Landscaping needs to be evaluated with a concern for sight distances. Is there adequate off-street storage provided for the activity? Delivery vehicles need to be evaluated for maneuvers required to load and unload. Turning radius requirements must be evaluated. AASHTO's *A Policy on Geometric Design of Highways and Streets* (*20*) provides information on vehicle turning radius. It is equally important to consider the effect of the access for smaller developments. Vehicle maneuvers and adequate storage for dwelling vehicles are sometimes overlooked. Safety problems may result from vehicles stacked into and on the through roadway, or there may be unsafe multiple access points if parking is developed in which vehicles are required to back out into the street. The access study should also address the issue of possible future expansion of the proposed development or how a change in the allowable use of the facility may affect the safety of the proposed development. Once these factors have been considered and a plan approved, it is important to ensure that the plan has been implemented as approved.
- Impact studies—This is also a proactive type of study that focuses on new development. Generally, an impact study determines the amount of traffic that will result from the new development. This situation becomes important from a safety perspective in considering whether or not additional or improved traffic control may be required. Traffic generated by the new development decreases with increasing distance from the development, although the impact may be significant for many miles, and traffic may affect safety well beyond the site. The ability of the network to accommodate the development and future growth, plus the existing level of operational service, are used in assessing the impact. Understanding the effect of traffic helps with decisions to initially size facilities and also to fully evaluate the impact of the changes in land use. Assessment of movement, access, and safety impact of the new development on the network should consider the functional classification of adjacent facilities. Figure 1 illustrates the need to separate movement and access, where and whenever possible, to achieve an overall safe and efficient system.
- Traffic conflicts—Conflicts are often viewed as near misses. Conflict studies assess actions that are taken to avoid a collision and are used in safety analysis to evaluate the types of safety problems at a particular location. This type of study may be initiated in response to citizen complaints. Conflict studies are an easy and efficient means to check a location's safety issues when there is limited or no crash data. Another form of conflict analysis is to explore all of the potential legal maneuvers of all road users at the location. Sketching the movements and locating the points where the various path lines cross can be done. Classifying potential conflicts as merge, diverge, or crossing helps to evaluate the issues associated with geometric design alternatives. This approach is useful in understanding maneuver situations for new road and street developments, as well as the impact of the location on various activities, such as mailbox placement and associated road safety issues. Evaluating the actual maneuvers at similar locations also provides behavioral data that will help to elevate safety (*52*).
- Pedestrian studies—Pedestrian studies focus on actual behavior and are used to guide safety decisions associated with the need for increased clearance time for signalized intersections where large numbers of pedestrians are crossing. Other applications are for safety considerations of special pedestrian groups such as the young, the elderly, or pedestrians with disabilities. Providing special crossings for pedestrians is often accomplished by considering the gaps that exist in the traffic stream that is being crossed and the number of opportunities available to make a safe crossing. These studies determine the number of gaps of adequate time for the type of pedestrian making the crossing. Observing the actual behavior of pedestrians making crossings also provides useful information for safety analysis. Established behavioral knowledge, such as noting that pedestrians almost always take the shortest path, should not be overlooked in guiding safety decisions. When possible, it is advisable to use known facts as an effective safety tool. Aspects of the Americans with Disabilities Act (ADA) should be considered and compliance with ADA requirements met (*32,34,53*).
- Compliance with traffic control devices—These studies concentrate on issues of behavior for different user groups as they relate to the safety of the traffic control device. There are a number of different types of compliance studies. Bicycle compliance as a special study may investigate the use of and need for more exclusive

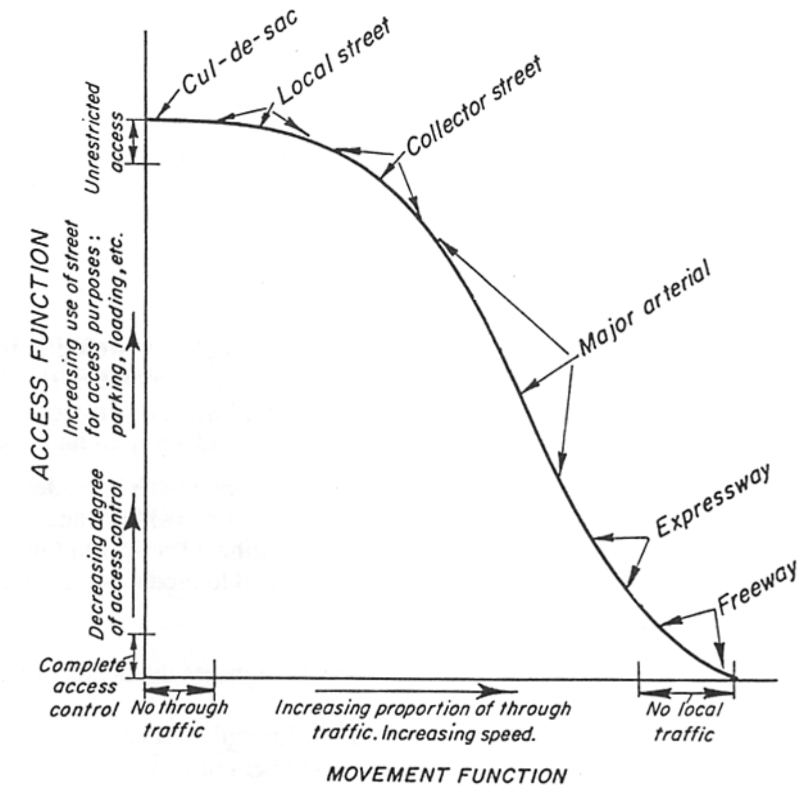


FIGURE 1 Schematic relationship between access and movement function of streets. [*Source*: *Fundamentals of Traffic Engineering*, 15th ed. (*47*).]

bicycle lanes. The need for special enforcement to help improve the safety at selected locations is often supported with a compliance study. With the recent focus on red light-running, similar studies at stop control locations may reveal problems related to excessive waiting times. These types of studies are often considered in a before-and-after analysis.

- Photographs and videotaping—Both aerial and at-grade photographs are useful safety tools. Aerial photographs provide data on the location of obstructions and are often used to check sight distances at corners. Photographs aid in the consideration of the effects of vegetation growth and landscape planting. Documenting and presenting situations where sight restrictions exist can be made easier with the use of digital technology. Video logs of the roadway provide a reference base for judging safety improvements and documenting the changes made.

## LOCAL PARTNERS—EFFECTIVE SAFETY TOOLS

Traditional partners in enhancing safety are engineering, education, enforcement, and emergency response services. Communication among partners is a tool that may produce value far beyond any site-specific improvement made in response to reactive crash analysis. Crash reactive analysis tools apply to site-specific evaluations only after the location has been identified as a high crash location.

Collaboration is the key. In most cases, there are several local jurisdictions with some responsibility for a given roadway. The interactions of partners advancing the safety of the local transportation network by working together on both general and specific issues are valuable safety tools that should not be overlooked. Establishing effective communications with local decision makers, the media, the general public, law enforcement, and other agency personnel is important. Locally, schools are often a focus of safety. It is important that the decisions on schools be undertaken in a cooperative partnership. Understanding the movement of all users into and out of a school is necessary to achieving safety (*16,32,54,55*). Separation of the various activities of passenger loading and unloading activities will often provide for increased safety. There is also an increased need to consider the ADA, which provides an increased focus on other special user needs. The needs of older drivers and pedestrians are also enhanced by forming partnerships. There are several excellent references which will help to enhance the needed safety considerations for these groups (*33,34*).

Facts, tips, and briefing sheets designed to help local agencies have been developed on a number of safety topics. Examples are provided in Appendixes F and G. These tools can help to educate groups toward understanding the positive benefits of many safety activities and are useful in responding to concerns from citizens or politicians. One such briefing is adapted and highlighted here to demonstrate the value of such tools. The FHWA, ITE, and the Advocates for Highway Safety have worked independently and cooperatively to develop many of these briefs. The content is adapted from a portion of Appendix G of this synthesis.

## BASIC COUNTERMEASURES TO MAKE INTERSECTIONS SAFER

Collisions occur at intersections because motor vehicles are in conflict with one another when crossing or turning in traffic. Improving the engineering of intersections is the first step toward reducing accidents, because vehicle conflicts—combined with flawed highway or street design and poor signage—often result in collisions of vehicles with roadside objects, pedestrians, and other vehicles.

### Types of Collisions at Intersections

There are four major types of vehicle crashes at intersections.

1. **Crossing collisions** occur when one vehicle strikes the side of another. These are the most severe types of crashes and can result from vehicles attempting to drive straight through or turning within an intersection.
2. **Rear-end collisions** are common at intersections. They can be the result of poor street design or inadequate traffic engineering measures, but usually are the result of dangerous driver behavior, such as speeding, following too closely, and braking too late.
3. **Vehicles changing lanes improperly** or crossing a road's centerline are less common at intersections than are crossing and rear-end collisions.
4. **Pedestrian and bicycle collisions** occur most frequently in urban areas, particularly with older and younger age groups. In 2000, 34% of pedestrian deaths among people aged 65 and older, and 10% of pedestrian deaths among children age four and younger, occurred at intersections. Only 2% of motor vehicle-related deaths involved bicyclists, but 33% of these deaths occurred at intersections (*56*).

### Multiple Causes of Intersection Crashes

There are four primary causes of intersection crashes.

1. **Poor physical design** of both the intersections and their approach roadways can be factors. A major aspect of safety design is restricted sight distances, where drivers do not have enough time to stop or avoid hitting a pedestrian or another vehicle.
2. **Traffic engineering** may be inadequate**.** In some cases, traffic control devices, such as signs, are improperly used, placed in the wrong locations, are too small to be seen, or have suffered damage or deterioration. In other instances, the growing number of automobiles on the road has outpaced what used to be acceptable traffic engineering measures.
3. **Driver licensing and education** often fails to train drivers to safely negotiate intersections. Some drivers do not know the basic traffic laws, fail to understand the meanings of certain signs and pavement markings, or do not respect the rights and safety needs of pedestrians (*57*).
4. **Drivers disregard traffic control at intersections.** Even knowledgeable drivers sometimes disregard the clear messages of traffic control devices—including stop signs, signals, and pavement markings—and repeatedly violate traffic laws. Combined with speeding, the disregard for traffic control at intersections is a major source of serious crashes. Driver distractions, such as cell phone use and inattention, as well as drug and alcohol use, are additional human factors that cause accidents with death and injuries.

### Countermeasures to Improve Intersection Safety

Safety problems must be identified by an engineering review. The most important point to remember when improving safety at intersections is that countermeasures that improve vehicle traffic flow or reduce vehicle crashes should not compromise pedestrian safety. There are three strategic decisions to consider when improving intersection safety design and operation.

1. Eliminate vehicle and pedestrian conflicts when possible.
2. When not possible, reduce unavoidable vehicle and pedestrian conflicts to lower the chances for collisions.
3. Design intersections so that when collisions do occur they are not as severe.

Studies have shown that providing turn lanes for left-turning vehicles can reduce accidents by 32%. Signalization countermeasures include using 12-in. signal heads; providing separate signals over each lane; installing higher intensity signals; and changing the length of signal cycles, including the yellow change interval and the red clearance interval.

Traffic engineering strategies to improve the movement of vehicles and pedestrians are crucial to improving intersection safety. They consist of a wide range of devices and operational changes such as the following:

- **Addition of turn lanes at intersections**—Turn lanes are used to separate turning traffic from through traffic. As mentioned, studies have shown that providing turn lanes for left-turning vehicles can reduce accidents by approximately 32%. Personal injury accidents involving left-turning vehicles can be decreased by as much as 50%. Separating right-turning vehicles from other vehicles can significantly affect operations at an intersection. The addition of a separate right-turn lane at an intersection with a signal can reduce the delay experienced by drivers on an approach. At intersections without a signal, right-turn lanes can safely remove turning vehicles that are slowing down in through traffic lanes. Turn lanes at major driveways can also improve safety, especially on high-volume or high-speed roadways.
- **Signals**—A number of actions can be taken including increasing the size of signal heads from 8 to 12 in. to increase their visibility; providing separate signals over each lane; installing higher intensity signal lenses; and changing the length of signal cycles, including the yellow clearance interval and the all-red phases.
- **Nontraditional intersection design**—There could be exploration of nontraditional intersection designs such as roundabouts or traffic circles.
- **Pavement condition**—The pavement quality could be upgraded to better drain the road and help resist skidding.
- **Improving drivers' sight distance**—Actions can include restricting parking near intersections and moving stop lines back from intersections.
- **Upgrading and supplementing signs**—Enforcing laws that prohibit dangerous intersection driving is a necessity to even well-designed and regulated intersections. Enforcement must be consistent because motorists who tend to violate traffic control are aware that the chances of receiving a citation are low. Sustained enforcement efforts have been proven to lower both intersection violations and crash rates, sometimes to a dramatic extent.

Many smaller local agencies do not have the resources to maintain a full-time engineering function, and without that function, the use of tools like reactive analysis may not be considered. For these smaller local jurisdictions, enhancing safety by working with the partners is a valuable approach. The facts, tips, and briefing sheets are useful tools for understanding and communicating safety issues. These tools will also be valuable in strengthening the partnerships.

One component of a successful partnership is cooperation. Understanding the issues of safety from different points of view is essential, although difficult to achieve. Any steps that elevate the consideration of safety will be beneficial.

### PROFESSIONAL ORGANIZATIONS—EFFECTIVE SAFETY TOOLS

Public and professional organizations also provide excellent sources for monitoring new safety developments. Such groups are identified in Appendixes D, L, and M. Appendix M provides the LTAP addresses and other contact information associated with LTAP centers. These centers can be excellent sources of information to assist local agencies in their safety program efforts. Appendix D contains a listing of free and low-cost publications, many sponsored by professional organizations, which can assist local agencies in staying current with the latest developments in safety tools.

### COMPUTER-BASED SOFTWARE—AN EFFECTIVE SAFETY TOOL

Appendix E provides information on computer-based safety software that is available in both the public and private sector. Descriptions of these software programs provide the reader with a quick overview of each program and cites the advantages and requirements for using each program. These tools range from easy to use to complex.

### WORLD WIDE WEB—AN EFFECTIVE SAFETY TOOL

Appendix C provides several computer websites that can provide local agencies with the most current information on safety tools, such as major reference publications, standards and guidelines, and additional safety information. Many of these websites provide links to other helpful sites. The websites listed in the appendix offer a wealth of safety tool information for local use.

### SAFETY REFERENCES—EFFECTIVE SAFETY TOOLS

Appendix C also contains brief summaries of key safety publications, subdivided into primary and supplemental sections. Acquiring and using these references could aid any local agency's safety program. These sources were developed in part by accessing the FHWA safety website (www.fhwa.dot.gov) and that of the ITE (www.ite.org). The publications listed in Appendix C provide additional information on practical tools that can benefit a local agency's safety program.

Many of the supplemental references are available directly from the websites listed in the appendix and can be downloaded at no cost. Although some of these sources are more than 20 years old, the concepts are still valuable. (One caution: be sure that guardrail and guardrail and bridge end treatments comply with the latest standards.) The other references included in the appendix can benefit local agencies by providing quick sources of information, as well as the methodology to evaluate safety issues.

There are new standards for work zone traffic control and sign supports. Although the purpose of this synthesis is not to focus on work zone traffic control issues, it is imperative that local agencies understand that new safety requirements exist. Therefore, work zone issues are presented in the next section.

## WORK ZONE SAFETY

The Millennium Edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) (*58*) contains a revised section on improvements to work zone safety. Most LTAP centers can supply local agencies with work zone traffic control publications, training, and the latest MUTCD updated information (*36,59,60*). Part 6 of the new MUTCD should be consulted to determine work zone traffic control plans, fundamental principals, and special requirements for safety. A few of the more important provisions are as follows:

- Work zone requirements in the MUTCD continue to be modified. The latest revisions of the manual can be accessed at the FHWA website, or go directly to the MUTCD and click on http://mutcd.fhwa.dot.gov/. Also available at this site is access to the publication on standard highway signs, which presents information on all MUTCD approved signs, including regulatory and warning signs. Part 6 sets forth the national guidelines and standards for work zone traffic control.
- Typical application diagrams are provided to aid an agency in setting up work zone traffic control. It is important for worker safety and the safety of all road users that these typical application diagrams be used with the idea that they represent a good beginning. Traffic control needs to be carefully evaluated before the work begins.
- Work zone traffic control devices are now required to meet crash test standards. Approved devices continue to change as new devices are approved and tested. To determine if your local devices are still approved traffic control devices in work zones, as well as to determine new approved devices, link to http://safety.fhwa.dot.gov/forthlevel/pro_res_road_nchrp350.htm.
- Flagging in a work area requires the use of an advanced flagger warning sign. Flaggers are required to use a "STOP–SLOW" paddle when flagging. The only exception is for emergency flagging.
- The LTAP center in each state or tribal area has training and pocket references on work zone traffic control that provide opportunities for local agencies to enhance safety in local work areas.

## ECONOMIC ANALYSIS AND PRIORITY IMPROVEMENT TOOLS

A question that often surfaces when evaluating safety concerns the benefits of an improvement versus the costs. In addition, local agencies must determine how best to allocate their limited resources among various projects; therefore, economic analysis is necessary.

There is no one specific method of undertaking an economic analysis. However, several are suggested in the *Manual on Identification, Analysis and Correction of High Crash Locations (the HAL Manual)* (*46*), including benefit–cost ratio analysis, cost-effectiveness method, net benefit method, incremental benefit–cost ratio, and dynamic programming (see Appendix C). When solving one specific safety problem there are generally a number of different solutions. The cost of each solution may vary widely as may the potential safety benefits. Spending more does not necessarily result in a better and safer solution.

Among the difficulties with economic analysis are the assumptions that need to be made. For example, the benefits pertaining to fewer crashes and the less severe nature of crashes need to be determined. The reductions in these two areas form the basis for determining the economic benefits. There are a number of sources available to help local agencies make these decisions.

The goal of economic analysis is to evaluate the benefits for each possible countermeasure and then to determine the best solution. Useful sources include the aforementioned *HAL Manual* (*46*) and the *Arizona Local Government Safety Project Analysis Model* (*21*) (see Appendix C). They offer more details on the value of various treatments and the value associated with the reduction of certain crashes. These sources provide an estimate of the reduction in crashes and severity correlated to the improvement alternative. This is referred to as the accident reduction factor, or crash reduction factor.

The cost of the improvement alternative includes the total cost and the potential service life of the countermeasure. The total cost includes costs of maintenance, operation of the countermeasures, and application of the appropriate rate of return for the public-sector investment. All costs are associated with the same time frame for the analysis by converting the different items and using the appropriate economic factors based on the rate of return. For example, a capital recovery factor is used to convert an initial cost to an equivalent annual cost. Generally, an equivalent annual cost and benefit approach is used.

The desired outcome is to maximize the benefits when compared with the costs. A benefit–cost ratio with at least a dollar return for each dollar of investment reflects a break-even investment. If there is only one solution, then a benefit–cost ratio greater than or equal to one is desired. When a number of alternatives are considered, the cost of each alternative needs to be ranked according to increasing costs, after which each alternative's costs and benefits can be compared. When a ratio is calculated that is greater than or equal to one, then the next higher cost alternative is compared with that of the better alternative. This comparison technique is called an incremental benefit–cost analysis. The last alternative to receive a benefit–cost ratio of one or greater is the best economic alternative.

There are some variations to the incremental benefit–cost ratio method, but they are all basically the same. The differences are related to the time frame of the analysis, what costs and benefits are considered, and the basis for comparison, that is, present value or annual value, and other analysis details. Other techniques are also presented in the *HAL Manual* (*46*).

Furthermore, there is the need to evaluate decisions with regard to which projects need to be undertaken. Simply stated, given a set of best alternatives, how does one select those to be undertaken first? Because this evaluation deals with a mutually exclusive set of best alternatives, the decision involves how best to spend a limited amount of resources among countermeasures for different locations.

The best alternatives improve different safety concerns with different levels of certainty. The evaluation of each independent best alternative provides its own set of costs and benefits. Economic analysis may also be a good tool to use in countering less desirable political alternatives, as well as for supporting an unpopular solution. There are a number of other factors, including environmental impacts, business effects, and jurisdictional implications; these are often not economically based factors.

## KNOWN SAFETY IMPROVEMENTS—AN EFFECTIVE SAFETY TOOL

The advantage of economic analysis is derived from the inclusion of a rationally based component into the decisions that are made. Although obvious issues are a part of any decision process, the goal is to implement a countermeasure after making the best decisions possible. However, applying proven improvements as solutions to known safety problems is also a viable option. The absence of an economic analysis tool should not prevent a local agency from developing a safety improvement program. Economic analysis is only one tool; implementing a safety improvement program is the key to improving local roadway safety.

## EMERGING RESEARCH AND GAPS IN KNOWLEDGE

This chapter has highlighted safety tools that are beneficial in evaluating safety issues. These tools are applicable to both reactive and proactive applications. To advance safety practice there is a need to better understand the effectiveness of emerging safety techniques. Tools continue to change and improve. This section highlights several sources of information that provide knowledge of products reflecting the advancing state of knowledge and practice.

Local agencies will find the following website of the Turner–Fairbank Highway Research Center (www.tfhrc.gov and click on the RD&T Performance Report Link) useful as they seek knowledge of the latest practice and answers to questions concerning emerging safety topics. In February 2003, this site provided a status report on topics that are of interest to local agencies, including the following:

- Red light running;
- Development of materials for asset management guidance;
- Evaluation of low-cost safety improvements—specifically, edgeline rumble strips on rural highways; and
- Interactive Highway Safety Design Model software development (see Appendix E)—a continuing project that will help local rural agencies assess geometric and crash issues.

The advancement of safety practice is an ongoing process. Research also continues on issues such as centerline rumble strips, traffic calming, the effects of traffic calming on safety, and older drivers and pedestrians (*16,32,53,59,62,63*). Also, see Appendix L for additional sources of information being developed on these diverse safety issues. It is important to remember that implementing ADA guidelines will become a greater safety concern. It is important to keep current by reviewing the latest references, accessing websites on research, and using LTAP centers as effective resources. At the local level, there is a major need to improve the collection of crash data and to adequately train those individuals who undertake this activity. The improvement of state and local cooperation and the issue of improving data collection will be addressed in an upcoming NCHRP synthesis on safety management systems that is scheduled for publication in late 2003.

AASHTO is a leading force in the advancement of safety and has developed a *Strategic Highway Safety Plan* (*64*) (see Appendix K). There are 22 specific goals associated with this plan, each of which has a series of strategies designed to address these goals. Local agencies will find this plan beneficial in communicating the broad array of safety issues and the needed local activities to help achieve these goals. A website, http://www.transportation1.org/safetyplan/plan/

index.asp, provides a link to each goal, and the associated strategies and an opportunity to stay current on the developments of the resource documents for implementing the strategies. The first six publication titles addressing these goals are in draft form and are cited as references in Appendix K, along with the AASHTO table of contents page for the strategic plan.

The recognition that all crashes are local puts a local focus on this quote from AASHTO's *Strategic Highway Safety Plan*.

> The current crash projections are unacceptable: 1 in 84 children will die violently in a highway crash during his or her lifetime; 6 in 10 will be injured, many more than once. We must not be lulled into complacency by day-to-day statistics. Existing efforts are not acceptable (*64*).

CHAPTER FIVE

# DEVELOPING A LOCAL SAFETY IMPROVEMENT PROGRAM: "THE BEST SAFETY TOOL"

Although there is widespread support for the concept of a program to enhance the safety of local roads and streets, effective implementation of such a program is much more challenging. The primary roadblock to implementation is the lack of resources, including both financial and personnel needs. Because of these limitations, most local agencies are able to concentrate only on their current pressing concerns. Adding a safety program is considered a great idea; however, many local agencies view this as a luxury they cannot afford. Often-stated concerns have impeded the development of a programmed approach, to the detriment of local road safety. Two such concerns are

1. If a safety issue is identified and then not corrected, this situation will result in an open invitation to tort liability if a crash occurs.
2. Similarly, if a safety issue is corrected in one location but not at all similar locations, and a crash occurs at one of the locations not fixed, the prevailing view is that there will be the loss of a tort liability lawsuit.

The purpose of this chapter is to alleviate these concerns, so as to develop a practical local safety program. The primary emphasis is that the application of safety improvement program tools presented here are very affordable and practical. The safety program is developed by integrating and documenting the selected tools into the local road and street agency's overall transportation program. Each agency must determine what works in its environment, because there is no one-size-fits-all solution, but there is a basic structure centering on the need for safety to become a priority program.

The framework of a program consists of the following elements: identifying safety issues, identifying possible solutions, selecting and implementing a solution, evaluating the effectiveness of the solution, and developing a written record. To some this effort may seem to present a hurdle that cannot be overcome. It is often expressed that with limited resources and the large number of miles under a local jurisdiction, developing a program is not practical. However, this is just a framework and one that can be followed by any agency within its resource limitations.

Each agency should "begin with the basics" and tailor a program using the concepts presented here.

- Subclassify the local road network. (See the following sections of this chapter and also Appendix I.)
- Develop a program to assess local safety issues.
  - It may be a reactive program (see chapter two),
  - It may be a proactive program (see chapter three), or
  - It may be a combination of both.
- Implement your safety program.
- Identify possible solutions for identified safety issues. (See Appendix H and the Summary of Safety Tools that concludes this chapter for specific reference sources.)
- Seek funding for alternative solutions. Funding alternatives can include contacting the Governor's Office of Highway Safety or the state DOT.
- Document the safety program and its results. Implement the program and document the results on a continuing basis.

The local road subclassification will help to frame the various safety alternatives that are practical and best to apply. The following subclassification is one alternative for a local rural jurisdiction (see Appendix I) and was developed specifically to help local rural agencies develop a proactive approach to safety. It can assist local agencies in overcoming two major obstacles: (1) assessing the safety issues of all roads at one period of time, which is generally beyond local resources; and (2) that improvement alternatives vary widely and the "ideal" solution may be far from a practical and affordable solution.

An alternative approach is discussed in the annotated reference *Arizona Local Government Safety Projects Analysis Model* (*21*). There are also other local road subclassifications that rural and urban agencies may want to consider. Several recent classification alternatives are discussed in more detail in the AASHTO *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400): 2001* (*23*). This publication uses a functional classification based on the primary type of road use as follows:

**Rural roads** are classified as
- Rural major access roads,
- Rural minor access roads,
- Rural industrial/commercial access roads,
- Rural agricultural access roads,
- Rural recreational and scenic roads, and
- Rural resource recovery roads.

**Urban roads** are classified as
- Urban major access streets,
- Urban residential streets, and
- Urban industrial/commercial access streets.

Tools that may aid in these approaches include a GIS-based inventory and a sign and road management program. Documentation of the implementation and ultimately desired improvements is an important component of this approach. Continual assessment of the needs of more of the system and implementation of safety improvements each year both lead to a safety program.

If an agency had unlimited resources, developing a safety program would be straightforward. However, in the real world, a more practical approach is to chip away at the safety needs of the system. The use of a subclassification system provides a realistic approach to stratifying the local road system and identifying the road safety improvements that fit the user needs. Cost-effective, this method allows for the development of solutions that recognize and recommend staging a series of improvements when resources are limited. Frequently, an improvement will be applied that will result in a major safety benefit, but that does not satisfy the prevailing guideline for safety design. Too often, local agencies are deterred from developing a safety program because resources are not available to satisfy prevailing standards. However, by acknowledging that unlimited resources do not exist, particularly at the local agency level, an agency can enhance safety in an affordable manner. The value of a local road and street subclassification is illustrated with the following hypothetical examples, one rural and one urban. The first is based on an actual case study.

**Rural example**—This particular county has more than 1,000 mi of local roads within its jurisdiction. Traffic volumes on the various roads range from under 50 vehicles per day to more than several thousand vehicles per day. There are many safety deficiencies; however, most do not result in crashes, although when a crash occurs, prevailing roadway deficiencies are often a contributing factor. Local tort liability claims are prevalent and the local county agencies have pooled their insurance resources owing to the inability to obtain affordable insurance. There is no safety program. Resources are limited, and the number of tort claims is increasing as road traffic and development in the rural areas increases. Local roads are both paved and unpaved. There is a recognized need to improve safety, but an uncertainty about how to go about it.

The recommended proactive approach is to use the concept of a subclassification to begin developing a local road safety program. This allows the agency to advance from the status of a nondefined or nonexisting program to an active program. In the past, the recommended approach was based on the *Highway Safety Improvement Program* (HSIP) (*65*). The HSIP was a front-end-loaded identification of safety needs for the system. Then, given these needs, priorities were established for implementation. The subclassification modification provides a reduced front-end cost loading. After the network has been subclassified, a realistic number of miles of each subclassification are identified each year to pinpoint safety issues. This programmed approach tailors the improvements to reflect the resources and needs associated with each type of road and results in a set of realistic recommendations.

The importance of this proactive approach is to establish credibility by using an outside assessment of the safety issues, and to then implement the improvement alternatives that fit the subclassification of the road. The focus is on the real world of limited resources, recognizing the many needs to be met on the extensive local roadway systems. This approach is the beginning of a safety program.

Materials developed for a local rural agency training program for using this proactive approach, in the context of the RSAR, can be found in Appendix I. In addition to the tool kit, a sample RSAR report is provided to illustrate the documentation provided. The final step is the implementation of selected safety issues and the documentation of the decisions made.

**Urban example—**This city has limited resources and faces a situation similar to that of the rural county. Growth is occurring and crashes are increasing, primarily at intersections. The question is "Will the basic reactive crash program identify needed safety improvements?" The advantage for smaller local agencies with limited resources is that the basic method of reactive crash analysis is a low-cost and practical approach that produces proven benefits to improving locations, based on less rigorous analysis evaluations. Local agencies can often apply the basic method by directly contacting their state DOTs for computer records of yearly crash reports and then requesting a more detailed analysis from the DOTs.

More detail is needed, however, to document that reactive crash analysis is the basis for the local agency safety program. Most importantly, it is necessary to document the improvements made and to reassess their effectiveness after implementation. Closing the loop to ensure that safety has been improved is important and may result in fewer successful tort claims and lower liability insurance.

CHAPTER SIX

# CONCLUSIONS

The following are the summary conclusions drawn from the text of this synthesis report. Detailed guidance on how to use this report in practice can be found in Table 1, chapter one.

- All crashes are local, which puts a local focus on this quote from AASHTO's *Strategic Highway Safety Plan.* "The current crash projections are unacceptable: 1 in 84 children will die violently in a highway crash during his or her lifetime; 6 in 10 will be injured, many more than once. We must not be lulled into complacency by day-to-day statistics. Existing efforts are not acceptable."
- To achieve the stated U.S. goal of a 20% reduction in fatalities, or saving 8,000 lives annually, local agencies will need help. The synthesis provides guidance to help local agencies implement safety improvement programs by applying the best and most appropriate tools. Local agencies are essential if there is to be success, and helping these agencies is the purpose of this synthesis.
- Safety practices should be tailored to the problems and resources of an agency; there is no one-size-fits-all safety solution.
- Large financial commitments and complex analysis are not always necessary to implement a successful local safety program.
- A documented local roadway safety program is a proven safety tool. Recognizing the need to implement even a rudimentary safety program is the necessary first step. The selection of safety tools to meet the individual local agency's needs is next. The key to local roadway safety then becomes developing and implementing the selected tools into a continuing program.
- Once the program is established, it is important to keep current by checking for the latest references, websites on research, and using Local Technical Assistance Program centers as effective resources.

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# APPENDIXES

# APPENDIX A

## Survey Questionnaires

To complete this survey, fill out the questionnaire, print and fax the completed survey form to (307) 766-6784,

or mail the completed survey form to: Eugene M. Wilson
3212 Reynolds Street
Laramie, WY 82072

**NCHRP Synthesis 33-06**
**Roadway Safety Tools for Local Agencies**

"Tools" are defined in a broad sense to include systems, procedures, practices, software, and other activities and actions beneficial in aiding local agencies to improve their roadway safety. The focus is on safety tools that are associated with physical and operational improvements.

## State DOT questionnaire for the state of ______________________________

1. Which tool or tools do you use to analyze road and street safety that would be most useful for local agencies?
   ______________________________
   ______________________________
   ______________________________

2. Does your state have a priority safety improvement program that would be useful for local agencies?
   Yes _____ No _____ (Please provide a copy or list of the major features.)
   ______________________________
   ______________________________
   ______________________________

3. Does your state have a systematic safety program to eliminate known hazardous elements? If so, what are the elements and are there any specific suggestions you would like to make for local agencies?
   ______________________________
   ______________________________
   ______________________________

4. Do you have a benefit/cost scheme to prioritize safety improvements?
   Yes _____ No _____ (Please provide a copy or list the major features.)
   ______________________________
   ______________________________
   ______________________________

5. Does your DOT partner with local agencies to assess safety? Yes ____ No ____ If yes, how?
   ______________________________
   ______________________________
   ______________________________

6. Please provide any additional comments to improve this synthesis.
   ______________________________
   ______________________________
   ______________________________

7. Who can we contact if more information is needed?
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Our LTAP Center is helping Gene Wilson, the Director of the $WYT^2$/LTAP Center, to develop an NCHRP Synthesis that will provide local agencies with roadway safety tools. Please help to make the synthesis a success by responding to this e-mail. These responses will help to complete NCHRP Synthesis 33-06: Roadway Safety Tools for Local Agencies.

