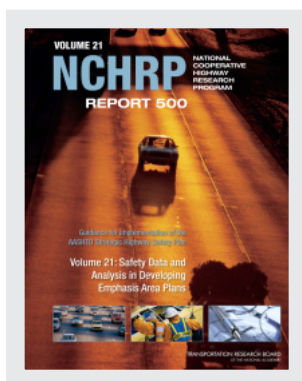


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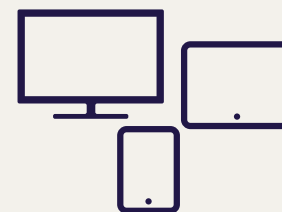
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP REPORT 500

**Guidance for Implementation of the
AASHTO Strategic Highway Safety Plan**

*Volume 21: Safety Data and
Analysis in Developing
Emphasis Area Plans*

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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

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

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

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FOREWORD

By Charles W. Niessner

Staff Officer

Transportation Research Board

The American Association of State Highway and Transportation Officials (AASHTO) has adopted a national highway safety goal of halving fatalities over the next 2 decades; or reducing fatalities by 1000 per year. This goal can be achieved through the widespread application of low-cost, proven countermeasures that reduce the number of crashes on the nation's highways. This twenty-first volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan* provides guidance on data sources and analysis techniques that can be employed to assist agencies in allocating safety funds. The report will be of particular interest to safety practitioners with responsibility for implementing programs to reduce injuries and fatalities on the highway system.

In 1998, AASHTO approved its Strategic Highway Safety Plan, which was developed by the AASHTO Standing Committee for Highway Traffic Safety with the assistance of the Federal Highway Administration, 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. Each of the 22 emphasis areas includes strategies and an outline of what is needed to implement each strategy.

NCHRP Project 17-18(3) is developing a series of guides to assist state and local agencies in reducing injuries and fatalities in targeted areas. The guides correspond to the emphasis areas outlined in the AASHTO Strategic Highway Safety Plan. Each guide includes a brief introduction, a general description of the problem, the strategies/countermeasures to address the problem, and a model implementation process.

This is the twenty-first volume of *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*, a series in which relevant information is assembled into single concise volumes, each pertaining to specific types of highway crashes (e.g., run-off-the-road, head-on) or contributing factors (e.g., aggressive driving). An expanded version of each volume with additional reference material and links to other information sources is available on the AASHTO Web site at <http://safety.transportation.org>. Future volumes of the report will be published and linked to the Web site as they are completed.

While each volume includes countermeasures for dealing with particular crash emphasis areas, *NCHRP Report 501: Integrated Management Process to Reduce Highway Injuries and Fatalities Statewide* provides an overall framework for coordinating a safety program. The integrated management process comprises the necessary steps for advancing from crash data to integrated action plans. The process includes methodologies to aid the practitioner in problem identification, resource optimization, and performance measurements. Together, the management process and the guides provide a comprehensive set of tools for managing a coordinated highway safety program.

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This volume of *NCHRP Report 500* was developed under NCHRP Project 17-18(3), the product of which is a series of implementation guides addressing the emphasis areas of AASHTO’s Strategic Highway Safety Plan. The project was managed by CH2M HILL, and the co-principal investigators were Ron Pfefer of Maron Engineering and Kevin Slack of CH2M HILL. Timothy Neuman of CH2M HILL served as the overall project director for the team. Kelly Hardy, also of CH2M HILL, served as a technical specialist on the development of the guides.

The project team was organized around the specialized technical content contained in each guide, and the overall team included nationally recognized experts from many organizations. The following team of experts, selected for their knowledge of this emphasis area, served as lead authors for this guide:

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S U M M A R Y

Safety Data and Analysis in Developing Emphasis Area Plans

In 1996, the American Association of State Highway and Transportation Officials (AASHTO), along with the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Transportation Research Board (TRB), convened a meeting of safety experts and highway safety stakeholders to develop a comprehensive Strategic Highway Safety Plan (SHSP). The plan developed by the team focused not only on engineering strategies for roadway improvement, but also incorporated education, enforcement and emergency response in order to reduce injuries and fatalities on the highways. The committee identified 22 emphasis areas in these 6 categories: Drivers, Vehicles, Special Users, Highways, Emergency Medical Services and Management.

In 2003, AASHTO's Board of Directors, the U.S. Department of Transportation, the Governor's Highway Safety Association and the American Association of Motor Vehicle Administrators set a goal to reduce annual highway fatalities by 5,000 to 7,000 by 2008. In order to meet this goal and help state and local jurisdictions implement the Strategic Highway Safety Plan, a series of implementation guides were developed under NCHRP Project 17-18(3), each focusing on one of the 22 emphasis areas outlined in the SHSP.

To date, 20 implementation guides have been published as individual volumes in the *NCHRP Report 500* series, addressing drivers, vehicles, special users, highways, and emergency medical services. Each guide provides users with helpful information about proven, tried and experimental countermeasures to address the objectives relative to that specific emphasis area. The guides encourage finding appropriate combinations of strategies from all of the guides to best address the specific safety concerns in each individual jurisdiction. This requires the coordination of efforts by all stakeholders, including enforcement and judicial officials, school and community educators, engineers and planners and emergency responders. However, guidance in how to develop this synergy has been limited.

The basic principal in developing an effective safety plan is to achieve the greatest results with the least cost, or, in other words, to identify the strategies and countermeasures with the greatest benefit-cost (B/C) ratio for each safety concern (whether it be location, user group, vehicle type or crash type), and the combination of strategies that provide the best B/C ratio across the entire system. In order to determine what these ratios are, data about crashes and the vehicles and people involved in them, as well as data associated with the effectiveness and costs of each countermeasure must be collected, organized, linked and analyzed.

In many cases, the available data will be limited or unknown. While police crash records are the most basic form of roadway safety data which can be made available to analysts in any jurisdiction, the information recorded on the report may vary from location to location, as different forms are used in different places. The crash location can be reported with varying levels of specificity, as well. Other data sources, such as hospital and other medical records, insurance records, and licensing information, may or may not be available and may or may

not be linked to crash data. Roadway inventory information in some jurisdictions is detailed and linked to crash records, while in others the information is limited and may be difficult to link to crash data. Also, for many of the strategies suggested in the implementation guides, there have been no valid studies which provide expected crash reduction factors. Therefore, it is up to the user to use the information provided about the strategy to estimate how effective he or she believes it will be in the jurisdiction's specific application of it. Because each jurisdiction is likely to have access to different types of data, and no jurisdiction will have perfect and complete data, determining the best set of strategies to include in a safety plan can be overwhelming for any highway safety official.

Description of the Data and Analysis Guide

This guide specifically addresses highway safety data, an emphasis area under the Management category in AASHTO's SHSP, and was developed to aid highway safety analysts in using the other implementation guides to make decisions about how to appropriately allocate safety funds to get the best results. Section I introduces a three-stage process for identifying a target emphasis area, setting an appropriate injury (and fatality) reduction goal, and defining the treatments that will allow the jurisdiction to reach that goal.

Section II steps the user through the types of data that are necessary for making good safety decisions, as well as the data that are helpful, but not required, to develop and implement a safety plan. Information regarding several national sources of data, as well as suggestions about how to obtain and organize local data, is also included in this section.

Section III lays out the details of the three-stage process introduced in Section I, and discusses the four procedures that may be used to follow the process. Each procedure is specific to the available combination of data a jurisdiction has for crash data, non-crash data, and strategy effectiveness.

The remaining sections provide a detailed description of the specific application of the three-stage process and appropriate procedures for roadway segments (Section IV), junctions (Section V), special road users (Section VI), illegal driver actions (Section VII), unsafe driver actions (Section VIII), special vehicles (Section IX), work zones (Section X) and EMS services (Section XI). Finally, Section XII describes how data improvements can improve a jurisdiction's ability to most appropriately use their safety funding to implement the best combination of strategies to reduce the greatest number of injuries and fatalities.

How to Use This Guide

We recommend that users become familiar with the other implementation guides in this series (especially those that address emphasis areas that are safety concerns in their jurisdictions) and the objectives and countermeasures detailed in them before attempting to follow the three-step process outlined in this "Data and Analysis Guide." However, Section II and Section XII are appropriate to consult in the beginning stages of the development of a safety plan. Section II outlines types of data that are required and helpful in understanding specific safety concerns and needs and also provides resources for national crash and non-crash data. Section XII discusses ways to improve crash and non-crash safety databases to allow the user to make more beneficial decisions regarding choice of strategies and allocation of funds. Users may want to make some of these data collection and management suggestions long-term goals within their highway safety plans.

Once users have an understanding of the accessibility, limits, and needs of their own data systems and are familiar with the other guides in this series, they can follow the process

introduced in Section I and detailed in Section III to begin defining injury reduction goals and identifying the strategies that will help to reach those goals in each relevant emphasis area. They can then choose which procedure is most tailored to the data that is available to follow the three-step process. The procedures address these data scenarios:

- **Procedure 1:** Treatment effectiveness is known, and both crash and non-crash (e.g., roadway inventory and traffic) data are available.
- **Procedure 2:** Treatment effectiveness is known and crash data are available, but detailed inventory is not available.
 - Crashes are mileposted
 - Crashes are not mileposted
- **Procedure 3:** Treatment effectiveness in terms of crash/injury reduction is not known.
- **Procedure 4:** Treatment effectiveness in terms of crash/injury reduction is known for some strategies under consideration, but not for others.

Procedures 1 and 2 allow the user to develop B/C ratios, which gives the most information about how far safety dollars will go to save lives and prevent injuries. B/C ratios cannot be developed in Procedure 3, because information is not known about the expected effectiveness of the strategies. Safety decision-makers must use other means, much more dependent on judgment, to rank strategies, and will have to make assumptions about how close those strategies will get them toward reaching their crash/injury reduction goals. Procedure 4 is a combination of the other strategies. Note that depending on the emphasis area being considered (as they are considered one at a time within this process), the same procedure may not always be used. For example, when addressing intersection crashes, the available data may allow you to use Procedure 1, but when addressing crashes involving bicyclists, you may have to use Procedure 3.

Once the user understands the procedures used to follow the three-step process, he or she can then choose an emphasis area and go to the specific section that addresses it (Sections IV through XI) to follow the detailed procedure outlined for that emphasis area. This process can be repeated for each of the emphasis areas that are to be addressed.

Other Helpful Resources

NCHRP Report 500, Volumes 1–20

As mentioned above, these implementation guides detail strategies and countermeasures to address safety concerns in several of the 22 emphasis areas outlined in AASHTO's Strategic Highway Safety Plan. Crash reduction factors (CRFs) and accident modification factors (AMFs) are provided for several of the strategies discussed. This information is required to determine the B/C ratio for the strategy you are considering. Research is continually progressing to develop the AMFs or CRFs for more strategies, as well as refining or confirming the factors already in use. It is recommended that users of this series continue to check the literature for new research in these areas.

NCHRP Report 501: Integrated Safety Management Process

This report addresses “Creating More Effective Processes and Safety Management Systems,” which is one of AASHTO's 22 emphasis areas, and, coupled with this “Data and Analysis Guide,” covers the emphasis areas under the Management category of the SHSP. *NCHRP Report 501* develops a six-step process for bringing together all highway safety stakeholders and

developing and implementing a comprehensive highway safety program. The “Data and Analysis Guide” supplements this process by providing detailed instruction on how to use the available data to make the decisions required in developing a safety plan.

AASHTO Strategic Highway Safety Plan

For background information, and to read the plan on which these implementation guides are based, visit: <http://safety.transportation.org/doc/Safety-StrategicHighwaySafetyPlan.pdf>.

SECTION I

Introduction

In 1998, AASHTO approved its Strategic Highway Safety Plan, with a goal of reducing annual highway fatalities by 5,000 to 7,000. The plan includes strategies in 22 key emphasis areas that affect highway safety. NCHRP Project 17-18(3) is developing a series of guides to assist state and local agencies in reducing injuries and fatalities. Each guide is focused on one of the key emphasis areas (e.g., head-on collisions, unsignalized intersection collisions, collisions involving unlicensed drivers, collisions involving pedestrians). Each emphasis-area guide includes a brief introduction, a general description of the problem, the strategies/countermeasures to address the problem, and a model implementation process. The guides are published as individual volumes within *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan (1–20)*, and copies can be obtained from the Transportation Research Board and downloaded from <http://safety.transportation.org/guides.aspx>.

In addition to the individual emphasis area guides, *NCHRP Report 501: Integrated Management Process to Reduce Highway Injuries and Fatalities Statewide* provides an overall framework for coordinating a safety program. The integrated management process comprises the necessary steps for advancing from crash data to integrated action plans. The process includes methodologies to aid the practitioner in problem identification, resource optimization, and performance measurements.

A series of meetings with “lead states” was held in 2004–2005 to test the first sets of *NCHRP Report 500* volumes produced. The lead states used the guidance documents in the development of emphasis-area plans. Technical assistance was provided to those states during that process under the NCHRP 17-18(3) project. Issues raised by those states during that process led to the development of additional supplemental resources, including example plans for lane-departure and intersection crash issues. These plans contained detailed example data analysis procedures that the states could use in choosing strategies/countermeasures within an emphasis area and in targeting those treatments to roadway locations.

Similar procedures for roadway-user and vehicle emphasis areas (e.g., older drivers, large trucks) were not developed at that time. It was subsequently decided that an additional guide would be produced to assist state and local users in locating and analyzing pertinent safety data in their planning effort for any of the 22 emphasis areas. The purpose of the “Data and Analysis Guide” is to provide guidance on the sources of safety data needed and on procedures for both choosing the best strategies/countermeasures within a given emphasis area and targeting those treatment strategies to either roadway locations or road-user subgroups.

There are many steps and procedures necessary to successfully plan and implement safety strategies within a given emphasis area. Many of these steps are related to developing the critical “safety team” of administrators, planners, program managers and analysts. These procedures are covered in detail in both the model implementation plans within each of the *NCHRP Report 500* volumes, and within *NCHRP Report 501 (18)*. While those procedures covered the entire safety-planning process, this “Data and Analysis Guide” is focused on the procedures and steps necessary in the data-related efforts involved in emphasis-area planning. The procedures were developed to be applicable in jurisdictions that have extensive safety data files (e.g., crash, roadway inventory, intersection inventory, traffic) and limited safety data (i.e., crash data only), and both for situations in which the crash-related effectiveness of a specific countermeasure has been defined and situations where countermeasure effectiveness is unknown at this time. The guide addresses emphasis-area safety planning for situations in which relevant crash data are available to guide the planning process. Safety planning for situations in which no crash data are available is outside the scope of this guide. However, safety managers should be aware that there are important emphasis areas, including pedestrian and bicycle safety, for which safety plans often need to be developed without crash data or with very limited crash data. The guide does suggest data types that

are potentially useful in safety plan development, as a supplement to crash data or when crash data are not available.

This guide addresses the development of safety plans for specific emphasis areas, but does not address the evaluation of the effectiveness of those plans after their implementation. For evaluation issues, the reader is referred to *NCHRP Report 501 (18)* and to specific safety evaluation tools such as *SafetyAnalyst*.

The goals of this guide are the following.

- Specify a basic three-stage procedure to be used in developing an emphasis area plan: (1) choosing an area, (2) setting a goal, and (3) choosing among potential strategies within the given area and targeting their implementation to subpopulations of road users, vehicle types, or roadway locations.
- Define data-related procedures for roadway, road user, and vehicle-based emphasis areas that will assist the user in the third stage – choosing among potential treatment strategies and targeting the strategies.
- Define procedures which can be used with three levels of safety data and treatment effectiveness:
 - Known treatment effectiveness combined with linkable crash, roadway inventory and traffic data
 - Known treatment effectiveness and crash data only (e.g., no inventory data)
 - Unknown treatment effectiveness and crash data only
- Customize the procedures and data descriptions for different groups of emphasis areas (e.g., lane departure crashes, special road-user populations including older and younger drivers, pedestrians and bicyclists).

The following text will provide an overview of the proposed data analysis procedures to be covered in this guide. Descriptions of potential safety data files for use in these and other procedures will be presented in Section II of the guide. General details of the procedures will be presented in Section III. The procedures will then be customized for specific groups of emphasis areas in Sections IV–XI. Finally, information on improving existing databases will be presented in Section XII.

Introduction to Proposed Procedures

As indicated above, the development of a safety-improvement plan is a multi-stage process. (For clarity, the term “stage” will be used to describe the major procedures required to develop the plan. The term “step” will then be used to describe individual steps/processes required to conduct a given major stage/procedure. Thus, there are “steps” within “stages.”)

Stage 1. Define/Choose Issue(s)/Emphasis Areas

The safety planning team will first define or choose an issue (emphasis area) or set of issues that need to be addressed.

Note that the AASHTO Strategic Highway Safety Plan and all of the supporting resources (e.g., *NCHRP Report 501*) intend that multiple issues should be addressed and multiple plans developed. The guide deals with addressing one issue at a time, but the procedures will be applied multiple times to address all issues of interest. As described later, the choice will most often be based on analysis or crash data which assist the user in determining which of the 22 issues/areas defined by AASHTO or additional jurisdiction-specific issues are most critical in his or her jurisdiction.

Stage 2. Set a Crash, Injury or Death Reduction Goal for That Issue

The emphasis-area team will then use a series of factors to define a reduction goal for death and injuries in each of the emphasis areas chosen. AASHTO has suggested that a “stretch goal” be established for both the overall safety program composed on a combination of emphasis areas, and within a given emphasis area. This “stretch goal” is one that is not likely to be met by existing safety efforts, or even a limited expansion of these efforts. The goal will push the jurisdiction to be innovative in defining new programs and procedures to achieve success. The agency may decide to define both a “stretch goal” and a series of reduced or lesser goals that can be met either within a given time period or with innovative, but realistic, efforts.

Stage 3. Define the Series of Treatments and the Target Subpopulation (Drivers, Highway Corridors, Intersections) for Each Treatment That Will Be Required to Meet Your Goal

The goal of this step is to develop a combination of treatment strategies and targets which will allow the user to meet the established goal. In general, this will require the following steps.

1. Define possible subpopulations (e.g., drivers, miles of specific highway types, intersection types in specific highway classes) for treatment.
2. Specify one or more proposed treatments for each target subpopulation.
3. If treatment effectiveness is known, determine if the number of targets (e.g., miles/drivers/intersections) that can be treated in each subpopulation will lead to reductions that meet the specified goal. If not, add additional treatments or new target populations (e.g., local roads if the original targets were on the state system).
4. If possible, determine whether the benefits derived from treating the target subpopulations exceed the costs. (Note that this assurance that the treatment is cost beneficial does

not have to be a separate step. With processes presented later in this guide, it can be done during the definition of target subpopulations if “full data” are available and if treatment effectiveness is known. This benefit-cost calculation will not be possible for treatments without defined effectiveness levels.)

5. If a treatment for a specific subpopulation is not cost-effective, consider other possible treatments with higher crash-reduction potential, consider alternative targets (e.g., local road systems if you are a state DOT), or consider ways to reduce the cost of the treatment implementation (e.g., combine roadway safety treatment with other non-safety work at chosen locations, piggy-back

public information campaign onto scheduled enforcement activities).

6. If cost-effective, implement the treatment(s)!

Note that all these steps may have to be done interactively until a final solution is reached. In addition, they may not be done in the sequence shown here. For example, as noted above, the final definition of target subpopulations may be done before the determination of strategies, and may also be done concurrently with the determination of B/C ratios, depending on the methodology used. The following sections will provide more specific guidance concerning this overall procedure tailored to the different types of emphasis areas.

SECTION II

Data Types Used in Preparing the Safety Plan

There are various types of data that can be used in the preparation of a safety plan. The procedures described in this guide are designed such that *crash data* are required as a minimum. For the higher-order procedures, the crash data must be “location-coded,” and for some procedures, additional roadway inventory and traffic volume data are required. Thus, as described in Section III, the choice of procedure will depend on the data available in the user’s jurisdiction.

There are other types of safety data that can also be used in the development of safety plans. These would include information ranging from driver citation/conviction data to observational surveys of occupant restraint usage. The following provides a brief description of the major types of data that might be used, and some information on where they might be found if not in the user’s own jurisdiction. Some of the following information was taken from *NCHRP Report 501 (18)*.

Crash Data and Related Files

Local and Statewide Crash Data

Records on traffic crashes are derived from the police report form that is usually completed by investigating police officers at the crash sites. A typical crash report contains data on about 100 different pieces of information that describe the crash, the location, and the people and vehicles involved. Crash reports may be used individually to explore the circumstances and factors that contributed to a particular event, and they may be used in aggregate to develop a picture of the safety performance of a given location or jurisdiction.

At the local level, the analyst will generally use police-reported crash data from his/her own files. However, some localities that investigate crashes may not retain their own files or may not automate their paper files. In these cases, the analyst should contact the state agency that serves as the custodian for the statewide crash database and request copies of the computerized data for their jurisdiction. The statewide crash

database custodian differs from state to state, but is usually either the State Police (or State Highway Patrol), the State Department of Revenue or Motor Vehicles, or the State Department of Transportation. In addition, the safety engineering staff within the state highways department (often the Traffic Engineering Branch) is a major user of the state crash files and can often provide assistance and information concerning how the local jurisdiction can obtain data. In many cases, this staff is also responsible for assigning location codes to the crashes and may maintain a separate crash database with more complete location coding. If the analyst is looking for crash data that have gone through a location validation process at the state level, it is often necessary to contact these staff. Note that in most cases, the location-validation process will only be conducted for state-system roads (i.e., Interstate, U.S., and state routes) in local jurisdictions, and not for all local streets and roads. However, the continuing development and refinement of spatial data systems in states (e.g., GIS systems) is increasing the ability to locate crashes to all roads in the state.

As noted in *NCHRP Report 501 (18)*, although these archives contain a wealth of information on the driver, the vehicle, and the circumstances of the crash, some caution is warranted. It is critical for the analyst to understand the boundaries and shortcomings in the crash database before using these data to support decision-making. Every state has a reporting threshold – usually a dollar amount of damage or a specific level of injury sustained in the crash – below which a crash report will not be entered into the statewide database. Local jurisdictions, however, may want to include all crashes in their automated systems, not just those resulting in damages or injuries above the state reporting threshold. Conversely, some local jurisdictions may use a higher threshold such that local police respond to fewer crashes. The statewide crash database may also contain additional crashes for a jurisdiction if more than one law enforcement agency reports (e.g., the local police department, the county sheriff’s office,

and the state highway patrol), with the possibility of each agency using a different crash reporting threshold.

In several states, crash reports are collected from the drivers involved in a crash (i.e., an operator report). These operator reports may take the place of police-reported data under certain conditions; for example, below-threshold crashes, crashes in which no one was seriously injured or killed, and weather- or animal-related crashes during peak seasons. In other states, operator reports and officer reports are blended in the final statewide crash database, thus affecting the overall consistency of data from one record to the next. Moreover, the NHTSA reports, “. . . various sources suggest that about half of motor vehicle crashes in the country are not reported to police . . .” (19, p. 5).

Crash data depend heavily on the subjective judgments of the officers who attempt to describe the crash after the fact. These judgments cannot be error-free since the officer does not see the crash occur, and must rely on physical evidence and driver and witness statements to draw conclusions. Moreover, officers are not experts in some areas that may be of crucial interest to a highway safety analyst, but which the officer is called upon to record for the crash report. A comparison of police-reported data to those collected by multidisciplinary crash-investigation teams on the same crashes indicate that the most reliable police data were those concerned with crash descriptors and the least reliable were driver/vehicle variables (20). The police were most accurate on six variables: location (note that most safety engineers in highway departments question this finding), date, day of week, number of drivers, number of passengers, and number of vehicles. The least reliable police data concerned vertical and horizontal road character, crash severity, road surface composition, and speed limit. The accuracy of police judgment of crash causes varies by the cause type, with more reliability in detecting human-direct causes than in detecting vehicular, environmental, and human-indirect causes. However, the authors also noted that in the area of human-direct causes, the police performance was relatively good in identifying “failure to yield” and “failure to stop” but was relatively poor with respect to “speeding,” “driving left of center,” and “other improper turns.”

Data accuracy and data completeness also vary from state to state and among jurisdictions within a state. While it is generally agreed that state police and highway patrol officers provide more consistent and accurate crash data than their local counterparts by virtue of their greater familiarity with crashes and, typically, more extensive training, few states maintain the kind of quality-control measurement program that would support interagency comparisons of accuracy or completeness of crash report data. When using crash data from a single source, such as a municipal police department, it is important to know that agency’s reporting practices and

how supervisors review each crash report before it is finally submitted. When using data from more than one source, such as when combining data from the state police, the local sheriff’s office, and the municipal police department, or when comparing crash experience among several jurisdictions, the differences in reporting practices among the various agencies can be critical. In these cases, the analyst should plan to conduct validation tests as part of the overall analytic process. For example, the analyst might compare the proportions of injury and property-damage-only crashes or the distributions of property damage amounts in the data received from various agencies. If that is not possible, the analyst should learn about the thresholds and reporting practices of each agency as a minimum.

Note that these warnings are not to indicate that police data are of questionable value in safety planning, but only to alert the analyst of issues that can affect conclusions. Police data provide large samples of data even in local jurisdictions. Moreover, even with the known problems, these data have been used successfully for years in identifying safety problems, in choosing and targeting treatments, and in evaluating the treatment effects. It is also worth noting that decisions made using the available crash data are going to be better than decisions made without any data at all.

Fatal Analysis Reporting System (FARS) Data

While most states maintain a database of all reportable crashes that occur on all public roadways, there are frequently limitations to the crash data available for local roadways, especially with respect to location coding and crashes involving property damage only. In addition, some states and local agencies may question the reliability of crash data for less severe crashes, may not have a usable computerized file, or may wish to conduct at least some safety-related analyses using only fatal crashes. In these cases, the Fatality Analysis Reporting System (FARS) data system maintained by NHTSA is an excellent database for analysis. FARS contains annual data on a census of fatal traffic crashes within the 50 states, the District of Columbia, and Puerto Rico. According to NHTSA, “. . . to be included in FARS, a crash must involve a motor vehicle traveling on a trafficway customarily open to the public, and must result in the death of an occupant of a vehicle or a non-motorist within 30 days of the crash.” FARS data are available annually back to 1975. Each new year’s file is typically available about 6 months following the end of the year; however, the FARS analyst in each state has access to his/her own state’s fatal crashes at all times. FARS contains more than 100 data elements related to the driver, vehicle, involved persons, and the crash itself. FARS has proven to be a rich information source for research and program evaluation focusing on fatal crashes. The quality of the FARS data is quite

high due to extensive training provided to the FARS analysts and the attention paid to each case.