"Tools" are defined in a broad sense to include systems, procedures, practices, software, and other activities and actions beneficial in aiding local agencies to improve their roadway safety. The focus is on safety tools that are associated with physical and operational improvements.

Your help in determining local safety issues and training needs is the purpose of this e-mail. It is only by your timely response that this NCHRP safety synthesis will produce information that contains safety tools that will be useful for local agencies.

Simply stated, the intent of the synthesis is to produce best practice responses in terms of safety tools and to identify needed additional tools to enhance the safety capabilities of local agencies.

To complete this survey via e-mail, fill out the questionnaire and send it to wilsonem@uwyo.edu, or print the completed survey and fax it to (307) 766-6784,

or mail the completed survey form to: Eugene M. Wilson
3212 Reynolds Street
Laramie, WY 82072

## Local Agency Questionnaire: Please provide additional comments where necessary to clarify the responses

1. Our local agency has an accident (crash) analysis program.
   Yes_____ No______

2. What is the most frequently used safety tool for your agency's assessment of safety issues:
   ______________________________________________________________________
   ______________________________________________________________________
   ______________________________________________________________________

3. Analyzing high accident (crash) locations is _____, or is not _____ part of your agency's safety program.

4. Does your agency have funding specifically set aside to make identified safety improvements?
   Yes_____ No_____

5. Does your agency have a priority safety improvement program? Yes____ No_____
   If yes, please provide a copy.

6. Your local program for safety involves using the assistance of the:
   a) State DOT Yes_____ No_____Comments ________________________________
   b) Local consultants Yes_____ No_____Comments ____________________________
   c) Other local agencies Yes_____ No_____Comments__________________________
   d) Only our staff Yes_____ No______ Comments _____________________________

e) Other ______________________________
f) None of the above Yes _____Comments ______________________________

7. We use the following to assist in our safety program:
a) Mile marker reference numbering Yes_____ No_____Comments ______________________________
b) Analysis of accident data Yes_____ No_____Comments ______________________________
c) Speed studies Yes_____ No_____Comments ______________________________
d) Safety priority improvement program Yes_____ No_____Comments ______________________________
e) Priority scheduling of safety improvements Yes_____ No_____
Comments ______________________________
f) Special safety funding programs Yes______ No______
If yes, which program funds? ______________________________

8. Other than more money, what would you like to have to help you improve the safety of your local roads?
______________________________
______________________________
______________________________

9. Please provide any additional comments that you believe would help other agencies with their local road safety.
______________________________
______________________________
______________________________

10. What type of agency are you? City _______ County _______ Township _______
Located in the state of ______________________________

Please provide any additional information or contacts you would suggest to result in a better product. Thanks for your assistance.

## LTAP Center Survey

I am the author of an NCHRP Synthesis that will provide local agencies with roadway safety tools. Please help to make the synthesis a success by responding to this e-mail.

LTAP centers are an excellent source for local safety assessments in terms of defining training skills needed to meet and improve roadway safety. Your help in determining local safety issues and training needs is the purpose of this e-mail. It is only by your timely response will this NCHRP safety synthesis produce information that contains safety tools that will be useful for local agencies.

Simply stated, the intent of the synthesis is to produce best practice responses in terms of safety tools and to identify needed additional tools to enhance the safety capabilities of local agencies. "Tools" are defined in a broad sense to include systems, procedures, practices, software, and other activities and actions beneficial in aiding local agencies to improve their roadway safety. The focus is on safety tools that are associated with physical and operational improvements.

To complete this survey via e-mail, fill out the questionnaire and send it as a reply to wilsonem@uwyo.edu, or print the completed survey form and fax it to (307) 766-6784,

or mail the completed survey form to:

Eugene M. Wilson
3212 Reynolds Street
Laramie, WY 82072

## LTAP questionnaire for the state of ______________________________

1. What do you think is the most significant safety tool to provide local agencies to advance safety on their roads and streets?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

2. What would you like to be able to provide a local agency to assist in their safety program? (not more money)

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

3. Road safety is an important topic for local agencies in my state. Yes_____ No_____

4. The following are the five most important tools we provide to local agencies for improving safety on their roads and streets.

   a) ________________________________

   b) ________________________________

   c) ________________________________

   d) ________________________________

   e) ________________________________

5. Please provide other comments that you feel will help this synthesis to better respond to local agency's safety issues.

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

# APPENDIX B

## Summary of Survey Results

**State DOTs were asked to identify tools they use to analyze road and street safety that would be most useful for local agencies. The following tools were identified:**

| | |
|---|---|
| Missouri: | Road Safety Audits<br>Work Zone Safety and Flagger Training<br>MUTCD Work Zone Pocket Guides<br>Analysis and Correction of High Accident Locations (*HAL Manual*). |
| Arizona: | Traffic Accident Database. |
| Maine: | TIDE (Transportation Information for Decision Enhancement), a GIS-linked data warehouse. |
| Washington: | Traffic Data Office has applications for analyzing crash history in categories of High Accident Locations (HAL), High Accident Corridors (HAC), and Pedestrian Accident Locations (PALS). |
| Wyoming: | Use crash data to look at accident concentrations—a computerized database, available to local agencies. |
| North Dakota: | Intersection Magic Crash Diagramming Software<br>Clear Zone Safety Review, Traffic Data, Crash Data. |
| Georgia: | Software written by the department for use with the accident data and road inventory database—not useful for local agencies. |
| Texas: | PASSER II, III, CORSIMS, SYNCRO, AASHTO's *Roadside Design Guide Hazard Elimination Manual.* |
| Massachusetts: | A good crash record system<br>Prioritize and publish high accident locations, the "High 1000" list. |
| Delaware: | Traffic Counts, Road Inventory, Critical Rate Ratio Methodology. |
| Colorado: | Databases of accidents on State Highways, referenced by MP<br>Software includes SYNCHRO/SIM TRAFFIC, Highway Capacity. |
| Florida: | High Crash Location listings for intersections with state routes. |
| Kansas: | Retain consultants to conduct traffic studies<br>Provide training to local transportation professionals in work zone traffic control and other safety areas. |
| Nebraska: | Analysis of mainframe crash database using QMF<br>A new hazardous location process is being developed for state highways. |
| New Mexico: | Roadway System Crash Database<br>New Mexico Highway Safety Improvement Program. |
| West Virginia: | Accident listings and summaries. |
| Iowa: | Access Accident Location Analysis System (customized Iowa software)<br>Intersection Magic Collision Diagram. |

| | |
|---|---|
| Montana: | Access to crash records<br>ITE Traffic Safety Tool Box<br>AASHTO *Yellow Book*<br>Northwestern University table correlating crash trends to causes and potential countermeasures<br>MUTCD, *Roadside Design Guide*, safety reports. |
| South Carolina: | Collision locations, engineering reviews of roadways. |
| Nova Scotia: | Provincial Collision Rate Book used to pinpoint sections of road with higher than average collision rates. |
| Calgary: | Automated Collision Analysis Systems<br>Collision Analysis and Conflict Analysis Training<br>Road Safety Audit Training (Design and Operational). |
| Alberta: | System of Special Monitoring Locations—locations with three similar type collisions in a period of five years are identified. |
| New Brunswick: | Transportation Association of Canada (TAC), MUTCD, and design manuals are used. Also share collision statistics with local agencies. |

State DOTs were asked if they have a priority safety improvement program that would be useful for local agencies. Of those who responded, 16 said "Yes" and 7 said "No."

State DOTs were asked if they partner with local agencies. Of those who responded, 20 said "Yes," whereas only 2 said "No."

**Local agencies were asked to identify the most frequently used safety tool for their agency's assessment of safety issues. The following tools were identified by local agencies:**

Electronic traffic counts
Citation statistics
Training in work zone traffic control
Inspections based on complaints or high accident rates
Intersection analysis signal warrant studies
Review of all crashes reported to law enforcement
Software to track roadside hazards—inventory and prioritize hazards
Crash report review
Accident records, collision diagrams
Accident record system
Magic software
Accident pattern diagrams from SCARS
Crash data
Access database for accident query and history for problem analysis and evaluation
Review of traffic safety proposals by a Technical Traffic Committee
Concerns of road crews
Citizen requests
Employee feedback/input
Monthly review of crash statistics—analyze and address the issues
Crash history of the area under investigation and cost–benefit analysis of proposed corrective measure
Accident data, traffic counts, and citizen complaints
Access
MUTCD, traffic engineering reference manuals, ITE publications, AASHTO publications, and sound engineering judgment
Site visits and highway patrol accident reports
Citizen complaints

Sheriff department reports
Common sense, MUTCD
Police Department
Crash analysis
Signs.

Local agencies were asked if they have funding specifically set aside to make identified safety improvements. Of those who responded, 14 said “Yes” and 18 said “No.”

Local agencies were asked if they have a priority safety improvement program. Of those who responded, 13 said “Yes” and 18 said “No.”

**LTAP centers were asked to identify what they thought was the most significant safety tool to provide local agencies to advance safety on their roads and streets. The following tools were identified by LTAP centers:**

Central clearinghouse of information on available resources
Crash Location Identification Program
Up-to-date training on application of standards and guidelines; this includes best practices, what’s working and what’s not, and new innovations
Workshops to emphasize work zone safety
One-on-one training that includes photos, case studies, and opportunities for discussion
Hands-on, on-site safety training courses
Traffic sign inventory
Proper training on the use of signs and pavement markings, the concept of clear zone, and increased funding for improvement of bridges and culverts
Hands-on, state-specific work zone training
MUTCD training, field visits, funds to erect adequate road signs
Better local road traffic safety data and the training to use it effectively
Competent inspections—having knowledgeable agency employees on the lookout for things that would adversely affect safety
A simple, 4-hour class and a short publication showing safety tools/practices to have available
Training and information on current best practices and the requirements to achieve and maintain a safe environment on their roads and streets
To help local road managers to assign appropriate priority to roads and street safety issues; provide information on accidents caused by inadequate design and maintenance
Work zone safety class, work zone safety guide, flagger training
Safety training workshops, our SAFER manual, and other publications that locals can use
Implementing a Safety Management System
Keeping work zone safety a key priority—double penalties in work zones (enforced)
Education, basic awareness, and training on all aspects of traffic standards of MUTCD and work zone safety
Training, training, training.

LTAP centers identified the five most important tools they provide to local agencies for improving safety on their roads and streets. The responses were varied, but boiled down to the following categories:

| | |
|---|---|
| Training/workshops | 41 responses |
| Publications and videos (MUTCD) | 26 responses |
| Technical assistance/advice | 10 responses |
| Equipment | 7 responses |
| Newsletter articles | 5 responses |
| Software | 4 responses |
| Technology transfer | 2 responses |

Responses to the question, “What would you like to be able to provide a local agency to assist in their safety program (not more money)?” were as follows:

Information helping them to identify a source to fulfill their needs.
More intense and comprehensive training in economic benefits of safe construction procedures from design to maintenance.
Workshops and/or training.
Enhanced training tools.
Heavy equipment training and operation awareness.
Computer software for signing.
A procedure for roadway safety reviews on existing local roads and intersections—used as criteria to distribute FHWA funds in an expedited fashion.
Expand current training curriculum to include computer-based training options and to involve them in Community Traffic Safety Teamwork—include city, county, state, and federal representatives.
Prepared formats for checking and inventorying roadside safety features—checklists.
Training on identifying and using effective, low-cost safety improvements.
Training in inspections, risk management, and management systems.
Offer class and publication showing different tools for safety within their community. Use site visits to help them use this tool. Such tools are frequently not used because the reference material they get is too far above their level.
The time and responses to provide a current reference source for worker personal safety issues (OSHA related).
To help local road managers assign appropriate priority to roads and street safety issues, provide information on accidents caused by inadequate design and maintenance.
Work zone safety guides and training.
Motivation to seriously review highway safety and implement safety improvements.
Simple, low-cost software tools to support implementation of an SMS and basic traffic collision and safety analysis. Develop a legal liability training program for local agency safety improvements.
Police presence in high traffic/high hazard work zones.
Training and “packages” of road signs and work zone products.
Educate the county and city commissions so they can better understand the need for a safety program.

# APPENDIX C

## Annotated References and Websites

### A POLICY ON GEOMETRIC DESIGN OF HIGHWAYS AND STREETS, 4TH EDITION

The 2001 "Green Book" contains the latest design practices in universal use as the standard of highway geometric design and features the following improvements and additions: (1) use of dual units (metric and U.S. customary) throughout; (2) larger format—pages are 8.5 × 11 in. with easier-to-read text and graphics; (3) available on CD-ROM (non-network version); (4) compliance with the Americans with Disabilities Act; (5) discussions of the latest AASHTO Guide for the development of bicycle facilities (see page 9, code D-GBF-3) and the proposed new AASHTO Pedestrian Guide; (6) incorporates research from *NCHRP Reports 375, 383, 400, 420,* and *439* on median width and median opening design; revised criteria for intersection sight distance; stopping sight distance model; access management techniques; and super elevation criteria. Also available on CD-ROM (Publication No. CD-014). The book covers the following areas: Highway Functions, Design Controls and Criteria, Elements of Design, Cross Section Elements, Local Roads and Streets, Rural and Urban Arterials, Freeways, Intersections, Grade Separations and Interchanges (AASHTO 2001).

### A PRACTICAL SAFETY TOOL FOR LOCAL LOW-VOLUME RURAL ROADS: THE RSAR

***Proceedings of the 8th International Conference on Low-Volume Roads*, TRB, Reno, Nevada, June 22–25, 2003**

**Abstract**

Practical tools for improving transportation safety are needed worldwide. It has been estimated that motor vehicle-related crashes account for more than one million fatalities each year and the number of serious injuries far exceeds fatalities. Local and low-volume roads are significantly overrepresented in crash statistics. Globally, the Road Safety Audit (RSA) concept has been recognized as an effective tool in identifying and reducing the crash potential of roadways when used to analyze the safety aspects of project plans and designs prior to completion.

In the local rural road arena, there are many safety issues associated with existing roadway networks. Many of these networks have developed over time with little or no planning and/or design. There is a critical need for a practical tool that focuses on the safety of the *existing*, as-built local road network. The RSA Review (RSAR) process has been developed for this purpose, giving specific recognition to the functionality of the road being evaluated for safety issues. There are significant numbers of safety improvements needed, and practical approaches to address these needs are crucial. The RSAR tool has the potential to be particularly beneficial to local governments in systematically addressing safety deficiencies on *existing* rural road networks. In addition, it is a proactive safety tool that has the potential to protect agencies from tort liability as it establishes a record of the organization's safety agenda.

An RSAR methodology that can be adapted by local agencies is presented. A case study illustrating the application of this process is included. Also highlighted is a local rural training program that has been presented in several states for county applications.

The focus of this paper is on U.S. county applications, but it is recognized that the process has utility for other agencies and has application in other countries. The necessity of training as a key component in the development of a sustainable safety program is emphasized.

### ACCIDENT MITIGATION GUIDE FOR CONGESTED RURAL TWO-LANE HIGHWAYS

**NCHRP Report 440**

This guide will assist planners, designers, and traffic engineers in identifying and designing projects to improve safety on congested rural two-lane highways. The guide assumes that widening the road to four lanes is not a practical solution because of financial, environmental, or societal constraints. Geometric, traffic control, and other types of countermeasures are discussed. TRB, 2000, 170 pp., ISBN No. 0-309066-24-7.

### ARIZONA LOCAL GOVERNMENT SAFETY PROJECT ANALYSIS MODEL
### FHWA-AZ-01-504

**Abstract**

Due to the time and expense required for the preliminary data collection and site assessment, some local governments lack the resources for an in-depth analysis of highway safety needs in their jurisdiction. This is significant because these jurisdictions may not determine candidate projects for safety program funding, and high-incident locations statewide may go without remedy despite the availability of federal aid for local safety improvements.

The focus of this research has been primarily on development of site identification and implementation strategies for local safety projects. This research is intended to provide local governments with an efficient and justifiable means of assigning priority to potential projects in a local safety program. Although some analysis has been devoted to the multiple variables that affect the outcome of a safety measure, the primary aim of that analysis was the synthesis of data such as traffic volumes, average speed, type and design of roadway, and special circumstances, in order to develop appropriate parameters for implementation strategies. This process was automated through the development of a database model intended to facilitate site identification and safety project selection by local jurisdictions and planning organizations.

By providing an automated method for identifying local safety hazards, prioritizing these locations, and evaluating the potential benefits of treatments designed to remedy these locations, the Arizona Local Government Safety Project (LGSP) affords local jurisdictions more time for in-depth research of specific sites and a rationale for decision making that is impartial and justifiable. It is expected that the Arizona LGSP model will help local governments address their highway safety needs on a timelier basis, and ensure that more attention is directed at the most hazardous locations, thereby improving the overall safety of the roadway system in Arizona.

This document is available to the U.S. public through the National Technical Information Service, Springfield, Va. 22161.

### BASIC REFERENCES FOR THE TRANSPORTATION ENGINEER

Provides information on major current references in 16 subject areas dealing primarily with surface transportation. Listing includes textbooks, manuals, reports, periodicals, and other documents that contain significant information of importance to the practicing transportation professional. Also includes information on how to obtain copies of those publications. Institute of Transportation Engineers, 1991, 9 pp.

### FUNDAMENTALS OF TRAFFIC ENGINEERING, 15TH ED.

Covers traffic engineering characteristics and studies, control devices, planning and design, control systems, environmental and energy aspects, and administration. Reflects new literature and changes in laws and regulations, as well as recent changes in the state of the knowledge, art, and practice of traffic engineering. By W.S. Homburger, J.W. Hall, E.C. Sullivan, and W.R. Reilly. This 15th edition is the metric version. Institute of Transportation Studies, University of California, 2001.

**GUIDELINES FOR GEOMETRIC DESIGN OF VERY LOW-VOLUME LOCAL ROADS (ADT ≤ 400): 2001**

This AASHTO publication addresses issues that engineers face when designing policies for low-volume, local roads. A new approach to this type of road is presented based on research of safety and cost-effectiveness. This book may be used in lieu of the “Green Book.” AASHTO, 2001, 96 pp.

**HIGHWAY SAFETY DESIGN AND OPERATIONS GUIDE**
**AASHTO’S “Yellow Book”**

This updated version of AASHTO’s “Yellow Book” combines results of research and state-of-the-art technologies with proven engineering practices for enhancing safety in the operation and management of highways. It identifies safety enhancements for new highway and 3R projects, introduces and consolidates new safety information, and suggests how existing situations might be upgraded to meet current standards and future needs. It is useful not only for design and planning purposes, but also for field reviews during planning, development, and evaluation. AASHTO, 1997, 132 pp.

**MANUAL ON IDENTIFICATION, ANALYSIS AND CORRECTION OF HIGH-CRASH-LOCATIONS**
**(the HAL Manual)**

**Technology Transfer Assistance Program**
**Missouri Department of Transportation**

The HAL Manual discusses the use of police crash reports to improve the safety and flow of traffic. By analyzing data from crashes and using a few simple formulas, locations in need of improvement can be determined. Then, through worksheets, diagrams, and observations, primary and secondary crash patterns can be established. Steps can then be taken to improve the safety of the roadway.

The manual provides all of the necessary worksheets and outlines how to use them. The manual also gives information on economic analysis and a list of possible solutions to traffic problems and the pros and cons of those solutions.

**MANUAL OF TRANSPORTATION ENGINEERING STUDIES**

Shows in detail how to conduct several transportation engineering studies in the field. Discusses experimental design, survey design, statistical analyses, data presentation techniques, and report writing concepts. Provides guidelines for both oral and written presentation of study results. Includes useful forms for various transportation studies. Preceded by the *Manual of Traffic Engineering Studies*. Edited by H.D. Robertson, Institute of Transportation Engineers, 1994, 526 pp.

**MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES (MUTCD 2000)**
**MILLENIUM EDITION**

Defines the standards used by road managers in the United States to install and maintain traffic control devices on all streets and highways. The purpose of these devices, which include signs, signals, and pavement markings, is to promote highway safety, efficiency, and uniformity so that traffic can move efficiently on the nation’s streets and highways. The Millennium Edition has been entirely rewritten and reformatted to improve the overall organization and discussion of the content and is available in a variety of formats (see MUTCD-1 through MUTCD-6). U.S.DOT/FHWA, 2000.

**NEIGHBORHOOD TRAFFIC CONTROL**
**ITE Publication**

The North Central Section of ITE has compiled a list of neighborhood traffic control techniques and their effects on traffic volumes, speed, environmental issues, and safety. These techniques offer a variety of potential alternatives with which to creatively solve problems in partnership with the neighborhoods and elected officials. Contained in this publication are additional technical briefings. Institute of Transportation Engineers, 1994, 64 pp.

**ROADSIDE DESIGN GUIDE 2002**

A synthesis of current information and operating practices related to roadside safety. It focuses on safety treatments that can minimize the likelihood of serious injuries when a motorist leaves the roadway. The document is written in dual units—metric and U.S. customary units. This publication supersedes the 1996 AASHTO publication of the same name. Includes CD-ROM. AASHTO, 2002, 328 pp., ISBN No. 1-560511-32-X.

**ROADWAY SAFETY**

**NACE Action Guide Volume III-4**

This guide has been prepared to assist county agencies—specifically, road superintendents, engineers, and assistant engineers—with highway responsibilities. It is intended to help identify various road hazards that may be present and to help develop safety improvements. It includes suggestions on ways to evaluate the seriousness of hazards and to develop priority lists for addressing those hazards. Standards of construction are indicated, and some comments are made on financing. Topics discussed at length include:

- Agency Management, Operations, and Training;
- Roadway Geometrics;
- Roadside Features;
- Traffic Control Devices; and
- Work Zone Safety.

**ROADWAY SAFETY GUIDE**

**Introduction**

This guide is designed to provide local elected officials and other community leaders with basic information to improve roadway safety in their communities. Written for nonengineers, it is designed to be a hands-on, user-friendly document, providing community leaders with

- Strategies they can use right away to begin making roads safer;
- Basic information to improve roadway safety in cooperation with state and local transportation departments, highway engineers, highway safety officials, Safe Communities groups, and other safety programs; and
- Clear descriptions of key funding and decision-making processes that affect roadway safety.

The guide is available on the Roadway Safety Foundation website: www.roadway.org, with updates to assist users in their ability to respond to emerging roadway safety problems. Full text is available at: http://www.roadwaysafety.org/toc.html.

**STATISTICAL EVALUATION IN TRAFFIC SAFETY STUDIES**

**ITE Publication**

This publication reports on the current practices of statistical techniques that governmental agencies are using in traffic safety studies, countermeasures, evaluation, and traffic safety research. The informational report covers transportation trends in five countries; summarizes a literature review that was conducted in Canada and the United States; and reports on the results of a questionnaire that was developed and distributed to governmental agencies, universities, and consultants throughout the United States, Canada, Australia, and England. Statistical techniques used in traffic safety studies are described and the advantages and disadvantages for each are presented. Institute of Transportation Engineers, 1999, 80 pp., ISBN No. 0-935403-35-3.

### TRAFFIC CONTROL DEVICES HANDBOOK

The new *Traffic Control Devices Handbook* replaces the out-of-print 1983 edition. The handbook will augment the 2000 edition of the *Manual on Uniform Traffic Control Devices* (MUTCD), now being published. The *Traffic Control Devices Handbook* provides guidance and information to implement the provisions of the MUTCD. The objective of the handbook is to bridge the gap between the MUTCD requirements and field applications. Additional guidance is provided on the new MUTCD requirements to clarify the provisions of the manual. The information is specifically written for smaller jurisdictions, replacing the need for outside technical expertise. The handbook does not establish policy, procedures, or standards for an agency, or set the "standard-of-care" for decisions on traffic control devices. It is meant as guidance material to assist in determining the appropriate device(s) for a specific condition based on judgment and/or study. The handbook includes 14 chapters covering the wide variety of traffic control devices available to meet the public needs. There are chapters on low-volume, rural roads, as well as residential streets. Separate chapters are provided for signs, markings, traffic signals, railroad–highway grade crossings, and temporary (construction) traffic controls. One chapter addresses installation considerations for traffic control devices. Another discusses the human factor considerations in the application of traffic control devices. The specific issues of traffic control devices for schools, pedestrians, and bicyclists are each addressed in separate chapters. Institute of Transportation Engineers, 2001, 521 pp., ISBN No. 0-935403-61-2.

### TRAFFIC SAFETY TOOLBOX: A PRIMER ON TRAFFIC SAFETY

The following topics are covered in this update of the 1993 edition: Safety Management; Traffic Planning; Traffic Control Devices; Tort Liability, Risk Management, and Sign Inventory Systems; Geometric Design; One-Way Streets and Reversible Lanes; Roadside Safety; Enforcement; Automated Enforcement of Red Light Running; Infrastructure Maintenance; Traffic Control Devices; Work Zone Traffic Management; Designing for Pedestrians; Bicycling Element; Driver Behavior and Qualification; Traffic Calming; Teaching Safety; Before–After Evaluations in Highway Safety; Statistical Approach to the Analysis of Intersection Safety; Safety Improvements and Secondary Roadways; Low-Cost Safety Improvements; Safety Impacts of Roundabouts; and Road Safety Audit. The material covered reflects the personal knowledge, experience, and expertise of the authors of the individual chapters. This combination of resources makes this publication a valuable document, useful toward improving traffic safety and saving lives. Institute of Transportation Engineers, 1999, 317 pp., ISBN No. 0-935403-43-4.

### BICYCLE LANES VERSUS WIDE CURB LANES: OPERATIONAL AND SAFETY FINDINGS AND COUNTERMEASURE RECOMMENDATIONS

#### Foreword

There is a variety of on- and off-road bicycle facilities—each with its advantages and disadvantages. A thorough evaluation of the various kinds of facilities implemented in pro-bicycling communities has been needed by the traffic engineering profession. One of the studies under the FHWA's Pedestrian and Bicycle Safety Research Program investigated the long-standing issue of whether bicycle lanes or wide curb lanes are preferable. Overall, the study indicated that both bicycle lanes and wide curb lanes can and should be used to improve riding conditions for bicyclists.

This document presents a summary of the research study, providing operational and safety findings and countermeasure recommendations regarding bicycle lanes and wide curb lanes. The information contained in this report should be of interest to state and local transportation engineers, planners, researchers, and bicycle coordinators. Report FHWA-RD-99-035, 1999. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/99035/intro.htm.

### CRASH MODELS FOR RURAL INTERSECTIONS: FOUR-LANE BY TWO-LANE STOP-CONTROLLED AND TWO-LANE BY TWO-LANE SIGNALIZED

#### Foreword

This report provides direct input into the Accident Analysis Module (AAM) of the Interactive Highway Safety Design Model. The AAM is a tool that highway engineers can use to evaluate the impacts of highway design elements in project planning and preliminary design. Three crash models were developed relating crashes to three types of rural intersections: (1) three-legged intersections with major four-lane roads and minor two-lane roads that are stop-controlled, (2) four-legged intersections with major four-lane roads and minor two-lane roads that are stop-controlled, and (3) signalized intersections with both major and minor two-lane roads.

Elaborate sets of data were acquired from state data sources (Michigan and California) and collected in the field. The final data sets consist of 84 sites of three-legged intersections, 72 sites of four-legged intersections, and 49 sites of signalized intersections. Negative binomial models—variants of Poisson models that allow for overdispersion—were developed for each of the three data sets. Significant variables included major and minor road traffic; peak major and minor left-turn percentage; peak truck percentage; number of driveways; and channelization, intersection median widths, vertical alignment, and, in the case of signalized intersections, the presence or absence of protected left-turn phases. Separate models were developed for crashes resulting in injuries and total crashes. Report FHWA-RD-99-128, 1999. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/99128/intro.htm.

## EFFECTIVE COMMUNICATIONS FOR THE TRANSPORTATION PROFESSIONAL

A manual on an organizational approach to communication dynamics. Includes case history examples of common communication problems in operations, design, and planning, with practical responses for transportation officials who have not had the benefit of practical, formal, or role-model education. By Technical Council Committee 2-22, chaired by William van Gelder. An ITE Informational Report. Institute of Transportation Engineers, 1984, 80 pp.

## GIS-BASED CRASH REFERENCING AND ANALYSIS SYSTEM

A geographical information system (GIS) can be simply defined as a collection of hardware and software that is used to edit, analyze, and display geographical information stored in a spatial database. In recent years, many transportation departments and other related organizations, such as the FHWA, have examined the feasibility of using GIS for transportation planning, systems management, and engineering applications. In some states and municipalities, GIS is being used to plan transportation routes, manage pavement and bridge maintenance, and perform a variety of other traditional transportation-related functions. One area where GIS has yet to be extensively applied is in the analysis of crash data.

Computerized crash analysis systems in which crash data, roadway inventory data, and traffic operations data can be merged are used in many states and municipalities to identify problem locations and assess the effectiveness of implemented countermeasures. By integrating this traditional system with a GIS, which offers spatial referencing capabilities and graphical displays, a more effective crash analysis program can be realized. The objective of this effort was to develop a crash referencing and analysis system within a GIS. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/99-081.pdf.

## HIGHWAY SAFETY EVALUATION: PROCEDURAL GUIDE

### Foreword

This guide describes procedures for evaluating highway safety programs and projects. It should be beneficial to state and local engineers and other professionals involved in evaluation.

The objectives of this guide are to describe how to:

1. Select appropriate measures of effectiveness and efficiency to perform evaluations by using either accident data or alternate measures of hazard reduction;
2. Perform an evaluation of implemented safety improvements to gauge their effectiveness and efficiency, and to use the results in recommending improvements for other safety or operational problems;
3. Describe and guide the organization and management of evaluation processes for providing feedback on the effectiveness of safety programs to the planning and implementation components of the Highway Safety Improvement Program; and
4. Perform program effectiveness and administrative evaluations.

Report FHWA-TS-81-219, 1981. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/81219/intro.htm.

## HIGHWAY SAFETY IMPROVEMENT PROGRAM (HSIP)

### Introduction

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

The manual provides guidance to state and local agencies for developing and implementing a highway safety improvement program that best suits their capabilities and needs. The manual should be beneficial to federal, state, and local highway engineers and other professionals involved in a highway safety improvement program. The manual describes how to

1. Implement a highway safety improvement program that complies with *Federal-Aid Highway Program Manual 8-2-3* and which contains the following components and processes:
   - Planning (collect and maintain data, identify hazardous locations and elements, conduct engineering studies, and establish project priorities),
   - Implementation (schedule and implement projects), and
   - Evaluation (determine the effect of safety improvements).
2. Select the most appropriate procedures based on an agency's particular goals, objectives, resources, and highway system.
3. Utilize current information concerning reporting requirements, funding sources, and practices of other highway agencies.

Report FHWA-TS-81-218, 1981, 41 pp. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/81218/intro.htm.

## IMPROVING HIGHWAY SAFETY AT BRIDGES ON LOCAL ROADS AND STREETS

### Foreword

This publication was developed by the FHWA's Office of Highway Safety and has been produced by the FHWA's Local Technical Assistance Program (LTAP) for distribution through the LTAP center network to the local, tribal, and rural governments.

The FHWA's LTAP is a network of 57 centers nationwide. The purpose of the LTAP is to stimulate the progressive and cost-effective transfer of highway technology and technical assistance to local, tribal, and rural governments. The LTAP accomplishes this by funding a variety of activities and projects that link local highway agencies, tribal governments, states, universities, and the federal government. The LTAP brings transportation technology transfer services, products, and educational resources to the local level. LTAP centers are located in all 50 states and Puerto Rico. Six additional centers assist American Indian Tribal governments.

Although each of the LTAP centers has the flexibility to tailor its program to the needs of local customers, there are six basic requirements that are common throughout the entire network: each center must (1) publish a quarterly newsletter; (2) distribute technology transfer materials; (3) provide an information service; (4) provide at least 10 training courses; (5) evaluate the effectiveness of the program; and (6) compile and maintain a mailing list of tribal, local, and rural officials having transportation responsibilities.

The centers use a mix of technology transfer tools and marketing activities to meet their customer needs. Some typical endeavors include training workshops; on-site demonstrations and hands-on training; road shows or circuit-rider programs that take training on the road; microcomputer software development; adaptation and distribution of technical publications and user manuals; studies on specialized topics; and lending libraries for videos, publications, and other such materials.

This pamphlet is intended as a general guide to effective, low-cost methods of improving and enhancing bridge and bridge approach safety. It is not a design manual or a substitute for engineering knowledge, experience, or judgment. Technical safety information such as bridge standards, crash-worthy approach rail systems and their attachment to the bridge rail, highway and bridge width, and development of highway alignments can be found in the material listed in the references. The guidance and information included in this pamphlet are based on actual situations and common existing bridge and roadway features identified through national reviews. Some of the information provided in this pamphlet reflects a type of cost-effective improvement that can be made as a temporary measure before a bridge and/or bridge approach is reconstructed to current standards. Nationally bridges and bridge approaches have been identified as one of the leading locations for severe, single-vehicle crashes. There are many bridges and large culverts on the highway system. Most have rigid rails and often span a potentially hazardous feature. Many of these structures were built decades ago for highways of lower speed and less traffic. Because of the high cost of replacing bridges and the long service life of many bridges, replacement of the bridge or major component of a bridge, such as the bridge deck or bridge rails, may not be a priority while the bridge remains structurally adequate. In situations where it is considered inappropriate to reconstruct the bridge or some element of the bridge to current standards, temporary improvements, although not resolving a substandard condition, can significantly contribute to improving highway safety. A temporary safety improvement may be considered when work is done to improve the safety or reduce the potentially hazardous nature of components or features of the bridge or roadway approaching the bridge. A safety improvement is considered temporary when it does not fully satisfy current design standards, but provides a significant improvement over existing conditions to warrant its application until the bridge and/or the approach roadway can be reconstructed to current design standards. Temporary improvements are not considered substitutes for design standards and should not be used as a substitute or justification for delaying rehabilitation of a bridge and/or bridge approach.