To assist users in analyzing these data related to fatal crashes, NHTSA provides a “FARS Web-Based Encyclopedia” at <http://www-fars.nhtsa.dot.gov/Main/index.aspx> that provides links to national reports and statistics. By clicking on the “Create a Query” link, the user can choose her/his own state and run univariate tables and cross-tabulations for any of the 100+ data items. City and county codes make it possible to isolate fatal crash data for local jurisdictions. (Note that the FARS data contain information on every vehicle and every occupant within each fatal crash, not just the fatally injured occupant. Thus, care must be taken in choosing the screens to be used and in interpreting the results.) While multi-year queries are no longer supported, the site contains multi-year reports for individual states under the “States” and the “Trends” links, and analysts can run an analysis for multiple years, one year at a time, to develop multi-year comparisons. FARS data can also be obtained from NHTSA (see “Request Data” link) on a CD or via download from an ftp site (<ftp://ftp.nhtsa.dot.gov/fars/>).

It is noted that the reliance on fatal-only data has its drawbacks in targeting treatments, with the main one being sample size. In addition, targeting roadway treatments with fatal data is questionable since most factors that turn a crash into a fatal crash are not roadway-related – they are other factors such as driver age or seatbelt use. It is often tempting to conduct analyses using only fatal crash data because the state and national targets all address the number and rate of deaths on highways. It is strongly recommended, however, that crash frequency and rate at all levels of severity be used in safety analyses to avoid the problems of small, unrepresentative samples.

It is also recommended that if the analyst is not already familiar with FARS data, an effort be made to learn about the way the records are created and the proper use of important data fields. Imputed Blood Alcohol Content (BAC) data is one example of a data field in FARS that contains data unlike that in most state or local crash databases. In FARS, BAC values are recorded from the information supplied by police officers and an additional imputed value is calculated for each driver for which a BAC value was not supplied on the original crash report or cannot be obtained from follow-up contacts with local hospitals or medical examiners. Analyses of alcohol-involved crash frequency can obtain markedly different results depending on whether the records or recorded-plus-imputed values are used. This is but one example of how use of FARS data may differ from the use of more familiar local or statewide crash databases.

Crash Outcome Data Evaluation System (CODES)

The Crash Outcome Data Evaluation System (CODES) is an enhanced state-based crash data system in which police

crash data are linked with detailed information on the medical consequences of the crash. Originally, seven states were funded by NHTSA to develop the CODES system (Hawaii, Maine, Missouri, New York, Pennsylvania, Utah, and Wisconsin). Twenty-two other states have had CODES demonstration grants or special projects (Alaska, Arizona, Connecticut, Delaware, Georgia, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Minnesota, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, and Texas). At a minimum, basic statewide police crash data are supplemented with hospital data and either Emergency Medical Services (EMS) data or emergency department data. Some states also add data for each driver and other occupants concerning driver license status, vehicle registration, citation/conviction records, insurance claims, rehabilitation and long-term care, and other items. The linkage of medical information to crash and driver data is done through “probabilistic linkage technology” since direct linkage is not often possible due to missing personal information and privacy concerns.

CODES data are used in safety studies of specific injury-related issues such as seatbelt and motorcycle helmet effectiveness – any crash-related issue in which more detailed injury data or injury cost data would be helpful. These data could also be used to study specific injuries occurring in roadside object crashes (e.g., head injury to right-front passengers in guardrail impacts) and truck crashes (e.g., abdominal injury for lap-belted truck drivers). Many states use their CODES data to develop a state-specific estimate of the economic impact of crashes that is based on the state’s own data.

While CODES is funded by NHTSA, access is controlled by the states. More detail on CODES including links to some participating states may be obtained at <http://www-nrd.nhtsa.dot.gov>.

Motor Carriers Management Information System (MCMIS)

This database is a very comprehensive truck safety database that is the source of data for many of the Federal Motor Carrier Safety Administration’s (FMCSA) other data files (e.g., SAFER) and analysis procedures (e.g., SafeStat). Data are entered into MCMIS via the SafetyNet system accessed by personnel in each state’s Motor Carrier Safety Assistance Program (MCSAP) agency. The database is maintained by the FMCSA to allow analysis of motor-carrier issues. MCMIS consists of five files, with input to each file from each state and from carriers subject to federal truck safety regulations in all states:

- Registration (“Census”) file – Carrier information including DOT numbers and descriptive information about a motor

carrier's size and operations, including the number of power units, drivers, and type of cargo. Information is based on Form MCS-150 – the Motor Carrier Identification Report – required of all carriers.

- **Crash file** – The National Governor's Association has recommended crash data elements for all trucks with gross vehicle weight >10,000 lbs who are involved in a towaway or injury/fatal crash in any state.
- **Roadside Inspection file** – Driver and vehicle information on roadside inspections conducted in all 50 states. Data include violations for both drivers and vehicles, out-of-service indicators, and, for drivers, moving violations (e.g., speeding) which are associated with the inspection/stop.
- **Compliance Review file** – Information on detailed on-site examinations of company records for targeted companies. This includes information on violations of Federal Motor Carrier Safety Regulations and Hazardous Materials Regulations found in driver qualification files, duty status files, vehicle maintenance records, and safety management information. It also contains the "safety rating" which results from the Review.
- **Enforcement file** – Information on safety-related sanctions imposed on carriers by FMCSA. These can range from placing the carrier (and all its vehicles) out-of-service to fines and civil penalties.

Data are input into the MCMIS files by state and federal truck safety staffs using the SAFETYNET software. Listings of the variables in the crash files can be found in the MCMIS Data Dissemination Program Catalog at <http://mcmiscatalog.fmcsa.dot.gov/beta/Catalogs&Documentation>.

These are the primary safety data used by FMCSA and state truck safety staff in all safety-related efforts. Data from MCMIS are either used directly or modified for use in such programs and methodologies as SAFER, SafeStat, and PRISM. State-based crash tables can be used to look at major factors associated with truck crashes, and comparisons can be made between states. A large number of reports and analysis tools can be found at <http://www.fmcsa.dot.gov/facts-research/facts-research.htm>. The "Crash Profiles Online" tool within the "Analysis and Information Online" (A&I Online) suite of tools provides state-by-state truck crash statistics (see <http://ai.fmcsa.dot.gov/mcspa.asp>). The A&I Online staff, as well as the MCSAP staff in each state can provide annual crash data for reportable crashes involving trucks, buses, and vehicles placarded to carry hazardous materials. A recent Government Accounting Office audit (21) pointed to serious data quality problems in MCMIS, especially in the crash data file. In 2001, FMCSA implemented a Crash Data Improvement Program (CDIP) and, in 2004, a quality measurement system. Combined, these efforts have resulted in a large increase in the number of crashes reported to MCMIS and in

overall quality and timeliness of the data. Analysts should use caution in making multi-year comparisons using MCMIS data until the reporting level and quality have stabilized at their new higher level. MCMIS crash data from 2004 onward are of considerably higher quality and completeness than are the data for prior years.

Roadway Inventory Data

State Inventory Data

Each state highway agency and some local transportation and public works departments, and regional planning agencies (e.g., MPO, RPA, RPC) collect and maintain roadway inventory data on each section of roadway within the highway systems they control. The data are generally "cross-section" information on the roadway – number of lanes, shoulder type and width, median descriptors, and pavement types. Most states also have supplemental files describing bridges (as part of the National Bridge Inventory) and railroad grade crossings (as part of the Federal Railroad Administration's Railroad Grade-Crossing Inventory) that can usually, but not always, be linked to the basic roadway inventory file. A very few state systems also include information on curves and grades, two important safety predictors. A limited number of states also have developed intersection and interchange inventory files providing detailed descriptions of such items as intersection type, traffic control type, turning lanes, mainline and cross-road traffic volumes, interchange type, and ramp length. There may also be additional roadway-oriented supplemental files on such safety-related information as skid numbers, intersection turning counts, intersection signalization phasing, pavement condition, and speed profiles. These files, which are not always computerized, will vary in the degree of completeness and accuracy. While the basic inventory files can usually be linked to the crash data, linkage between some of the supplemental files may be difficult.

The basic inventory file is usually organized as "homogeneous sections" of a given route, where all the basic inventory items are constant. If an item changes value, a new homogeneous-section record begins. This leads to very short sections in most state files. Each section has an "address" which often consists of a route and beginning and ending "milepost." Crashes are given a route and mileposts based on the investigating officer's location description so that they can be linked to the roadway file. Currently, these files are becoming geo-coded (i.e., coordinates are added), so that they can be used in Geographic Information Systems (GIS). The move toward GIS mapping is causing some major changes in the way locations are coded in roadway inventory files, and, in many states, crash databases as well. At present, the most useful and effective systems support multiple ways to define

locations, sections/segments, and routes so that data entered or stored in one form can be linked to all other relevant data.

The lack of intersection and interchange inventory data in most highway agencies is a key limitation in safety planning and safety management for intersections and for interchange features such as ramp, speed-change lanes, and collector-distributor roads. It is hoped that the development of uniform requirements for such inventory data (see the discussion of the Minimum Inventory of Roadway Elements [MIRE] in Section XII of this guide) and the development of tools like *SafetyAnalyst* that can use such data will encourage the wider use of intersection and interchange inventory data.

Some local jurisdictions will also maintain inventory files, but many do not have them computerized or in a central location. Generally, they will be maintained and stored by different departments (e.g., traffic engineering, street maintenance). The more extensive files will contain similar information to that collected by the states. Files on signalization at intersections are usually maintained for legal purposes, but are sometimes not easily linkable with other inventory or crash data. Some localities also maintain supplemental files related to sidewalk presence, crosswalks, bicycle paths, bus stops, and other variables.

Highway Performance Monitoring System (HPMS)

Many of the above described state roadway inventory systems were expansions of the HPMS system, a 1978 congressionally mandated data system to collect data on the nation's highways. HPMS is similar to the state inventory systems, but is based on a sample of locations from different functional classifications in each state, rather than containing the full state system. It contains limited data on all public roads. Data are inputted each year by each state, and collected, analyzed and reported to Congress by FHWA. While earlier versions of the system contained crash information for each sample section, this is no longer the case. However, since HPMS samples are usually flagged in the basic state inventory system, crashes could be linked with them. In general, the state analyst will use the state system rather than HPMS data in state-based safety analyses.

Other Roadway and Intersection Characteristic Data

Other data on roadway and intersection characteristics can be obtained from aerial photographs. In particular, orthophotos are geographically converted to allow accurate measurements to be made. The ongoing development of asset management databases by state and local highway agencies will also provide a potentially valuable source of roadway and intersection characteristics data. These data sources may be

particularly useful in development of safety plans if they can be linked to the location reference system used in crash data.

Traffic Volume Data

State highway agencies collect and maintain data on traffic volumes (Average Annual Daily Traffic [AADT]) for roads on the state-controlled system. The AADTs are based on counts made at both a limited number of permanent count stations and a much greater number of sampling locations where 2- to 3-day counts are taken on each highway system. The standard is that the entire state system is covered on 2- to 3-year cycles. The "short" counts are then converted to AADTs using factors based on the day of the count, season, and other factors, and are extrapolated to all sections of roadway and to years when counts are not made at a given count station. The AADTs are either retained as a variable on the roadway inventory file, or in a separate file that is linkable with the inventory. Not all states conduct counts on the recommended 2- to 3-year cycle. Even in states that do adhere to the standard data collection cycle, traffic counts for some scheduled locations are not collected. In such cases, states typically replace the missing data with estimates.

In addition to AADTs, state agencies also collect and maintain large-truck counts or percentages for each roadway section. These are based on counts made with special equipment that can separate vehicles into classes by length and number of axles. These "classification counts" are usually made at many fewer locations than the basic traffic counts, so their accuracy is less than for the AADT estimates. Supplemental truck counts may be made at other locations where "weight-in-motion" systems are in place for use in truck-weight regulation efforts.

Local jurisdictions will also have traffic volume information, but the consistency and quality varies by jurisdiction. While AADTs may be calculated for each city block in some cities, it is often the case that only intersection turning-volume counts made in signalization studies are available. In some locations, linkage of count data to other inventory files may be problematic. In general, traffic volume data is more limited in local jurisdictions than for the state-system roads.

Driver History Files

Departments of motor vehicles maintain driver records of all licensed drivers in the state. Driver records are typically generated when a person enters the state licensing system to obtain a license or when unlicensed drivers have had a violation or crash in the state. The record contains basic identifiers (e.g., name, address, driver license number), demographic information on the driver (e.g., birth date, gender), and information relevant to license and driver improvement actions

(e.g., license issuance and expiry/renewal dates, license class, violation dates, suspension periods). In some states, information on crash involvements (e.g., occurrence date, crash severity) is also available.

Driver records are especially useful for examining issues related to driving history and rates of recidivism (e.g., re-offending for moving violations and traffic-related criminal convictions). However, many states purge the driver record of information on driving history after a certain period of time. Consequently, driver records are incomplete and drivers identified as first-time offenders may have had previous convictions for the same offence. Analysts should also be aware that a driver history file used for aggregate data analysis is certain to be a snapshot of the statewide data at the time the request was made. The data update and purge cycles can have a dramatic effect on the information available for analysis at any given time, so care must be taken to work with the driver file custodians to ensure that the resulting analyses and conclusions are valid and representative of the driver population of interest.

Vehicle Registration Files

Departments of motor vehicles maintain motor vehicle registration files for use in vehicle licensing and taxation. These files contain information on the vehicle identification number (VIN); plate number; and vehicle weight, model, make, and year. Vehicle registration data can be used in developing safety strategies when, for example, information on the number of licensed vehicle by type is needed. Note, however, that it would be unusual for these files to contain annual mileage driven, so a measure of “miles of exposure by vehicle type” cannot be developed. Even when the file does contain annual miles driven, the reliability of the mileage data and their utility in analyses are questionable. Analysts are cautioned to be sure they know exactly how the data are collected and how the state handles missing, incomplete information and odometer readings that are greater than a certain threshold (usually 100,000 miles).

Statewide Injury Surveillance System Files

With the growing interest in injury control programs within the traffic safety, public health, and enforcement communities, there are a number of local, state, and federal initiatives which drive the development of a Statewide Injury Surveillance System (SWISS). These systems typically incorporate pre-hospital (EMS), trauma, emergency department (ED), hospital in-patient/discharge, rehabilitation and morbidity databases to track injury causes, magnitude, costs, and outcomes. Often, these systems rely upon other components of the traffic records system to provide information on injury

mechanisms or events (e.g., traffic crash reports). The custodial responsibility for various files within the SWISS is typically distributed among several agencies and/or offices within a State Department of Health.

Depending on its component data systems, the SWISS system can provide information that tracks magnitude, severity, and types of injuries sustained by persons in motor-vehicle-related crashes. There are standard coding systems for injuries and injury causal factors that can be gathered from the health-related datasets. Although traffic crashes cause only a portion of the injuries within any population, they often represent one of the more significant causes of injuries in terms of frequency and cost to the community. The SWISS should support integration of the injury data with police reported traffic crashes and make this information available for analysis to support research, public policy and decision-making. In most states, this integration is most likely to happen through a CODES probabilistic linkage process.

National Emergency Medical Services Information System (NEMSIS)

The ability to evaluate and improve Emergency Medical Services (EMS) systems has long been hampered by the lack of consistent and detailed EMS data at either the state or national level. While a state’s EMS system is usually coordinated at the state level, with EMS providers trained and certified by the state EMS office, the system itself is composed of multiple local providers. Thus, the data required in a sound state (and ultimately national) database must be collected by these local agencies. Because of both the lack of a universal set of “endorsed” data variables and the fact that there is often no legal requirement for systematic collection of such data, state EMS data systems have varied greatly in terms of the composition and completeness of their data. Working with the Centers for Disease Control (CDC) and the Health Resources and Services Administration (HRSA), NHTSA is coordinating the NEMSIS project which will ultimately lead to a national EMS database, populated from participating-state databases. The raw data will continue to be collected by the individual local providers, but the data collected will be based on a data dictionary containing standardized variables and codes. These data elements were developed by the three sponsoring agencies in consultation with a number of national EMS associations ranging from the National Association of State EMS Directors to the National Association of Emergency Medical Technicians. For computer storage, the data will be defined using an XML (extensible markup language) standard which will allow easy transfer of the data between different local (e.g., private EMS and fire-based EMS), state, and national computer systems. The data dictionary contains a set of core elements

that will be required in the national system, but also many additional standardized elements that the state and local agencies can choose to collect for their own use.

To facilitate the development of this database, the NEMSIS project is also funding a Technical Assistance Center (TAC) that will not only build the National EMS Repository, but will also provide assistance to state and local agencies in their data collection efforts. The TAC will conduct site visits of states to assess current and planned systems, certify EMS software products developed by vendors to ensure that they are compliant with the new NHTSA 2.2.1 data dictionary, and provide other assistance to the states such as example legislation and data collection policy and procedures (including privacy policies). The collection of data from seven states that meet all the necessary criteria began in 2006, with additional states expected to join the effort in 2007.

Population Census Files

The U.S. Census Bureau and the state demographer maintain data on population characteristics that can be useful in safety analyses. Typically, these data will give estimates of total population and gender, age, and ethnicity subpopulations broken out within political subdivisions. These data can be used to develop measures of crash risk, injury risk, and fatality risk for specific groups based upon their residence location and any demographic characteristics that are recorded in the crash and population databases. While these types of analyses are most often used for epidemiological research, they are gaining acceptance among highway safety practitioners because of the additional insight they can provide into a jurisdiction's crash experience, especially when countermeasures may involve education or driver behavior-related programs.

Citation Tracking and DUI Tracking Files

A special case of multi-agency data sharing is the creation of citation tracking and DUI tracking databases. The citation tracking system is viewed as a "cradle to grave" database of every citation issued in the state. From the point of initial printing, through assignment to an agency, an individual officer, issuance by that officer, processing by the Court or administrative processes, and final disposition, the citation is trackable. This supports a variety of safety-related analyses that are not possible if each agency controls their own citations and does not track what happens after the officer issues them. In particular, states have found that citation tracking systems are useful in detecting recidivism for serious traffic offenses earlier in the process (i.e., prior to conviction) and for tracking the behavior of law enforcement agencies and the courts with respect to dismissals and plea downs. Such analyses can be useful in identifying training

needs for law enforcement officers, prosecutors, court clerks, and judges.

DUI tracking systems incorporate some features of a citation tracking system (however, only for drunk- or drugged-driving offenses) and add several other functions beyond those. In particular, a DUI tracking system is likely to contain data that could be used to evaluate the effectiveness of court-ordered and administrative actions required of offenders. The system can be used to track recidivism rates for people assigned to various treatment programs, or those subject to various license restrictions. In this way, the state can learn which measures are most effective in ensuring that offenders do not reoffend.

Local Data Files

Local engineering and law enforcement agencies, especially, are likely to maintain data on roadways and incidents (e.g., crashes, citations) in their jurisdiction. The roadway data may closely mirror that in a statewide system, but could also contain additional traffic counts, more precise or up-to-date information on changes to the roadway network and, perhaps, inventories of signs, markings, traffic control devices, and other roadside appurtenances. Where such data exists, the state DOT and other users can potentially access it to develop a more complete description of safety experience in the state by including details for the local roadway system that may not already exist in state files. Many local engineering agencies use a GIS and have sophisticated mapping capabilities that users can tap into.

Local law enforcement agencies often have a record of every crash in their jurisdiction, and may have complete citation records as well. Law enforcement agencies use these records for manpower allocation and crime mapping, among other purposes. Other users may find the data useful in developing a more comprehensive view of traffic safety in a local area. Crashes that fall below the state's reporting threshold may still be of interest to engineers looking for high-crash locations. Even crashes on private property may have some use for special analyses. One example would be an analysis of crashes in which one or more vehicles is backing up – the vast majority of such crashes occur in parking lots and are usually not recorded in the statewide crash database. The crash database at a local law enforcement agency is a potential source for valuable information not already captured in the statewide crash database.

Other types of local databases may exist. For example, in the absence of a statewide EMS-run database, or a statewide trauma registry, it may still be possible to obtain this information from local sources (the EMS providers or trauma registries at designated trauma centers). A metropolitan planning organization (MPO) or regional planning council/commission

(RPC) is often an excellent source of traffic data, projections, and other highway design and usage information. With a few notable exceptions, court records are almost always obtainable only at the local level (if at all). These may be used to track citations through the court processes, look at recidivism rates, and document the frequency of plea bargaining in traffic-related cases.

Other Safety Files

A variety of other files that might be useful in safety studies is sometimes available in a jurisdiction. Speed surveys are collected by both state and local agencies. Note, however, that since statewide speed surveys on Interstate roads were essentially ended in 1995 with the repeal of the National Maximum Speed Limit, there are very few jurisdiction-wide speed surveys conducted. Instead, speed surveys are usually conducted at specific sites where a change in speed limit is being considered or has been recently implemented. The speed data collected at these “special” locations should not be considered good indicators of jurisdiction-wide speeds. Thus, safety planning needing speed data will usually require in-field speed data collection.

Trauma registry data and emergency medical services (EMS) data can potentially be used to enhance the completeness of crash data in much the same way as medical records are used to enhance crash data through the CODES database (see above). Data on roadway maintenance histories including the types of maintenance actions and their locations and dates may be useful in the development of safety plans.

Because of their effectiveness in reducing fatalities and serious injuries, perhaps the most important of the “other” safety data is occupant restraint (shoulder belt) use data collected in each state since 1998 in compliance with TEA-21 requirements. NHTSA developed detailed sampling criteria for this data collection, and produces annual reports on changes in restraint usage for all states (see, for example, <http://www.nhtsa.gov/people/injury/airbags/809713.pdf>). These data are usually collected by the state Highway Safety Office (or Office of the Governor’s Highway Safety Representative), and data and information can be obtained there.

Finally, public opinion and customer service data can provide key inputs in the development of safety plans. Many highway agencies conduct or have access to results of surveys of the general public or, more specifically, of motorists. For example, NHTSA has a requirement for telephone surveys to measure the effect of media-based public information programs. Some state and local agencies may maintain customer

service call logs, where the type and number of reported concerns can be tracked by location. Customer service data, including complaints from the public and their disposition, may provide useful information on problem locations or safety programs that are not functioning as designed.

Time Dimension of Data

Some types of data used in safety planning by their nature cover specific time periods. For example, crash data and citation data document events that occurred at a specific time, and data files generally cover a specified time period.

A second type of data file provides supplementary information gathered subsequent to a crash that, in order to be useful, must be linked to the crash record. Examples include medical records, which can be linked through the CODES database, and trauma registry data. Such data may not include the actual time or location of the crash and must, therefore, be linked through the victim’s identity.

A third type of data represents a snapshot of a population at a given point in time, but does not necessarily include the full history of that population. For example, driver history files typically include only drivers with active licenses at a specific point in time. The records for drivers who die or move out of state are deleted, so a current driver “history” file does not necessarily contain the history for all drivers during a given time period. Planning based on complete driver history data may need to consider historical files as well as current files.

Closure

In general, the most basic safety data – the police-reported crash report – will be available for use by analysts in almost all state and

“Lack of adequate safety data” is almost never a valid excuse for not developing a sound safety program.

local jurisdictions. The analyst will sometimes have to locate and acquire the data. Procedures are presented in this guide that require only basic crash data. Additional non-crash data (e.g., roadway inventory and AADT data) that can be used in planning safety efforts for roadway-, driver-, and vehicle-based treatments are usually available for state-system roadways and sometimes available for local roads. With some effort, additional supplemental files that can further enhance safety analyses can be located. In summary, “lack of adequate data” is almost never a valid excuse for not developing a sound safety program.

SECTION III

Details of the Three-Stage Process

This section will further define the three-stage process for developing an emphasis-area plan introduced in Section I. It is again noted that the AASHTO Strategic Highway Safety Plan intends that multiple issues should be addressed and multiple plans developed. Much of the emphasis in this guide is on Stage 3 procedures – choosing treatment strategies and targeting them. This is because procedures for choosing emphasis areas of interest and setting the injury and death-reduction goals are covered in *NCHRP Report 501* in detail. However, an overview of all three stages will be presented here.

Stage 1 – Define/Choose One or More Issues/Emphasis Areas

As noted above, the safety planning team will first need to define or choose an issue (emphasis area) or set of issues that need to be addressed. There is a large array of safety problems that could be treated in any jurisdiction. Thus, at first glance, the possible issues are boundless. However, it should be noted that extensive analytical effort was conducted in the development of AASHTO's Strategic Highway Safety Plan to identify 22 critical safety issues/emphasis areas. In addition, extensive efforts have been made to identify the best possible low-cost but effective treatment strategies for use in these 22 areas, thus making the development of a jurisdiction-specific safety program much easier. While not always the case, the same critical problems would most likely exist in any jurisdiction. So “defining” here is usually related to determining which of the 22 identified emphasis areas are most critical in your jurisdiction.

The choice of emphasis area(s) is usually done with some type of “problem identification” analysis of crash and other safety-related data. This is a critical part of the safety planning process, but the presentation of detailed procedures for conducting such analyses is outside the scope of this guide. Instead, the user is referred to *NCHRP Report 501: Integrated*

Safety Management Process (18), which provides details of more than one type of problem-identification procedure in Section D1.3 of Appendix D. The focus of this guide is on the development of safety improvement plans for each emphasis area once the allocation of funds between emphasis areas has been determined. However, these processes can be performed in iterative fashion. Once the safety improvement plans for individual emphasis areas have been developed, it may be desirable to revisit the allocation of funds between emphasis areas and increase or decrease the funding for specific emphasis areas as appropriate.

As described in detail there, the analyst will generally first perform multiple data runs of perhaps each variable in the crash data (e.g., driver age, crash type) to determine which of the data codes within each variable show high frequencies of crashes. Since some crashes are more severe than others, crash severity as well as frequency should be considered in choosing the emphasis areas. As detailed below in Section III, Stage 3 of this guide, one method of combining both frequency and severity is through weighting each crash in each crash type by an economic cost based on its severity. Information on economic cost per crash by severity level for 22 different crash types categorized by speed limit category can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). The use of crash costs rather than just crash frequency will provide the analyst with overall information on which crash types are most important in his/her jurisdiction. Analysts who do not wish to assign explicit costs to individual crash severity levels can use an alternative cost-effectiveness approach using weights for specific severity levels to generate equivalent property-damage-only crash frequencies. This approach is analogous to using estimates of crash costs by severity level, except in this case the severity-based crash costs are replaced by severity-based weights.

Both frequency and severity-based crash costs provide initial information based on most important crash types

and/or combinations of crash types with other crash-related variables (e.g., crash type by time of day). As further described in Appendix D of *NCHRP Report 501 (18)*, a more detailed procedure in which categories within a given variable (e.g., crash type) can be shown to be “over-represented” is provided in the CARE (Critical Analysis Reporting Environment) (23). In general, and as described in *NCHRP Report 501*, the analyst will conduct a series of “drill down” analyses to gain details on which issues/emphasis areas are most important for his/her jurisdiction.