Report FHWA-SA-98-083, 1998, 41 pp. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/98083/intro.htm.

### IMPROVING TRAFFIC SIGNAL OPERATIONS

For elected and appointed officials and the public, this report describes how properly timed and operated signals can reduce congestion and lead to improvements in time savings, environmental benefits, and safety. Topics include strategies, how signals work, when are signals needed, maintenance, legal aspects, and funding for improvements. Prepared by ITE under a grant from the FHWA. Institute of Transportation Engineers, 1995, 16 pp.

### INTRODUCTION TO TRAFFIC ENGINEERING: A MANUAL FOR DATA COLLECTION AND ANALYSIS

Thomas R. Currin's new manual is useful in transportation engineering courses as well as in the office of the professional traffic engineer. This book presents step-by-step data collection and analysis techniques for 13 topics encountered in the daily practice of traffic engineering, from Determining Roadway Speeds to Traffic Control Compliance. Each topic is introduced in a consistent manner, with data collection and analysis forms provided for each study. Linkages between field data collection and estimation of field conditions using standard equations are also included. Brooks/Cole, Pacific Grove, Calif., 2001, 140 pp., ISBN No. 0-534378-67-6.

### MAINTENANCE OF SMALL TRAFFIC SIGNS

#### Foreword

This handbook is intended to help maintenance workers do a good job of maintaining small traffic signs. Maintaining small signs is important for driver safety. The following three kinds of signs help direct traffic flow safely and efficiently:

- Regulatory signs,
- Warning signs, and
- Guide signs.

Report FHWA-RT-90-002, 1990. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/90002/90002.pdf.

### RAILROAD–HIGHWAY GRADE CROSSING HANDBOOK

#### Foreword

This handbook provides general information on railroad–highway crossings, including characteristics of the crossing environment and users, and the physical and operational improvements for safe and efficient use by both highway and rail traffic. The handbook will be of interest to federal, state, and local highway agency personnel, railroad officials, consulting engineers, and educators involved with railroad–highway grade crossing safety and operation.

The late William J. Hedley contributed generously of his background and experience toward the completion of this handbook.

This is the second printing of the second edition of the handbook. The only change from the first printing is a revision of Figure 24, page 103, to reflect the guidance for placement of the railroad crossing pavements marking symbol in relation to the location of the advance warning sign.

A standard distribution of the handbook was made to the FHWA Region and Division offices, the state highway agencies, and the $T^2$ Centers in 1986. Copies of the handbook were also provided to the Federal Railroad Administration and the Association of American Railroads for their use. A limited number of copies are available from the Railroads, Utilities and Programs Branch, HNG-12, Federal Highway Administration, Washington, D.C. 20590 and the RD&T Report Center, HRD-11, Federal Highway Administration, 6300 Georgetown Pike, McLean, Va. 22101-2396. Copies may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

Report FHWA-TS-86-215. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/86215/intro.htm.

### RED LIGHT GREEN LIGHT—INTERSECTION SAFETY

#### Video Tape and CD-ROM

Intersection-related crashes account for approximately 50% of the combined fatal and injury crashes and more than 20% of all fatal crashes in the United States each year. As a result, transportation organizations, including representatives from the education, enforcement, and engineering communities, are working together to address intersection safety deficiencies. This video provides the general traveling public and the entire transportation community with an increased awareness of the critical importance of intersection safety. The video allows the viewers to identify steps they can take to improve their own safety, as well as provides information on what the transportation profession is doing to help create safer intersections. This video was prepared by the Institute of Transportation Engineers under contract with the U.S. Department of Transportation.

### RESIDENTIAL STREETS, THIRD EDITION

Updated throughout, this third edition takes a practical approach to planning and designing streets that is cost-effective and enhances the livability of subdivisions and master-planned and new urbanist communities. It offers a fresh look at street widths, geometrics, traffic flow, and other design considerations, as well as intersections, drainage systems, and pavement. Endorsed by traffic engineers and in compliance with the requirements of state highway officials, the book provides street designs that can save on land costs, reduce the environmental impacts of runoff, provide a marketing advantage, and win approval. It will be useful to developers, builders, designers, and local officials who wish to create streets in residential communities that encourage walking and bicycling and that discourage speeding by through traffic. Urban Land Institute, National Association of Home Builders, American Society of Civil Engineers, Institute of Transportation Engineers, 2001, 76 pp., ISBN No. 0-874208-79-3.

### ROADSIDE IMPROVEMENTS FOR LOCAL ROADS AND STREETS

#### Introduction

This pamphlet is intended as a general guide to effective, low-cost methods of improving and enhancing roadside safety. It is not intended as a design manual or a substitute for engineering knowledge, experience, or judgment. Technical safety hardware information such as hardware standards, warrants for selecting safety hardware, installation details, and cost-effectiveness analysis can be found in the material listed in the references. The guidelines and examples included in the pamphlet are based on actual situations and observations made in a series of national reviews. They reflect the actual needs and opportunities for highway safety improvements existing on many local roads and streets.

There are three general types of changes that can be made to improve highway safety. These include:

*Roadway improvements*—help drivers stay on the roadway and in their own lanes; consists of improvements made to the geometric features of the roadway such as lane and shoulder width, horizontal and vertical alignment, and pavement cross slope. Roadway improvements can reduce the number of accidents occurring by providing consistent and uniform conditions and improving driving comfort.

*Operational improvements*—provide the driver with necessary and important information; consists of improvements generally made to the signs, pavement markings, traffic signals, delineation, and other features. Operational improvements are often used to supplement or mitigate the effects of substandard or unexpected roadway features by providing the driver with information on potential hazards ahead or establishing rules (speed limit, etc.) under which the section of road can be safely negotiated.

*Roadside improvements*—provide the driver with a better chance of recovering from an accident and/or reduce the potential severity of accidents along the edge of the highway. These improvements include such work as slope flattening, culvert extensions, tree removal, ditch shaping, and installing guardrail.

This pamphlet deals only with the area of roadside improvements and was originally published October 1986. Full text available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/00002/00002.pdf.

### ROADSIDE SAFETY ISSUES

This circular features papers/presentations on: Evolution of Roadside Safety; The Roadside Safety Program; The Evolution of Vehicle Safety and Crashworthiness; Evolution of Vehicle Crashworthiness as Influenced by the National Highway Traffic Safety Administration; Methods for Analyzing the Cost-Effectiveness of Roadside Features; and Applications of Simulation in Design and Analysis of Roadside Safety Features; Data and Analysis Needs; Selection and Design of Roadside Safety Treatments; Efficacy of Simulation Methods; and Assessing and Developing Roadside Hardware. TRB, 1995

### SAFER ROADS: A GUIDE TO ROAD SAFETY ENGINEERING

A comprehensive review of the best practice approaches of road safety engineering from Europe, North America, and Australia—illuminating the practices and procedures used in the identification of hazardous sites and the development of road and traffic countermeasures. Outlines the key components of creating and maintaining a database, methods of statistical analysis, and the essential features of human behavior as they influence road and traffic design. Also covered are the economic appraisal of road safety projects and methods of project monitoring. The intended audience includes those in local government; road and traffic agencies; consultants in road safety engineering, traffic engineering, or highway engineering; and students of courses in these disciplines and in road safety. By K.W. Ogden. Ashgate, Brookfield, Vt., 1996, 516 pp.

### SAFETY IMPROVEMENTS FOR LOW-VOLUME RURAL ROADS

#### Abstract

The justification of safety improvements for low-volume rural roads has been difficult. Roadblocks of a primarily economic nature have prevented the improvement of many features associated with this type of road; features that have been known to have adverse safety implications for many years. In this report, traditional methods of developing a safety index for these roads have been explored and found unsuitable. These methods include the correlation of accident rates with specific roadway features and the location of "black spots" where atypical numbers of accidents occur. Neither of these approaches in general is of value on low-volume (ADT ≤ 1000) rural roads. The combination of two relatively new concepts for safety improvements is recommended as a result of this study. They are process-based improvements and low-cost safety improvements. For example, one process is to eliminate all hazardous concrete culvert headwalls in a district. The low-cost aspect relates to either breaking the headwall off at ground level or building up the soil of the roadside to the level of the headwall top surface. A procedure is presented here to identify those combinations of processes and low-cost improvements that should be given

priority in a low-volume roadway safety improvement program.

FHWA Research Report TX-90/1130-2F, 1990.

## SAFETY MANAGEMENT

Safety management is a systematic process that can help states reduce the number and severity of traffic crashes through highway safety improvement programs. The process provides ways for planning, implementing, and evaluating safety programs and projects. Through safety management, all opportunities to improve highway safety are identified, considered, implemented as appropriate, and evaluated in all phases of highway planning, design, construction, maintenance, and operations.

The procedural guides on this CD show how to develop a highway safety improvement program, how to conduct highway safety engineering studies, and how to conduct highway safety evaluations. Other publications present information about different safety data-collection technologies and the use of GIS for safety analysis. GIS safety-analysis techniques are tools to analyze and manipulate safety data in a spatial environment. The data-collection technologies include mobile computers, Global Positioning Systems, expert systems, bar-code readers, GIS, and others.

The National Model is a partnership of FHWA, Iowa, and others to demonstrate the successful integration of technologies for data collection, management, and communication of safety information. The National Model was recognized by Vice-President Gore with a National Partnership for Reinventing Government Hammer Award. The objectives of the National Model are to improve data acquisition for roadway incidents, leverage proven technology for law enforcement, streamline the communication of safety information to key stakeholders, and enhance the use of this information for safety programs. New approaches are being used to shorten data-collection time, minimize disruption to traffic, increase officer safety and efficiency, and improve data quality.

Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/safety.htm.

## SYNTHESIS OF SAFETY RESEARCH RELATED TO SPEED AND SPEED MANAGEMENT

### Introduction

This document provides a review of safety research related to speed and speed management. This review builds on a similar synthesis prepared in 1982. The current synthesis highlights the relationships among vehicle speed and safety; factors influencing speeds; and the effects on speed and crashes of speed limits, speed enforcement, traffic calming, and other engineering measures intended to manage speed.

Despite the substantial social and technological changes that have occurred since the original speed synthesis was published, vehicle speed remains an important public policy, engineering, and traffic safety issue. Speed is cited as a related factor in 30% of fatal crashes and 12% of all crashes (Bowie and Walz 1994). Based on on-scene investigations of more than 2,000 crashes in Indiana by teams of trained technicians, excessive speed for conditions was identified as the second most frequent causal factor out of approximately 50 driver, vehicle, and environmental factors (Treat et al. 1977).

Excessive vehicle speed reduces a driver's ability to negotiate curves or maneuver around obstacles in the roadway, extends the distance necessary for a vehicle to stop, and increases the distance a vehicle travels while the driver reacts to a hazard.

Presented are the results of a systematic review of the literature concerning safety research related to speed and speed management. Initial listings of citations were generated using multiple keyword filters on several bibliographic databases. The most productive databases were those of the National Technical Information Service, the Knight–Ridder Transportation Resources Index, and the Transportation Research Information Service. The initial inventory of approximately 700 citations was supplemented by searches of the ITE index and more than 100 items that either predated the on-line databases or otherwise were known to be pertinent.

Bowie, N.N., Jr., and M. Walz, "Data Analysis of the Speed-Related Crash Issue," *Auto and Traffic Safety*, Vol. 1, No. 2, Winter 1994, pp. 31–38.

Treat, J.R., et al., "Tri-Level Study of the Causes of Traffic Accidents, Vol. I: Causal Factor Tabulations and Assessment," Report No. DOT-HS-805-085, National Highway Traffic Safety Administration, Washington, D.C., 1977.

Full text available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/speed/spdtoc.htm.

## TRADITIONAL NEIGHBORHOOD DEVELOPMENT STREET DESIGN GUIDELINES: RECOMMENDED PRACTICE

This report is an ITE recommended practice on traditional neighborhood development (TND) street design guidelines. The report includes a discussion of the concepts of TND, also referred to as The New Urbanism, as they relate to the role of streets in TND communities; a discussion of the community design parameters under which the guidelines would apply; presentation of the design principles underlying the guidelines; specific guidance on geometric street design; and an appendix that summarizes some recent findings on the relationship between urban design and travel demand. Institute of Transportation Engineers, 1999, 44 pp., ISBN No. 0-935403-34-5.

## TRAFFIC CONFLICT TECHNIQUES FOR SAFETY AND OPERATIONS: OBSERVER'S MANUAL

### Foreword

This Observer's Manual provides basic background information for persons who are assigned to observe traffic conflicts in the field. The manual contains definitions of traffic conflicts that typically occur at intersections as well as step-by-step instructions for conducting the survey.

Experienced observers and engineers will find the manual to be a handy reference source and an aid in training new personnel. Persons who have not previously conducted a traffic conflict survey should read this manual carefully as a first step in learning how to accurately observe and record traffic conflicts.

### Chapter 1: Introduction

A traffic conflict is a traffic event involving the interaction of two or more road users, usually motor vehicles, where one or both drivers take evasive action such as braking or swerving to avoid a collision. A traffic conflict survey is a systematic method of observing and recording traffic conflicts and other events associated with safety operations. A person who conducts the field survey is known as a traffic conflict observer. This manual provides basic background information and standard procedures for traffic conflict observers. The manual contains definitions of traffic conflicts that typically occur at intersections, as well as step-by-step instructions for conducting the survey.

Experienced observers and engineers will find the manual to be a handy reference source and an aid in training new personnel. Persons who have not previously conducted a traffic conflict survey should carefully read this manual as a first step in learning how to observe and record conflicts. Because the results of a traffic conflict survey are used to make important decisions concerning traffic safety and operations, it is imperative that conflicts be recorded in a uniform or standard manner. Observers must participate in a formal training program to help them recognize conflicts under a variety of traffic and roadway conditions. One should not be expected to count conflicts based on reading this manual alone. The training program, conducted by an engineer, is essential to ensure uniform and accurate data collection. Training procedures, as well as methods for analyzing and interpreting conflict data, are described in the engineer's guide.

The survey techniques described in this manual provide a cost-effective method for accurately measuring traffic conflicts at signalized and unsignalized intersections. The definitions and procedures are based on the results of years of extensive research, experimentation, and practice. In the future, it is anticipated that standardized procedures will be developed for other roadway situations such as freeway entrances and exits, weaving areas, midblock locations, and construction zones.

Report FHWA-IP-88-027, 1998. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/88027/intro.htm.

## VEGETATION CONTROL FOR SAFETY

### Foreword

The purpose of this handbook is to help maintenance workers be aware of safe ways to increase traffic safety.

- Mow,
- Cut brush, and
- Control other vegetation.

During the growing season, grass, weeds, and brush often limit a driver's view of approaching vehicles. Likewise, lush vegetation can act as a screen that hides pedestrians and bikers from drivers, and vice versa. Be alert for places where vegetation needs to be cut back.

Report FHWA-RT-90-003, 1990. Full text is available at: http://www.fhwa.dot.gov/tfhrc/safety/pubs/90003/intro.htm.

# APPENDIX D

## Free and Low-Cost Periodicals

***American City & County***
Voice of Local Government Since 1909
847-647-6933
www.americancityandcounty.com

***APWA Reporter***
Official Magazine of the American Public Works Association
800-848-APWA
www.apwa.net

***Better Roads***
For the Government/Contractor Project Team
847-391-9070
www.BetterRoads.com

***Concrete Repair Bulletin***
Bimonthly Publication of the International Concrete Repair Institute
847-827-0830
www.icri.org

***HMAT***
Voice of the Asphalt Pavement Industry
800-369-6220
www.naylor.com

***Public Roads***
Federal Highway Administration Magazine
202-512-1800
www.tfhrc.gov

***Public Works***
Engineering, Construction, and Maintenance
201-445-5800
www.pwmag.com

***Roads & Bridges***
A Scranton Gillette Communications Publication
847-298-6622
www.roadsbridges.com

# APPENDIX E

## Crash Analysis Software

**PC-Crash** from MacInnis Engineering Associates
(www.maceng.com)

PC-Crash is a Windows collision and trajectory simulation tool that enables the accurate analysis of a wide variety of motor vehicle collisions and other incidents. Results are presented true-to-scale and in the form of clear reports, tables, diagrams, and 3-D animations.

From the website you can download the software, order it, and view demos of 3-D simulations created with the program. A product tour is also available. The site offers access to a crash database as well.

Price: $1,995.00 for the 2-D version of the software
$4,895.00 for the 3-D version

**PC-Rect** from MacInnis Engineering Associates
(www.maceng.com)

PC-Rect is a 2-D photogrammetry program for rectification of photographs. It converts oblique scene photographs pixel-by-pixel into scaled plan views. From the plan view, users can then measure in-plane distances and angles of accident scene evidence.

This program can be ordered from the MacInnis website.

Price: $995.00

**CARE** (Critical Analysis Reporting Environment) from the University of Alabama (http://care.cs.ua.edu/)

CARE is a sophisticated analytical tool that has been specifically developed for accident countermeasure problem identification and evaluation.

This software is free and available to download from the CARE site. The site allows you to view data submitted by the state of Alabama using the CARE software.

Price: Free to download from the CARE site.

**Highway Safety Analysis Software V. 2.2**
(www.x32group.com/HSA_Soft.html)

HSA Software is a computer program for conducting traffic accident investigations on major highways and local roads. The program organizes crash data by categories, types, and locations to reveal existing accident patterns and develop road safety improvements.

There is a free demo available on the website, as well as more information regarding the software's capabilities. Sample diagrams from the program may also be viewed.

Price: $500 per one single user license and $250 for each additional license.
Multiuser licenses are also available (contact the site for details).
A 50% discount is offered for government agencies, universities, and nonprofit organizations.

**M-SMAC** from McHenry Software
(http://www.mchenrysoftware.com/msmac.htm)

SMAC is a time-domain mathematical model in which the vehicles are represented by differential equations derived from Newtonian mechanics combined with empirical relationships for some components (e.g., crush properties and tires) that are solved for successive time increments by digital integration.

The website offers more information on the capabilities of the program as well as demos of crashes reconstructed with their software.

Price: $1,650 for a 1-year license

**HVE (Human Vehicle Environment)** from Engineering Dynamics Corporation
(http://www.edccorp.com/products.html)

Engineering Dynamics Corporation (EDC) offers a variety of software applications for virtual testing. HVE (Human Vehicle Environment) is a software package that is available in 2-D and 3-D versions. EDC also offers a number of physics programs that are compatible with HVE to do tests such as commercial vehicle simulations, passenger vehicle simulations, and human impact simulator. The site also offers demos of simulations created with their software.

Price: No price is available for any of EDC's software from its website.
The website does give contact numbers where pricing is available.

**V-TRAX** from Rec-Tec
(http://www.rec-tec.com/default.htm#REC-TEC)

V-TRAX allows for the introduction of individual distances, perception–reaction times, angles, lateral acceleration factors, and other information to generate a scale animation of the incident. The program allows tracking for four objects drawn to scale to show the time and space relationship between the vehicles. Acceleration/deceleration, approach angles, and distance can all be modified and observed within the program.

Rec-Tec also offers a variety of other software packages that are similar to V-TRAX. More information about these packages and V-TRAX is available on the website, as well as the numbers of people to contact with questions.

Price: Prices for Rec-Tec software and software packages are available from the website.
A single license for Rec-Tec costs $750.

**WinSMAC** from ARSoftware
(http://www.arsoftware.com/arsw/prod.htm)

WinSMAC is a prediction–simulation program that is based on the original SMAC. It completes the reconstruction process. WinSMAC allows the user to test assumptions and validate solutions obtained by traditional reconstruction techniques.

ARSoftware also offers a variety of programs to complement WinSMAC as well. These programs may be viewed at the website, as well as sample reports for the WinSMAC program.

Price: $769.00

**AIMS** from JMW Engineering
(http://www.jmwengineering.com)

Accident Information Management System (AIMS) is the first GIS accident software with 3-D mapping. With this software, you can manage millions of accident records with the AIMS database system for data management. Accidents can be displayed on a map in 3 dimensions with the software's GIS system for mapping.

You can retrieve data by clicking areas on the map or by querying and sorting. With the AIMS software you can also analyze intersection and nonintersection accidents; customize accident reports and summaries by adding texts, symbols, lines, and curves; display results in bar, pie, area, or line graphs; and export data/results to other software.

Price: For 1 to 4 users, $3,280 (up to 50,000 records); $4,280 (up to 2 million records); $2,000 for each additional user.

**Intersection Magic** from Pd' Programming Inc.
(http://www.pdprog.com/im/index.cfm)

Intersection Magic is an MS Windows-based PC application for crash records analysis. It generates automated collision diagrams, pin maps of high accident locations, high accident location lists, frequency reports, presentation graphics (e.g., crashes by time of day or month of year) and much more.

Intersection Magic has been used by jurisdictions across the country to reduce their accident counts, accident severity, and exposure to lawsuits.

Intersection Magic's support for node-based systems, milepost systems, intersections, and corridors makes it the only software package designed with the needs of state DOTs, counties, and local agencies in mind.

Intersection Magic provides analysis at the macro or micro level. It provides access to data from individual crashes all the way to jurisdiction-wide pin maps. Intersection Magic is a tool for transportation planners, traffic engineers, and others involved in crash records analysis and safety planning.

Price: Depends on the size of the city, with quotes available for county or state DOTs as well as statewide licenses.
For details visit http://www.pdprog.com/im/sales/pricing.cfm.

**Interactive Highway Safety Design Model (IHSDM)** by FHWA
(http://www.tfhrc.gov/safety/ihsdm/ihsdm.htm)

IHSDM is a road safety evaluation software package that marshals available knowledge about safety into a more useful form for highway planners and designers.

The FHWA has been developing IHSDM with initial focus on two-lane rural highways. The 2003 release of IHSDM for two-lane rural highways is now available for testing and evaluation purposes.

IHSDM consists of several modules: crash prediction, design consistency, driver/vehicle, intersection review, policy review, and traffic analysis modules are all part of the software package. For more information on these individual modules, go to the website listed above.

Price: IHSDM is free to download from their website at: http://216.161.62.248/ihsdm_public/index.html.

# APPENDIX F

## Traffic Information Program Series (TIPS)

**These briefs are reprinted with permission from ITE and are available on the ITE website: (http://www.ite.org/councils/tengineering.htm#tips)**

The Institute of Transportation Engineers' Traffic Engineering Council has produced a series of information and fact sheets that address common questions relating to transportation. The Traffic Information Programs Series (TIPS) answer frequently asked questions about many aspects of transportation planning, traffic operations, and traffic control. The TIPS are written in lay language so they serve as an information source not only for transportation professionals, but for the general public as well. The TIPS are formatted so that they can be copied on to a single piece of paper and placed in a notebook or folder. The TIPS format also allows for their mailing as a tri-fold self-mailer. A box on each TIPS is where the sender's and recipient's address can be placed.

- Bicycling
- Bus Signs
- Citizen Participation
- Construction Signs
- Four-Way Stop Signs
- HOV Lanes
- Lower Speed Limits
- Maximizing Transportation Operations
- Median Treatments
- Right of Way Regulations
- School Zones
- Sign Shapes
- Speed Humps
- Speed Limits
- Stop Sign and Bar Placement
- Stop Signs
- Traffic Engineering
- Traffic Sign Colors
- Traffic Sign Types
- Traffic Signal Warrants
- Tree Removal
- Turn Lanes

**Note: Additional briefs are contained in "Neighborhood Traffic Control" (see the annotated references in Appendix C).**

# Bicycling

In the National Bicycling and Walking Study, the U.S. Department of Transportation set national goals for bicycling and walking. The goals proposed are:

- To double the current percentage (from 7.9% to 15.8%) of total trips made by bicycling and walking; and
- To simultaneously reduce by ten percent the number of bicyclists and pedestrians killed or injured in traffic crashes.

According to 1996 statistics from the National Highway Traffic Safety Administration, 761 bicyclists were killed and an additional 59,000 were injured in traffic crashes, whereas 5,412 pedestrians were killed and 82,000 were injured in traffic crashes.

Several actions can be taken to improve bicycling conditions and encourage the use of bicycles. The following are the steps for a model strategy that can be used to improve conditions for bicycling in your community:

- Develop policies and plans to support bicycling;
- Provide adequate infrastructure of bicycle travel and supporting facilities;
- Provide public education and awareness; and
- Provide incentives and eliminate disincentives for bicycling.

Federal funds are available for bicycle-pedestrian facilities through several categories within the federal transportation legislation (TEA-21), most notably the Transportation Enhancements and Congestion Mitigation/Air Quality categories. Nearly $200 million of these federal funds have been spent every year since 1992 for bicycle and pedestrian facilities.

The following sections describe the steps of this model strategy.

***Develop policies and plans to support bicycling***—The development of policies and plans to support bicycling should be first and foremost in any bicycle strategy. The policy statements and plans will help set the direction of the remaining steps and actions to be taken. Policies and plans should be developed with input from various user groups in the area (e.g., bicycling clubs, advocacy agencies, etc.). Policy statements can be something as simple as "The City of Anywhere supports and encourages bicycling for transportation and recreation, as it reduces congestion, improves air quality, and enhances this community's quality of life." Bicycle plans should address a number of issues, including a policy statement, goals and objectives, existing conditions and/or problem areas, and a recommended strategy (with action items and measurable benchmarks) for improving conditions for bicycling. Facility design guidelines are also commonly incorporated into bicycle plans.

***Provide adequate infrastructure of bicycle travel and supporting facilities***—Once the necessary bicycle policies and plans have been formulated, the bicycle travel and supporting infrastructure should be provided to support bicycling throughout the community. Bicycle travel and supporting facilities include:

- Shared roadway/wide curb lanes (Class IV);
- Signed bicycle routes (Class III);
- Bicycle lanes (Class II);
- Separated bicycle paths (Class I); and,
- Bicycle racks/parking.

The bicycle plan developed in the previous step should provide guidance on the type and design dimension for bicycle facilities. With bicycling, the quality of the trip is part of the motivation for bicycling, and is affected by vehicle interaction, route continuity, directness, and connection to desired land uses. These factors should be taken into consideration when providing bicycle facilities in your community. The resource section at the end of this article provides bicycle facility design guidelines. Bicycle racks/parking should be provided at popular bicycling destinations, such as public libraries, parks, shopping centers, schools, and other locations where the existing presence of bicycles indicates a need for bicycle parking.

***Provide public education and awareness***—Public education and awareness efforts are necessary for several reasons:

- To encourage potential bicyclists by informing them of the benefits of bicycling;
- To provide information about bicycle safety and operating a bicycle in motor vehicle traffic;
- To inform bicyclists and motorists of their legal rights and obligations for operating under the same rules and regulations; and
- To provide training for potential bicyclists.

***Provide incentives and eliminate disincentives for bicycling***—At a minimum, various incentives can be provided to bicyclists, or disincentives can be eliminated, to encourage bicycling. Disincentives to bicycling that should be eliminated include things such as:

- muddy paths;
- no space for bicycles on high-speed roadways;
- hazardous roadway conditions such as debris or drainage grates; and
- no bicycle parking/racks.

Incentives that can be provided to encourage bicycling include things such as:

- travel time savings compared to motor vehicle travel (due to dedicated facilities, location of parking, etc.);
- aesthetic and/or recreational value, such as shared-use paths along greenways;
- convenient access to businesses; and
- shower and changing facilities at workplaces.

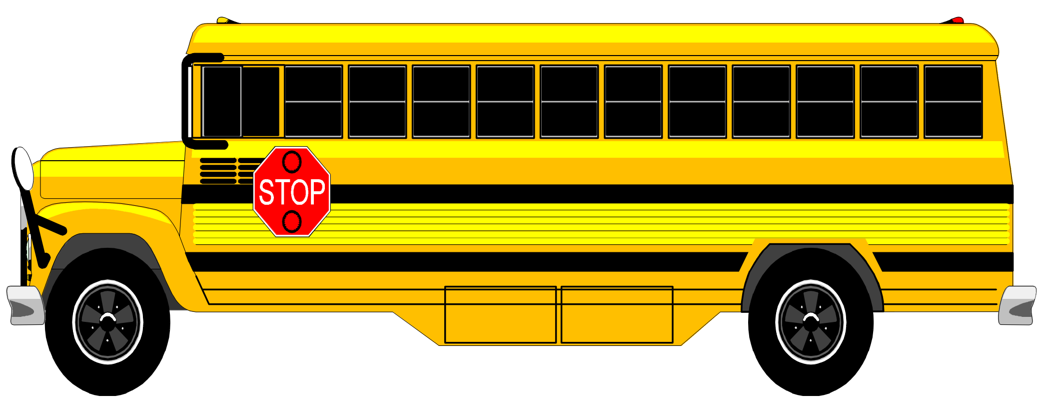
# Bus Signs

***What is the law concerning school buses?***

School buses can be identified by their unique yellow/orange color; black "SCHOOL BUS" and number or district markings in black; and the red and yellow (and now strobe) lights at the top of the bus.

When meeting a school bus with *red* flashing lights, you must stop when approaching the bus from either direction. School bus drivers usually flash yellow warning lights before  stopping to load or unload passengers; when you see them, slow down and prepare to stop.  Once stopped for a school bus, you may not proceed until the red lights stop flashing or until a traffic officer waves you on.

If you are driving on a separate roadway from the one the school bus is on, you do not need to stop when passing or meeting a school bus.  Also, you don't have to stop if you are traveling on a controlled access highway and the school bus is stopped in a loading zone which is part of or adjacent to the highway and where pedestrians are not allowed to cross the roadway.



***Why include this?***

The School Bus Stop Ahead sign may be used when a school bus stopped to load or unload passengers is not visible for a distance of 500 feet in advance. This sign is not intended for use everywhere a school bus stops: it should be used *only* where terrain and roadway features limit the sight distance and where there is no opportunity to relocate the stop to another location with adequate visibility.

# Citizen Participation

***What can a citizen do to help reduce traffic accidents?***

A primary goal of any traffic engineer is to make our roadways as safe as possible. The public plays an important role in achieving that goal. Road users, whether they are driving, walking or cycling, are our eyes in the street.

Citizens can do their part to help reduce the high cost of traffic crashes by taking the following actions:

- **Drive Carefully** - Concentrate on driving and use seat belts; do not speed or drink while driving.
- **Don't Take Chances** - Play it safe. Drivers should not try to "beat the light" or "beat the train" at railroad crossings. Drive defensively at all times.
- **Report Roadway Hazards** as soon as possible to city, county or state officials responsible for road maintenance and safety. Roadway hazards that should be reported are:

  . Traffic signs down or damaged.
  . Traffic signal malfunctions.
  . Traffic signs obstructed by vegetation.
  . Street lights that are burned out.
  . Shoulder washouts.
  . Obstructions, potholes, bumps or dips in roadway.
  . Water ponding on roadway.

- **Property Owners Should Keep Vegetation Trimmed** to ensure that good intersection and driveway sight distances are provided and that traffic control signs and signals are visible.

- **Report Acts of Vandalism** to law enforcement, traffic engineering and maintenance officials.
- **Support Traffic Safety Officials** to ensure that they have adequate budgets for staff, equipment and supplies to do their jobs properly.
- **Turn on Vehicle Headlights** between dusk and dawn and anytime visibility is reduced by rain, smoke, fog, etc.
- **Keep Vehicles in Good Mechanical Condition** by regularly checking brakes, tires, wipers and other safety equipment.
- **Obey Traffic Control Devices** such as signs, signals and pavement markings. These devices were installed to enhance safety.

# Construction Signs

***Why are those orange signs around road construction sites?***

Whenever work is done on or near the roadway, drivers are faced with changing and unexpected traffic conditions. These changes need to be conveyed to motorists, bicyclists, and pedestrians to ensure their safety and protect the workers.

Drivers and pedestrians should take special care to observe signs, signals, pavement markings and flaggers near roadway construction sites. Special traffic control devices (usually a black legend on an orange background) are installed to assist and safely guide and protect motorists, bicyclists, pedestrians and workers in a work zone and warn them of unexpected roadway or traffic conditions.

Most traffic control zones are divided into the following areas:

- Advance Warning Area - tells drivers what to expect.
- Transition Area - begins to move traffic from its normal area.
- Buffer Space - provides protection for traffic and workers.
- Work Area
- Termination Area - directs drivers to resume normal driving.