Stage 2 – Set a Crash, Injury or Death Reduction Goal for an Emphasis Area

The emphasis-area team will then use a series of factors to define a reduction goal for deaths and injuries in each of the emphasis areas chosen. This decision will be based on outputs of the Stage 1 analyses (i.e., the problem-size, total crash cost, over-representation, and related outputs of the problem-identification/drill-down analyses), on some estimate of the possible effects of strategies, and on the budget established for the emphasis area. *NCHRP Report 501 (18)* defines both an initial process and a revised process for establishing these goals. The initial process will most likely be based on “best judgment” of the factors above. The revised process is much more iterative and analysis-driven where initial goals are modified based on analyses that indicate what is realistic given the nature and size of the problem, the known or assumed countermeasure effectiveness for the final list of chosen countermeasures, and the optimization of the existing budget either within a given emphasis area or across emphasis areas.

Stage 3 – Define Treatment Strategies and Target Populations

Having now defined the issue/emphasis area to be treated (e.g., run-off-road crashes, crashes involving drinking drivers) and having defined the crash/injury reduction¹ goal (e.g., a 10 percent reduction in the number of fatal and serious injury run-off-road crashes on two-lane rural roads), the next step is to define the treatment strategies to be employed and the target population for each strategy. Note that the terms

¹ Note that the term *crash/injury reduction* will be used instead of *crash reduction* throughout this guide. In most cases, the two terms can be thought of as interchangeable. However, because the ultimate goal of safety programs is to reduce death and injury, and since this can be accomplished both by reducing crash frequency and by reducing the severity of crashes, the former term is considered more appropriate than the latter. In addition, it should be understood that the term “injury” includes both fatal and nonfatal injuries. Thus, the crash/injury reduction from a treatment may represent a reduction in crash frequency, a reduction in crash severity, or both.

“treatment strategy,” “treatment,” and “strategy” are used interchangeably in the following text. Here, depending on the emphasis area and strategy being addressed, the term “population” may refer to humans (e.g., older drivers, pedestrians); vehicles (e.g., large trucks, motorcycles); or roadway sites (i.e., individual roadway features, segments, corridors, intersections, and interchanges). High-level safety planning requires that the limited available safety funds be used in the most effective ways. Funds should not be spent on treatments whose effects are small if those same funds could be used for other treatments that would provide greater benefits. Thus, as a minimum, the goal should be to only implement treatments whose benefits exceed their costs, and the ultimate goal should be to implement the treatments with the highest ratio of benefits to costs. However, to base safety planning decisions on benefits and costs requires that the effectiveness of each potential treatment be defined (e.g., treatment “X” will reduce run-off-road crashes by 15 percent or treatment “Y” will reduce older driver crashes by 20 percent).

However, a review of any of the *NCHRP Report 500* guides will indicate that there are many treatments that have been tried – in some cases used very widely – and are generally considered to have a positive effect on safety, but have never been formally evaluated in a well-designed study from which an acceptable quantitative *level of effectiveness* (i.e., a specific CRF or AMF) has been developed.

For this reason, the process of choosing treatments and choosing targets for each treatment will be covered in four different procedures:

- Procedure 1 – for application to roadway-based treatments with a known effectiveness level where a complete set of data (e.g., crash, roadway inventory,

Crash Reduction Factor vs. Accident Modification Factor

The *level of effectiveness* of a treatment is referred to in much of the current safety literature as a Crash Reduction Factor (CRF) or Accident Modification Factor (AMF). The two terms are just different ways of expressing treatment effectiveness levels. A CRF provides the expected proportional reduction in crash frequency, for all crashes or for specific crash severity levels, so a 15 percent reduction in crashes would correspond to a CRF = 0.15. Likewise, a 20 percent reduction in fatal and serious injury crashes would correspond to a CRF = 0.20. An AMF is developed by subtracting the CRF from 1.00, with an AMF of 1.00 representing no effect on safety. Thus, a treatment with a 15 percent effectiveness would have an AMF of 0.85 (i.e., 1.00 – 0.15). AMFs above 1.00 indicate that the treatment can be expected to result in an *increase* in crashes.

Why Perform the Higher Level Analysis Shown in Procedure 1?

- Selects treatments better
- More detail on target roadways or intersections for each treatment
- Provides better assurance that established goals can be met
- Provides better allocation of limited safety dollars

intersection inventory, traffic counts) are available for planning purposes

- Procedure 2 – for application to roadway-based treatments with known effectiveness, but where only crash data, but not inventory or traffic volume data, are

available (e.g., for local jurisdictions without inventory data)

- Procedure 3 – for application to both roadway treatments that do not have specified levels of effectiveness and driver-based treatments with or without known effectiveness
- Procedure 4 – a hybrid of Procedures 1, 2, and 3 for considering treatments with known effectiveness and treatments without known effectiveness in the same process

Procedures 1 and 2 are based on an economic (benefit-cost) analysis. Procedure 3 is not based on economic analysis, while Procedure 4 combines economic and non-economic procedures. The selection and targeting of driver- and vehicle-based treatments is not based on an economic analysis. The following discussion provides an overview of each of these four procedures. Details of each of the procedures will be presented in the individual sections concerning specific treatment types.

Procedures 1 and 2 generally result in plans whose expected safety benefits are more accurately known than Procedures 3 and 4, because Procedures 1 and 2 are applicable to treatments whose effectiveness has been well documented. Therefore, the safety planning process should generally exhaust funding opportunities under Procedures 1 and 2 before proceeding to Procedures 3 and 4.

Exhibit III-1 will guide the user to the appropriate procedure for each analysis situation. The key considerations in choosing one of the four procedures are whether the effectiveness of the treatment(s) is known and whether the available crash data are “mileposted.”

In many states, the achievement of a statewide goal for crash reduction will involve consideration of treatments both with and without known effectiveness and consideration of roads under both state and local jurisdiction, which are likely to involve crash datasets that are both mileposted and not mileposted. Thus, many states may need to use more than one of the four procedures. The application of each of these procedures is described below.

Procedure 1 – Choosing Roadway-Based Treatments and Target Populations When Treatment Effectiveness Is Known, and Both Crash and Non-Crash Data are Available

As indicated above, the highest level of treatment selection/targeting analysis represented by Procedure 1 is based on an economic analysis procedure. This procedure is applicable to treatments intended to improve safety on roadway segments or at intersections. If required data are available or can be developed, Procedure 1 will provide the user with best selection of treatments and with the most detail on where the treatments should be targeted. It will also provide better assurance to the user in the planning process that the established crash/injury reduction goal can be met. The increase in the precision of the analysis, in comparison to the other procedures discussed below, will result in much better allocation of safety dollars. For these reasons, Procedure 1, where feasible, is strongly recommended to the user. Detailed examples of the application of Procedure 1 in which multiple potential treatments and treatment targets are examined to produce a final recommended program are presented at two FHWA web sites: http://safety.fhwa.dot.gov/roadway_dept/docs/lanedeparture/index.htm and http://safety.fhwa.dot.gov/intersections/intersection_sap.htm (24,25).

Procedure 1 is suitable for roadway-based treatments that address specific crash types and are aimed at modifying roadway segments or intersections. However, it should be noted that Procedure 1 can also be applied to driver- or vehicle-related treatments if the effectiveness of the treatment is known, and if the treatment is to be targeted to specific locations on the highway. Examples include red-light-running enforcement targeted to intersections with high numbers of

Treatment Effectiveness Known?	Inventory Data Available and Linkable to Crashes?		
	Yes	No	
	Mileposted Crashes	Mileposted Crashes	Unmileposted Crashes
Yes	Procedure 1	Procedure 2A	Procedure 2B
No	Procedure 3	Procedure 3	Procedure 3
Some known, some unknown	Procedure 4	Procedure 4	Procedure 4

Exhibit III-1. Guide to choice of procedures based on knowledge of treatment effectiveness and crash data quality.

such crashes or truck inspection programs targeted to locations or corridors with high numbers of crashes associated with truck speeding or mechanical failure.

It should also be noted that, while Procedure 1 is driven by hard data (e.g., information on costs, benefits, crash counts, roadway mileage), there are other policy issues that must also be considered before implementation, including user acceptability. The FHWA Sample Plans (24, 25) noted above also provide thoughts on such issues. For example, the first plan recommends limiting “the installation of shoulder rumble strips to rural highways where there are no concentrations of homes due to the noise issue,” and conferring “with state or local pedestrian/bicycle coordinator concerning potential application of shoulder rumble strips on bicycle routes.” Since these are policy decisions, each user will need to decide what criteria are necessary. However, the point is that careful consideration of such issues is important.

To implement Procedure 1, which provides the highest level analysis of roadway-based treatments, the following data are required:

- A specified effectiveness level (Crash Reduction Factor or Accident Modification Factor) for each treatment to be considered
- A computerized crash data file which includes sufficient crash details to identify crash types that will be affected by each treatment (“target crashes” such as run-off-road crashes, head-on crashes, run-off-road on curves), and which includes crashes for all potential target populations
- Computerized roadway inventory data and/or intersection inventory data that can be linked to the crash data by location of the crash
- A network screening computer program which will examine each segment of roadway of a given length (e.g., 1 mile) or each intersection and calculate the number of *target* crashes that have occurred on each segment in the past 3 to 5 years (see further discussion below)
- Computerized traffic count data that is part of the roadway or intersection inventory data or can be linked to it
- Unit cost for each treatment – both original implementation costs and annual maintenance costs

If these data are available, Procedure 1 will lead the user through a series of steps that will allow the user to choose a set of treatments and a set of targets (e.g., locations or subpopulations) for each chosen treatment that will both meet the established crash/injury reduction goal, and will be cost-beneficial at some prescribed level. To do this, the user must analyze each potential treatment separately (choosing targets for each) and sum potential crash injury reductions across all treatments to determine if the established goal can be met. If not, new treatments or strategies should be added.

While the detailed procedure will be presented in the individual strategy-based sections, the steps include the following:

1. Specify the types/classes of roadway segments that are potential targets for the treatments.
2. Develop *critical crash frequencies* for each candidate treatment – the frequency of target crashes per mile or per intersection that, if treated, will result in crash/injury reductions whose economic benefit will exceed implementation costs by some specified factor. In the examples provided in the two FHWA Sample Plans (24, 25), the benefit-to-cost ratios used were 2.0 or greater.
3. Using the inventory file, stratify potentially treatable roadway segments by roadway class.
4. Link target crashes with roadway segments or intersections from the appropriate inventory data file, and then perform a computer screening of all potential locations (segments or intersections) to determine which have crash frequencies that exceed the critical crash frequencies.
5. If performing a roadway segment analysis, correct the output for “treatment gaps” along the same route resulting from the network-screening computer program.
6. Estimate the expected crash injury reductions on all the identified target locations.
7. Repeat the above steps for each potential treatment type.
8. Correct for multiple treatments on the same segment.
9. Sum all expected crash injury reductions for all chosen treatment types and chosen target locations and compare that total to the established goal.
10. Add either new treatments or new targets or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.

The following flow chart shown in Exhibit III-2 illustrates this procedure.

A key advantage of having effectiveness measures for each treatment, as is the case in Procedure 1, is that the full set of treatments needed to reach the crash/injury reduction goal can be determined. The user can also determine the cost of implementing those treatments and, thus, determine the cost of meeting the established crash/injury reduction goal. The cost of meeting the goal should then be compared to the available budget for safety improvement. If the cost of achieving the goal is within the available budget, the required funds should be programmed; depending on the size and nature of the improvement program needed to reach the goal, the programming of these treatments may be in a single year or over a multi-year period. If the cost of achieving the goal exceeds the available budget, the user can request an increased budget from agency management, which may in turn inform higher political authorities (executive and legislative) of the funding level needed to meet the goal. If the funds required to meet

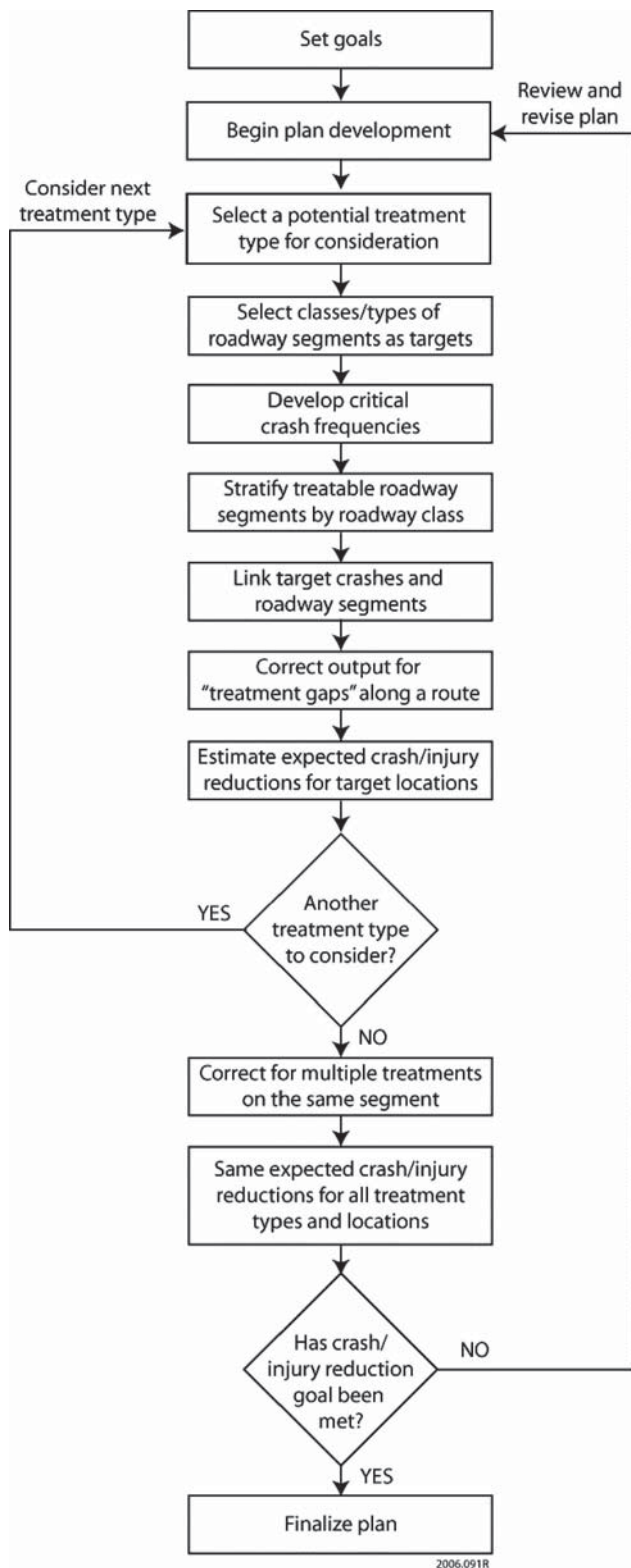


Exhibit III-2. Flow chart illustrating procedure 1.

the goal are not available, the user should proceed with the portion of the program that can be implemented and should inform agency management that the program will proceed as far as practical, but that the established goal cannot be met.