Construction and maintenance warning signs are a special series with the black legend on an orange background. The orange color is used to indicate the temporary nature of the condition and the additional potential hazard of the worksite. Traditionally, work activities have included construction, maintenance, and

| | |
|---|---|
| utility operations. However, orange color warning signs have application for all work activities within the right of way such as survey crews or temporary weighing stations. | Construction detour routing signs may have a black legend on an orange background. Special information signs relating to the work being done must also have a black message on an orange background. |

# Four-Way Stop Signs

***Why can't we have an all-way stop to reduce accidents?***

Many people believe that installing STOP signs on all approaches to an intersection will result in fewer accidents. Effects of unwarranted stop signs on driver behavior and safety are difficult to substantiate. Also, there is no real evidence to indicate that STOP signs decrease the overall speed of traffic. Impatient drivers view the additional delay caused by unwarranted STOP signs as "lost time" to be made up by driving at higher speeds between STOP signs. Unwarranted STOP signs breed disrespect by motorists who tend to ignore them or only slow down without stopping. This can sometimes lead to tragic consequences.

Generally, every State requires the installation of all traffic control devices, including STOP signs, to meet state standards of the Department of Transportation. The state standards are based on the Manual on Uniform Traffic Control Devices (MUTCD). The MUTCD is published by the U.S. Department of Transportation, is the national standard for traffic control devices. The MUTCD prescribes standards for the design, location, use and operation of traffic control devices.


The installation of multi-way stop control must first meet the warrants as set forth in the MUTCD. Any of the following conditions may warrant an all-way STOP sign installation:

1. Where a traffic signal is warranted, multi-way stop control is an interim measure that can be implemented

quickly to control traffic until the signal is designed and installed.

2. The occurrence within a twelve-month period of five or more reported accidents of a type susceptible to correction by multi-way stop control. Such accident types include turn collisions, as well as right-angle collisions.

3. Total vehicular volume entering the intersection from all approaches must average 500 vehicles per hour for any eight hours of an average day and the combined vehicular and pedestrian volume from the minor street or highway must average at least 200 units per hour for the same eight hours, with an average delay to minor street vehicular traffic of at least 30 seconds per vehicle during the maximum hour. However, when the 85th percentile speed of traffic approaching on the major street exceeds 40 miles per hour, the above minimum volumes are reduced to 70 percent.

STOP signs should not be viewed as a cure-all for solving safety problems but, when properly located, can be useful traffic control devices to enhance safety for all roadway users.

# HOV Lanes

***What is an HOV Lane?***

In recent years, high-occupancy vehicle (HOV) lanes have become a successful alternative transportation mode in areas with heavy traffic congestion. HOV lanes are sometimes termed commuter lanes, busways, or transitways. Although known by several names, they all refer to one or more roadway lanes allocated for special use. Special use may be defined in several ways, including passenger vehicles with 2 or 3+ people, transit vehicles, and sometimes motorcycles, taxis, or trucks. Priority pricing, allowing single-occupant vehicles to "buy into" HOV lanes, is also being evaluated.

HOV facilities may be used to improve the mobility of a corridor by:

- Increasing the people-moving capacity of the facility;
- Providing a reliable travel-time savings to HOV users; and
- Providing an incentive for people to share rides.


The basic concept of an HOV lane is to encourage an increase in the number of persons traveling in a vehicle by providing a reliable travel time savings to select vehicles (e.g., buses, vanpools, and motorcycles) or other vehicles meeting the minimum occupancy requirement. The occupancy requirement may be as low as 2 persons per vehicle, or may be as high as 4 persons. Increasing the number of HOVs in the corridor increases the average vehicle occupancy for the entire freeway. The increased person-movement results in improved freeway travel times during peak periods, improved transit service, and improved overall traffic flow. It may also decrease overall fuel consumption and vehicle pollution.

There are essentially four different types of high-occupancy vehicles (HOV) lanes used on freeways:

- **Exclusive HOV Facility - Separate Right-of-Way.** A roadway or lane(s) developed in a separate and distinct right-of-way and designated for the exclusive use of HOVs.
- **Exclusive HOV Facility - Freeway Right-of-Way.** Roadways or lanes built within the freeway right-of-way which are physically separated from the other freeway lanes but reserved for exclusive use by HOVs, at least during portions of the day.
- **Concurrent Flow Lane**. A freeway lane in the peak direction of flow (normally the inside lane) that is not physically separated from the other freeway lanes but is designated for use by HOVs at least for a portion of the day.
- **Contraflow Lane**. A freeway lane in the off-peak direction of flow (normally adjacent to the median) that is designated for use by HOVs traveling in the direction of peak flow for at least a portion of the day. Normally, the contraflow lane is "separated" from the off-peak (or opposite) flow by insertable cones or pylons.

# Lower Speed Limits

***Why not lower the speed limit to reduce hazards in our area?***

An unrealistically low speed limit can actually lead to accidents. Here's why:

- First, many studies conducted over the last several decades in all parts of the country have shown that a driver's speed is influenced more by the appearance of the roadway and the prevailing traffic conditions than it is by the posted speed limit.
- Second, some drivers will obey the lower posted speed while others will feel it's unreasonable and simply ignore it. This disrupts the uniform traffic flow and increases accident potential between the faster and the slower drivers. Research has shown that when vehicles travel about the same speed, accidents are minimized.
- Third, when traffic is traveling at different speeds, the accuracy of the judgement of speeds by crossing pedestrians and motorists decreases.

<u>State Speed Laws</u>


Although each state has its own separate set of laws, speed limit laws are generally derived from very similar language. For instance, the foundation for most speed limits laws generally states that "No person shall drive a vehicle on a highway at a speed greater than is reasonable and prudent under the conditions, and having regard to the actual and potential hazards, then existing."

# Maximizing Transportation Operations

***What can be done to provide a safe and efficient transportation system in existing or new development corridors?***

Traffic engineers are striving to provide roadway conditions that contribute to smooth and efficient traffic flow. Experience has shown that safety is enhanced by smooth traffic flow. Disrupting the smooth flow of traffic increases the probability of accidents.

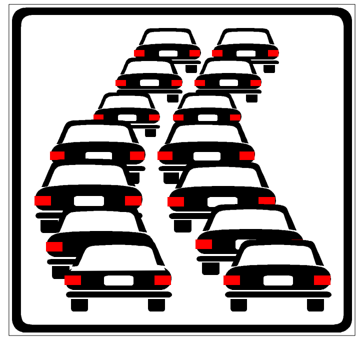
Erratic traffic operation may be caused by vehicles stopping or slowing in the roadway, passing and weaving maneuvers, uncoordinated or poorly timed traffic signals, the lack of guide signs, and unreasonably low speed limits. Slower speed does not insure safer traffic operation. The chances of a vehicle becoming involved in an accident are less when the driver is traveling at the average speed of traffic.

The population growth in many areas poses great challenges for traffic engineers. These engineers are utilizing many traffic management techniques to ease and optimize traffic operations. These techniques include the following:

- Interconnecting traffic signals located within close proximity of each other on a major street.
- Installing computerized signal systems to improve traffic flow.
- Limiting the number of driveways from new development.
- Increasing spacing between driveways.
- Limiting indiscriminate access to major roads by requiring connecting drives between adjacent shopping centers.
- Providing access to driveways at signalized access points.
- Providing adequate turning radii at driveways, to ease turning into entry and exit roads.
- Providing turn lanes when needed.
- Providing traffic control devices such as signs, pavement marking, and signals where necessary.
- Installing bikeways and sidewalks where needed.

- Reducing new demand on the highway system by implementing techniques such as ride sharing and alternative work hours.
- Promoting mass transit where feasible.

Direct benefits to the public include improved safety and air quality and reduced travel cost due to a decrease in travel time. Safety can be enhanced by improving the uniformity of traffic flow and reducing the number of vehicles on the roadway. Air quality can be improved by reducing the number of stops and motorized vehicles on the road. Travel cost can be reduced by minimizing delays at traffic signals and in heavy traffic congestion.



# Median Treatments

***Why are two-way left-turn lanes and raised medians used?***

The two most commonly used median treatments on urban and suburban arterials are two-way left-turn lanes (TWLTLs) and median islands. TWLTLs are typically employed in areas of moderate to intense roadside development where the demand for mid-block left turns is currently (or expected to be) high. With a TWLTL, left-turn access can be provided at any point along the roadway. For this reason, they are typically used on arterials where there are frequent and randomly organized access points. On the other hand, raised medians present a physical barrier to drivers and, as such, cannot be easily traversed. For this reason, raised medians are often used where it is desirable to prevent mid-block left turns. On roadways with raised medians, left-turn maneuvers are concentrated at established openings in the median or at signalized intersections.

Both of these types of median treatments have advantages and disadvantages in terms of operations and safety. The primary advantage of a raised median is that left-turning traffic can be concentrated at established median openings. Raised medians have been found to reduce crashes 25 to 40 percent, depending on traffic volumes. This makes it easier to regulate crossing traffic. In addition, raised medians can be used to provide a refuge area for pedestrians crossing the roadway.

The primary disadvantage of a raised median, however, is that it often increases the amount of travel time and delay experienced by some left-turning traffic. Because a raised median forces left-turns to occur at established openings only, some left-turning motorists must travel circuitous routes to reach their destination. This can lead to undesirable turning movements (e.g., u-turns on roadways with insufficient width) and unwanted travel patterns (e.g., traffic entering neighborhood areas). In addition, the raised median island can pose a potential safety hazard on streets serving high-speed traffic. If accidently struck, a raised median could cause the driver to lose control of the vehicle. Furthermore, a raised median (particularly a narrow island) may be difficult to see at night unless a fixed lighting source is provided. The main advantage of a TWLTL is that it provides a storage area for left-turning vehicles as they wait for gaps in the opposing traffic stream. This not only improves the operations of through traffic by removing the left-turning vehicle from the traffic stream, but also reduces the potential for read-end accidents. When TWLTLs are installed on two-lane, undivided facilities, they have been found to reduce accidents by approximately 35 percent in suburban areas and from 70 to 85 percent in rural areas. Since turning traffic is not physically restricted in any way with TWLTLs, drivers can take more direct routes when entering and exiting adjacent properties. For this reason, drivers and adjacent property owners generally prefer TWLTLs over raised medians.

# Right of Way Regulations

***What gives a public agency the right to dig up my front yard?***

Ask a homeowner where they believe the property line is in front of their house. In general, many will say that their property line ends at the curb or sidewalk.

In fact, a homeowner's property line ends somewhere behind the curb or sidewalk. If there is no sidewalk, then it ends a number of feet behind the edge of the traveled way or shoulder. The line that denotes the private/public property split is known as the right-of-way line.

Although the sidewalk lies on the public property side, most towns charge the maintenance (i.e., shoveling of snow and keeping it free from obstructions) of the sidewalk and grassy area to the homeowner.

The county or municipality has the right to excavate or widen the roadway as required for maintenance or rehabilitation work. (NOTE: Different municipalities or states may have different statutes or jurisdictional responsibilities. Consult you town or borough engineer for specific responsibilities and ownership issues).

If the road work extends onto private property, then an agreement (known as an easement) is drafted between the public agency and the homeowner. This easement can be a temporary one (for construction, etc.) or a permanent one (for drainage inlets, pipes, etc.). In any event, no public agency (except of course, police and fire) has the right to infringe upon private property. In all cases, the owner must be contacted for permission. The nature of the work or project is explained to the owner along with the anticipated duration.

Sometimes, it is necessary for a public agency to acquire a piece of private property to facilitate a roadway improvement. In this case, the piece of property needed is bought by the public agency. The piece of property in question is assessed for value by the public agency and the appropriate documents are prepared (i.e., property acquisition mapping). The price set is agreed upon by both the public agency and the owner. Legal mechanisms are available to resolve disputes should both parties be unable to agree upon the fair market value of the property in question. Once bought, a new right-of-way line is indicated on appropriate documents (tax maps, etc.) and the once private property now becomes public property.

In conclusion, a public agency does have the right to "dig up" someone's front yard, provided the agency remains within its right-of-way. Right-of-way lines are often behind the actual roadway or curb line and facilitate maintenance and rehabilitation efforts, such as future widening of the road, if required. At no time can a public agency excavate or work on private property without first obtaining consent from the owner. Although sidewalks are within the public right-of-way, the owner of the property is usually responsible for sweeping them and removing snow.

# School Zones

***What is the law with regard to school speed zones?***

Reduced speed limits may be desirable or necessary for school zones during the hours when children are going to and from school. Usually such school speed zones are only considered for schools located adjacent to highways or visible from highways. Pedestrian crossing activity is usually the primary basis for reduced school speed zones.

Generally, each state's laws governing School Zones can be found in that state's Vehicle and Traffic Law literature. These laws typically include limitations in the amount of speed reduction and the reduced speed zone location.

Once a reduced speed zone for a school area has been established (in accordance with law, after an engineering study or traffic investigation), the school speed limit sign is installed with two supplemental plaques. Above the speed limit sign, a black on yellow sign reads "School." Below the speed limit sign, a black on white supplemental plaque defines when the school speed limit shall be enforced. Flashing beacons may also be added to the sign with the bottom mounted plaque reading, "When flashing."


In addition to the school speed limit sign, the School Advance Warning Sign may be used to in advance of established school crossings not adjacent to a school ground. Where used, the sign is generally erected 150 to 700 feet in advance of the crossing.

**School Crossing Sign**

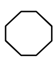
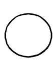
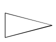
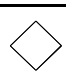
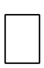
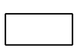
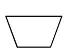
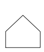
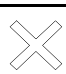
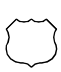
The school crossing sign, sometimes confused with the school advance sign, is intended for use at established crossings including signalized intersections used by pupils going to and from school. The sign should be omitted at crossings controlled by stop signs. Only crossings adjacent to schools and those on established school pedestrian routes shall be signed.

**School Advance Sign**

# Sign Shapes

***Why are traffic signs different shapes?***

Traffic signs convey information to travelers through their shape, color, message, and placement. The standard sign shapes and their respective meanings are:

| | |
|---|---|
|  | Octagon—Exclusively for STOP signs |
|  | Equilateral Triangle, Point Down—Exclusively for YIELD signs |
|  | Circle—Exclusively for Railroad Advance Warning Signs and Civil Defense Evacuation Route Signs |
|  | Pennant—Exclusively for NO PASSING ZONE signs |
|  | Diamond—Used for warning signs |
|  | Rectangle, Longer Dimension Vertical—Used for regulatory signs |
|  | Rectangle, Longer Dimension Horizontal—Used for guide signs |
|  | Trapezoid—Used for recreational area guide signs |
|  | Pentagon—Used for school advance and crossing signs |
|  | Crossbuck—Used for railroad crossing signs |
|  | Other shapes—Used for route marker signs The objective of traffic signs is to convey traffic control information to the driver viewing them on the roadway. |

# Speed Humps

***Can speed humps be installed on my street?***

A speed "hump" is a raised area in the roadway pavement surface extending transversely across the travel way. Not to be confused with a speed hump, a speed "bump" is a raised area in a private driveway or parking lot.


Speed hump dimensions and characteristics vary from agency to agency. They are typically 12 foot long by 3 to 4 inches high and are usually placed across the roadway between intersections. They are typically requested by residents as a means to slow traffic in residential neighborhoods or decrease the amount of "cut-though" traffic. In general, speed humps may:

1. Reduce traffic speeds in the immediate vicinity of the speed humps,
2. Decrease traffic volume, and
3. Reduce accidents in some areas.

At the same time, however, speed humps may also have the following detrimental effects:

1. Divert traffic to other neighborhood streets thereby moving the problem rather than solving it,
2. Increase noise level due to vehicle brakes, tires and engine,
3. Increase vehicle emissions due to deceleration and acceleration,
4. Increase response time of emergency vehicles,
5. Conflict with school and transit bus operation,
6. Present a potential hazard to bicyclists and motorcyclists.

Most agencies have a Speed Control Plan which either advocates the use of speed humps as a system wide tool to reduce speeds and/or vehicular volumes or eliminates their use unconditionally. When determining whether to install speed humps, the following restrictions may apply:

1. Streets serving transit buses.
2. Streets with daily traffic volumes above some predetermined threshold.
3. Streets designated as collector streets.
4. Rural roads.

The Institute of Transportation Engineers has developed a report covering the design and application of speed humps. The report (*Guidelines for the Design and Application of Speed Humps*) was prepared by the ITE Technical Council Speed Humps Task Force in 1995. It can be obtained by contacting ITE headquarters at 202/554-8050.

# Speed Limits

***How are speed limits established?***

In general, the governing body which has jurisdictional control over a roadway has the power to establish the speed limit for that roadway. This is done by adopting a resolution or by passing an ordinance to establish the speed limit. The State's Department of Transportation gives the final authority to establish and enforce the speed limit.


The matter of establishing the posted speed limit for a given roadway is a serious concern for the traffic engineer. It is based in part upon the characteristics of the roadway and its associated design speed. The design speed defines the values used for the design of a particular road and includes elements such as curve radii, stopping sight distance, and lengths of merges and tapers.

Speed limits are also established in part by the drivers themselves. In order for a speed limit to be effective, it must be reasonable to the driver. Most drivers tend to regulate the speed of their vehicle relative to traffic, road and weather conditions.

For a speed limit to be effective, the majority of the drivers must voluntarily comply with the law. It has been determined that the speed at which 85 percent of the motorists travel is reasonable and safe. The determination of the 85 percentile speed is made by conducting a speed survey of vehicles traveling along the roadway in question during normal operating conditions. Therefore, basing the speed limit upon this 85th percentile speed will insure a higher level of compliance and create a reasonable uniform flow of traffic.

Other factors which are also used in making a determination of the posted speed limit include road surface characteristics, shoulder condition, grade (i.e., steepness of the road), roadside development, parking practices, pedestrian activity, and accident experience.

Once the engineering study has been completed and forwarded to the proper governing bodies for passage and approval, the required signs are then posted. Their placement and installation conforms to the Manual on Uniform Traffic Control Devices (MUTCD), which serves as the standard for the design, placement and installation of all traffic control devices.

Speed limits cannot be posted in excess of legislatively mandated speed limits. From 1974 to 1995, the U.S. Congress also imposed the 55 mph National Maximum Speed Limit (NMSL). In 1995, Congress repealed the NMSL and returned control of maximum speed limits to the states.

# Stop Sign and Bar Placement

***Where should a stop sign and stop bar (line) be placed at an intersection?***

In placing a STOP sign at an intersection, visibility of the sign by the motorist is of prime concern. The STOP sign should not be blocked by other signs or vegetation. It is placed on the right hand side of the traffic lane to which is applies. In cases where the road is wide, an additional STOP sign is placed on the left side of the road.

Where two roads intersect at an acute angle, the STOP sign is positioned at an angle, or shielded, so that the message is out of view of traffic to which it does not apply.

In order to provide adequate lateral clearance for the motorist who may leave the roadway in rural areas and strike the sign support, a STOP sign should be located at least 6 feet from the edge of the shoulder or if there is no shoulder, 12 feet, with a maximum of 14 feet from the edge of the traveled way. The height to the bottom of the STOP sign in rural areas should not be less than 5 feet or more than 8 feet above the edge of the roadway.

In urban areas a lesser lateral clearance may be used where necessary. Although 2 feet is recommended as a working minimum, a clearance of 1 foot from the curb face is permissible where sidewalk width is limited or where existing poles are close to the curb. The height of the bottom of a STOP sign in urban areas should not be less than 7 feet or more than 8 feet above the top of the curb.

In the case of stop bars, the MUTCD indicates that a stop bar (line) is a solid white line, normally 12 to 24 inches wide, extending across all approach lanes to a STOP sign or traffic signal. A stop bar should be placed parallel to the centerline of the intersecting street. A stop bar should be used in both rural and urban areas where it is important to indicate the point, behind which vehicles are required to stop, in compliance with a STOP sign, traffic signal, officer’s direction, or other legal requirement.

A stop bar, when used, should ordinarily be placed 4 feet in advance of and parallel to the nearest crosswalk line. In the absence of a marked crosswalk, the stop bar should be placed at the desired stopping point and in no case more than 30 feet or less than 4 feet from the nearest edge of the intersecting roadway.

When a stop bar is used in conjunction with a STOP sign, it should be placed in line with the STOP sign. However, if the STOP sign cannot be located exactly where vehicles are expected to stop, the stop bar should be placed at the desired stopping point. Finally, the stop bar should be placed so that vehicles have optimum sight distance along the intersecting roadway.

# Stop Signs

***How do you decide where to install STOP signs?***

STOP signs are traffic control devices that drivers encounter every day. They impose an inconvenience on the driver that cannot be ignored. Many drivers feel that more or fewer STOP signs are needed depending on the location and the time of day. Since they impose a significant amount of control over traffic, traffic engineers are very selective about STOP sign installation.

In order to ensure that the advantages of installing a STOP sign outweigh the disadvantages, and to provide some consistency in the application of STOP signs, four warrants have been developed that define the ***minimum*** conditions under which further consideration of a STOP sign is appropriate. Using these warrants, traffic engineers look at an intersection based on various criteria:


- Does a minor road intersect a major road where application of normal right-of-way rule is particularly hazardous?
- Does a street enter a through highway or street?
- Is the intersection an unsignalized one in a signalized area?
- Does the combination of high speed, restricted view, and serious accident history indicate a need for a STOP sign?

If one or more of these criteria describe the intersection, the traffic engineer then determines if a STOP sign is the best solution for the problem. It is important to note that a STOP sign should not be installed unless it meets one or more of the warrants. However, if an intersection meets a warrant, a STOP sign does not have to be installed. The engineer should consider lesser control of the intersection, such as a YIELD sign, before installing a STOP sign.

Some intersections may require a multi-way STOP sign installation as a safety measure. There are three warrants to help determine if multi-way STOP signs are needed at an intersection. The engineer performs the same analysis as that for two-way STOP signs.

Many citizens believe that installing a STOP sign at an intersection will control speed along the roadway. However, unwarranted STOP signs can actually create other problems both at the intersection and along the roadway. When unwarranted STOP signs are used, drivers must stop more frequently. Thus, they tend to drive faster between intersections in order to save time. Unwarranted STOP signs also encourage disobedience and the use of alternate, inadequate routes.

Properly located STOP signs can have various benefits. Aside from providing orderly traffic movement, they can reduce some types of accidents and allow minor street traffic to enter or cross a major roadway. Thus, before installing a warranted STOP sign, an engineer should determine that the STOP sign will improve the overall safety and/or operation of the intersection.

# Traffic Engineering

***What is traffic engineering?***

The Institute of Transportation Engineers defines traffic engineering as “that phase of engineering which deals with the planning, geometric design and traffic operations of roads, streets and highways...their networks, terminals, abutting lands and relationships with other modes of transportation...for the achievement of safe, efficient and convenient movement of persons and goods.”

When roads and streets were built many years ago, the biggest task facing the road builder was to keep them passable in all types of weather. The problem of moving large numbers of cars and parking them was not significant. As the number of cars increases, taxing the capacity of our streets and highways, the field of traffic engineering has become increasingly prominent.

Each year more people own and operate cars. Urban growth has increased the need for improving the movement of people and goods. Funding for new facilities has decreased due to resistance to higher taxes as well as energy and environmental concerns. This has resulted in an increased emphasis on finding ways to better use the existing road system as well as finding ways to better move people and goods. Examples of alternative solutions to these challenges include promoting travel during off-peak hours and the use of public transportation.

The traffic engineer is concerned with groups and individuals and their needs, desires, actions, characteristics, capabilities and limitations as related to the roadway system. Decisions made by the traffic engineer affect drivers, passengers, and pedestrians.

# Traffic Sign Colors

***Why are traffic signs different colors?***

The objective of traffic signs is to convey traffic control information to the driver. One manner in which signs accomplish this objective is through color. Each color used on a sign has a general meaning attached to it. Thus, the color alerts the driver of what to expect ahead.

The Manual on Uniform Traffic Control Devices (MUTCD), a document published by the U.S. Department of Transportation, establishes standardized meanings for each color used in traffic signs. It also reserves three other colors for future use. The color code is as follows:

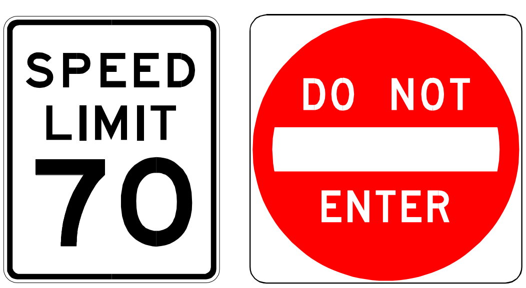
| COLOR | MEANING |
|---|---|
| Yellow | General Warning |
| Red | Stop or Prohibition |
| Blue | Motorist Services Guidance |
| Green | Indicated Movements Permitted, Direction Guidance |
| Brown | Recreational and Cultural Interest Guidance |
| Orange | Construction and Maintenance Warning |
| Black | Regulation |
| White | Regulation |
| Strong Yellow-Green | Pedestrian, Bicycle, and School Crossings |
| Purple | Unassigned |
| Light Blue | Unassigned |
| Coral | Unassigned |

# Traffic Sign Types

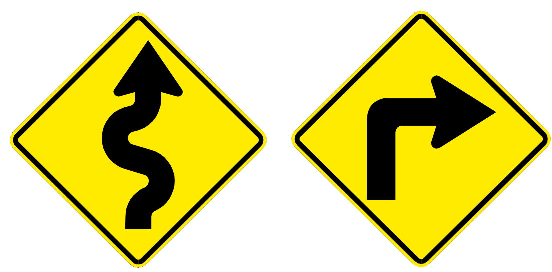
***Traffic signs are classified as:***

- regulatory signs
- warning signs, and
- guide signs.

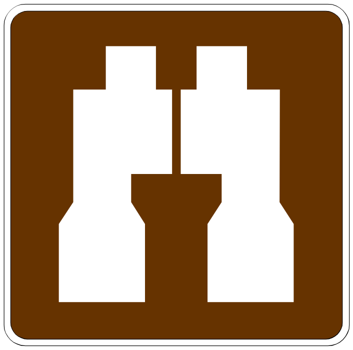
Regulatory signs give notice of traffic laws or regulations. Regulatory signs (except of STOP and YIELD signs) are typically rectangular in shape with the long dimension vertical. The standard color scheme is black lettering on a white background. A red circle with a white diagonal line may be used in conjunction with a black diagram to indicate a prohibited maneuver. Red is used as a predominant color for STOP, YIELD, DO NOT ENTER, and WRONG WAY signs.




Warning signs call attention to conditions on, or adjacent to, a highway or street that are potentially hazardous to traffic operations. These signs are used particularly when the hazard is not obvious or cannot be seen by the motorist. Warning signs are typically diamond-shaped and have a black legend on a yellow background.



Guide signs show route designations, destinations, directions, distances, services, points of interest, and other geographical, recreational, or cultural information. Destination guide signs typically have white lettering on a green background. Service and recreational signs have blue and brown backgrounds, respectively. Other guide signs such as route designations may use a variety of colors depending on the type of road and state or local practice.

# Traffic Signal Warrants

***What are traffic signal "Warrants?"***

In order to ensure that the advantages outweigh the disadvantages of installing a traffic signal, and to provide some consistency in the application of traffic signals, a series of warrants has been developed to define the ***minimum*** conditions under which further consideration of a traffic signal is appropriate. Simply meeting the warranting criteria does not mean that a signal is justified at a given location. There are many factors that impact the effectiveness of a signal, and all should be evaluated before a decision to install a signal is made. However, failure to meet any of the warranting criteria indicates that a traffic signal should not be installed, as there should be a better way of addressing the problems or needs at that location. Furthermore, if an existing traffic signal no longer meets any of the warrants, it should be removed. The traffic signal warrants currently contained in the national Manual on Uniform Traffic Control Devices (MUTCD) are summarized below. It is important to note that your local or state transportation agency may have modified or added additional warrants to the list below.

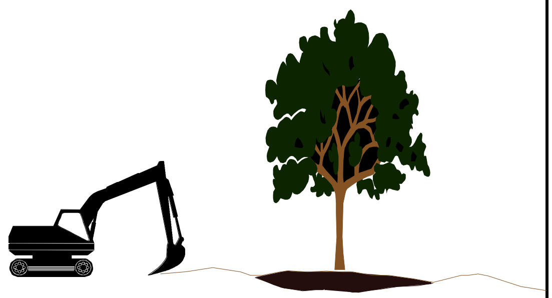
| **Number and Title** | | **Basis** |
|---|---|---|
| 1 | Minimum Vehicular Volume | 8-hour volumes |
| 2 | Interruption of Continuous Traffic | 8-hour volumes |
| 3 | Minimum Pedestrian Volume | 4-hour pedestrian volumes and gaps |
| 4 | School Crossing | number of school children and gaps |
| 5 | Progressive Movement | signal progression |
| 6 | Accident Experience | accidents and warrant #1, #2 or #3 volumes |
| 7 | Systems Warrant | volumes |
| 8 | Combination of Warrants | volumes and pedestrians |
| 9 | Four Hour Volume | 4-hour volume |
| 10 | Peak Hour Delay | volume and delay on minor street |
| 11 | Peak Hour Volume | 1-hour volume |

# Tree Removal

***Why do they have to remove those trees next to my roadway?***

One of the most critical elements of design in considering the layout of a driveway or intersection is sight distance. The amount of sight distance required for a given circumstance is dependent upon a number of factors, including posted speed limit, and curves and hills. However, in all cases, clear and unobstructed sight of vehicles on both the travel way and intersecting street or driveway is of paramount concern.

When trees were planted years ago, many of the current safety design standards did not exist. At the time the trees were planted, consideration was not given as to whether or not the line of sight to a driver would be impeded or whether motorists would hit the trees. Now, as the trees reach full maturity, their location may block a driver's line of sight. Since the safety criteria for sight distance have been established, it becomes necessary to remove trees which cause a hazard to drivers by impeding their line of sight or creating a hazard along the side of the raod..



Design engineers try to save as many of the existing trees as possible when redesigning a road or planning driveway access, recognizing the aesthetic value of older trees. However, safety and proper design always take precedence. In many instances, when older trees need to be removed they are replaced with new plants. The new trees are planted in locations that will not impede a driver's line of sight now or in the future.

Besides blocking a driver's line of sight, consideration must also be given to errant vehicles that may stray from the travel way. If trees are immediately adjacent to the roadway (or in some instance actually encroach into it), the potential for an accident involving serious injury is greatly increased. Therefore, a clear (or recovery) zone is often an integral part of proper roadway design. The amount of space required in the zone is related directly to speed.

In summary, trees can serve to beautify a roadway as well as cause the potential for serious accidents by either impeding sight or from errant vehicles striking them. The design engineer must use established guidelines, practices and standards when considering the layout of a driveway or intersection. These criteria are the minimum requirements which must be satisfied to ensure a proper design; it is encouraged that these minimum criteria be exceeded whenever possible. Although every attempt is made to preserve as many existing trees as possible, they must sometimes be removed if their location prevents fulfilling these requirements.

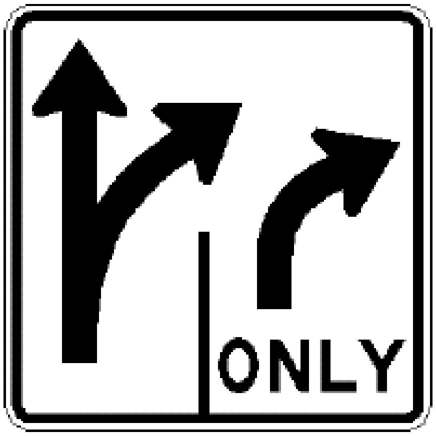
# Turn Lanes

***Why are turn lanes used?***

Turn lanes at intersections are used primarily to separate turning traffic from through traffic. With turn lanes, vehicles waiting to turn are removed from the through lanes thereby reducing delay to through traffic. Turn lanes can also be used by vehicles as a deceleration area when leaving the major street.

By removing turning vehicles from the through lane, turning lanes can also improve safety. Studies have shown that providing turn lanes for left-turning vehicles can reduce accidents by an average of 32.4 percent. Personal injury accidents involving left-turning vehicles can be decreased by as much as 50 percent. Intersection channelization projects have been shown to produce an average benefit/cost ratio of 2.31.

Although, the treatment of right-turning vehicles is generally less critical than left-turning vehicles, separating right-turning vehicles from other traffic can significantly affect operations at an intersection. By adding a separate right-turn lane at a signalized intersection, the delay experienced by drivers on an approach can be reduced. At unsignalized intersections, right-turn lanes can serve to safely remove turning vehicles that are decelerating from the through traffic lanes.




Turn lanes at major driveways can also improve efficiency and safety, especially on high volume or high speed roadways. When turn lanes are added, studies have shown a 52% decrease in rear-end accidents as well as 6% decrease in left-turn accidents.

# APPENDIX G

## Intersection Safety Briefs

These briefs concerning intersection safety were developed by the Federal Highway Administration, Advocates for Highway and Auto Safety, and the Institute of Transportation Engineers.

1. The National Intersection Safety Problem
2. Basic Countermeasures to Make Intersections Safer
3. Pedestrian Safety at Intersections
4. Human-Factors Issues in Intersection Safety
5. Intersection–Safety Enforcement
6. Traffic Control Devices: Uses and Misuses
7. Red-Light-Running Issues
8. Red-Light Cameras
9. Workzone Intersection Safety
10. Intersection Safety: Myth Versus Reality
11. Intersection Safety Resources

Intersection Safety Brief

Introduction

# Intersection Safety Briefing Sheets: An Introduction

This toolkit contains a series of briefing sheets on various intersection safety-related topics. The purpose of this toolkit is to enhance communications with the media, decision-makers, the general public and others about intersection safety. The primary audiences are decision makers and officials who are called upon to comment or make decisions on intersection issues, including:

- Chief Administrative Officers of Departments of Transportation;
- Mayors and other local officials;
- Traffic and safety engineers at the federal, state and local levels; and
- Law enforcement officers, predominantly at the State and local levels.