The reason for using a network screening program is that crashes are not uniformly distributed along a route; the network screening program identifies locations where crashes of particular types are concentrated, which represent potential improvement locations.

Many highway agencies have developed computer programs to screen the highway network for high crash frequencies and new software tools to perform such screening are under development. Existing highway agency screening programs typically use a “sliding window” approach in which a “window” of specified length is moved forward along the road in steps of specified length and the crash frequency within the “window” is checked at each step. Such existing network screening programs can be used to implement Procedure 1. A window length of 1 mile is recommended for use with existing network screening programs.

A more sophisticated network screening approach will be possible with FHWA’s *SafetyAnalyst* software tools which are currently under development. *SafetyAnalyst* (see <http://www.safetyanalyst.org>) uses a new screening approach, known as “peak searching” and a variation of the “sliding window” approach based on improved statistical methods. The “peak searching” algorithm in *SafetyAnalyst* uses a variable window length based on homogeneous roadway segments. The *SafetyAnalyst* “sliding window” approach uses window lengths that can be selected by the user; this will allow the use of window lengths shorter than 1 mile and will allow the window length to move forward in steps that are shorter than the window length. Network screening has typically been performed by highway agencies in computer database programs, but techniques for performing network screening in a Geographic Information Systems (GIS) environment are being developed.

Procedure 2 – Choosing Roadway-Based Treatments and Target Populations When Treatment Effectiveness Is Known and Crash Data Are Available, but Detailed Inventory Data Are Not Available

Procedure 2 for roadway-based treatments is intended for application on roadway segments or at intersections in “limited-data” situations. Here, crash data are required, but a formal roadway segment or intersection inventory database is not required. Thus, Procedure 2 is intended for application by highway agencies that do not have detailed computerized inventory data on the characteristics of each roadway segment and/or intersection. The goal is the same – to select a set of treatments with target locations identified for each treatment that, if treated, will ultimately allow the user to meet the established crash/injury reduction goal, and to do so such that the economic benefits of the crash-injury reductions exceed

the treatment implementation costs. The lack of detailed inventory data on individual roadway segments or intersections means that estimates concerning treatment effects are not as accurate as in Procedure 1, and that the targets identified are not as likely as those in Procedure 1 to provide the intended results. Thus, the user cannot have as much faith in the benefit-to-cost results as was the case with Procedure 1.

Procedure 2 has two variations. In the first, designated below as Procedure 2A, while an inventory database is not required, each crash must be “mileposted” (i.e., given a specific “address” on a specific route) with sufficient accuracy such that clusters of crashes can be found and the locations at which those clusters occur can be identified as candidate improvement locations. This is likely to be the case for many state highway agencies when intersection treatments are being analyzed, since most highway agencies will have mileposted all crashes but do not have an “intersection inventory” that provides the (mileposted) location of each intersection on each route. This may also be the case for local agencies (e.g., counties, cities, towns) that can provide a “milepost” or other “address” for their crashes. Currently, more highway agencies have developed roadway-segment inventory data files than have developed intersection-inventory data files. Therefore, some highway agencies may find that they can apply Procedure 1 to roadway segment improvements, but that they must apply this first variation of Procedure 2 to intersection improvements.

The second variation of Procedure 2, designated below as Procedure 2B, requires crash data that is addressed to a given street or route within the jurisdiction (e.g., a route within a given county), but the crash data does not have to be “mileposted” to a specific location on that route. The disadvantage of this procedure as compared to either Procedure 1 or the “mileposted-crash version” of Procedure 2A is that only *full routes within a jurisdiction* (e.g., a county or township) can be analyzed. Thus, a route will not pass the benefit-cost screen unless there are sufficient crashes (and thus potential crash/injury reductions) on the full route to overcome the cost of treating the full route, and the user will not be able to determine which segments of a given route would produce results that have a higher B/C ratio.

Since Procedure 1 is likely to provide better and more accurate safety improvement plans than either of the versions of Procedure 2, it is important to the future expansion of highway safety programs that more agencies move toward the development of roadway segment and intersection inventory data files. Since the information on safety improvements provided by Procedure 2B will not be as accurate or as detailed as that for Procedure 2A, it is also important that agencies move toward a system where all crashes are “mileposted.”

Procedure 2A – For Mileposted Crashes. To implement the mileposted-crashes version of Procedure 2, designated as

Procedure 2A, which applies a “medium level” analysis of roadway-based treatments, the following data are required:

- A specified effectiveness level (CRF or AMF) for each treatment to be considered
- A computerized crash data file which includes sufficient crash details to isolate target crash types (run-off-road, head-on crashes, and run-off-road on curves) and potential target populations that will be affected by each treatment, and which is “mileposted” such that the location of each crash is included
- A network screening computer program which can read an input file composed of *target* crash records sorted by route and milepost, and can count the number of target crashes within a given specified length (e.g., 1 mile for segment-based treatments and 500 ft for intersection treatments) that have occurred in the past 3 to 5 years
- Unit cost for each treatment – both original implementation costs and annual maintenance costs

If these data are available, Procedure 2A will lead the user through a series of steps that will allow the user to choose a set of treatments and a set of targets for each chosen treatment that will both meet the established crash/injury reduction goal, and will be cost-beneficial at some prescribed level. As with Procedure 1, one must analyze each potential treatment separately (choosing targets for each), implement a procedure which estimates “combined effectiveness” for segments or intersections where multiple treatments for the same crash types will be applied, correct for “treatment gaps” along the same route if a segment-based program, and sum potential crash injury reductions across all treatments to determine if the established goal can be met. If not, new targets or strategies should be added.

While the detailed procedure will be presented in the individual strategy-based sections (e.g., see Section IV, “Roadway Segment Programs”), the steps in the process are essentially identical to the steps in Procedure 1, with the exception that the network screening program is used somewhat differently. The steps include the following:

1. Develop *critical crash frequencies* for each candidate treatment – the frequency of target crashes per mile or per intersection that, if treated, will result in crash/injury reductions whose economic benefit will exceed implementation costs by some specified factor.
2. Sort crashes by route/milepost in ascending order, and then perform a computer screening of all segments on all routes that are potential treatment locations to determine which segments have target crash frequencies that exceed the critical crash frequencies calculated in Step 1.

3. If performing a segment-based program, correct the output for “treatment gaps” along the same route resulting from the network screening computer program.
4. Estimate the expected crash injury reductions on all the identified target locations.
5. Repeat the above steps for each potential treatment type.
6. Correct for multiple treatments on the same segment or at the same intersection.
7. Sum all expected crash/injury reductions for all chosen treatment types and chosen target locations and compare that total to the established crash/injury reduction goal.
8. Add either new treatments or new targets or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the crash/injury reduction goal is met.

Procedure 2B – For Unmileposted Crashes. To implement the version of Procedure 2 without mileposted crashes, which applies a “medium level” analysis of roadway-based treatments, the following data are required:

- A specified effectiveness level (CRF or AMF) for each treatment to be considered.
- A computerized crash data file which includes sufficient crash details to identify crash types that will be affected by each treatment (“target crashes” such as unsignalized intersection crashes, run-off-road crashes, head-on crashes, and run-off-road on curves), and which includes crashes for all potential target roadways. Each crash record must contain a county or jurisdiction name where the crash occurred, and a “route/road on” variable – the name of the route or road where the crash occurred. If intersection treatments are being considered and the crash record consistently includes the name of the crossing roadway, then it may be possible to treat the intersection crashes as mileposted, and Procedure 2A may be used, even though the “mileposts” are not numerical. However, in this situation, it may not be possible to consider intersection-related crashes that occur on the intersection approaches at some distance from the intersection.
- “Route length” information that will provide the length in miles of each road or route within a county that is a potential target for any treatment, or at least the approximate length.
- Unit cost for each treatment – both original implementation costs and annual maintenance costs.

If these data are available, Procedure 2B will lead the user through a series of steps that will allow the user to choose a set of treatments and a set of targets for each chosen treatment that will both meet the established crash/injury reduction goal, and will be cost-beneficial at some prescribed level. As with Procedure 1, one must analyze each potential treatment

separately (choosing targets for each), implement a procedure which estimates “combined effectiveness” for segments or intersections where multiple treatments for the same crash types will be applied, and sum potential crash injury reductions across all treatments to determine if the established goal can be met. If not, new targets or strategies should be added.

While the detailed procedure will be presented in the individual strategy-based sections, the steps include the following:

1. Develop *critical crash frequencies* for a candidate treatment – the frequency of target crashes per mile or per intersection that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor.
2. Link target crashes with each route or intersection in each jurisdiction (but not to a specific point on the route). This will require computer sorting of crashes by each named route or at each named intersection. Some manual effort will be required to correct misspelled names and to group routes or streets that have multiple names.
3. Count target crashes for each route or intersection and enter the total counts into a spreadsheet (one route or intersection per row), along with the route mileage for that route (if using a segment-based program). Repeat this step for each route and/or intersection in the jurisdiction under study.
4. Use the spreadsheet to calculate annual crash frequencies for each potential route or intersection.
5. Define possible target routes or intersections by determining which have calculated annual frequencies that exceed the developed critical crash frequencies.
6. Estimate the expected crash injury reductions on all the chosen target locations by adding up target crashes and multiplying by the treatment effectiveness level.
7. Repeat the above steps for each potential treatment type.
8. Correct for multiple treatments on the same route or at the same intersection.
9. Sum all expected crash injury reductions for all chosen treatment types and chosen target locations and compare that total to the established goal.
10. Add either new treatments, new targets or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.

Procedure 3 – Choosing Driver, Vehicle or Roadway Treatments and Target Populations When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Not Known

The two procedures described above allow the user to choose treatments and treatment targets for a given problem while ensuring that the economic value of the crash-injury

reductions will exceed the cost of implementing the program. Both procedures require that the treatments being examined each have a known level of effectiveness expressed in terms of an expected crash/injury reduction – a defined CRF or AMF. Unfortunately, many of the roadway-oriented treatments and many of the non-roadway-oriented treatments (i.e., driver- and vehicle-oriented strategies) in the *NCHRP Report 500* guide series do not have defined levels of effectiveness. Thus, economic analyses like those that are the basis for Procedures 1 and 2 are not possible for these treatments.

Despite the inability to perform formal economic analyses, the user can still make an educated choice of which treatments will be most effective in their jurisdiction, and can develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide (e.g., where specific counties, communities, roads, or driver groups are to be targeted). In general, the choice of treatment will be based on “what is likely to work best for the target group” and the choice of targets will be based on identification of locations “where the crash/injury problem of interest is found.” From the description of Procedure 3 presented below, it should be apparent to the user that this procedure could produce results that are far less likely to fulfill the established safety goal than the results of Procedures 1 and 2. Nevertheless, when data to use Procedures 1 and 2 are lacking, Procedure 3 is the best available substitute. The obvious drawbacks of Procedure 3 highlight the need for better data systems to implement analysis procedures that are expected to be more accurate.

The analysis of treatments without documented crash/injury reduction effectiveness should focus on those treatments for which the user decides that there is *some evidence of a crash/injury reduction benefit*, even if a documented CRF or AMF based on research using crash data is not available. The *NCHRP Report 500* guide series classifies treatments into three types – proven, tried, and experimental – based on whether credible evaluations based on crash data have been performed (i.e., a CRF or AMF has been defined). The *proven* treatments are those that have been shown through credible evaluations to be effective in reducing crashes. However, not all treatments classified as proven will have a CRF, since some evaluations are based on outcomes that are *related to* crash/injury reduction but do not actually have a measured and quantified value for the expected reduction in crash/injury frequency. For example, the effect of occupant restraint laws is stated in terms of “restraint use increase” rather than crash-injury reduction. The treatments classified as *tried* include those treatments that have been used by agencies (in some cases used often), where there is little possibility of negative impacts on crash/injury frequency, and where there is an expectation (but not scientific proof) that the effect of the treatment on safety is likely to be a positive one. The evidence could include poorly designed or executed crash/injury evaluations and indirect or *surrogate*

measures that may be related to safety (e.g., behavioral changes that may be related to crash/injury reduction). The treatments classified as *experimental* are treatments that have the potential to be beneficial, but have had only limited use and cannot be considered either proven or extensively tried. As stated in each of the *NCHRP Report 500* guides, these experimental treatments should be used with care, only in pilot programs, and should be evaluated carefully before widespread implementation. The Sample Plans presented at the FHWA web sites (24, 25) include example plans for such pilot programs. Thus, the process described below is intended for application only to proven and tried treatments.