The briefing sheets could also be used by a far wider audience of people and organizations who want to promote intersection safety within their area of influence.

The topical areas that are included within this intersection safety communications toolkit include:

- The National Intersection Safety Problem
- Basic Countermeasures to Make Intersections Safer
- Pedestrian Safety at Intersections
- Human-Factors Issues in Intersection Safety
- Intersection Safety Enforcement
- Traffic Control Devices: Uses and Misuses
- Red-Light-Running Issues
- Red-Light Cameras
- Workzone Intersection Safety
- Intersection Safety: Myths versus Reality
- Intersection Safety Resources

The intersection safety briefing sheets are available in print form and electronically on the Federal Highway Administration and Institute of Transportation Engineers Web sites (see below). The briefing sheets are available for other organizations to use and post on their Web sites. The goal is to provide this information to the widest audience possible within the education, law enforcement, and engineering communities and to the general public.

To provide comments on this toolkit or suggestions for additional Intersection Safety topics, or to request additional print copies of the completed toolkit, please contact:

**Patrick Hasson**
Federal Highway Administration
19900 Governors Dr.
Suite 301
Olympia Fields, IL 60461
Tel: 708-283-3595
Fax: 708-283-3501
Email: patrick.hasson@fhwa.dot.gov

**Edward Stollof**
Institute of Transportation Engineers
1099 14th Street, NW
Suite 300 West
Washington, D.C. 20005-3438
Tel: 202-289-0222 ext. 132
Fax: 202-289-7722
Email: estollof@ite.org

# The National Intersection Safety Problem

Intersection safety is a national priority for numerous highway-safety organizations. Driving near and through intersections is one of the most complex conditions drivers will encounter.

In 2000, more than 2.8 million intersection-related crashes occurred, representing 44 percent of all reported crashes. About 8,500 fatalities (23 percent of total fatalities) and almost one million crashes with injuries occurred at or within an intersection. The cost to society for intersection-related crashes is approximately $40 billion a year.[1]

## Identifying the Problem

Intersections are areas of highways and streets that produce conflicts among vehicles and pedestrians because of entering and crossing movements. Reducing fatalities and injuries can be accomplished through a combination of efforts, including the careful use of good road design, traffic engineering, comprehensive traffic safety laws and regulations, consistent enforcement efforts, sustained education of drivers and pedestrians, and a willingness among drivers and pedestrians to obey traffic safety laws.

**In 2000, more than 2.8 million intersection-related crashes occurred, representing 44 percent of all reported crashes. About 8,500 fatalities (23 percent of the total fatalities) and almost one million injury crashes occurred at or within an intersection.**

Despite improved intersection design and more sophisticated applications of traffic engineering measures, the annual toll of human loss due to motor vehicle crashes has not substantially changed in more than 25 years.

## Crash Types

***Rear end***. Seventy-five percent of all rear-end crashes involve a vehicle that is either stopping or has already stopped. More than half of these kinds of crashes occur at or near intersections. Both human and property damage losses from rear-end crashes cost the United States billions of dollars each year in medical expenses, lost productive time and numerous property insurance claims. NHTSA estimates that the injury costs alone for rear-end crashes exceed $5 billion per year.

***Side impact***. Each year, more than one-third of all deaths to vehicle occupants occur in side-impact crashes. These are the most serious kind of collisions, which occur most frequently at intersections.

***The elderly***. Elderly drivers do not deal with complex traffic situations as well as younger drivers do, which is particularly evident in multiple-vehicle crashes at intersections. People 65 years and older have a higher probability of causing a fatal crash at an intersection, and about one-half of these fatal crashes involved drivers who were 80 years and older. Older drivers are more likely to receive traffic citations for failing to yield, turning improperly, and running stop signs and red lights.

***Pedestrians.*** Intersections are disproportionately responsible for pedestrian deaths and injuries. Almost 50 percent of combined fatal and non-fatal injuries to pedestrians occur at or near intersections. Pedestrian casualties from vehicle impacts are strongly concentrated in densely populated urban areas where more than two-thirds of pedestrian injuries occur.

## Intersection Safety Problems: A Complex Public Health Issue

Intersection safety is a complex pubic health issue that cannot always be solved by making changes in signs and signals, but can be helped by a national comprehensive effort of improved intersection vehicle and pedestrian safety management.

The following actions address ways to achieve substantial reductions in annual crash figures.

1. Alter key features of the physical design of a highway or street.
2. Analyze the reasons for traffic conflicts at intersections.

## The Problem (continued)

- The American Association of State Highway and Transportation Officials (AASHTO) Strategic Highway Safety Plan includes 22 key emphasis areas, one of which is improving the design and operation of highway intersections. The AASHTO Strategic Plan is a comprehensive plan that brings together engineering, enforcement, education and emergency response management.
- The Institute of Transportation Engineers (ITE) has developed a Safety Action Plan that includes intersection crashes as an element of the plan. ITE has identified 10 strategies that call for, among other things, the promotion of best practices and new technologies for improving intersection safety.

3. Engage in innovative and strategic thinking. Engineers must delicately balance the requirement for efficient traffic movement and congestion reduction and, at the same time, the need to protect vehicle occupants and pedestrians from the consequences of dangerous vehicle maneuvers and unwise pedestrian behavior.
4. Provide sustained and consistent law enforcement efforts.
5. All levels of government must play a central role by providing:
   - Improved funding, and
   - Cooperation with highway and vehicle engineers, health care authorities, law enforcement, national safety organizations, and local citizen safety groups.

The following are some organizations that have strategic plans to improve intersection safety:

- The Federal Highway Administration (FHWA) has identified intersection safety as one of four safety priority areas in the agency's performance plan.

**Key Year 2000 National Highway and Traffic Safety Administration (NHTSA) statistics are as follows:**

| | Number | Percent Total |
|---|---|---|
| Total fatality crashes | 37,409 | |
| Total intersection-related fatality crashes | 8,474 | 22.6 |
| Total injury crashes | 2,070,000 | |
| Total intersection-related injury crashes | 995,000 | 48.1 |
| Total property-damage-only (PDO) crashes | 4,286,000 | |
| Total PDO intersection-related crashes | 1,804,000 | 42.1 |
| All crashes | 6,394,000 | |
| Total intersection-related crashes | 2,807,000 | 43.9 |
| Total fatalities | 41,821 | |
| Total intersection-related injured persons | 1,596,128 | |

[1] Federal Highway Administration, National Agenda for Intersection Safety, May 2002.

# Basic Countermeasures to Make Intersections Safer

Collisions occur at intersections because motor vehicles are in conflict with each other when crossing or turning in traffic. Improving the engineering of intersections is the first step toward reducing accidents because vehicle conflicts—combined with flawed highway or street design and poor signage—often result in collisions of vehicles with roadside objects, pedestrians and other vehicles.

## Types of Collisions at Intersections

There are four major types of vehicle crashes at intersections.

***Crossing collisions*** are when one vehicle strikes the side of another; these are the most severe type of crashes. They can result from vehicles attempting to drive straight through or turning within an intersection.

***Rear-end collisions*** are common at intersections. They can be the result of poor street design or inadequate traffic engineering measures; but usually are the result of dangerous driver behavior, such as speeding, following too closely, and braking too late.

**Studies have shown that providing turn lanes for left-turning vehicles can reduce accidents by 32 percent. Signalization countermeasures include using 12 inch signal heads, providing separate signals over each lane, installing higher intensity signals and changing the length of signal cycles including the yellow change interval and the red clearance interval.**

***Vehicles changing lanes improperly*** or crossing a road's center line are less common at intersections than crossing and rear-end collisions.

***Pedestrian and bicycle collisions*** occur most frequently in urban areas, particularly with older and younger age groups. In 2000, 34 percent of pedestrian deaths among people aged 65 and older, and 10 percent of pedestrian deaths among children age four and younger, occurred at intersections. Only two percent of motor vehicle-related deaths involved bicyclists, but 33 percent of these deaths occurred at intersections.[1]

## Intersection Crashes have Multiple Causes

***Poor physical design*** of both the intersections and their approach roadways. A major aspect of safety design is restricted sight distances. With restricted sight distances, drivers do not have enough time to stop or avoid hitting a pedestrian or another vehicle.

***Inadequate traffic engineering***. In some cases, traffic control devices—such as signs—are improperly used, placed in the wrong locations, too small to be seen, or have suffered damage or deterioration. In other instances, the growing number of cars on the road have outpaced what used to be acceptable traffic engineering measures.

***Driver licensing and education*** often fails to train drivers to safely negotiate intersections. Some drivers do not know the basic traffic laws, they fail to understand what certain signs and pavement markings mean, or they do not respect the rights and safety needs of pedestrians.[2]

***Drivers disregard traffic control at intersections.*** Even knowledgeable drivers sometimes disregard the clear messages of traffic control devices—including stop signs, signals and pavement markings—and repeatedly violate traffic laws. Combined with speeding, disregard for traffic control at intersections is a major source of serious crashes. Driver distractions, such as cell phone use and inattention and drug and alcohol use, are additional human factors that cause accidents with death and injuries.

## Countermeasures to Improve Intersection Safety

Safety problems must be identified by an engineering review. The most important thing to remember when improving safety at intersections is that countermeasures that improve vehicle traffic flow or reduce vehicle crashes should not compromise

## Countermeasures (continued)

pedestrian safety. There are three strategic decisions to consider when improving intersection safety design and operation:

- Eliminate vehicle and pedestrian conflicts when possible;
- When not possible, reduce unavoidable vehicle and pedestrian conflicts to lower the chances for collisions; and
- Design intersections so that when collisions do occur, they are not as severe.

Traffic engineering strategies to improve movement of vehicles and pedestrians are crucial to improving intersection safety. These consist of a wide range of devices and operational changes such as:

- **Addition of turn lanes at intersections**. Turn lanes are used to separate turning traffic from through traffic. Studies have shown that providing turn lanes for left-turning vehicles can reduce accidents by about 32 percent. Personal injury accidents involving left-turning vehicles can be decreased by as much as 50 percent. Separating right-turning vehicles from other vehicles can significantly affect operations at an intersection. By adding a separate right-turn lane at an intersection with a signal, the delay experienced by drivers on an approach can be reduced. At intersections without a signal, right-turn lanes can safely remove turning vehicles that are slowing down in through traffic lanes. Turn lanes at major driveways can also improve safety, especially on high-volume or high-speed roadways.


- **Signals**. Increase the size of signal heads from 8 to 12 inches to increase their visibility; provide separate signals over each lane; install higher-intensity signal lenses; and change the length of signal cycles, including the yellow clearance interval and the all-red phases.
- **Non-traditional intersection design**. Consideration of non-traditional intersection designs such as roundabouts or traffic circles.
- **Pavement condition**. Upgrade pavement quality to better drain the road and resist skidding.
- **Improve drivers' sight distance.** Restrict parking near intersections and move stop lines back from intersections.
- **Upgrade and supplement signs**. Enforcing laws that prohibit dangerous intersection driving is a necessity to even well-designed and regulated intersections. Enforcement must be consistent because motorists who tend to violate traffic control are aware that the chances of receiving a citation are low. Sustained enforcement efforts have been proven to lower both intersection violations and crash rates, sometimes to a dramatic extent.

[1] FARS, 2002
[2] Federal Highway Administration, Stop Red Light Running Facts, May 2002

# Pedestrian Safety at Intersections

Although intersections represent a very small percentage of U.S. surface road mileage, more than one in five pedestrian deaths is the result of a collision with a vehicle at an intersection. An average of 5,475 pedestrians died in traffic crashes annually between 1990 and 2000.[1]

## Overview

The Year 2000 National Highway Traffic Safety Administration pedestrian crash facts are as follows:

- 4,739 pedestrians were killed in traffic crashes.
- On average, a pedestrian is killed in a traffic crash every 111 minutes.
- 78,000 pedestrians were injured in traffic crashes.
- On average, a pedestrian is injured in a traffic crash every seven minutes.
- Most pedestrian crashes occurred in urban areas (71 percent), at non-intersection locations (78 percent), in normal weather conditions (91 percent) and at night (64 percent).
- Almost one-fourth (23 percent) of all children between the ages of five and nine years who were killed in traffic crashes were pedestrians.
- Studies have shown that children under the age of 10 are not yet capable of crossing a roadway alone. Young children have not fully developed an awareness of the direction of sound (e.g., an approaching car), peripheral vision, focus and concentration levels, or proper judgment of a car's speed and distance until after the age of 10.
- Older pedestrians (ages 70 and above) accounted for 17 percent of all pedestrian fatalities and 6 percent of all pedestrians injuries.
- 42 percent of all young pedestrian fatalities (under age 16) occurred between 4 p.m. and 8 p.m.
- Alcohol involvement—either for the driver or for the pedestrian—was reported in 47 percent of the traffic crashes that resulted in pedestrian fatalities.

**In 2000, 4,739 pedestrians were killed in traffic crashes in the United States. On average, a pedestrian is killed in a traffic crash every 111 minutes.**

## Pedestrian Safety Problems at Intersections

Hazardous intersection types for pedestrian crossings include high-volume, high-speed and multi-lane intersections with complex signal phasing or without any traffic control at all.

Pedestrians are at risk even at simple stop sign or yield sign intersections because of the common disregard of traffic control devices by motorists.

Pedestrians have not been accorded equal status with vehicles at intersections. Roadways have been designed and constructed primarily to accommodate vehicular traffic rather than pedestrians.

Traffic improvements that include widening streets, adding lanes, and using traffic engineering solutions that increase vehicular efficiency can decrease pedestrian safety.

A high percentage of pedestrians, especially in large urban areas, regularly violate pedestrian traffic control and place themselves at risk of collisions with motor vehicles.[2]

About one-third of fatal collisions with pedestrians is the result of pedestrians disobeying intersection traffic control or making dangerous judgments in attempting to cross a street.[3]

Pedestrian traffic control violations generally receive low levels of enforcement.

The design and improvement of roadways often fail to meet the needs of pedestrians of all ages and

Photo provided courtesy of: www.pedbikeimages.org/danburden

# Pedestrians (continued)

capabilities for safely crossing intersections, including older persons, young children and those with impaired vision or difficulty in walking.

Many intersection reconstruction projects and traffic control installations have increased the distances that one must walk to cross at an intersection. Intersection signal timings may be too short to permit safe intersection crossings. Traffic engineers may use a walking speed that is too fast for many pedestrians in determining the necessary time for pedestrians to cross the street.

Crash data consistently show that collisions with pedestrians occur far more often with turning vehicles than with straight-through traffic. Left-turning vehicles are more often involved in pedestrian accidents than right-turning vehicles, partly because drivers are not able to see pedestrians to the left as well.[4]

Pedestrians involved in crashes are more likely to be killed as vehicle speed increases. The fatality rate for a pedestrian hit by a car at 20 mph is 5 percent. The fatality rate rises to 80 percent when vehicle speed is increased to 40 mph.[5]

Right turn on red (RTOR) contributes to pedestrian crashes because it creates reduced pedestrian opportunities to cross intersections without having to confront turning vehicles.

Pedestrian visibility to drivers is much poorer during hours of darkness, especially in areas where there is poor lighting on the road. This is a common shortcoming of rural and suburban intersections.

## How Can We Reduce Pedestrian Injuries and Fatalities at Intersections?

**Visibility**. Pedestrians need to make themselves more visible during evening and nighttime hours. One way to do this is to wear reflective clothing and accessories.

**Coordination among engineers, educators and enforcement personnel**. Improved pedestrian safety at intersections requires coordination among public authorities, professional engineers, media, education experts and vehicle designers to reduce both the number and severity of pedestrian collisions. Pedestrian safety cannot be improved by traffic engineering alone.

**Focus enforcement on**:

- Motorist compliance with pedestrian safety laws;
- Pedestrian compliance; and
- Reducing speeding through intersections.

**Education**. Develop a sustained, comprehensive public awareness campaign that reaches both motorists and pedestrians.

**Pedestrian signal timing/pedestrian signals:**

- Re-assess the adequacy of pedestrian-signal timings;
- Consider pedestrian-only phasing in a traffic signal cycle; and
- Ensure that the pedestrian signal is visible and that any push-buttons are accessible. Signals may be supplemented with audible messages for visually impaired persons.

**"Stop for Pedestrians" paddle signs** can be placed at the roadway centerline at crosswalks without signals in central business districts and other areas of high pedestrian activity to reinforce the right-of-way of pedestrians.

**Identify and decrease road and traffic hazards:**

- Repair/re-stripe crosswalks and stop lines;
- Improve lighting;
- Provide additional signage where necessary;
- Install barriers such as fences, shrubs, or uncomfortable median surfaces to discourage pedestrians from crossing at unsafe locations;
- Provide a wide refuge island on a median with fencing; and
- Make crosswalk improvements such as:
  - A ladder pattern that is more visible to motorists;
  - Crosswalks with flashing lights embedded in the roadway pavement; and
  - Flashing "Pedestrian Crossing" signs that alert oncoming traffic to pedestrians in the crosswalk.

1 Insurance Institute for Highway Safety, Pedestrian Fatality Facts, May 2002.
2 Insurance Institute for Highway Safety, Q&A: Pedestrians, December 2000.
3 FARS, 2000.
4 Insurance Institute for Highway Safety, Q&A: Pedestrians, December 2000.
5 Insurance Institute for Highway Safety, Status Report 35 (5), May 13, 2000.

# Human-Factors Issues in Intersection Safety

Intersection safety is a product of the decisions that engineers make about the physical design and traffic control of each intersection. Understanding the way people react to vehicle and pedestrian conflicts (drivers vary widely in their skills and their willingness to take risks at intersections) is also a part of a comprehensive safety improvement program.

## Driver Abilities and Limitations

- Driver ability to see signs, markings and signals: Many signs and signals, even when new, are not large or bright enough—especially at night or in dim lighting—for drivers to act safely on the information these traffic control devices are providing. Many drivers may have good vision but are not able to see well at night because of poor sensitivity to the contrast between light and dark.

**In crashes involving pedestrian fatalities, alcohol involvement—either for the driver or for the pedestrian—was reported in 47 percent of the traffic crashes.**

- Driver risk taking: Older drivers usually are much less inclined to take risks with narrow margins of error than are younger drivers, especially those in their teens and 20s. However, older drivers often take risks unknowingly because of the diminished motor skills, poor vision and reduced cognitive ability that can come with old age. This can lead them to make poor judgments at intersections that can result in crashes.[1]
- Older drivers: Drivers 85 years of age and older are more than 10 times as likely as drivers in the 40-to-49 age group to have multi-vehicle intersection crashes.[2]
- Younger drivers: The youngest driver age groups have the highest traffic violation and crash involvement rates. This is often due to poor judgment and inexperience, especially among teenage drivers. This problem is also due to a willingness of young drivers to take risks that include speeding, dangerous maneuvers and violating red light signals and stop signs.[3]
- On crashes involving pedestrian fatalities, alcohol involvement—either for the driver or for the pedestrian—was reported in 47 percent of the traffic crashes..

## Road Conditions that Compound Human Limitations

- Complex intersection designs: Drivers often commit errors and violations by mistake because of complex intersection design.
- Signal timing and phasing: Signal timing must be set so that drivers with slower perception and reaction times may brake in time to stop without entering an intersection and to clear an intersection before the red phase occurs. However, excessively long yellow signal phases can tempt drivers to enter intersections that cannot be cleared before the red phase.
- Roadway characteristics: Roads with bi-directional, multi-lane traffic, high speeds and/or high vehicle and pedestrian volumes are often difficult to ensure pedestrian safety.

## Technologies that Limit Human Issues in Intersection Safety

Intelligent Transportation System (ITS) technologies can help make up for some human and vehicle limitations. Some examples of ITS that could be used to limit the human-factor aspect of crashes are automated braking, limiting the distance of queued-vehicle trails and notifying drivers in advance of upcoming intersections that may not be seen quickly enough.

[1] Insurance Institute for Highway Safety (IIHS), States Report, September 2001.
[2] Insurance Institute for Highway Safety (IIHS), States Report, September 2001.
[3] Insurance Institute for Highway Safety (IIHS), Fatality Facts, October 2001.

# Intersection–Safety Enforcement

## Intersection Enforcement Challenges

***Traffic congestion***. Increases in traffic volume can decrease the safety and efficiency of an intersection. Additional police enforcement to reduce violations becomes more crucial at congested intersections.

***Intersection signal timing***. One of the key limitations of making intersection traffic control more efficient is the lengthening of vehicle wait times at signals. High traffic volumes, congestion and complicated signal timing and phasing can cause long vehicle queues. When this occurs, impatient drivers and pedestrians often commit traffic control violations.

***Disregard for compliance with traffic control devices***. Even a well-designed intersection with a high volume of vehicles and pedestrians can suffer an increase in traffic control violations and crashes. This has been a growing problem over the last few decades in the United States because of a growing disregard for the messages of signs, pavement markings and other traffic control devices.

***Insufficient staffing for traditional enforcement.*** Applying enforcement measures to deter violations and reduce the risk of crashes is an unavoidable task for public authorities. Traditional police enforcement rarely captures all of the violations that occur.

**Consistent and sustained enforcement of traffic laws and a strong public education campaign are two effective methods of reducing intersection crashes. In addition, sound traffic planning/engineering and roadway design are important elements of an integrated approach to reducing crashes at intersections.**

## The Need for Efficient Highway Design and Sound Traffic Planning and Engineering

A basic principle of highway and traffic engineering is to make intersections as efficient as possible. Maximum efficiency implies minimal delay and minimal hazards for both drivers and pedestrians. If this is accomplished, an intersection should require less emphasis on enforcement to prevent crashes. Sound traffic planning and effective intersection design help to prevent and reduce congestion; in this way, drivers can avoid frustration and commit fewer violations. Traffic infrastructure (e.g., local controller hardware) should be upgraded to make signal operation more efficient.

## Automated Enforcement

Automated means of monitoring driver and pedestrian compliance with traffic control at intersections is one tool that can reduce crashes.


Several studies indicate that red light cameras placed at intersections that have a history of speeding and signal violations create better compliance by drivers not only at red light camera-monitored intersections, but also at intersections without cameras. Red light cameras generally improve the quality of driver compliance with other traffic control devices as well, including stop signs.[1]

The use of advanced technologies can also provide assistance to enforcement efforts.

Such technologies are collectively referred to as Intelligent Transportation Systems (ITS). ITS can be installed in vehicles and on the highways to assist motorists and pedestrians in anticipating and reacting to intersection conflicts.

Photo and radar enforcement should be used along routes where the violation rate is high to reduce speeding, which increases the severity of a crash.

## More Resources Needed

Intersection enforcement efforts need to be bolstered dramatically to address the fatalities and injuries occurring at intersections. A significant increase in resources devoted to enforcement efforts is necessary to achieve this goal.

[1] Insurance Institute of Highway Safety States Report, April 28, 2001.

# Traffic Control Devices: Uses and Misuses

Traffic control devices are signs, signals, pavement markings and other devices placed along highways and streets to move vehicles and pedestrians safely and efficiently. They are placed in key locations to guide traffic movement, control vehicle speeds and warn of potentially hazardous conditions. They also provide important information to drivers about detours and traffic delays.


## Functions of Traffic Control Devices

The main purpose of a traffic control device is to provide information to drivers so they can operate their vehicles safely along a highway or street. The five basic requirements of a traffic control device are to:

- Fulfill a need;
- Command attention;
- Convey a clear, simple meaning;
- Command respect from road users, and
- Give adequate time for response.

Transportation engineers attempt to provide "positive guidance" through a combination of devices to provide information to drivers when they need it.

**When traffic control devices are properly selected and located... driver and pedestrian compliance can ensure safe operations.**

Signs, signals, pavement markings, cones, barricades and warning lights are designed with dedicated colors, shapes and sizes based on the different functions they provide. They regulate, guide and warn vehicle and pedestrian traffic about road conditions. Uniformity of design (color, shape and size) helps drivers to quickly understand the messages of traffic control devices. Consistency is crucial for ensuring driver respect, recognition and proper reaction.

When traffic control devices are properly selected and located for good day and night visibility, recognition and comprehension, driver and pedestrian compliance can ensure safe operation of vehicles.

## Characteristics of Uniform Traffic Control Devices

***Color***. Certain colors are used to trigger instant recognition and reaction; for example, stop signs are always red. Similarly, signals at intersections must have the same sequence of red/yellow/green to communicate stop/warning/go to drivers and pedestrians.

***Nighttime visibility***. Traffic control devices are made visible under nighttime operating conditions by either being separately lighted or retroreflectorized so that the light coming from vehicle headlamps is bounced off signs and other devices back to the eyes of drivers.

***Daytime visibility***. Traffic control devices are designed with highly visible colors or a sharp contrast of messages against a background. Sometimes traffic control devices are lighted even for daytime viewing to draw the attention of drivers to their messages.

***Shape and size***. Signs have standard shapes and sizes to trigger instant recognition and reaction. For example, stop signs have an octagonal shape of a particular size that no other sign is permitted to have. There are similar specifications for the shapes and sizes of many other traffic control devices for both permanent and temporary conditions.

***Location***. Traffic control devices must be placed in locations that provide enough time for all drivers to make the appropriate safe maneuvers, such as entering or departing a road or stopping and turning to avoid conflicts with other vehicles and pedestrians.

***Messages***. Traffic control devices are designed with carefully chosen symbol or word messages of specific sizes and content. Locations and functions are then selected in relation to the amount of time that drivers need to detect, read and understand messages to make appropriate vehicle maneuvers.

## How to Select the Correct Traffic Control Device

Traffic control devices work in concert with the basic "rules of the road" contained in traffic laws and ordinances, including each States' uniform code that regulates vehicle movements. One example is the "right-of-way" principle that determines which driver has priority when approaching or entering an intersection.

Traffic control devices have undergone a long evolution of design and installation criteria. Current designs and the standards for using them are the result of several decades of scientific investigation and the combined experience of many professional engineers, human behavior and vision researchers and safety policymakers.

One of the major resources for determining the design and use of traffic control devices is the *Manual on Uniform Traffic Control Devices* (MUTCD). The Millennium Edition of the MUTCD offers guidance and application information for signs, markings, traffic signals and other traffic control devices. This document can be found on the Web site: http://mutcd.fhwa.dot.gov.

Additional basic design guides have been produced by professional engineering organizations, such as the Institute of Transportation Engineers' *Traffic Engineering Handbook* and *Traffic Control Devices Handbook*.

## Problems with Traffic Control Device Placement and Installation

1. ***Use of an improper device***. Placing a yield sign where a stop sign is needed will result in an inadequate amount of time and distance for drivers to react to another vehicle or pedestrian.
2. ***Improper placement***. A traffic control device at the wrong location may result in the device being seen too late by drivers to safely react (e.g., placing a properly designed sign too far around the bend of a sharp curve).
3. ***Wrong size***. Using a small warning or information sign may result in the inability of drivers to detect and comprehend the need to make safe maneuvers.
4. ***Wrong color***. Using yellow or some other color for lane lines instead of white.
5. ***Wrong shape***. Using a diamond warning shape for a traffic regulation.


6. ***Excessive installation*** of specific devices that often results in increasing driver disregard of their important messages. One example is the blanket use of four-way stop signs in residential neighborhoods. The public generally has the mistaken belief that four-way stop signs will always promote better driver caution and achieve vehicle speed reductions. Many times, however, the placement of a four-way stop sign promotes increased speeding between intersections. Similarly, it is a common mistake to assume that signals will necessarily make a dangerous intersection safer. A more effective approach in reducing speeds in residential neighborhoods is enforcement along with reduced residential speed limits and traffic calming measures.
7. ***Failure to use traffic control devices at necessary locations***. Traffic signs that may have controlled the movement of vehicles and pedestrians for years may no longer be effective in doing so.
8. ***Failure to warn or notify drivers and pedestrians of unexpected, potentially hazardous conditions***. Neglecting to provide advance warning of an upcoming signal or stop sign over the top of a steep hill can result in inappropriate braking and steering maneuvers that may result in collisions.

## Red-Light-Running

# Red-Light-Running Issues

The National Highway Traffic Safety Administration (NHTSA) reports that about 6.4 million crashes occurred on America's roadways in 2000. According to the United States Department of Transportation (U.S. DOT), around 40 percent of them occurred at intersections or were "intersection-related." Red-light-running, which results in roughly 950 deaths and 90,000 injuries a year, is estimated to be the cause in 92,000 annual crashes.

**Red light runners cause an estimated 92,000 crashes, resulting in about 950 deaths and 90,000 injuries annually.**

### When Does Red-Light-Running Occur?

Red-light-running is one of the leading problems at urban intersections with traffic signals. Red-light-running occurs when a driver enters an intersection after the traffic signal has turned red. A motorist who is already in an intersection when the signal changes to red, such as when waiting to make a left turn, is not a red-light-runner.

### Red-Light-Running Facts

Fatal motor vehicle crashes at traffic signals increased 18 percent nationally between 1992 and 1998. By comparison, a six percent increase occurred at all other collision location types with fatalities.[1]

Researchers at the Insurance Institute for Highway Safety (IIHS) studied police reports of crashes on public roads in four urban areas. Of 13 crash types identified, violating traffic control devices accounted for 22 percent of all crashes. Of those, 24 percent were attributed to red-light-running.[2]

Motorists are more likely to be injured in crashes involving red-light-running than in other types of crashes. Occupant injuries occurred in 45 percent of the red light running crashes, compared to 30 percent for other crash types.[3] This is due, in part, to the higher frequency of side-impact crashes.

According to a survey conducted by the U.S. DOT and the American Trauma Society, 63 percent of Americans witness a red-light-running incident more than once a week. One in three Americans knows someone who has been injured or killed because of a red-light-runner.

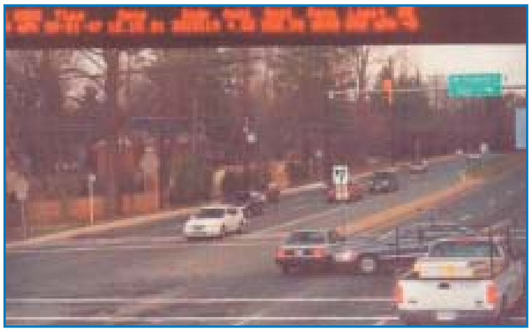
The IIHS conducted a study on who runs red lights. As a group, red-light-runners were younger, less likely to use safety belts, had worse driving records and drove smaller and older vehicles than older drivers. Red-light-runners were more than three times as likely to have multiple speeding convictions on their driving records. No gender differences were discernible.

Numerous public opinion surveys demonstrate strong support for improving intersection safety. In a 1998 U.S. DOT survey, 95 percent of Americans were concerned about red-light-running. In a September 2001 Harris poll, 78 percent of the public wanted more attention paid to improving intersection safety.

### Addressing the Problem of Red-Light-Running

Comprehensive, national data on red-light-running is needed to understand the magnitude and complexity of the problem. Identifying the causes of red light running allows authorities to focus on specific ways to reduce violations.

Photos taken from a Red-Light Enforcement camera.



The most common crash type—a driver violating a traffic control device—might be reduced by re-timing a signal, improving signal and sign visibility, increasing decision sight distances and reducing vehicle speeds near intersections.

The Federal Highway Administration (FHWA) and the Institute of Transportation Engineers (ITE) are developing guidance related to engineering countermeasures for the problem. This guidance should be available by Fall 2002.

Red light enforcement cameras can be used to supplement police enforcement. Upholding traffic laws can be dangerous for law officers when they must also run the red light to pursue the violator. The safety of other motorists and pedestrians at an intersection may be threatened if police themselves run the light.

Crashes may be prevented or mitigated through the use of Intelligent Transportation System (ITS) technologies that attempt to overcome human and vehicle limitations. Examples of ITS technologies include infrastructure-based systems, which can provide a warning to drivers who are going to violate a signal and to drivers who may be in the path of an oncoming offender. These systems may eventually interface with in-vehicle warnings, or automated actions, to prevent crashes. However, it is expected to take many years for this technology to reach the market.

The U.S. DOT is committed to a 20 percent reduction in road-related fatalities and serious injuries by 2008. Red-light-running is an identified problem that has been targeted. In 1995, the FHWA created the *Stop Red-Light-Running Program*. It is a community-based safety program focused on raising awareness and reducing fatalities through combined and coordinated education, engineering and enforcement efforts.

[1] American Trauma Society, Stop Red Light Running, May 2002.
[2] Insurance Institute for Highway Safety, Q&A: Red Light Cameras, November 2001.
[3] Insurance Institute for Highway Safety, Q&A: Red Light Cameras, November 2001.

# Red-Light Cameras

Red-light-runners cause about 106,000 crashes a year in the U.S., resulting in nearly 1,000 deaths and 89,000 injuries. Drivers and passengers are injured in 45 percent of red-light-running crashes.

Unlike collisions in which drivers have no control of the outcome, those caused by red-light-running are preventable, and the problem can be solved with engineering, education and enforcement solutions. One such solution is an automated red-light-running photo-enforcement system. The "red-light camera" can be an effective and reliable tool to help reduce the number of red-light-running violations and associated crashes.