Procedure 3 is intended for application to tried or experimental treatments for which the analyst has decided that there is likely to be a crash/injury reduction benefit, but for which the analyst does not have sufficient evidence to estimate a specific CRF or AMF value. In the event that the analyst is able to estimate a specific CRF or AMF value, even if the estimate is only an approximation, it is recommended that Procedure 4 be used rather than Procedure 3.

Unlike Procedures 1 and 2, when crash/injury reduction effectiveness of a treatment is not known, guidance on how to choose among several potential treatments and how to target the treatments selected is much more general in nature, and will require “best judgment” on the part of the user. The following general approach to Procedure 3 is suggested for a single issue or emphasis area (e.g., head-on crashes on two-lane roads or older driver crashes), but can be repeated for multiple emphasis areas.

Procedure 3 should be applied in two steps. First, choose the “best treatments” (i.e., the treatments most likely to be applicable in a given jurisdiction) from among the set of all treatments presented in the *NCHRP Report 500* guide applicable to the emphasis area in question. Second, choose the target locations or populations to which the selected treatments should be applied. The choice of the “best treatments” from a listing of many potential treatments can be based on the following factors:

- a. *Which of the many potential treatments is judged to be the most effective?* Even though the exact crash/injury reduction effects of each potential treatment are not known, there may be some knowledge of which treatments are more likely to be the most effective. To develop an implementation plan in the absence of treatment effectiveness estimates, the user must exercise judgment about which treatments are best suited to a particular problem. The detailed information in the *NCHRP Report 500* guide series, particularly in the section of each strategy discussion labeled “Expected Effectiveness,” will provide the user with a summary of current knowledge on which judgment can be based. The knowledge in the *NCHRP Report 500* guides

may be supplemented with the past experience of the agency with the treatments under consideration. There are also some general approaches that can be based on past examinations of different strategy types over time. For example, for programs aimed at drivers and vehicles, treatments that incorporate legal sanctions will usually be more effective than education, and education linked with enforcement will usually be more effective than either alone. For roadway-based treatments, the best of multiple choices without known effectiveness will often be the treatment that can potentially affect the crash types and severity levels that are most prevalent at the locations or on the portions of the roadway system under consideration for treatment (see factor “b” below).

- b. *The relative magnitude of the crash types and severity levels that the treatment will affect.* In general, the user should focus on treatments that could affect the largest portion of the existing crash experience at the locations or on the portion of the roadway system under consideration for treatment. The use of a “drill down” approach to crash data analysis to determine as many specifics of crash type and severity distributions related to the issue under study is recommended. Thus, if one is attempting to reduce older driver crashes, then a preliminary analysis should be performed using available crash data to determine the frequencies and proportions of different types of crashes involving older drivers. Then, treatments that target the most prevalent crash types should be selected. Problem analysis of this type is an iterative process; the results of one analysis of crash data may suggest another. A sequence of analyses may eventually lead to the identification of a treatment or a set of treatments that appear to address the most prevalent crash types. It cannot be ensured that the treatments that address the most prevalent crash types will, in fact, produce the largest crash reductions, but in the absence of treatment effectiveness estimates, a focus on treatments that address the most prevalent crash types is a logical choice.
- c. *The cost of the potential treatments per target unit (either per person or per mile or per intersection).*
- d. *Other technical or policy considerations* – there may be reasons you can’t implement a potential strategy in your jurisdiction, even if it’s potentially the “best” (e.g., some jurisdictions may not allow the removal of roadside trees, or some treatments require enabling legislation such that municipalities cannot use the treatment without authorization under state law).

These factors must be combined in some fashion to first decide which treatment to choose. While there are multiple ways of making this choice, the following represents one such procedure.

- 1. Prioritize the specific crash types (within your chosen emphasis area) to be addressed.**

This is related to Factor b in the above list. Here, for the roadway-departure area, the issue is whether to treat run-off-road, head-on, tree-related or other roadway segment crash types, and on which roadway systems (e.g., two-lane rural roads, four-lane divided roads, free-ways). For driver-related programs, the issue might be whether to treat younger or older drivers, or even which crash types affecting older drivers to target. Whatever the issue, the prioritization will be based on the frequency and severity of the specific types of target crashes occurring in a user’s jurisdiction. For each crash type, the user could begin the process by analyzing 3 to 5 years of crash data to determine the frequency of each type. However, since some crash types are more severe than others (e.g., head-on crashes are more severe than run-off-road crashes), total crash frequency alone does not provide the complete answer. While an alternative is to restrict the analysis to only fatal and serious-injury crashes, this will severely limit the crash sample, and will also omit a large component of the crash problem – non-serious injury and no-injury crashes. A better solution is to weight each crash by an economic cost based on its type and severity, and then accumulate the total crash cost within each target crash type. Information on economic cost per severity level within 22 different crash types can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). This analysis of crash costs will provide the user with overall information on which lane-departure crash type has the greatest economic impact.

It is noted that the 22 crash types covered in this FHWA report are types defined by what is hit (vehicle-pedestrian, vehicle-vehicle, vehicle-object, vehicle rollover) and the nature of the impact (angle, rear-end, head-on, etc.); the type of crash location (intersection or non-intersection); and two speed limit groups (≤ 45 mph or ≥ 50 mph). The types do not include crashes for specific vehicle types (e.g., truck and motorcycle crashes), specific driver populations (older vs. younger drivers), or for certain crash situations (e.g., crashes in work zones). However, since the economic costs are derived for each level of crash severity, the user can develop a weighted per-crash cost for any crash scenario (e.g., work zone crashes, truck-car crashes, older driver crashes) by using the severity distribution of that crash scenario in their own data sample.

The user may further refine this analysis by examining crash frequency or total crash cost within roadway classes. If the crash data are mileposted and linkable inventory data are available, details of roadway types can be linked to each crash record (e.g., number of lanes by divided/undivided). If inventory data are not available, there may be variables on the crash record itself that can be used in a less-detailed analysis (e.g., number of lanes, rural vs. urban, route type).

This analysis will then produce a listing of potentially treatable crash types (perhaps by road class) that can be sorted by crash frequency or total crash cost, thus providing a ranked listing. For the higher-ranked crash types, the user can then conduct additional analyses to determine more of the specifics of the crash circumstances (e.g., nighttime vs. daytime distributions of total crash costs). These additional “drill-down” analyses should be designed to provide additional information that could lead to the choice of one treatment over another (e.g., raised pavement markers are primarily effective at night or in rainy weather).

2. Identify possible treatments for use for each high-priority crash type.

The user will then review the pertinent *NCHRP Report 500* guides and list treatments that would be most appropriate for each of the high-priority crash types identified in the above step. The choice should be limited to those treatment strategies that are classified as *tried* in the guides. (*Proven* treatments have known effectiveness levels and can be analyzed in one of the three procedures above.) If not already conducted in the “drill-down” analysis in the preceding step, more specific information on the crash costs related to each potential treatment strategy could be developed by specifying the crash types that are most likely to be affected by each strategy (e.g., nighttime run-off-road-right crashes for raised pavement markers), producing crash frequencies for each specified crash type, and multiplying the frequencies by cost per crash. For some strategies, the *NCHRP Report 500* guide presents information concerning which crash types are most likely affected by that treatment strategy.

3. Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular crash type/road class combination, it may be feasible to make a judgment concerning which treatment strategy would be expected to be most effective. For example, for run-off-road crashes on two-lane rural roads, one would assume that rumble strips on two-lane rural roads would be more effective than wider edge lines or raised delineators. For alcohol-related crashes or occupant-restraint-related crashes, treatments involving enforcement coupled with public information are more effective than either approach by itself. At times, this will clearly be a very difficult judgment to make.

4. Choose “best” treatment(s) by considering estimated effectiveness, unit cost and other technical and policy considerations.

The user will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost per mile of the

treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The user will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined. The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected (e.g., raised delineators will affect run-off-road crashes at night).

The user should be able to work backwards using the number of crashes likely to be affected by a given treatment and the cost of applying that treatment to a given population or location (see items b and c described at the beginning of this procedure) to determine the treatment effectiveness needed to maintain a cost-benefit ratio greater than or equal to one.

$$\frac{B}{C_t} \geq 1.0$$

Where:

- B = economic benefit of applying a selected treatment to a given location or population
- C_t = the cost of applying that treatment to the selected location or population

$$B = N * C_c * \text{Eff}$$

Where:

- N = Number of target crashes for the subpopulation or location where the treatment is to be applied
- C_c = average economic cost per target crash
- Eff = treatment effectiveness, or the percent reduction in target crashes

Since different severity levels have different crash costs, the value used for C_c can be a weighted average of the crash costs associated with the crash types likely to be affected. Solving for the treatment effectiveness, the equation reads:

$$\text{Eff} = \frac{C_t}{N * C_c}$$

The analyst can then determine whether the calculated treatment effectiveness required to reach the breakeven point is likely to be achievable.

5. Target the chosen treatments to the roadway segments or subpopulations where the problem is found.

Since this procedure concerns treatment strategies without known effectiveness, it will not be possible to target the

treatments based on any type of economic analysis such as those in Procedures 1, 2A and 2B. Instead, the treatment will be targeted to roadway segments, intersections, or vehicle or driver subpopulations showing the highest total crash cost or frequency, coupled with user judgment concerning other characteristics of the potential target groups (e.g., the nature of the roadway and roadside at potential target locations, driver subpopulations most likely to be reached by the treatment), and technical and political issues. More guidance on targeting using Procedure 3 is included in the individual sections that follow.

6. Decide what to do with multiple treatments on the same segments/routes or subpopulations.

The above steps could possibly produce roadway locations, intersections, and vehicle or driver subpopulations within a jurisdiction that could be treated with multiple treatments. Unlike the earlier procedures where it is possible to estimate combined effectiveness for multiple treatments on the same segments or routes, since treatment effectiveness is not known here, the user will have to use other factors in the final treatment choice for these locations. Again, more guidance is given in the sections that follow.

7. Add new treatments, new targets or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the available funding is used.

In Procedures 1, 2A, and 2B, an iterative process is used until sufficient treatment types and locations are selected such that the established crash reduction goal can be reached. In Procedure 3, without effectiveness measures for the treatments, it is not possible to verify whether or not a specific set of treatment types and treatments will meet the established goal. Therefore, the best that can be done is to proceed in selecting treatment types and treatments until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined by evaluations conducted after its implementation.

Procedure 4 – Choosing Treatments and Target Populations in Emphasis Areas for which Some Candidate Treatments Have Known Effectiveness Estimates and Other Treatments Do Not

In many situations, users considering a safety improvement program in a particular emphasis area will need to consider both treatments that have known effectiveness measures and treatments that do not. In this situation, it is recommended that the user give priority to treatments that have known effectiveness measures (*proven* treatments). Treatments that have been used extensively but for which effectiveness

measures are not available (*tried* treatments) should then be considered. *Experimental* treatments may have a modest role in a safety improvement program, particularly if the program is structured to evaluate the effectiveness of the experimental procedure.

The recommended planning approach in this situation is a hybrid of Procedures 1, 2, and 3 described above and includes the following steps described below:

1. *Determine if **proven** treatments can meet the established goal.* Consider treatments with known effectiveness measures using either Procedure 1, 2A, or 2B, as appropriate, depending on the types of data available. Determine the crash/injury reduction achieved and compare it to the established crash/injury reduction goal. If the goal has not yet been met, proceed to Step 2.
 2. *Consider **tried** treatments to supplement the proven ones.* Consider treatments without known effectiveness measures that have been used extensively by highway or driver/vehicle agencies. If effectiveness measures for these treatments can be estimated based on imperfect information, then proceed to Step 3; otherwise, proceed to Step 4.
 3. *Estimate the effectiveness of tried treatments if possible, and analyze them using the appropriate procedure above.* This step involves attempting to estimate the effectiveness of treatments without known CRFs or AMFs. **Note that estimating treatment effectiveness is very difficult and can lead to poor treatment choices unless the estimates are realistic.** This estimation was not suggested in Procedure 3 for this reason. It is only suggested at this point since the user has already considered all proven treatments before reaching this stage. It is suggested that the following guidelines be used in making such estimates:
 - a) In general, be as conservative as possible. Very few treatments can be expected to affect crash frequency by more than 15 to 25 percent.
 - b) When possible, formulate an effectiveness estimate that is applicable to particular target crash types only, not to total crashes.
 - c) Base estimates for *tried* treatments on CRFs for similar treatments if they exist. For example, a CRF exists for shoulder rumble strips. Other treatments that also try to keep the driver from leaving the roadway by alerting him (e.g., enhanced edgeline marking, raised profile marking) but do not give the same level of warning would be expected to have somewhat similar, but lower, CRFs.
- Once effectiveness is estimated, apply Procedure 1, 2A, or 2B as appropriate, depending on the types of data available. Determine the crash/injury reduction achieved in Steps 1 and 3 combined and compare it to the established crash/injury reduction goal. If the goal has not yet been met, proceed to Step 4.

4. *Consider additional **tried** treatments.* For treatments for which reliable effectiveness measures cannot be estimated, apply Procedure 3 to select additional treatment types and target locations or subpopulations, until all available funds have been budgeted.