**Automated Enforcement Systems can be effective and reliable tools to help reduce the number of red-light-running violations and associated crashes.**

## When Does Red-Light-Running Occur?

Red-light-running occurs when a driver enters an intersection after the traffic signal has turned red. The traditional way of enforcing this violation is to station a patrol vehicle near an intersection. This method is dangerous for the officer, expensive to localities and a drain on valuable police resources. Red-light cameras can supplement police efforts by being where officers cannot be all the time.

## How Do Red-Light Cameras and Automated Enforcement Programs Work?

Typically, these systems detect a motor vehicle that passes over sensors in the pavement after a traffic signal has turned red. The sensors are connected to computers in high-speed cameras, which take two photographs of the violation. The first photo is taken of the front of the vehicle when it enters the intersection and the second when the vehicle is in the intersection.

Law enforcement officials review the photograph, and in many localities with the systems, a citation is mailed to the registered owner of the vehicle. The owner can challenge the citation if he or she was not the driver at the time of the violation.

## Red Light Camera Program Facts

- The objectives of red-light cameras are to stop red-light-running, reduce crashes, save lives, prevent injuries, lower health care costs and respond to community concerns about drivers who break traffic laws.
- Red-light cameras have been shown to deter red-light-running, and are an effective supplement to traditional means of law enforcement. For many localities using red light cameras, violations and crashes have been dramatically reduced.
- Red-light cameras are being used to enforce traffic laws and save lives in about 70 communities in the United States. Six States and the District of Columbia have statewide red-light camera laws. Other States have laws authorizing camera use in specific areas or under specific circumstances. Internationally, red-light cameras are used in the United Kingdom, the Netherlands, Israel, Austria and other countries.[2]
- In Oxnard, California, front-into-side crashes at intersections with traffic signals (the type of collision most commonly associated with red light running) were reduced by 32 percent. There were 68 percent fewer front-into-side crashes involving injuries.[3]

# Cameras (continued)

- In Fairfax, Virginia, after one year of camera enforcement, violations were reduced by 41 percent.[4]
- San Francisco and Los Angeles, California, realized a 68 and 92 percent reduction in violations, respectively.
- The Charlotte, North Carolina, program cut red-light-running violations by more than 70 percent during the first year of operation. Crashes throughout the city were reduced by more than 10 percent.
- A 1998 Harris public opinion poll found that 65 percent of the public supported State adoption of automated enforcement laws. Approximately three-fourths of the respondents supported adopting automated enforcement laws in a poll the following year. A September 2001 Harris poll found that 73 percent of Americans want more attention given to red-light-running, and a majority of more than two to one favored State red-light camera authorization laws.[5]
- An April 2001 survey of 10 cities by the Insurance Institute for Highway Safety found that opinions about red-light camera use are favorable in communities both with and without programs (between 84 and 77 percent and between 82 and 72 percent, respectively).
- Fairness is a critical ingredient to any automated enforcement system. Motorists should be made aware of systems through extensive public education campaigns and signs notifying them that red-light cameras are in use. An engineering review should take place before the installation of cameras. Engineering and law enforcement officials should review citations after the program begins to identify traffic engineering elements and operational compliance issues that need to be addressed.

[1] Federal Highway Administration, Stop Red-Light-Running facts, May 2002.
[2] Insurance Institute for Highway Safety, Red-Light Cameras in Action, November 2001.
[3] Insurance Institute for Highway Safety, Status Report, April 28, 2001.
[4] Insurance Institute for Highway Safety, Automated Enforcement Laws, April 2002.
[5] Lou Harris Poll for Advocated for Highway and Auto Safety, April 1998 and September 2001.
[6] Insurance Institute for Highway Safety, Status Report, April 28, 2001.

# Workzone Intersection Safety

It is a challenge to maintain safety and mobility at intersections in a work zone. For drivers unfamiliar with an intersection, a work zone can be a sudden, potentially dangerous surprise. For motorists who regularly drive through an intersection, a work zone can be a frustrating nuisance because of the way it adds to travel time. But the development and application of well-designed temporary traffic control plans can ensure safe mobility for both workers and drivers in an intersection work zone.

## Overview

Work zones are highway and traffic engineering design challenges. The task of maintaining mobility and ensuring safety for workers, pedestrians, bicyclists and vehicle occupants is more demanding in work zones than on ordinary roads. The realignment of travel lanes and reduction of road capacity are often necessary to accomplish reconstruction or rehabilitation, such as pavement replacement, pavement patching, widening a street, utility work and reapplying pavement markings. All of these can cause delays and pose a threat to safety.

**The task of maintaining traffic mobility and ensuring safety for workers, pedestrians and vehicle occupants is more demanding in work zones.**

Transportation agency coordination with transit, police, fire, emergency medical services, utilities, schools and railroads is a good idea (especially in urban areas) to alert these organizations to changes in road conditions. Suggesting alternate routes is time well spent to ensure safety and travel time reliability, particularly for school buses and emergency providers.

## MUTCD, Part 6, Temporary Traffic Control

The *Manual on Uniform Traffic Control Devices* (MUTCD), contains the basic principles of design and use of traffic control devices for all streets and highways open to public travel, regardless of type or class, or the public agency having jurisdiction. The latest version of the MUTCD was adopted in December 2000. Part 6 of the 2000 MUTCD, "Temporary Traffic Control," contains the standards, guidance, options and support information related to work zones. Part 6 has been significantly revised and expanded with many "Typical Applications" detailed for a variety of street and highway work situations commonly encountered by road users. The MUTCD can be accessed at the following Web site: http://mutcd.fhwa.dot.gov.

Work sites should be regularly checked by qualified temporary traffic control personnel to ensure that the placement and operation of traffic control devices within work zones continue to conform with applicable plans. Cones or drums knocked out of alignment by an errant driver or a work vehicle, for example, could result in vehicles being channeled into oncoming traffic. The condition of devices should also be checked regularly to ensure that they continue to perform as intended. Modifications may also be necessary based on changing road conditions or work staging and progress.

## Work Zone Intersection Safety Goals

Motorists entering and traveling through work zones must be provided with adequate time and distance to make decisions and stop when required. Drivers should never be forced to make unexpected stops or perform unanticipated steering or crash-evasion maneuvers when approaching or within a work zone.

Traffic congestion in intersections should be mitigated to the greatest extent possible. If long queues are expected or are occurring because of a work zone, additional advance traffic control devices may be necessary to provide users with information about lane choice or alternate routes before being trapped in a queue. Long delays often create impatient drivers who may change their usually good driving habits and take unnecessary risks that result in potential hazards to themselves and others. Pedestrians and bicyclists may ignore signs and walk against traffic signals if they are forced to wait too long to be accommodated in a work zone. This increases their vulnerability to vehicles whose drivers may also be frustrated.

## Improving Work Zone Intersection Safety

Ensuring a high level of intersection safety in work zones depends on the use of the devices that offer dependable guidance. They must provide safe travel both day and night for vehicles diverted onto temporary paths. Warning, regulatory and/or guide signs in advance of and through the work zone advise motorists of specific hazards that may be encountered ahead.

Rather than closing and detouring traffic for intersection improvements, work crews will sometimes close one or more lanes to perform work activities. The factors that affect the choice to perform work under live traffic conditions may include ensuring access to local businesses and residences in the area and saving motorists from lengthy detours. In lane reduction situations, vehicles are funneled gradually into fewer travel lanes or onto temporary realignment paths with the use of high-visibility traffic control devices, such as drums, cones and barricades. These devices are often supplemented with advance arrow boards and portable, changeable message signs, particularly on higher volume and/or higher speed routes where advance warning is needed to guide traffic approaching the work zone.

Larger, brighter, or redundant devices supplemented with lighting may also be used to safely guide vehicles, pedestrians and bicyclists at intersection work zones. Where traffic must be intermittently slowed or stopped when approaching or within the work zone, flaggers are used to control and guide the users.

## Pedestrians, Bicyclists and Workers at Intersections Within Work Zones

Pedestrian and bicycle safety at intersection work zones is often addressed by diverting them to other crossing locations to minimize potential hazards at the intersection. In these circumstances, pedestrians must be given adequate advance warning and guidance so they do not get to the closure and then have to backtrack to use the safer crossings. People who may be trapped because of inadequate advance guidance will often attempt to cross at the closed intersection or in mid-block, putting themselves at risk.

Bicyclists and pedestrians, especially persons with disabilities, should be provided with a safe and reasonable travel path that allows them to negotiate changes in terrain; they should never be forced into direct confrontations with traffic or operating work zone equipment. In some instances, where other travel paths are not readily available or reasonable, barriers may be used to protect pedestrians and bicyclists from potential collisions with road traffic or work equipment. Overhead protection may also be necessary where falling construction debris is a possibility.

The safety of workers in work zones, especially at intersections, is an overarching consideration for engineers, road construction firms and utility companies. Workers are especially vulnerable to collisions and, therefore, need to be highly visible to drivers. Worker safety can be improved by means of special clothing that is conspicuous to drivers at all hours and by extra lights for illuminating the intersection.

## Resources

The FHWA developed the Best Practices Guidebook for Work Zone Safety to give state and local transportation agencies, construction contractors, transportation planners, trainers and others with interest in work zone operations, access to contacts and information about current best practices for achieving work zone mobility and safety. More information on this guidebook can be obtained on the following Web site: http://ops.fhwa.dot.gov/wz/wzguidbk/.

Intersection Safety Brief

10 Myth vs Reality

# Intersection Safety: Myth Versus Reality

Traffic engineering decisions about intersection safety are often the product of factors and relationships that are more complex than the casual observer may realize. In many cases, evaluating potential solutions to crash or violation problems may reveal aspects of intersection safety and efficiency that are in conflict with one another. In reality, traffic engineers must always consider a balance between managing safety and improving intersection operations before making their final choice for intersection control.

**Over the years, a number of misconceptions about traffic-control solutions have become apparent. This briefing sheet attempts to shed some light on the rationale for why certain traffic-control decisions are appropriate and required.**

The driving public has developed a number of misconceptions about traffic control solutions over the years. This brief attempts to expose some of those myths and shed light on the rationale behind certain traffic control decisions.

Additional traffic safety measures are sometimes necessary to offset increased traffic and speeding through neighborhood streets. One way of improving waiting times at an intersection with a new signal is to make sure the minor street waiting times are less than they were before installation of the signal. This improvement will encourage motorists to use signals on main roads instead of neighborhood streets.

On occasion, other traffic control options, such as stop control or the introduction of roundabouts can perform as well as, or even better than, signals in managing both vehicle and pedestrian traffic safety at intersections. This is particularly true when signals are inappropriately placed at locations where traffic volume is relatively low. Intersections with signals that have very low traffic volumes tend to tempt drivers and pedestrians to violate that red light.

## Myth 1: Installing signals always makes intersections safer.

### Reality:

The installation of unwarranted signals, or signals that operate improperly, can create situations where overall intersection congestion is increased, which in turn can create aggressive driving behavior.

When more complex signal phasing causes longer waiting times at intersections, both drivers and pedestrians tend to become impatient and violate red lights, or drivers are tempted to cut through neighborhood streets. This subjects local residents to a greater risk of collisions, worse congestion and more air and noise pollution.

Clearly traffic diversion to side streets is an undesirable side effect of long cycle lengths and congestion. This diverted traffic may increase risk on the side streets, but the cause of this increased safety risk should not be attributed to the new signal.

## Myth 2: Having a stop sign is always better than no stop sign, OR, more stop signs are always safer than fewer stop signs.

### Reality:

Unwarranted stop signs create problems at both the intersection and along the roadway by:

- Encouraging motorists to drive faster between intersections in order to save time. Placing stop signs on every low-volume local street promotes speeding between the stop signs as drivers try to offset the delays caused by stopping at every intersection;
- Encouraging violation of traffic laws. As the number of stop signs increase so that nearly every intersection has one, the rate of stop sign violations tends to increase;
- Encouraging the use of alternate routes. Placing too many stop signs in some areas

often causes traffic to use other neighborhood routes to avoid a sequence of intersections that may be controlled by stop signs; and

- Increasing the chance that drivers will disregard conflicting vehicle and pedestrian traffic, which raises the risk of collisions.


There is no evidence to indicate that stop signs decrease the overall speed of traffic. Impatient drivers view the additional delay caused by unwarranted stop signs as "lost time" to be made up by driving at higher speeds between stop signs.

Unwarranted stop signs breed contempt in motorists who tend to ignore them or only slow down without stopping. This can sometimes lead to tragic consequences.

Stop signs should never be installed as a routine, cure-all approach to curtail speeding, prevent collisions at intersections, or discourage traffic from entering a neighborhood. Stop signs should be installed only after an engineering study determines that there is a need. Stop signs are not a solution to intersection safety problems caused by poor sight distances and deficient road design.

### Myth 3: Installing stop signs on all approaches (four-way stop) to an intersection will always result in fewer accidents.

#### Reality:

Four-way stop signs do not necessarily improve pedestrian or vehicle safety. In fact, pedestrians in stop sign-congested neighborhoods often have a false sense of security about crossing local streets with four-way stop signs. The application of traffic control devices, to the casual observer, often creates this sense of security, but in reality may actually increase safety risk. If control devices are improperly applied, they can create confusion between the pedestrians and the driver as to who has the right-of-way, thereby increasing the risk that one of the two will make an improper decision resulting in serious consequences.

Placing four-way stop signs on roads of very unequal design, speed and traffic volume will tend to promote stop-sign violations by drivers, especially on main roads. Driver expectancies are violated in situations like this and when this occurs, improper actions result which can increase safety risk at intersections.

Placing four-way stop signs at every intersection where there were formerly only two-way stop signs also usually increases congestion. Four-way stop signs should only be considered after an engineering study and a capacity analysis are performed.

Generally, every State requires the installation of traffic control devices, including stop signs, to meet State standards of the department of transportation.

The State standards are based on the *Manual on Uniform Traffic Control Devices* (MUTCD). The MUTCD is the national standard for traffic control devices. It prescribes standards for the design, location, use and operation of traffic control devices. The MUTCD is located at the following Web site: http://mutcd.fhwa.dot.gov.

### Myth 4: Signals are always better than stop signs.

#### Reality:

Installing stop signs instead of signals when there is no intersection traffic control, increasing the size or visibility of existing stop signs, or placing them in a better location often increases both vehicle and pedestrian safety without the initial expense and later maintenance costs of signals. While waiting for signals to qualify for installation, the substantial amount of money saved can be used to make roads safer.

11 Resources

# Intersection Safety Resources

Numerous funding and information sources are available to help create and advance programs to improve intersection safety.

The last two major Federal assistance funding bills enacted by Congress in 1991 and 1998 included provisions for a wide variety of funding possibilities for the research, design and implementation of intersection safety improvement projects, as well as targeted money that is available for working in cooperation with private organizations to fund intersection safety projects.

## Where to Get More Information

**Transportation Equity Act for the 21st Century (TEA-21), Surface Transportation Program, Section 1108**

Provides for a block grant program that can be used on roads that were never part of any Federal-aid highway system. The provision authorizes any operational or highway safety improvement projects to be Federally funded, including automated intersection enforcement technologies. The Federal share of project costs is 80 percent, but some States can qualify for up to 95 percent Federal funding if large portions of the State contains Federal lands.

**This briefing sheet includes legislative and organizational resources to allow individuals to access current information on all aspects of Intersection Safety.**

**Congestion Mitigation and Quality Improvement Program (CMAQ), Section 1110**

The primary use of CMAQ funds is to improve air quality. CMAQ funds can be used for intersection projects on arterial or collector roadways, including signal-retiming projects to increase intersection efficiency and therefore reduce emissions. This program also encourages public/private partnerships with any level of government, or even with non-governmental organizations, to cooperatively implement any project—including intersection projects—funded through CMAQ. The Federal share of project costs is 80 percent.

**Section 5207 of TEA-21**

Intelligent Transportation Research and Development. This section allows local governments to apply directly to the Federal Highway Administration (FHWA) for grants to conduct traffic management research, development and operational tests in several qualifying areas.

**National Highway System Designation Act of 1995**

The National Highway System Designation Act of 1995 includes provisions for safety studies and projects: Section 347 (Safety Report), Section 351 (Railroad Highway Grade Crossings) and Section 358 (Safety Research Initiatives).

Funds available through cooperative planning and program approval submissions with a State transportation department can be applied to major construction and reconstruction intersection projects, depending on the provision in Federal law. Funds can also be applied to the limited rehabilitation, installation, or upgrading of traffic control devices or, for some programs, for maintenance work to correct deteriorated road and traffic control features at intersections.

Local governments can reach their State transportation departments and determine which programs can be accessed for intersection funding by contacting:

**The FHWA Office of Budget and Finance**

Union Center Plaza, Suite 750
820 1st St., NE
Washington, DC 20002
Telephone: (202) 366-2288;
www.fhwa.dot.gov/innovativefinance.

The FHWA also has State divisions and regional resource centers to assist local governments in obtaining funding assistance. The best way to locate a division office or resource center is to access the listing entered on the FHWA Web site: www.fhwa.dot.gov/fhwaweb.htm.

**Local Technical Assistance Program (LTAP) and Tribal Technical Assistance Program (TTAP)**

LTAPs and TTAPs provide training and technical assistance to local and tribal transportation agencies. The LTAP and TTAP clearinghouse is located at:

**American Public Works Association**

1401 K St., NW, 11th Floor
Washington, DC 20005 USA
Telephone: 202-408-9541
Fax: 202-408-9542
www.ltapt2.org

*(More resources on back.)*

**American Association of State Highway and Transportation Officials (AASHTO)**

444 N. Capitol St., NW
Suite 249
Washington, DC 20001
Telephone: 202-624-5800
www.aashto.org

Local governments can also contact AASHTO for assistance in reaching their State highway or transportation departments.

State budget and contracting authority is authorized by Federal law and permits States to set aside funds for specific safety projects before the money is actually appropriated by Congress and distributed by FHWA to the States. This allows for good lead times in planning and designing intersection safety improvement projects.

**Association of Metropolitan Planning Organizations (AMPO)**

1730 Rhode Island Ave., NW
Suite 608
Washington, DC 20036
Telephone: 202-366-2288
www.ampo.org

Local governments are also able to work in concert with their Metropolitan Planning Organizations (MPOs) in States and regions. The MPOs help form a list of planned intersection safety improvement projects that can receive combined Federal and State funding.

**Advocates for Highway and Auto Safety**

750 First St., NE, Suite 901
Washington, DC 20002 USA
Telephone: 202- 408-1711
www.saferoads.org

The Advocates for Highway and Auto Safety recently produced a primer that local governments can use in seeking Federal funding sources for intersection safety improvements. This report, Driving the Agenda: Intersection Safety—Potential Federal Funding Sources for Safety Improvements, April 2001, can be downloaded from the Advocates' Web site.

**FHWA Safety Core Business Unit**

Information on intersections can be found on the FHWA Safety Core Business Unit Web site:
http://safety.fhwa.dot.gov/programs/intersections.htm

**Institute of Transportation Engineers (ITE)**

1099 14th St., NW, Suite 300 West
Washington, DC 20005 USA
Telephone: 202-289-0222 x132
www.ite.org

The ITE Web site contains technical resources and materials on intersection safety, including the papers and presentations from the National Workshop on Intersection Safety (Milwaukee, WI, November 14–16, 2001). The National Agenda for Intersection Safety can also be downloaded.

**ITS America**

400 Virginia Ave, NW
Suite 800
Washington, DC 20024-2730
Telephone: 202-484-4847
www.itsa.org

Projects that use advanced technologies for traffic control and could be funded under one or more provisions of TEA-21 addressing Intelligent Transportation Systems (ITS) can be explored for their potential Federal support through ITS America.

***National Association of Governors' Highway Safety Representatives***

750 First St., NE, Suite 720
Washington DC 20002 USA
Telephone: 202-789-0942
www.naghsr.org

***National Association of Counties***

440 First St., N.W., Suite 800
Washington, DC 20001 USA
Telephone: 202-393-6226
Fax: 202-393-2630
www.naco.org

**Strategic Highway Safety Plan**

In 1998, AASHTO approved the Strategic Highway Safety Plan that was developed by the AASHTO Standing Committee for Highway Traffic Safety with the assistance of the FHWA, the National Highway Traffic Safety Administration, and the Transportation Research Board Committee on Transportation Safety Management. The plan includes strategies in 22 key emphasis areas that affect highway safety; Area 17 of the Strategic Plan is to improve the design and operation of highway intersections. The Web link for this document is:
http://safetyplan.tamu.edu

# APPENDIX H

## Reactive Crash Analysis Tables

ABNORMAL CRASH PATTERNS & POSSIBLE CAUSES

| ABNORMAL CRASH PATTERNS | POSSIBLE CAUSES |
|---|---|
| **Section 1: Intersections** | |
| Rear-end collisions at unsignalized intersections | 1. Drivers unaware of intersection<br>2. Slippery surface<br>3. Large turning volume<br>4. Inadequate roadway lighting<br>5. Excessive speed on approaches<br>6. Lack of adequate gaps for turning vehicles<br>7. Absence of turning lanes<br>8. Crossing pedestrians<br>9. Uncontrolled access at intersection<br>10. Short turning radius<br>11. Inadequate directional signing |
| Rear-end collisions at signalized intersections | 1. Slippery surface<br>2. Large turning volume<br>3. Poor visibility of signals<br>4. Inadequate signal timing<br>5. Unwarranted signal<br>6. Inadequate roadway lighting<br>7. Excessive speed on approaches<br>8. Crossing pedestrians<br>9. Uncontrolled access at intersection<br>10. Short turning radius<br>11. Inadequate directional signing |
| Right-angle collisions at unsignalized intersections | 1. Restricted sight distance<br>2. Large total intersection volume<br>3. Excessive speed on approaches<br>4. Inadequate roadway lighting<br>5. Inadequate advance warning of intersection<br>6. Inadequate traffic control devices |
| Right-angle collisions at signalized intersections | 1. Restricted sight distance<br>2. Excessive speed on approaches<br>3. Poor visibility of signals<br>4. Inadequate signal timing<br>5. Inadequate roadway lighting<br>6. Inadequate advance warning of intersection<br>7. Large total intersection volume |
| Left-turn head-on collisions at intersections | 1. Large volume of left turns<br>2. Restricted sight distance<br>3. Short amber phase<br>4. Absence of special left-turning phase<br>5. Absence of left-turn lane<br>6. Excessive speed on approach |
| Sideswipe collisions at intersections | 1. Inadequate pavement markings<br>2. Inadequate roadway design (narrow lanes, restrictive alignment, etc.)<br>3. Short turning radius<br>4. Uncontrolled access at intersection<br>5. Parking too close to intersection<br>6. Inadequate directional signing |

*Continued on next page*

ABNORMAL CRASH PATTERNS & POSSIBLE CAUSES (*continued*)

| ABNORMAL CRASH PATTERNS | POSSIBLE CAUSES |
|---|---|
| **Section 1: Intersections** (*continued*) | |
| Pedestrian–vehicle collisions at intersections | 1. Restricted sight distance<br>2. Inadequate pedestrian signs, signals, or markings<br>3. Inadequate signals<br>4. Improper signal phasing<br>5. Inadequate warning to drivers of frequent pedestrian crossings<br>6. Inadequate pavement markings<br>7. Inadequate gaps at unsignalized intersections<br>8. Inadequate roadway lighting<br>9. Excessive vehicle speeds |
| **Section 2: Environmental conditions** | |
| Wet-pavement collisions | 1. Slippery surface<br>2. Inadequate drainage<br>3. Inadequate delineation<br>4. Excessive vehicle speeds<br>5. Irregular pavement surface |
| Nighttime collisions | 1. Poor visibility or lighting<br>2. Poor sign quality<br>3. Inadequate channelization or delineation<br>4. Excessive vehicle speeds<br>5. Variable lighting conditions |
| Reduced-visibility collisions | 1. Inadequate warning of dense fog or smoke conditions<br>2. Inadequate delineation for conditions<br>3. Inadequate route guidance<br>4. Highly variable visibility conditions<br>5. Large vehicle speed variations<br>6. Excessive vehicle speeds |

*Source*: *Traffic Safety Toolbox: A Primer on Traffic Safety* (*9*), Table 25-2.

BASIC FIELD OBSERVATIONS USED TO STUDY PROBLEM LOCATION

| Operational Problem Symptoms | Physical Inventory Parameters (supplement construction plans) |
|---|---|
| • Length of vehicle queues<br>• Erratic vehicle maneuvers such as<br>– Stopping or backing at gore points<br>– Wrong-way movements<br>– Gore area encroachments<br>– Shoulder encroachments<br>– Traffic violations<br>• Vehicles experiencing difficulty in making turning movements<br>• Evidence of unreported accidents such as damaged guardrail or skid marks or tire tracks off of the pavement<br>• Pedestrians on roadway<br>• Pedestrian–vehicle conflicts | • Sight distance restrictions<br>• Pavement and shoulder conditions<br>• Signal visibility<br>• Signs, including speed limits<br>• Curb radii<br>• Pavement markings<br>• Lighting<br>• Driveway locations<br>• Fixed objects and roadside design |

*Source*: *NCHRP Report 440*: *Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Table 10.

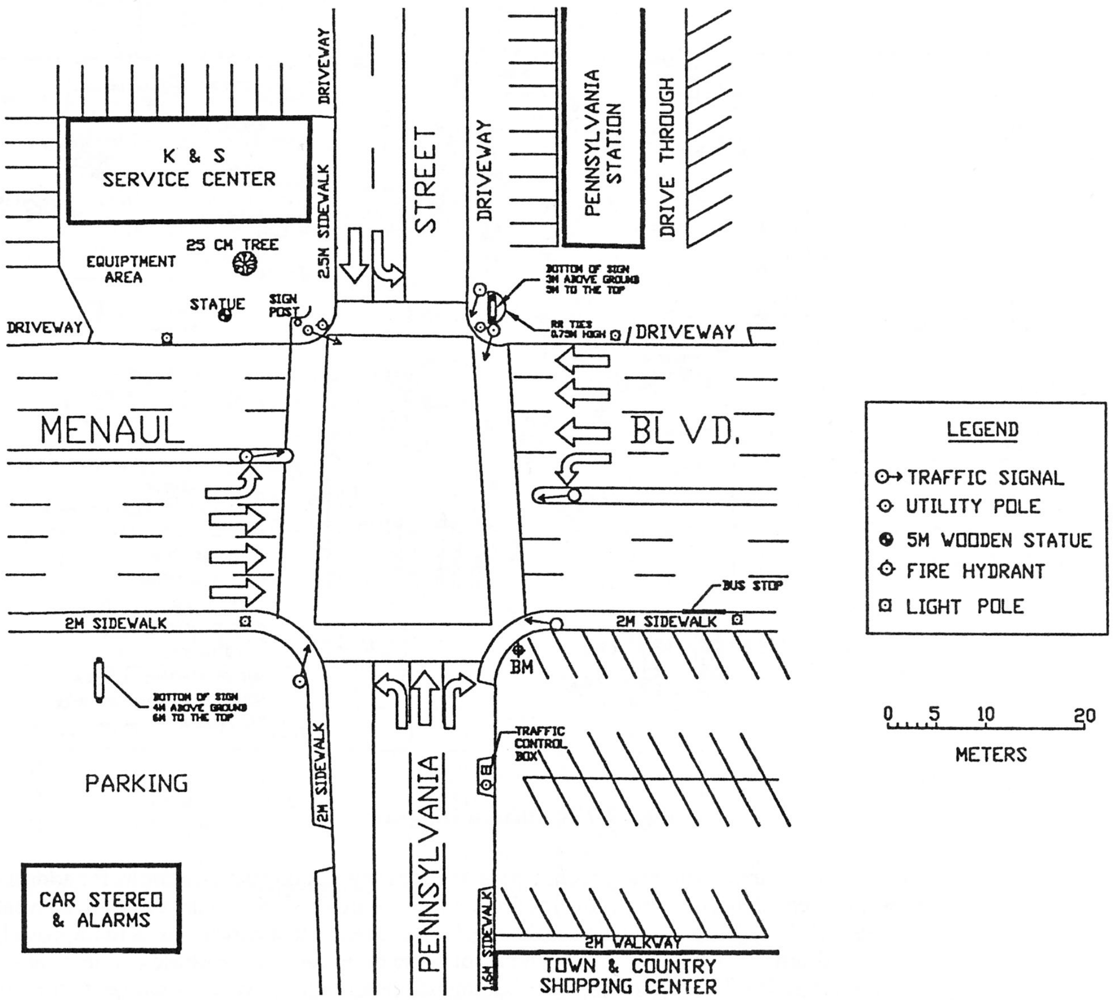



**Fig. 9-6--Condition Diagram**

*Source*: Homburger et al., *Fundamentals of Traffic Engineering* (*47*), Figure 9-6.

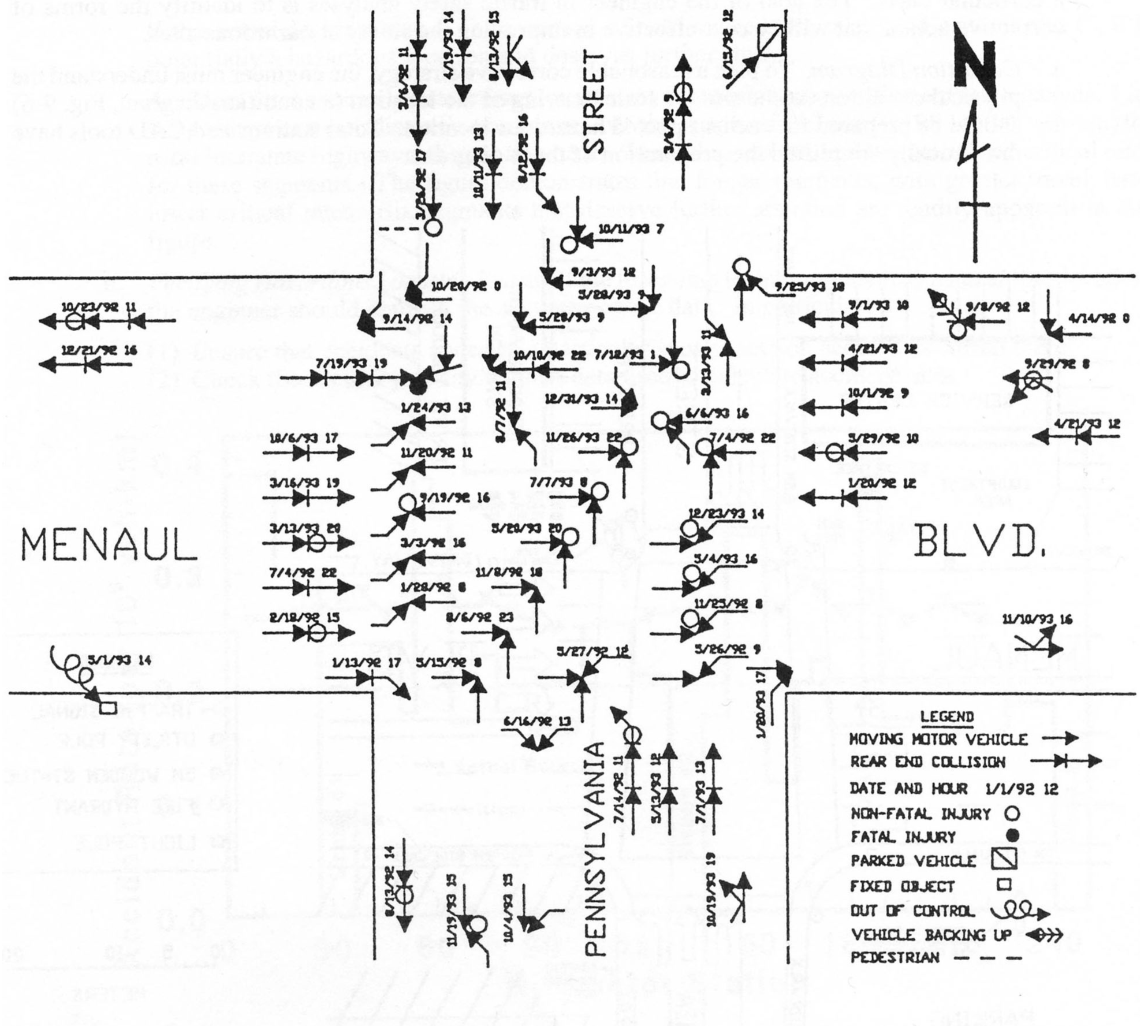



**Fig. 9-7--Collision Diagram**

*Source*: Homburger et al., *Fundamentals of Traffic Engineering* (*47*), Figure 9-7.

POTENTIAL COUNTERMEASURES FOR INTERSECTION ACCIDENTS

**TYPE OF INTERSECTION ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**LEFT TURNS**
**Restricted Sight Distance**
- Remove sight obstruction
- Provide turn lane
- Prohibit left turns
- Install or improve warning signs
- Reduce speed limit if justified by a study

**Large Volume of Left Turns at Unsignalized Intersection**
- Prohibit left turns
- Reroute left-turn traffic
- Add turn lane
- Install STOP signs (see MUTCD)
- Provide traffic signal
- Provide left-turn signal
- Increase left-turn bay length or taper length

**Large Volume of Left Turns at Signalized Intersection**
- Prohibit left turns
- Reroute left-turn traffic
- Add turn lane
- Provide left-turn signal
- Provide adequate channelization
- Revise signal timing (length, phase sequence, etc.)
- Provide turning guidelines (if there is a dual left-turn lane)
- Increase left-turn bay length or taper length

**Amber Phase Too Short at Signalized Intersection**
- Adjust amber phase
- Provide all-red phase
- Increase amber phase if signal is located after a downgrade and there is a high percentage of trucks

**Absence of Left-Turn Phase at Signalized Intersection**
- Provide left-turn signal phase
- Prohibit turns
- Split phase

**RIGHT TURNS**
**Restricted Sight Distance**
- Remove sight obstructions
- Restrict parking near corners
- Install STOP signs (see MUTCD)
- Install/improve street lighting
- Reduce speed limit if justified by a study
- Install YIELD signs (see MUTCD)
- Provide adequate channelization
- Provide traffic signal
- Install or improve warning sign
- Install or improve pedestrian crosswalk
- Install STOP bars

**Short Turning Radii for a Right Turn**
- Increase curb radii
- Prohibit right turn on reds
- Add right-turn indication to signal

**Large Total Intersection Volume**
- Install signals (see MUTCD)
- Add lane
- Retime signal if signal is present

**Inadequate Roadway Lighting**
- Improve or add roadway lighting

**Advance Intersection Warning Signs**
- Install or improve warning signs
- Install hazard beacons

**High Approach Speed**
- Reduce speed limit if justified by a study
- Install rumble strips
- Adjust amber phase

**Signal Timing**
- Adjust amber phase
- Provide all-red clearance phases
- Add multi-dial controller
- Install signal actuation
- Retime signals
- Provide progression through a set of signalized intersections

*Continued on next page*

POTENTIAL COUNTERMEASURES FOR INTERSECTION ACCIDENTS (*continued*)

**TYPE OF INTERSECTION ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**REAR END**
**Pedestrian Crossing**
- Install/improve signing or marking of pedestrian crosswalks
- Relocate crosswalk
- Install traffic signal (see MUTCD)
- Provide pedestrian “WALK” phase if signal is present

**Driver Not Aware of Intersection**
- Install/improve warning signs
- Reduce speed limit if justified by a study
- Install hazard beacons

**Large Numbers of Turning Vehicles**
- Create left- or right-turn lanes
- Prohibit turns
- Increase curb radii
- Provide left-turn signal phase if signal is present

**Inadequate Roadway Lighting**
- Improve roadway lighting

**Poor Visibility of Signals**
- Install/improve advance warning devices
- Install 12-in. signal lenses (see MUTCD)
- Install visors
- Install back plates
- Improve location of signal heads
- Add additional signal heads
- Reduce speed limit if justified by a study
- Remove sight obstruction
- Install overhead signal
- Relocate signal
- Increase amber phase

**Slippery Surface**
- Overlay pavement
- Provide adequate drainage
- Groove pavement
- Reduce speed limit if justified by a study
- Provide “Slippery When Wet” signs
- Improve roadway lighting

**Excessive Speed**
- Reduce speed limit if justified by a study

**Inadequate Signal Timing**
- Adjust amber phase
- Provide progression through a set of signalized intersections
- Provide all-red phase

**Unwarranted Signals**
- Remove signals (see MUTCD)

**RIGHT ANGLE**
**Inadequate Signal Timing**
- Adjust amber phase
- Provide all-red clearance phases
- Add multi-dial controller
- Install signal actuation
- Retime signals
- Provide protective movement phases

**Restricted Sight Distance**
- Provide adequate channelization
- Remove sight obstruction
- Install or improve warning sign
- Install hazard beacons
- Prohibit parking
- Provide markings to supplement signs

*Source: NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Table 14.

## ON-SITE OBSERVATION REPORT

Location ________________________________________ Control ____________
Date ___________________________________________ Time ______________

OPERATIONAL CHECKLIST:

| | | NO | YES |
|---|---|---|---|
| 1. | Do obstructions block the drivers' view of opposing vehicles? | ___ | ___ |
| 2. | Do drivers respond incorrectly to signals, signs, or other traffic control devices? | ___ | ___ |
| 3. | Do drivers have trouble finding the correct path through the locations? | ___ | ___ |
| 4. | Are vehicle speeds too high? Too low? | ___ | ___ |
| 5. | Are there violations of parking or other traffic regulations? | ___ | ___ |
| 6. | Are drivers confused about routes, street names, or other guidance information? | ___ | ___ |
| 7. | Can vehicle delay be reduced? | ___ | ___ |
| 8. | Are there traffic flow deficiencies or traffic conflict patterns associated with turning movements? | ___ | ___ |
| 9. | Would one-way operation make the location safer? | ___ | ___ |
| 10. | Is this volume of traffic causing problems? | ___ | ___ |
| 11. | Do pedestrian movements through the location cause conflicts? | ___ | ___ |
| 12. | Are there other traffic flow deficiencies or traffic conflict patterns? | ___ | ___ |

PHYSICAL CHECKLIST:

| | | NO | YES |
|---|---|---|---|
| 1. | Can sight obstructions be removed or lessened? | ___ | ___ |
| 2. | Are the street alignments or widths inadequate? | ___ | ___ |
| 3. | Are curb radii too small? | ___ | ___ |
| 4. | Should pedestrian crosswalks be relocated? Repainted? | ___ | ___ |
| 5. | Are signs inadequate as to usefulness, message, size, conformity, and placement? (See MUTCD) | ___ | ___ |
| 6. | Are signals inadequate as to placement, conformity, number of signal heads, or timing? (See MUTCD) | ___ | ___ |
| 7. | Are pavement markings inadequate as to their clearness or location? | ___ | ___ |
| 8. | Is channelization (islands or paint markings) inadequate for reducing conflict areas, separating traffic flows, and defining movements? | ___ | ___ |
| 9. | Does the legal parking layout affect sight distance, through or turning vehicle paths, or traffic flow? | ___ | ___ |
| 10. | Do speed limits appear to be unsafe or unreasonable? | ___ | ___ |
| 11. | Is the number of lanes insufficient? | ___ | ___ |
| 12. | Is street lighting inadequate? | ___ | ___ |
| 13. | Are driveways inadequately designed or located? | ___ | ___ |
| 14. | Does the pavement condition (potholes, washboard, or slick surface) contribute to accidents? | ___ | ___ |

Comments:

_______________________________________________________________________________
_______________________________________________________________________________
_______________________________________________________________________________

*Source*: *NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Figure 3.

POTENTIAL COUNTERMEASURES FOR OTHER ACCIDENTS

**TYPE OF OTHER ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**PEDESTRIAN**
**Pedestrians Walking on Roadways**
- Install sidewalks

**Driver Has Inadequate Warning of Frequent Midblock Crossings**
- Prohibit parking
- Install or improve warning signs
- Reduce speed limit if justified by a study
- Install pedestrian barriers

**Excessive Speed**
- Install or improve warning signs
- Reduce speed limit if justified by a study
- Increase enforcement
- Install pedestrian barrier

**Inadequate or Improper Pavement Markings**
- Install thermoplastic markings
- Provide signs to supplement markings
- Improve or install pavement markings

**Inadequate Roadway Lighting**
- Improve roadway lighting

**Lack of Adequate Gaps**
- Provide traffic signal
- Install or improve pedestrian crosswalk
- Provide pedestrian signal

**Large Turning Volumes**
- Create left- or right-turn lanes
- Prohibit turns
- Increase curb radii
- Provide pedestrian-only phase if signal is present

**Restricted Sight Distance**
- Remove sight obstructions
- Install pedestrian crossings
- Improve/install pedestrian crossing signs
- Reroute pedestrian paths
- Restrict parking

**Inadequate Protection for Pedestrians**
- Add pedestrian refuge islands
- Install pedestrian barrier to channelize pedestrian to a better crossing point

**Inadequate Signals**
- Install pedestrian signals (see MUTCD)

**Inadequate Signal Phasing**
- Add pedestrian “WALK” phase
- Change timing of pedestrian phase

**School Crossing Area**
- Use school crossing guards

**Sidewalk Too Close to Traveled Way**
- Move sidewalk laterally away from highway

**ANIMAL**
**High Number of Animal Accidents**
- Install advance warning sign
- Install fencing and underpasses to control animals crossing the roadway
- Install warning reflectors
- Encourage driver education about local animal behavior

**NIGHT**
**Poor Traffic Control Device Visibility**
- Install or improve warning sign
- Improve roadway lighting
- Improve or install delineation
- Install hazard beacons

**Inadequate Delineation**
- Install or improve warning sign
- Improve or install delineation
- Provide raised markings

**Inadequate Channelization**
- Install or improve warning sign
- Improve or install pavement markings
- Improve or install delineation
- Provide raised markings

**Inadequate Signing**
- Upgrade traffic control devices
- Provide illuminated sign

*Continued on next page*

POTENTIAL COUNTERMEASURES FOR OTHER ACCIDENTS (*continued*)

**TYPE OF OTHER ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**DRIVEWAY/ACCESS ACCIDENTS**
**Left-Turning Vehicles**
Provide turn-lane barrier
Install median
Install two-way left-turn lanes
Prohibit turn
**Improperly Located Driveway**
Regulate minimum spacing of driveways
Regulate minimum corner clearance
Move driveway to side street
Install curb to define driveway location
Consolidate adjacent driveways
**Large Volume of Main Street Traffic**
Move driveway to side street
Construct a local service road
Reroute through traffic
Add traffic signal (see MUTCD)
**Right-Turning Vehicles**
Provide right-turn lanes
Restrict parking near driveways
Increase the width of the driveway
Widen through lanes
Increase curb radii
Prohibit turn
Add acceleration lane
**Large Volume of Driveway Traffic**
Provide traffic signal
Provide acceleration and deceleration lanes
Provide adequate channelization
**Restricted Sight Distance**
Remove sight obstructions
Restrict parking near driveway
Install/improve street lighting
Reduce speed limit if justified by a study
Install hazard beacons
**Excessive Speed**
Reduce speed limit if justified by a study
**Inadequate Roadway Lighting**
Improve roadway lighting
Regulate minimum driveway spacing

**EXCESSIVE SPEED**
**High Speeds**
Increase conventional enforcement
Target specific locations or vehicle types
Use speed radar trailers or speed display boards
Begin automated enforcement program
Implement public relations campaign (perhaps using NHTSA materials)
**High Speeds at Intersections**
Install intersection ahead warning signs
Install signal ahead warning signs
Install rumble strips on intersection approach

**WET PAVEMENT**
**Slippery Pavement**
Overlay with skid resistant surface
Provide adequate drainage
Groove existing pavement
Reduce speed limit if justified by a study
Provide “Slippery When Wet” signs
**Inadequate or Improper Pavement Markings**
Improve or install pavement markings

**BICYCLE ACCIDENTS**
**Inadequate or Improper Pavement Markings**
Improve or install pavement markings
Provide signs to supplement markings
**Inadequate Roadway Lighting**
Improve roadway lighting

*Continued on next page*

POTENTIAL COUNTERMEASURES FOR OTHER ACCIDENTS (*continued*)

**TYPE OF OTHER ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**WORK ZONE**
**Narrow Work Zone Roadway**
Widen roadway by moving channelizing device or by using narrower devices
Improve reflectivity and delineation of devices
Illuminate or reflectorize channelizing devices
Increase roadway width by routing traffic onto the shoulder
**Insufficient Advance Warning**
Move taper upstream to increase sight distance
Add arrow board
**Drums Rolling into Travel Lane**
Replace drums with barricades
Increase traffic control device inspection frequency
**Too Many Traffic Control Devices in or Near Roadway**
Provide portable concrete median barriers
Increase spacing between devices
**Speeds Too High or High Variance in Speeds**
Increase design speeds
Provide speed enforcement patrols
Add advisory speed plates
Add rumble strips
Use variable message signs
**Large Vehicles**
Provide truck detours
Widen work zone roadway
Increase pavement strength
Provide climbing lanes
**Insufficient Work Zone Traffic Capacity**
Provide alternative routes
Change work schedule to exclude peak traffic periods
Increase capacity by routing traffic onto shoulder
Reduce length of work area
Install warning area
**Poor Work Vehicle Access or Egress to Traffic Stream**
Change work vehicle access or egress points
Provide flaggers
**Improper Flagging Technique**
Train flaggers
Move flaggers upstream
Replace flaggers with signal
Provide extra flaggers positioned near the upstream end of vehicle queue
**Insufficient Taper Length**
Lengthen taper
Add arrow board
Position arrow board near start of taper
Move taper upstream to increase sight distance
**Insufficient Acceleration Lane Length**
Lengthen taper
Install YIELD or STOP sign on on-ramp
Close on-ramp
Build temporary ramp downstream

*Source: NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Table 13.

SUPPLEMENTARY ENGINEERING STUDIES

| Supplementary Study | Purpose of Study | Symptom of Operational Study Problem that Indicates Study Needed |
|---|---|---|
| Capacity Studies | To determine operating condition and pinpoint bottlenecks | - Congestion delays |
| Travel Time and Delay Studies | To determine location and extent of delay and average travel speeds | - Intersection congestion<br>- Other congestion along roadway<br>- Rear-end accidents during peak period |
| Speed Studies | To determine actual vehicle speeds, actual speed profiles, and adequacy of legal and advisory speed limits | - Extremely high or low speeds observed during on-site visits<br>- Run-off-road accidents<br>- Rear-end accidents near intersections |
| Traffic Conflict and Erratic Maneuver Studies | To supplement traffic accident data and identify potential accident problems | - Hazardous driver actions observed during on-site visits<br>- Public complaints of safety problems not evident in accident data |
| Traffic Signal Studies | To determine need for and design of traffic signals, to identify improper phasing, timing, or interconnect strategy, and to identify unwarranted signals | - Right angle accidents at unsignalized intersections<br>- Excessive delay at STOP sign controlled intersections<br>- Excessive delay at existing signalized intersections |
| Sight Distance Studies | To determine adequacy of the length of highway visible to the driver | - Rear-end accidents at horizontal curves, crest vertical curves, or decision points<br>- Right-angle accidents at uncontrolled intersections<br>- Turning accidents at intersections |
| Turning Radius Studies | To determine adequacy of existing curb radii | - Sideswipe accidents involving vehicles traveling in opposite directions<br>- Rear-end accidents in right-turn lanes<br>- Evidence of large vehicles encroachment on curb or shoulder |
| Skid Resistance Studies | To determine the coefficient of tire-pavement friction | - Run-off-road or skidding accidents under wet-pavement conditions |

*Source: NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Table 11.

POTENTIAL COUNTERMEASURES FOR ROADWAY ACCIDENTS

**TYPE OF ROADWAY ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**LEFT TURNS**
**Large Volume of Left Turns**
- Add two-way left-turn lane
- Add turn bays at selected locations

**Restricted Sight Distance**
- Remove sight obstruction
- Install or improve warning signs
- Reduce speed limit if justified by a study
- Provide turn lane

**Excessive Speed**
- Reduce speed limit if justified by a study

**Lack of Adequate Gaps**
- Provide stop sign (see MUTCD)
- Improve roadway lighting
- Provide traffic signal (see MUTCD)

**RIGHT TURNS**
**High Approach Speed**
- Reduce speed limit if justified by a study
- Install rumble strips

**Roadway Design**
- Increase curb radii
- Install acceleration or deceleration lane

**REAR END**
**Driver Not Aware of Intersection**
- Install/improve warning signs
- Reduce speed limit if justified by a study

**Large Numbers of Turning Vehicles**
- Create left- or right-turn lanes
- Prohibit turns
- Increase curb radii
- Install acceleration or deceleration lane

**Excessive Speed**
- Reduce speed limit if justified by a study

**Inadequate Roadway Lighting**
- Improve roadway lighting

**SIDESWIPE ACCIDENTS**
**(Including opposite- and same-direction sideswipe accidents)**
**Roadway Design**
- Widen lanes
- Provide turn bays
- Install advanced route or street signs
- Install/improve pavement lane lines
- Prohibit parking
- Install median barrier
- Install rumble strips
- Upgrade or widen roadway shoulder
- Provide turn lane
- Install acceleration or deceleration lane
- Repair road surface

**Inadequate Signing/Marking**
- Install illuminated street name sign
- Install advance guide sign
- Improve or install pavement markings

**HEAD-ON ACCIDENTS**
**Roadway Design**
- Widen lanes
- Provide turn bays
- Install/improve pavement lane lines
- Remove parking
- Install median barrier/rumble strips

*Source: NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Table 12.

POTENTIAL COUNTERMEASURES FOR ROADSIDE ACCIDENTS

**TYPE OF ROADSIDE ACCIDENT**
**Contributing Factor**
Potential Countermeasure

**RUN-OFF-ROAD ACCIDENTS**
**(Including fixed-object, rollover, and other run-off-road accidents)**
**Objects Near Traveled Way**
- Remove obstacles
- Relocate obstacle away from roadway
- Install breakaway feature to light poles, signposts, etc.
- Install guardrail or crash cushioning device
- Reduce number of utility poles

**Roadway Design**
- Increase recovery distance
- Flatten sideslopes
- Install rumble strips
- Provide proper superelevation
- Widen lanes
- Repair road surface
- Reshape ditch
- Convert ditch to a closed drainage system
- Design drainage facility flush with roadside terrain
- Install or improve warning signs

**Shoulder Drop-off**
- Upgrade shoulder
- Repair shoulder

**Slippery Pavement**
- Overlay existing pavement/improve skid resistance
- Provide adequate drainage
- Groove existing pavement
- Reduce speed limit if justified by a study
- Provide "Slippery When Wet" signs
- Widen lane or shoulders

**Poor Delineation**
- Improve/install pavement markings
- Install roadside delineators
- Install advance warning signs (e.g., curves)
- Install raised pavement markers

**Excessive Speed**
- Reduce speed limit if justified by a study

**Inadequate Roadway Lighting**
- Improve roadway lighting

**Poor Traffic Control Device Visibility**
- Increase sign size
- Install reflectors on obstruction
- Use larger letters on sign
- Illuminate sign
- Use brighter grade material
- Add beacons on advanced warning signs

*Source: NCHRP Report 440: Accident Mitigation Guide for Congested Rural Two-Lane Highway* (*43*), Table 13.

# APPENDIX I

## RSAR Tool Kit and Sample RSAR Reports

**LINCOLN COUNTY**
**ROAD SAFETY AUDIT REVIEW**
**August 27, 2001**

(*Note: This is a real RSAR Report; however, the names of the roads and the county have been changed.*)

**Audit Team:** DOT Traffic & Safety Engineer, County Highway Superintendent, LTAP Field Services Manager, LTAP Coordinator, FHWA Operations & Technology Deployment Team Leader, FHWA Safety & Traffic Engineer.

**County Road 24 from the junction with US 52 to the junction with County Road 37. (East and West of Plains)**

This roadway was classified for the purposes of the Roadway Safety Audit Review (RSAR) as a combination of Rural Minor and Rural Local. The westerly one mile is a paved surface with the remainder of the section being a gravel road. Posted speed limit on the roadway is 65 MPH. For the purposes of the audit, the Milepost (MP) location information is referenced from the west end of the job (MP 0.0) increasing by miles heading east. Following are the findings and recommendations of the RSA team:

**The following items were identified as areas where immediate safety improvements should be made:**

- The vegetation along side the roadway has grown to the point where mowing is needed in the very near future to prevent animal vehicle collisions and increase sight distance at approaches.
- At MP 4.99, the existing culvert ends are inside the clearzone and immediately adjacent to the driving surface. Delineation should be installed at this location.

**The following items were identified as areas where low-cost improvements could have a positive impact on safety and should be considered in a reasonable period of time:**

- At MP 0.0, the "axle weight limit" sign is too close to the intersection and should be moved 100′ to the east.
- Centerline and edgeline striping is deteriorated and should be replaced for the first mile of the section.
- The no passing zones on the paved portion should have no passing zone pennants installed.
- At MP 0.50 (7th Street), the stop sign should be upgraded. The sign should be 30″ × 30″ and mounted at least 5′ above the roadway surface. Additionally, the existing post is non-breakaway; the new post should be breakaway (if wood, less than 24 sq. in. or drilled).
- At MP 0.70 (Main Street), intersection:
  - The "yield" sign should be replaced with a 30″ × 30″ "stop" sign on a breakaway post. This sign should be placed back around the radius on Main Street from where the existing sign is.
  - The steel posts on the northeast corner should be removed and replaced with 4″ × 4″ delineators on delineator posts, if needed at all.
  - The "double arrow" sign across from the approach is deteriorated and should be replaced. The new sign could be located further from the roadway (to the south) to decrease the chances of impact.
- At MP 0.78 (private approach on south side of roadway), there is restricted sight distance to the east. The trees (that appear to be on the right of way) should be trimmed.
- At 4th Street (no MP indicated), the "stop" sign is 24″ and should be upgraded to 30″ × 30″.
- There were several mailboxes throughout the project, although none appeared to be extremely hazardous (such as an old plow or a drum filled with concrete) most did not appear to be crashworthy. It is recommended that the county work with the landowners to get crashworthy mailboxes and turnouts installed where appropriate.

- At the intersection with Spider Road, the four-way stop should have supplemental “all way” plaques. Also, the height of the signs above the roadway did not appear adequate (especially on the northbound approach). The height should be checked to ensure they are the required 5′ from the top of the roadway to the bottom of the sign.
- At MP 1.05, the trees on the south side of the roadway are within the clearzone and should be cut. If cutting is not an acceptable option, they should be trimmed to minimize their encroachment into the roadway.
- The gravel surface on the section was in need of blading to re-establish ride and reshaping at crossroads and approaches to match up with the roadway. It also appeared that the road was getting in need of future regraveling.
- At MP 1.22, westbound, the “crossroad” warning sign at this location is unnecessary and could be removed.
- The posted speed limit of 65 MPH is too fast on the gravel section of this roadway. A reduction in the speed limit should be explored. As a minimum, the 65 MPH signs should be taken down, although statutorily this will not change the limit, the undesired effect of encouraging higher driving speeds may be eliminated.
- At MP 3.82, westbound, the “pedestrian crossing” sign should be removed. It is the wrong sign for advanced warning, and a “farm machinery” sign with a “supplemental distance” plaque would be more appropriate.
- At MP 4.00, due to the reduced sight distance at this intersection, the “yield” signs should be replaced with “stop” signs.
- At the intersection with County Road 37, the “crossroad” warning signs and/or the “cattle xing” warning signs should be removed. The sight distance coming into the yield control is adequate to where both are unneeded.

**The following items were identified as high cost improvements that should be considered as funds become available for a major rehabilitation or reconstruction of the roadway:**

- The intersection at MP 4.0 should be reconstructed to improve the sight distance.
- The vertical alignment at several locations is restrictive and could be improved. Limitations were noted at MP 1.1, 1.25, 4.5. Others may exist.
- The culvert at MP 4.99 should be extended to the clearzone.

### ROAD SAFETY AUDITS & ROAD SAFETY AUDIT REVIEWS

Road safety audits (RSAs), adaptable to local needs and conditions, are a powerful tool for state and local agencies to enhance the state of safety practices in their jurisdictions. With fewer new projects being constructed, the focus of RSAs is shifting to use by local agencies on existing roadways. For an existing road, the RSA is called a road safety audit review (RSAR).

What is a road safety audit? Simply put, an RSA is an examination of a future or existing roadway, in which an independent, qualified audit team reports on safety issues. The step-by-step procedure of an RSA can be performed during any or all stages of a project, including planning, preliminary design, detailed design, construction, pre-opening, and on existing roads.

RSAs are a proactive approach to improving transportation safety. Agencies in the United States are just beginning to focus on RSAs. Considering the unacceptable number of motor vehicle crashes that occur each year, the potential savings—in lives, serious injuries, and property damage—is incalculable.

Although concerns have been raised that the use of RSAs would increase an agency’s liability, in fact, just the opposite should be true. Implementing a plan to reduce the crash potential and improve the safety performance of a roadway using a proactive approach to safety can be used in defense of tort liability. Identifying and documenting safety issues on an existing roadway is not an admission of guilt. Rather, it is the first step in a process designed to improve safety. Proper documentation, communication and logical prioritization of an agency’s plan to address safety issues would be difficult to fault.

An RSAR program need not be disruptive to an agency’s ongoing operations; it can be implemented in small stages as time and resources allow. Classifying the roads in your jurisdiction, and tailoring the RSAR to fit your needs, is a practical approach to improving road safety that can be implemented in spite of limited resources and the ongoing need to focus on maintenance and operations. Consider using the expertise of personnel from neighboring counties to lend more eyes and fresh viewpoints in assessing the safety of your roadways. Seek additional and special funding from 402 safety funds using the results of the audit.

Determine the value of an RSAR by (1) having a roadway section audited using a team of three or four road supervisors and engineers from adjacent counties, and/or (2) auditing a major project being designed to improve one of your roads. The value of the RSA/RSAR process as an important component of any agency’s safety strategy will become evident.

**PLANNING FOR AN RSAR PROGRAM**

I. Classify your roadway system functionally.
   a. Identify several sections of roadways in each functional classification for an RSAR trial.

II. Begin a trial RSAR program.
   a. Solicit reviews from team of adjacent local county engineers and road supervisors (three or four).
   b. Provide the RSAR for one another's selected roadways. (Use the attached RSAR Tool Kit.)

III. Prepare a brief statement of your findings.
   a. Briefly summarize the safety issues.
   b. Prioritize the issues identified.
   c. Recommend actions to be taken.
   d. Provide an overall evaluation of the road section.
   e. Discuss the findings with each county.

IV. Seek special funding as needed.
   a. Consider applying for 402 safety funds.

V. Implement and evaluate the RSAR program.
   a. Implement improvements.
   b. Evaluate the RSAR concept.
   c. Evaluate the effectiveness of the improvements.

VI. Make the decision on beginning an RSAR trial program.
   a. Begin an RSAR program by developing a four or five-year plan to look at all roadways.
   b. Consider auditing the design of a major project from a safety viewpoint for all road users.

VII. Promote the proactive RSA/RSAR program.

# RSAR TOOL KIT

**Developed by Eugene M. Wilson, Ph.D., PE, PTOE**

## LOCAL RURAL GOVERNMENT RSAR PROCESS

**Functional Local Rural Road Classifications**

**RSAR Form**

**Instructions for Local Rural Road Safety Audit Review Program**

**Safety Issues to LOOK FOR**

**Sample Report of RSAR Findings**

**“The key to safety is implementing improvements for safety issues identified as urgent.”**

**Functional Local Rural Road Classification**

**Rural Major High-Speed**

Serves larger towns and other traffic generators not served by higher functional classification systems and serves more important intracounty travel corridors.

Typically:
- Paved surfaces
- Traffic volumes up to 400 v.p.d.
- Operating speed 40–65 m.p.h.
- Limited intersections and accesses

**Rural Minor**

Accumulates traffic from local roads, brings all developed areas within reasonable distances of collector roads, provides service to the remaining smaller communities, and links the locally important traffic generators within their rural region.

Typically:
- Unpaved surfaces, but some may be paved
- Traffic volumes up to 250–400 v.p.d.
- Operating speed 30–60 m.p.h.

**Rural Local**

Provides access to land adjacent to the higher functional classification network and serves travel into isolated areas over relatively short distances.

Typically:
- Unpaved surfaces
- Traffic volumes 100–250 v.p.d.
- Operating speed 20–45 m.p.h.

**Rural Major Medium-Speed**

Serves smaller towns and other traffic generators not served by higher functional classification systems, links these places with nearby cities and larger towns or with higher systems, and serves more important intracounty travel corridors.  Links to rural major and collector classifications.

Typically:
- Paved surfaces but some may be unpaved
- Traffic volumes up to 400 v.p.d.
- Operating speed 30–45 m.p.h.
- Frequent accesses

**Rural Low-Volume Local**

Provides access to adjacent land and serves travel over relatively short distances.

Typically:
- Unimproved surfaces and some may be considered improved, but unpaved
- Traffic volumes 0–100 v.p.d.
- Operating speed variable

# Road Safety Audit Review for Local Rural Roads

Jurisdiction: ____________________________________________County

Date: ____________________________________________

Location: ____________________________________________

Weather: ____________________________________________

Auditor(s): ____________________________________________

Road Class: ________________________________________

Paved______ Unpaved______ Unimproved______ Speed_____

Sketch of road section:

→Please include **exact start and end point**, **north arrow**, and other features as appropriate, i.e. cattleguards, etc.

N

Overall Evaluation of Road Section, check one and/or comment:

| | |
|---|---|
| 1. Leave section as it is, no improvement needed at this road section | |
| 2. Schedule Routine Maintenance | |
| 3. Major Reconstruction Required | |
| 4. Perform Routine Maintenance Immediately | |
| 5. Spot Improvement(s) Needed | |
| 6. Comments: | |

Page____ of ____

- ☐ **Main Route Safety Evaluation**
- ☐ **Evaluation of Intersection/Approaches to Main Route**

Direction of travel: **N NW W SW S SE E NE** (please circle appropriate direction)

| **Approximate Location** | **Description of Concern or Insert a Number from the LOOK FOR** | **Urgency** | **Recommended Improvement Number and/or Specify** |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

| **Urgency, considering classification of the roadway and cost of improvements** | **Recommended improvement, considering classification of the roadway and cost of improvements** |
|---|---|
| 1. Leave as it is<br>2. No urgency, but should be addressed<br>3. Schedule improvement in reasonably short time<br>4. As soon as possible | 1. Remove<br>2. Repair<br>3. Relocate<br>4. Replace<br>5. Delineate<br>6. Shield<br>7. Other, please indicate action |

**Instructions for Local Rural Road Safety Audit Review Program**

When you get to the road section:

1. Remember to evaluate the road section based on its functional rural road classification.

2. Review the "Look For."

3. Remember to consider all road users.

4. Drive slowly through the road section and look for potential safety issues. Focus on these issues in the travel way and to the right, as the initial review will be completed when you return to the starting point.

5. Next, drive through the test section at the posted speed limit or at safe operating speed.

6. Start RSAR by resetting odometer at start point, and drive slowly, with hazard lights activated. Stop and evaluate all potential safety deficiencies, looking at the travel way and to the right. Do one direction at a time.

7. Identify potential safety deficiencies. Use the odometer reading to approximate beginning and ending points or spots of deficiency. Repeat in the opposite direction and remember to reset odometer before you start that direction.

8. Next, check access approaches on the right side of the road. Drive access into the road section noting issues needing to be corrected, sight obstructions, signing, etc. Indicate the access location using the approximate mileage on the road section identified previously. Check for both travel directions.

9. For the road classification of this section, indicate how deficiencies should be corrected:
   a) Leave section as it is, no improvement needed for this road section, i.e. do nothing.
   b) Schedule Routine Maintenance.
   c) Major Reconstruction Required.
   d) Perform Routine Maintenance Immediately.
   e) Spot Improvement(s) Needed.

Have a safe trip!

**Safety Issues to LOOK FOR:**

**Roadside Features**

1. Are clear zones free of hazards and non-traversable side slopes without safety barriers?
2. Are the clear zones free of nonconforming and/or dangerous obstructions that are not properly shielded?

**Road Surface-Pavement Condition**

3. Is the pavement free of defects that could result in safety problems (e.g., loss of steering control)?
4. Are changes in surface type (e.g., pavement ends or begins) free of poor transitions?
5. Is the pavement free of locations that appear to have inadequate skid resistance that could result in safety problems, particularly on curves, steep grades, and approaches to intersections?
6. Is the pavement free of areas where ponding or sheet flow of water may occur resulting in safety problems?
7. Is the pavement free of loose aggregate/gravel, which may cause safety problems?

**Road Surface-Pavement Markings**

8. Is the road free of locations with pavement marking safety deficiencies?
9. Is the road free of pavement markings that are not effective for the conditions present?
10. Is the road free of old pavement markings that affect the safety of the roadway?

**Road Surface-Unpaved Roads**

11. Is the road surface free of defects that could result in safety problems (e.g., loss of steering control)?
12. Is the road surface free of areas where ponding or sheet flow of water may occur resulting in safety problems?
13. Is the road surface free of loose gravel or fines that may cause safety problems (control, visibility, etc.)?
14. Are changes in surface type (e.g., pavement ends or begins) free of drop-offs or poor transitions?

**Signing and Delineation**

15. Is the road free of locations where signing is needed to improve safety?
16. Are existing regulatory, warning, and directory signs conspicuous?
17. Is the road free of locations with improper signing which may cause safety problems?
18. Is the road free of unnecessary signing which may cause safety problems?
19. Are signs effective for existing conditions?
20. Can signs be read at a safe distance?
21. Is the road free of signing that impairs safe sight distances?
22. Is the road free of locations with improper or unsuitable delineation (post delineators, chevrons, object markers)?

**Intersections and Approaches**

23. Are intersections free of sight restrictions that could result in safety problems?
24. Are intersections free of abrupt changes in elevation or surface condition?
25. Are advance warning signs installed when intersection traffic control cannot be seen a safe distance ahead of the intersection?

**Special Road Users, Railroad Crossings, Consistency**

26. Are travel paths and crossing points for pedestrians and cyclists properly signed and/or marked?
27. Are bus stops and mail boxes safely located with adequate clearance and visibility from the traffic lane?
28. Is appropriate advance signing provided for bus stops and refuge areas?
29. Are railroad crossing (crossbucks) signs used on each approach at railroad crossings?
30. Are railroad advance warning signs used at railroad crossing approaches?
31. Are railroad crossings free of vegetation and other obstructions that have the potential to restrict sight distance?
32. Are roadway approach grades to railroad crossings flat enough to prevent vehicle snagging?
33. Is the road section free of inconsistencies that could result in safety problems?

# APPENDIX J

## Sample RSA Reports

**PRELIMINARY DESIGN ROAD SAFETY AUDIT**

**June 29, 2001**

(*Note: This is a real Road Safety Audit report, but the names of the roads and the County have been changed*.)

**Project Location:**
The project is located at the existing interchange of I-118 and SR 10/Riverview Drive. The project extends along Riverview Drive from the Mountain Drive/Riverview Drive intersection easterly to a point approximately 800 feet west of Imperial Drive/ Riverview Drive intersection. The project also includes realignment of Parkway Drive to the east to intersect Riverview Drive at an existing median opening across from the Garden Center driveway.

**Synopsis of Approved Concept:**
The project proposes to reconstruct the I-118 interchange at Riverview Drive and relocate Parkway Drive away from the northbound ramp location. The Riverview Drive bridge over I-118 would be replaced along with modifications to the I-118 bridge College Park Road.

**Audit Team:**
District Design Engineer (Team Leader)
District 6 Traffic Engineer
District 6 Pre-Construction Engineer
District 6 Construction Engineer
District 5 Traffic Operations Engineer
District 2 Construction Estimator
Urban Design Engineer
District 1 Traffic Engineer

**Information Used for Audit:**
- Concept Report
- Revised Concept Report
- Preliminary Plans
- Site Visit

**Findings:**

Median nose point location at Mountain Drive needs to be redesigned.

Check all intersections for pedestrian refuge provisions in medians and islands.

Heavy pedestrian use was observed upon site visit. Plans not up to date with revised concept audited.

Median opening spacing is less than 660 foot standard. This may introduce operational and safety problems.

Potential weave problem from Ramp B to Northern Avenue.

Lighting of interchange is not in plans and should be considered, particularly under the new Riverview Drive Bridge over I-118.

Driveway profiles at Sta 110+70 LT & RT should be treated as side street to provide smoother alignment. These serve major government complex facilities.

Some drainage issues left unresolved in the median.

Typical sections need refined to address how turn lane is to be handled.

May need additional R/W for Signal Strain Poles to provide for horizontal clearance.

Consider increasing the radius of Ramp C/Riverview Drive to 75 ft.

Examine operation of Emergency vehicles in the project vicinity.

Consider prohibiting left turn from driveways at Sta 110+70 LT and RT.

Consider removing unnecessary driveways.

Consider adding stamped colored concrete for 18 inches behind the curb to serve as a buffer from the motor vehicles.

Team leader July 1, 2001

**ROAD SAFETY AUDIT REPORT**

**Intersection VT Route 100 / US 2–Class I TH**
**Washington County**
**05 June 2001**

(*Note: This is a real Road Safety Audit report, but the names of the roads and the County have been changed.*)

**Stage of Road Safety Audit**
The audit review team reviewed planning stage documentation for this report.

**Description of Project and Background**
Proposed roundabout at the westerly intersection of—Route #220 and US Route #35 within the Town Highway limits of Village in the city of XXX. That information as listed below resulted in the recommendation of a roundabout at this location.

**RSA Team Review: List of RSA Audit Team**
The Road Safety Audit Team met on Tuesday, June 5, 2001, to review the subject project, Team members included:

- FHWA Safety Engineer—(Team Leader)
- Planning Engineer—DOT
- Construction Engineer—DOT
- Traffic Engineer—DOT

**Information Used in the Completion of the Road Safety Audit**

- Village of XXX—Transportation Infrastructure, Parking, and Circulation Study
- Local Knowledge of Project Area
- Project Manager Presentation of Project Area and History
- MUTCD—Millennium Issue
- AASHTO—Green Book, 2001 Edition
- State Access Policy—1999 Edition

**A Listing of Potential Safety Concerns**
This section describes overall corridor and specific area concerns related to safety.

1. Pedestrian Mobility to include School and Recreational Areas
2. Access to Abutting Properties
3. Bicycle Mobility through Proposed Improvement
4. Proximity to Recreational and Elderly Use Facilities
5. Ability of Improvement to Accommodate Traffic Volumes
6. Speed of Oncoming Traffic
7. Ability of Improvement to Accommodate Variety of Traffic Types
8. Ability of Improvement to Accommodate Turning Movements
9. Accommodation of Union Street Leg
10. Proximity of Railroad Overpass—Sight Distance (pedestrians + vehicles)
11. Night Visibility
12. Work Zone Safety during Construction Activities
13. Ability to Appropriately Maintain Facility during Winter Season
14. Encroachment on Limited-Access ROW
15. Sight Distance/Hazard Introduction with Introduction of Landscaping Plan
16. Proposed Improvement to “Correct” Current Accident History? (HAL)
17. Driver Expectancy

**Audit Team Findings and Guidance**

1. Finding 1(a): Abundance of elementary school age and younger children that must cross US 21 and Highway 220 to get to recreational facilities and school premises.

   Guidance: Investigate possibility of eliminating proposed crosswalks (6) and determine through local input preferred path of travel. Additionally, in conjunction with that above, investigate possibility of eliminating proposed sidewalk to further define pedestrian travel way. Would propose providing a school crosswalk guard under state guidance during those hours of school activity and sign those crosswalks as such.

   Finding 1(b): In that there is present in the project area a significant number of persons elderly and/or of diminished capacity.

   Guidance: Would again propose investigating the possibility of simplifying pedestrian traffic patterns in an effort to reduce the decision-making process while negotiating the proposed improvement.

2. Finding: There is at least one drive that introduces possible conflict to those traffic patterns that will be the result of constructing the proposed improvement.

   Guidance: Explore possibility of improved access control. Suggestions would be to eliminate drive to the pool area and couple with other access present in the area or provide new access through other existing facility or through acquisition of property. Also consider acquisition of Local XXX paint property in an effort to eliminate conflicting access and perhaps provide additional green space with that area purchased.

3. Finding: Due to adjacent land uses (recreational areas, housing, school), bike presence in the proposed project area is prevalent.

   Guidance: Would consider bike path independent of proposed project to divert bicycle traffic away from the project area.

4. Finding: Projected that future traffic will result in proposed improvement being functionally obsolete.

   Guidance: Promote alternate work schedules at State complex. Explore opportunities for park and ride lots for I-90 and US 21 (west of intersection) traffic.

5. Finding: Concern of exit speed into village downtown will accelerate to excess.

   Guidance: Continuation and perhaps accentuation of traffic control for US 21 west traffic. Investigate possibility of installing rumble strips and speed carts for the short term for incoming traffic.

6. Finding: Presence of large vehicles to include national guard vehicles, delivery trucks, semi trailers, emergency vehicles, and school buses raise turning movement questions.

   Guidance: Consider installing temporary installation at preliminary design stages prior to committing to a final design. Consider revising simple roundabout design to a "kidney" shape design in an effort to smooth traffic flow and further accommodate Union Street.

   8 and 9 (see 7 above).

10. Finding: Questionable sight distance at this structure.

    Guidance: As design progresses, ensure that sight distance is greater that minimum.

11. Finding: Question of sufficient current illumination.

    Guidance: Consider incorporation of street lighting in project design.

12. Finding: Concern of all traffic types being to safely traverse during construction activities.

    Guidance: Traffic control details are a must to accommodate pedestrian and bicycle traffic during construction. Consider oversize vehicles that will be present during project construction and provide appropriate traffic control devices and lane widths. Consider phased construction. Consider local events that may occur during the construction phase and provide appropriate traffic control.

13. Finding: Introduction of curbing and other vertical elements cause concern over winter maintenance activities.

    Guidance: Review all curbing lines and other vertical elements to perhaps provide smooth transitions to facilitate snow removal. Consider design to provide for durable materials for vertical elements. Ensure design can be maintained by standard class 17 dump trucks.

14. Finding: Possible encroachment on limited access row.

    Guidance: Review further designs such that existing limited access limits are maintained and not compromised.

15. Finding: Concern of sight distance with introduction of landscaping elements.

    Guidance: Consider the longer term in landscape planting material for impacts on sight distance issues.

16. Finding: Question of whether proposed design addresses accident history of the area being a known HAL.

    Guidance: Project or predict the effects of the design on crashes and monitor the intersection for five years to demonstrate actual effect.

17. Finding: Question as to whether the "new" concept of proposed design will fit with driver expectancy.

    Guidance: Provide adequate and standard warning devices to warn, alert, and educate drivers. Consider use of educational plaques under warning signs for a period of three years. Working with the school and recreation department, distribute brochures and educate the youths in the proper use of crossings at the roundabout.

Team Leader June 7, 2001

# APPENDIX K

## AASHTO Strategic Highway Safety Plan

**AASHTO Strategic Highway Safety Plan**
**A Comprehensive Plan to Substantially Reduce Vehicle-Related Fatalities and Injuries on the Nation's Highways**
**September 1997**

**Table of Contents**



Source: http://www.transportation1.org/safetyplan/plan/index.asp

**Guidance for Implementation of the AASHTO Strategic Highway Safety Plan***

Aggressive-Driving Collisions

Collisions with Trees in Hazardous Locations

Head-On Collisions

Run-Off Road Collisions

Unlicensed Drivers and Drivers with Suspended or Revoked Licenses

Unsignalized Intersection Collisions

*A series of guides are being developed for the strategies indicated in the AASHTO Plan. The titles of the first six are indicated above. Others are being developed and linking to the AASHTO web page will provide the latest development information.

# APPENDIX L

## Transportation Agencies

**American Association of State Highway and Transportation Officials (AASHTO)**
444 N. Capitol Street, NW
Washington, D.C. 20001
Telephone: 202-624-5254
Fax: 202-624-5469
Website: http://www.aashto.org

**American Public Works Association (APWA)**
Headquarters
2345 Grand Boulevard, Suite 500
Kansas City, MO 64108-2625
Telephone: 816-472-6100
Fax: 816-472-1610
Website: http://www.pubworks.org/

**American Red Cross National Headquarters**
430 17th Street, NW
Washington, D.C. 20006-5307
Telephone: 703-248-4222
Website: http://www.redcross.org

**American Road and Transportation Builders Association (ARTBA)**
The ARTBA Building
1010 Massachusetts Avenue, NW
Washington, D.C. 20001-5004
Telephone: 202-289-4434
Fax: 202-289-4435
Website: http://www.artba-hq.org

**American Traffic Safety Services Association, Inc. (ATSSA)**
ATSSA Building
15 Riverside Parkway, Suite 100
Fredericksburg, VA 22407-1022
Telephone: 540-368-1701
Fax: 540-369-1717
Website: http://www.atssa.com/

**Federal Highway Administration (FHWA)**
Office of Safety
400 Seventh Street, SW
Washington, D.C. 20590
Telephone: 202-366-2288
Fax: 202-366-3222
Website: http://www.ota.fhwa.dot.gov

**Institute of Transportation Engineers (ITE)**
1099 14th Street, NW
Suite 300 West
Washington, D.C. 20005-3438
Telephone: 202-289-0222
Fax: 202-289-7722
Website: http://www.ite.org/

**Local Transportation Assistance Program (LTAP)**
Clearinghouse
American Public Works Association (APWA)
1301 Pennsylvania Avenue, NW, Suite 501
Washington, D.C. 20004
Telephone: 202-347-7267
Fax: 202-737-9153
Website: http://patriot.net/~ltap/ltap.html

**Center for Microcomputers in Transportation (McTrans Center)**
University of Florida
Transportation Research Center, 512 Weil Hall
P.O. Box 116585
Gainesville, FL 32611-6585
Telephone: 352-392-0378
Fax: 352-392-3224
Website: http://mctrans.ce.ufl.edu

**National Association of County Engineers (NACE)**
440 First Street, NW
Washington, D.C. 20001-2028
Telephone: 202-393-5041
Fax: 202-393-2630
Website: http://www.nace@naco.org

**National Highway Institute (NHI)**
4600 N. Fairfax Drive, Suite 800
Arlington, VA 22203
Telephone: 1-877-558-6873
Fax: 703-235-0593
Website: http://www.nhi.fhwa.dot.gov/

**National Highway Traffic Safety Administration (NHTSA)**
400 Seventh Street, SW
Washington, D.C. 20590
Telephone: 202-366-4198
Fax: 202-366-6916
Website: http://www.nhtsa.dot.gov/

**National Safety Council (NSC)**
1121 Spring Lake Drive
Itasca, IL 60143-3201
Telephone: 800-620-7619
Fax: 630-285-1315
Website: http://www.nsc.org/

**National Work Zone Safety Information Clearinghouse**
P.O. Box 3135
College Station, TX 77843
Telephone: 888-447-5556
Fax: 408-845-0568
E-mail: workzone@tamu.edu
Website: http://wzsafety.tamu.edu

**Personal Computers in Transportation (PC-TRANS)**
University of Kansas Transportation Center
2011 Learned Hall
Lawrence, KS 66045
Telephone: 913-864-5655
Fax: 913-864-3199
E-mail: pctrans@kuhub.cc.ukans.edu
Website: http://kuhub.cc.ukans.edu/~pctrans

**Transportation Research Board (TRB)**
500 Fifth Street, NW
Washington, D.C. 20001
Telephone: 202-334-2934
Fax: 202-334-2003
Website: http://www.nas.edu/trb

# APPENDIX M

## Local Technology Assistance Program and Technology Transfer Assistance Program Centers

Alabama Technology Transfer Center, Department of Civil Engineering, 238 Harbert Engineering Center, Auburn University, Auburn, AL 36849-5337; Telephone: (334) 844-4320; Fax: (334) 844-6290; E-mail: tsqjrmc@eng.auburn.edu; Website: http://www.AlabamaT2.org.

Alaska Transportation Technology Transfer Center, 2301 Peger Road, Fairbanks, AK 99709-5399; Telephone: (907) 451-5320; Fax: (907) 451-5340; E-mail: david_waldo@dot.state.ak.us; Website: http://www.dot.state.ak.us.

Arizona LTAP, 1130 N. 22 Avenue, Phoenix, AZ 85009; Telephone: (602) 712-8461; Fax: (602) 712-3007; E-mail: aparris@dot.state.az.us; Website: http://www.azltap.org.

Arkansas Technology Transfer Program, Arkansas State Highway and Transportation Dept., P.O. Box 2261, Little Rock, AR 72203; Telephone: (501) 569-2074; Fax: (501) 569-2070; E-mail: LTAP@ahtd.state.ar.us; Website: http://www.ahtd.state.ar.us/planning/T2/index.htm.

California LTAP, Institute of Transportation Studies, Technology Transfer Program, University of California at Berkeley, 1355 S. 46th Street, Bldg. 155, Richmond, CA 94804; Telephone: (510) 231-9590; Fax: (510) 231-9459; E-mail: lkhs@uclink.berkeley.edu; Website: http://www.its.berkeley.edu/techtransfer.

Colorado LTAP, University of Colorado at Boulder, UCD 561, 3100 Marine Street, Boulder, CO 80309-0561; Telephone: (303) 735-3530; Fax: (303) 735-2968; E-mail: cltap@colorado.edu; Website: http://ltap.colorado.edu.

Connecticut Technology Transfer Center, Connecticut Transportation Institute, University of Connecticut, Unit-5202, Storrs, CT 06269-5202; Telephone: (860) 486-5400; Fax: (860) 486-2399; E-mail: shea@engr.uconn.edu; Website: http://www.cti.uconn.edu/ti/Technology/technology.htm.

Delaware T2 Center, Delaware Center for Transportation, 360 DuPont Hall, University of Delaware, Newark, DE 19716; Telephone: (302) 831-6241; Fax: (302) 831-0674; E-mail: lklepner@ce.udel.edu; Website: http://www.deldot.net/static/t2/index.html.

Florida Transportation Technology Transfer Center, University of Florida, P.O. Box 116587, Gainesville, FL 32611-6587; Telephone: (352) 392-2371; Fax: (352) 392-3224; E-mail: t2@ce.ufl.edu; Website: http://t2.ce.ufl.edu.

Georgia Department of Transportation LTAP Center, 276 Memorial Drive SW, Atlanta, GA 30303; Telephone: (404) 656-5364; Fax: (404) 657-5193; E-mail: Rick.Smith@dot.state.ga.us; Website: www.dot.state.ga.us/dot/personnel/training/training_ext/index.shtml.

Hawaii Local Technical Assistance Program, University of Hawaii, Department of Civil Engineering, 2540 Dole Street, Holmes Hall #383, Honolulu, HI 96822; Telephone: (808) 956-6538; (808) 956-9006; Fax: (808) 956-8851; E-mail: juli@wiliki.eng.hawaii.edu; Website: http://www.eng.hawaii.edu/~hltap.

Idaho Technology Transfer (T2) Center—LTAP, University of Idaho, P.O. Box 440911, Moscow, ID 83844-0911; Telephone: (208) 885-4334; Fax: (208) 885-2877; E-mail: idahot2@uidaho.edu; Website: http://www.its.uidaho.edu/idahot2.

Illinois Technology Transfer Center, Illinois Department of Transportation, 2300 S. Dirksen Parkway, Room 205, Springfield, IL 62764; Telephone: (217) 785-5048; Fax: (217) 785-7296; E-mail: T2LRSDOT@nt.dot.state.il.us; Website: http://www.dot.state.il.us/blr/t2center.html.

Indiana LTAP, Vision Technology 1, 1435 Win Hentschel Blvd., Ste. B100, West Lafayette, IN 47906-4145; Telephone: (765) 494-2164; Fax: (765) 496-1176; E-mail: mondell@ecn.purdue.edu; Website: http://www.ecn.purdue.edu/INLTAP.

Iowa LTAP, Center for Transportation Research and Education (CTRE), Iowa State University Research Park, 2901 S. Loop Drive, Suite 3100, Ames, IA 50010-8632; Telephone: (515) 294-8103; Fax: (515) 294-0467; E-mail: desmith@iastate.edu; Website: http://www.ctre.iastate.edu/ltap/.

Kansas University Transportation Center, 1530 W. 15th St., 2011 Learned Hall, Lawrence, KS 66045; Telephone: (785) 864-5658; Fax: (785) 864-3199; E-mail: weaver@ku.edu; Website: http://www.ksltap.kutc.ku.edu/index.html.

Kentucky Transportation Center, University of Kentucky, 140 Raymond Building, Lexington, KY 40506-0281; Telephone: (800) 432-0719; (859) 257-4513; Fax: (859) 257-1061; E-mail: panderso@engr.uky.edu; Website: http://www.ktc.uky.edu.

Louisiana LTAP Technology Transfer Center, 4101 Gourrier Avenue, Baton Rouge, LA 70808-4443; Telephone: (225) 767-9117; Fax: (225) 767-9156; E-mail: dgrouchy@ltrc.lsu.edu; Website: http://www.ltrc.lsu.edu.

Maine Local Roads Center, Maine DOT, Sta. 16, Community Services Division, Augusta, ME 04333-0016; Telephone: (207) 624-3270; Fax: (207) 624-3301; E-mail: peter.coughlan@state.me.us; Website: http://www.state.me.us/mdot/planning/csd/mlrc.htm.

Maryland Transportation Technology Transfer Center, University of Maryland, Myers Building 806, Suite 3102, College Park, MD 20742-6602; Telephone: (301) 403-4623; Fax: (301) 403-4591; E-mail: ttc@eng.umd.edu; Website: http://www.ence.umd.edu/tttc.

Baystate Roads Program—Massachusetts, University of Massachusetts Transportation Center, Marston Hall 214, Amherst, MA 01003-5205; Telephone: (413) 545-2604; Fax: (413) 545-6471; E-mail: ahmadjia@ecs.umass.edu; Website: http://www.ecs.umass.edu/baystate_roads/.

Michigan Local Technical Assistance Program, 309 Grover C. Dillman Hall, 1400 Townsend Drive, Houghton, MI 49931-1295; Telephone: (906) 487-2102; Fax: (906) 487-3409; E-mail: ltap@mtu.edu; Website: http://www.MichiganLTAP.org.

Minnesota Technology Transfer/LTAP Program, Center for Transportation Studies, Suite 200 Transportation and Safety Building, 511 Washington Avenue SE, Minneapolis, MN 55455; Telephone: (612) 626-1077; Fax: (612) 625-6381; E-mail: jgrothaus@cts.umn.edu, cmarti@cts.umn.edu; Website: http://www.cts.umn.edu/T2/.

Mississippi Center for Technology Transfer, P.O. Box 18125, Jackson State University, Jackson, MS 39217-0625; Telephone: (601) 979-2339; Fax: (601) 973-3703; E-mail: tsquare@ccaix.jsums.edu; Website: http://www.jsums.edu/~tsquare/index.html.

Missouri Local Transportation Resource Center, University of Missouri–Rolla, Civil Engineering Department, 134 Butler–Carlton Hall, 1870 Miner Circle, Rolla, MO 65409-0030; Telephone: (573) 341-4693; Fax: (573) 341-4729; E-mail: qureshim@umr.edu; Website: http://web.umr.edu/~mltrc/.

Montana Local Technical Assistance Program, 416 Cobleigh Hall, P.O. Box 173910, Bozeman, MT 59717-3910; Telephone: (406) 994-6100; Fax: (406) 994-1697; E-mail: MTLTAP@coe.montana.edu; Website: http://www.coe.montana.edu/ltap/.

Nebraska Technology Transfer Center, P.O. Box 880560, Lincoln, NE 68588-0560; Telephone: (402) 472-5748; Fax: (402) 472-0685; E-mail: jstasenka1@unl.edu; Website: http://www.engext.unl.edu/t2.

Nevada Transportation Technology Transfer Center, Nevada T2 Center/257 University of Nevada, Reno, NV 89557; Telephone: (775) 784-1433; Fax: (775) 784-1429; E-mail: maria@unr.edu; Website: http://www.t2.unr.edu.

University of New Hampshire Technology Transfer Center, 33 College Road, Durham, NH 03824-3591; Telephone: (603) 862-2826; Fax: (603) 862-2364; E-mail: kathy.desroches@unh.edu; Website: http://www.t2.unh.edu.

Center for Advanced Infrastructure and Technology–LTAP, College of Engineering, Civil and Environmental Engineering, Rutgers, the State University of New Jersey, 623 Bowser Road, Piscataway, NJ 08854-8014; Telephone: (732) 445-3632, (732) 445-5236; Fax: (732) 445-5636; E-mail: jorth@rci.rutgers.edu, jleli@rci.rutgers.edu; Website: http://www.ltap.rutgers.edu/.

New Mexico LTAP Center, 1001 University Blvd. SE, Suite 103, Albuquerque, NM 87106-4342; Telephone: (800) 523-3028; Fax: (505) 246-6473; E-mail: olivastj@unm.edu; Website: http://www.nmshtd.state.nm.us/general/gen_depts/ gen_depts_tpd/ gen_depts_tpd_rb/LTAP.html.

Cornell Local Roads Program (New York LTAP), 416 Riley–Robb Hall, Ithaca, NY 14853-5701; Telephone: (607) 255-8033; Fax: (607) 255-4080; E-mail: clrp@cornell.edu; Website: http://www.clrp.cornell.edu/.

North Carolina Technology Transfer Center, ITRE at North Carolina State University, Campus Box 8601, Raleigh, NC 27695-8601; Telephone: (919) 515-8899; Fax: (919) 515-8898; E-mail: jbm@unity.ncsu.edu, pcloer@unity.ncsu.edu, ronnie_williams @ncsu.edu; Website: http://itre.ncsu.edu/LTAP/.

North Dakota Transportation Technology Transfer LTAP Center, Civil/Industrial Engineering Bldg., Room 201H, College of Engineering/Architecture, Civil Engineering/Construction Department, Civil Engineering Division/North Dakota State University, Fargo, ND 58105; Telephone: (701) 231-7051, (800) 726-4143; Fax: (701) 231-6185; E-mail: Donald_Andersen@ndsu.nodak.edu; Website: http://www.ce.ndsu.nodak.edu/ndltap.

Ohio LTAP Center, Ohio Department of Transportation, 1980 W. Broad Street, Columbus, OH 43223; Telephone: (614) 292-2871; Fax: (614) 292-0449; E-mail: William.McPherson@dot.state.oh.us; Website: http://www.ohioltap.org/ltap/.

Oklahoma Center for Local Government Technology, Oklahoma State University, 200 Cordell North, Stillwater, OK 74078-8808; Telephone: (405) 744-6049; Fax: (405) 744-7268; E-mail: wright@okstate.edu.

Oregon Technology Transfer Center, 200 Hawthorne SE, Suite B-240, Salem, OR 97301-5192; Telephone: (503) 986-2854; Fax: (503) 986-2844; E-mail: elizabeth.a.hunt@odot.state.or.us; Website: http://www.odot.state.or.us/tddt2/.

LTAP—The Pennsylvania Local Roads Program, Penn State Eastgate Center, 1010 North 7th Street, Suite 304, Harrisburg, PA 17102; Telephone: (717) 772-1972; Fax: (717) 772-1998; E-mail: LTAP@psu.edu; Website: http://www.ltap.psu.edu/.

Puerto Rico Transportation Technology Transfer Center, Civil Engineering Department, P.O. Box 9041, University of Puerto Rico at Mayaguez, Mayaquez, PR 00681-9041; Telephone: (787) 834-6385; Fax: (787) 265-5695; E-mail: t2pr1@ce.uprm.edu; Website: http://www.prt2.org.

Rhode Island Technology Transfer Center, Statewide Planning, One Capitol Hill, Providence, RI 02908-5870; Telephone: (401) 222-1235; Fax: (401) 222-2083; E-mail: wslocomb@doa.state.ri.us; Website: http://www.planning.state.ri.us/t2/t2.htm.

South Carolina Transportation Technology Transfer Service, Civil Engineering Department, 114 Lowry Hall, Clemson, SC 29634-0911; Telephone: (864) 656-1456; Fax: (864) 656-2670; E-mail: t3s@ces.clemson.edu; Website: http://www.ce.clemson.edu/t3s.

South Dakota Local Transportation Assistance Program, Box 2220, SDSU, Harding Hall, Brookings, SD 57007-0199; Telephone: (605) 688-4185; Fax: (605) 688-5880; E-mail: SDSU_SDLTAP@sdstate.edu.

Tennessee Transportation Assistance Program (TTAP), 309 Conference Center Building, Knoxville, TN 37996-4133; Telephone: (865) 974-5255; Fax: (865) 974-3889; E-mail: ttap@utk.edu; Website: http://ctr.utk.edu/ttap/.

Texas Local Technical Assistance Program, Engineering, Utilities and Public Works Training Institute, Texas Engineering Extension Service, 301 Tarrow, Suite 119, College Station, TX 77840-7896; Telephone: (979) 458-6768; Fax: (979) 458-6771; E-mail: JW.Chism@teexmail.tamu.edu; Website: http://teexcit.tamu.edu/texasltap/.

Utah Technology Transfer Center, Utah State University, 4111 Old Main Hill, Logan, UT 84322-4111; Telephone: (435) 797-2931; Fax: (435) 797-1582; E-mail: utaht2@cc.usu.edu; Website: http://www.utaht2.usu.edu/.

Vermont Local Roads Program, Saint Michael's College, One Winooski Park, Box 260, Colchester, VT 05439; Telephone: (802) 654-2652; Fax: (802) 654-2555; E-mail: hlambert@smcvt.edu; Website: http://personalwebsite.smcvt.edu/vermontlocalroads/test.htm.

Virginia Transportation Technology Transfer Center, 530 Edgemont Road, Charlottesville, VA 22903; Telephone: (804) 293-1966; Fax: (804) 293-1429; E-mail: vtttc@vdot.state.va.us; Website: http://www.vtrc.net/vtttc/.

Washington State Technology Transfer Center (WST2), Transportation Building, P.O. Box 47390, Olympia, WA 98504-7390; Telephone: (360) 705-7386; Fax: (360) 705-6858; E-mail: wst2center@wsdot.wa.gov; Website: http://www.wsdot.wa.gov/TA/T2Center/T2hp.htm.

West Virginia Transportation Technology Transfer Center, P.O. Box 6103, Morgantown, WV 26506-6103; Telephone: (304) 293-3031, ext. 2612; Fax: (304) 293-7109; E-mail: mblanken@wvu.edu; Website: http://www.cemr.wvu.edu/~wwwtt.

Wisconsin Transportation Information Center, University of Wisconsin–Madison, 432 N. Lake Street, Room 805, Madison, WI 53706; Telephone: (608) 262-7988; Fax: (608) 263-3160; E-mail: donald@engr.wisc.edu; Website: http://epd.engr.wisc.edu/centers/tic/.

Wyoming Technology Transfer Center (WyT2/LTAP), Box 3295, University Station, Laramie, WY 82071; Telephone: (307) 766-6743; Fax: (307) 766-6784; E-mail: mharman@uwyo.edu; Website: http://wwweng.uwyo.edu/wyt2.

Alaska Village Technical Assistance Program, Eastern Washington University, Department of Urban & Regional Planning, 216 Isle Hall, Cheney, WA 99004; Telephone: (800) 583-3187; Fax: (509) 359-6829; E-mail: rrolland@ewu.edu; Website: http://www.cbpa.ewu.edu/~LTAP.

TTAP–California–Nevada, 11138 Valley Mall, Suite 200, El Monte, CA 91731; Telephone: (626) 350-4446; Fax: (626) 442-1115; E-mail: vfuentez@ncaied.org.

Tribal Technical Assistance Program at Colorado State University, Rockwell Hall, Room 321, Colorado State University, Fort Collins, CO 80523-1276; Telephone: (970) 491-8653; Fax: (970) 491-3502; E-mail: rhall@lamar.colostate.edu; Website: http://ttap.colostate.edu/.

Tribal Technical Assistance Program (TTAP), TTAP/301-E Dillman Hall, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931-1295; Telephone: (888) 230-0688; Fax: (906) 487-1834; E-mail: balkire@mtu.edu; Website: http://www.ttap.mtu.edu.

Northern Plains Tribal Technical Assistance Program, United Tribes Technical College, 3315 University Drive, Bismarck, ND 58504; Telephone: (701) 255-3285, ext. 262; Fax: (701) 530-0635; E-mail: nddennis@hotmail.com; Website: http://www.unitedtribestech.com/orgs/nttap/npttap.htm.

Oklahoma Tribal Technical Assistance Program, 200 Cordell North, Oklahoma State University, Stillwater, OK 74078-8808; Telephone: (405) 744-6049; Fax: (405) 744-7268; E-mail: dbraven@okstate.edu; Website: http://www.okstate.edu/ceat/clgt/native.html.

Northwest Tribal LTAP, Eastern Washington University, Department of Urban & Regional Planning, 216 Isle Hall, Cheney, WA 99004; Telephone: (800) 583-3187, (509) 359-6828; Fax: (509) 359-6829; E-mail: rrolland@ewu.edu; Website: http://www.cbpa.ewu.edu/~LTAP/.

Lisa Haakon Pogue, LTAP Clearinghouse, Director of Technology Transfer, American Public Works Association, 1401 K Street NW, 11th Floor, Washington, D.C. 20005; (202) 408-9541; Fax: (202) 408-9542; www.ltapt2.org.

# NOTES

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# APPENDIXES

**APPENDIX A** Survey Questionnaires

**APPENDIX B** Summary of Survey Results

**APPENDIX C** Annotated References and Websites

**APPENDIX D** Free and Low-Cost Periodicals

**APPENDIX E** Crash Analysis Software

**APPENDIX F** Traffic Information Program Series (TIPS)

**APPENDIX G** Intersection Safety Briefs

**APPENDIX H** Reactive Crash Analysis Tables

**APPENDIX I** RSAR Tool Kit and Sample RSAR Reports

**APPENDIX J** Sample RSA Reports

**APPENDIX K** AASHTO Strategic Highway Safety Plan

**APPENDIX L** Transportation Agencies

**APPENDIX M** Local Technology Assistance Program and Technology Transfer Assistance Program Centers

Abbreviations used without definition in TRB Publications:

| | |
|---|---|
| AASHO | American Association of State Highway Officials |
| AASHTO | American Association of State Highway and Transportation Officials |
| APTA | American Public Transportation Association |
| ASCE | American Society of Civil Engineers |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| ATA | American Trucking Associations |
| CTAA | Community Transportation Association of America |
| CTBSSP | Commercial Truck and Bus Safety Synthesis Program |
| FAA | Federal Aviation Administration |
| FHWA | Federal Highway Administration |
| FMCSA | Federal Motor Carrier Safety Administration |
| FRA | Federal Railroad Administration |
| FTA | Federal Transit Administration |
| IEEE | Institute of Electrical and Electronics Engineers |
| ITE | Institute of Transportation Engineers |
| NCHRP | National Cooperative Highway Research Program |
| NCTRP | National Cooperative Transit Research and Development Program |
| NHTSA | National Highway Traffic Safety Administration |
| SAE | Society of Automotive Engineers |
| TCRP | Transit Cooperative Research Program |
| TRB | Transportation Research Board |
| U.S.DOT | United States Department of Transportation |