Other Safety Analysis Tools

The procedures presented above supply a goal-oriented approach to developing plans for safety improvement programs. Users should be aware of other analytical tools that are being developed to assist in this process. FHWA's *SafetyAnalyst* software, planned for release in 2006 or beyond, is intended for application to safety management of a highway system, but may be an effective tool for safety planning as well. Key capabilities of *SafetyAnalyst* include:

- Screening a highway network to identify sites with potential for safety improvement.
- Diagnosing selected locations to identify collision patterns.
- Selecting of countermeasures potentially applicable to the identified collision patterns.
- Using economic analysis tools to perform cost-effectiveness and benefit-cost analyses. These economic analysis tools will include an optimization routine to select a mix of improvement locations and countermeasures that maximizes the total safety benefits from a given budget for safety improvement.
- Priority ranking potential safety improvements based on economic analysis results.
- Evaluating the effectiveness of countermeasures after they are implemented.

SafetyAnalyst is location-oriented and budget-oriented, unlike the procedures presented above which are goal-oriented. More information is available at www.safetyanalyst.org.

FHWA's Interactive Highway Safety Design Model (IHSDM) may assist in the design and analysis of candidate

safety improvements on rural two-lane highways. IHSDM will likely be expanded in the future to address facility types in addition to rural two-lane highways.

The forthcoming *Highway Safety Manual* (HSM), scheduled for publication in 2008, will present formal procedures for estimating the crash/injury reduction effectiveness of specific improvement types, including an expanded set of CRFs and AMFs representing countermeasure effectiveness. In the meantime, an expanded set of AMFs developed in NCHRP Project 17-25 has been presented in *NCHRP Research Results Digest 299* (27).

Summary

The procedures presented above have defined the overall process for planning safety improvements in any specific emphasis area. At this point, it is assumed that the user will have completed Stage 1 (i.e., define/choose the issue to be addressed) and Stage 2 (i.e., setting a stretch goal) using the guidance provided earlier and guidance provided in other documents such as *NCHRP Report 501*. The following sections of this manual will provide more detail on how to conduct the final step – treatment selection and targeting – for each of the 22 emphasis areas in the AASHTO Strategic Highway Safety Plan, or for groups of emphasis areas for which the data needed and the procedures to be applied are similar. Subsequent sections provide guidance on how to proceed with the planning process when relatively complete data are available, and when only limited data are available. It is again noted that a jurisdiction's full safety plan should include multiple issues/emphasis areas (e.g., run-off-road crashes, crashes involving heavy trucks, and crashes involving drinking and driving). Stage 1 will have defined the full set of issues/areas to be addressed, and Stage 2 will have defined goals for each issue. The user can then use the information provided in each of the individual sections below to conduct Stage 3 – treatment choice and targeting – for each of the issues in the full plan.

SECTION IV

Roadway Segment Programs

Planning Programs Related to Reducing Crash Types Including Run-Off-Road, Head-On (Including Head-Ons on Freeways), Curve, Utility Pole, and Tree-Related Crashes

This section of the guide provides the details of the four levels of treatment choice and targeting procedures described previously in the Stage 3 discussion in Section III, but oriented to those issues/emphasis areas that are specifically related to roadway segments – run-off-road crashes (including those involving utility poles and trees), head-on crashes, and curve-related crashes. This group of crashes is sometimes referred to as “lane departure” crashes. In most instances, a given procedure will follow the same basic steps, regardless of the crash type being addressed. Where the procedure differs between crash types, this will be noted. In addition, the data needed for the different roadway-segment-oriented crash types will differ and will be specified. The user is **strongly urged** to carefully review the material in each of the pertinent guides before beginning this planning process. These roadway-segment-oriented guides are found within *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. The specific volumes pertinent to this section are:

- *Volume 3: A Guide for Addressing Collisions with Trees in Hazardous Locations* (3)
- *Volume 4: A Guide for Addressing Head-On Collisions* (4)
- *Volume 6: A Guide for Addressing Run-Off-Road Collisions* (6)
- *Volume 7: A Guide for Reducing Collisions on Horizontal Curves* (7)
- *Volume 8: A Guide for Reducing Collisions Involving Utility Poles* (8)
- *Volume 20: A Guide for Reducing Head-On Crashes on Freeways* (26).

A link to these downloadable guides can be found at <http://safety.transportation.org/guides.aspx>.

Possible Program Types – Spot versus System Programs

Before moving to the specific treatment choice/targeting procedures for these emphasis areas, it is noted that states who were early participants in the AASHTO safety planning process for roadway-segment (and intersection) programs started from two different perspectives, and the perspective chosen determines the choice and targeting of treatments. Some states chose to try to expand their current “high-crash location” (HCL) program to include more locations to meet their overall goal. Others chose to orient their planning methods to the identification and treatment of “systems” of roadways, not just those locations that fell under the HCL program. Indeed, guidance provided in each of the guides, in companion training courses, and in the draft implementation plan on the FHWA website is that system-based programs will need to be included. If the jurisdiction is really attempting to reach a goal which represents a significant change from the current situation – a stretch goal – it is very unlikely that expansion of the HCL program will suffice. While such an expansion is clearly a component of a stretch-goal plan, large-scale treatment of systems and corridors will also likely be necessary.

Indeed, a jurisdiction can use the following procedure to determine approximately how much the existing HCL program will have to be expanded, which will provide some guidance on whether system programs should also be considered.

1. Examine the most recent listing of HCL projects that were chosen for treatment in your jurisdiction and identify those that were related to lane-departure crashes. (Note that the same procedure could be used for intersection crashes).

2. Add the numbers of before-treatment crashes, injuries and fatalities from each lane- departure site and divide by the number of years of before data to produce a total number of “potentially treatable lane-departure crashes and crash injuries per year.”
3. Multiply these totals by 20 percent to get the number of lane-departure crashes, injuries and fatalities that are expected to be reduced per year by your current program. (This assumes an average Crash Reduction Factor of 20 percent for all lane-departure strategies. This is probably too high, but in the ballpark of reality, and good enough for this exercise.)
4. Compare the numbers of crashes and injuries reduced and lives saved to your statewide lane-departure goal and calculate the proportion of your total goal that this represents (e.g., 20 percent or 0.20).
5. To calculate approximately how much you will have to expand the lane-departure part of your HCL program to meet your goal, divide 1.0 by the proportion from the previous step. For example, if the fatality and injury savings from your current program is 20 percent of your goal, then you will have to identify and treat five times as many lane-departure sites in the future (i.e., $1.0 / 0.20 = 5$).

The user will then need to make the determination of whether enough sites with high numbers of lane-departure crashes can be identified. Usually the HCL program identifies more sites than can be treated. This full “census” of potential HCL sites can be examined to determine whether enough sites with high numbers of lane-departure crashes are available. In most cases, if a stretch goal has been set, the answer will be “no.” In that case, the user should consider adding system improvements to the plan.

While all states and some local jurisdictions have procedures in place to identify and treat high-crash locations, it is noted that an improved methodology is currently being developed by FHWA in the *SafetyAnalyst* program described in the preceding Section (also see <http://www.safetyanalyst.org>). This set of the software tools for safety management of specific highway sites includes a series of procedures that will allow the user to identify high-crash locations or sites with potential for safety improvement, diagnose potential treatment sites to

identify correctable crash patterns, conduct an economic analysis to ensure a minimum B/C ratio, and develop a combined treatment program which maximizes the benefits that can be gained from a given total treatment budget. The network-screening tools within *SafetyAnalyst* provide a good approach for applying Procedure 1.

The primary emphasis of this guide is on planning site-specific projects at high-crash locations. If preliminary analysis indicates that even an enhanced and expanded high-crash location program will not meet the goal, then the users will need to add systems-based or systemwide treatment programs to the effort. This guide is not specifically intended for planning such systemwide treatments, but the four procedures described earlier and detailed below can be applied by the user to identify roadway systems or corridors (or even large numbers of individual segments) to treat and to help define the treatments that should be implemented for those systems or corridors. Again, the choice between which procedure is appropriate is defined by three factors – whether or not treatment effectiveness is known, whether the jurisdiction has inventory data that can be linked to their crash data, and whether the crashes are “mileposted” or not. Exhibit IV-1 will guide the user to the appropriate procedure.

Procedure 1 – Choosing Roadway-Based Treatments and Target Populations When Treatment Effectiveness Is Known, and Both Crash and Non-Crash Data Are Available

The following text identifies the data needed for conducting Procedure 1, followed by the individual steps in the procedure.

Data Needs

The following are the specific data needed to use Procedure 1 when choosing and targeting roadway-based treatments.

- **A specified effectiveness level (CRF or AMF) for each treatment to be examined.**

The “Treatment Effectiveness” section under each treatment in each *NCHRP Report 500* series guide provides a

Treatment Effectiveness Known?	Inventory Data Available and Linkable to Crashes?		
	Yes	No	
	Mileposted Crashes	Mileposted Crashes	Unmileposted Crashes
Yes	Procedure 1	Procedure 2A	Procedure 2B
No	Procedure 3	Procedure 3	Procedure 3
Some known, some unknown	Procedure 4	Procedure 4	Procedure 4

Exhibit IV-1. Guide to choice of procedures based on knowledge of treatment effectiveness and crash data quality.

description of what is known about CRFs. It is important that the user review the material in the guides for a given treatment. Valuable information about the stability of the CRF, cautions about the use of the treatment and other valuable information is included there, but will not be repeated here.

For a significant proportion of the treatment strategies defined in the six guides covered in this section, a specific AMF is not presented. Since the preparation of some of the earlier guides, additional information on treatment CRFs has been developed in both NCHRP 17-25, and in preliminary work for the Highway Safety Manual. The AMFs from NCHRP Project 17-25 have been published in *NCHRP Research Results Digest 299 (27)*. The AMFs developed in NCHRP Project 17-27 will be incorporated in the forthcoming *Highway Safety Manual*.

- **A computerized crash data file which includes sufficient crash details to isolate target crash types (run-off-road, head-on crashes, and run-off-road on curves), and potential target populations that will be affected by each treatment.**

Here, the user will need to examine the data formats for variables in their crash file to identify variables and codes within variables that can be used in determining whether or not each crash in the file is a “target crash.” Crash databases often categorize crash data for a given crash into up to three subfiles – general accident/crash variables, variables for each vehicle in the crash, and variables for each occupant in the crash. The variables needed to determine whether a crash is a “target crash” or not for roadway-segment-based crashes can usually be found in one of the first two subfiles – crash or vehicle data. Crash files differ from jurisdiction to jurisdiction. While certainly not always the case, the following variables (or similar variables) listed in Exhibit IV-2 will be used in this determination.

- **Computerized roadway inventory data and/or intersection inventory data that can be linked to the crash data by location of the crash.**

Most state DOTs have computerized roadway inventory files for the full state highway system that can be linked to crashes, since both the homogeneous segments in the inventory file and the crashes are identified by “addresses” – usually route and milepost or GIS coordinates. Most local jurisdictions (i.e., counties, towns, townships, cities) do not have such an inventory system. For jurisdictions that do not have an inventory file, Procedures 2A and 2B below can be used.

- **A network screening computer program which will examine a fixed-length portion of each route (e.g., 1 mile) and calculate the number of target crashes (e.g., run-off-road crashes, curve-related crashes) that have occurred in each “window” in the past 3 to 5 years.**

This program exists in some jurisdictions, but may not exist in others. If not, a knowledgeable computer analyst can build one. The process/program will require that counts of target crashes can be made and “attached to” each homogeneous section on a route, and that each segment includes a “segment length” variable. The program must then be able to examine each segment, starting from the first segment on a route, and accumulate both target crash counts (by adding up the numbers in the segment-specific counters) and segment length (by adding up the individual segment lengths). When the total accumulated segment length reaches the window length (e.g., 1 mile), the total number of crashes is recorded in an output file, along with the route number, the beginning milepost of the first homogeneous segment analyzed, and the ending milepost of the final segment analyzed in the current window. The program would then begin again the accumulation of target crash counts and segment lengths on the next homogeneous section of the route, and would repeat the same process until the full route has been completed. The process would be repeated for all routes in the system. Most current highway agency network screening programs operate in a database environment. Efforts are underway

Crash Type	Variable	Crash Database Subfile
Run-Off-Road (ROR) Crashes	Accident/Crash Type	Crash
	Manner of Collision	Crash
	Sequence of Events	Crash or Vehicle
	First Harmful Event	Crash
	Most Harmful Event	Vehicle
	Crash Location (Off-road)	Crash
	Number of Vehicles or Units	Crash
Run-Off-Road Crashes into Trees and Utility Poles	Same as ROR plus Object Struck	Vehicle (Sometimes Crash)
	Most Harmful Event	Vehicle
	Same as ROR Crashes plus Location Type	Crash (Sometimes Vehicle)
Head-On Crashes	Accident/Crash Type	Crash
	Sequence of Events	Crash or Vehicle
	First Harmful Event	Crash
	Most Harmful Event	Vehicle

Exhibit IV-2. Crash variables and subfile location by crash type.

to develop network screening programs that operate in a GIS environment as well.

- **Computerized traffic count data that can be linked to the roadway inventory data (unless they are already contained in the same database).**

While the procedure can be operated without computerized count data, these data are almost always available in state DOT files that have a roadway inventory system. This is not always the case in urban systems. If available, the traffic count information can be used to further target the potential treatment sites in two ways. First, if the user only wishes to treat “high-traffic” sites, these data can be used to screen out “low-traffic” roadway segments prior to running the network screening program. Second, after the program has been run, the identified sites can be further screened by a given AADT level, or the sites can be sorted by AADT to assist the user in final site choice.

- **Unit cost for each treatment – both original implementation costs and annual maintenance costs**

The guides do not provide treatment costs due to differences between states and expected changes over time. The user will need to obtain information on such costs, either from vendors or from other jurisdictions that have used the treatment. The guides do provide “Information on Agencies or Organizations Currently Implementing This Strategy” that could be contacted for help under each of the treatment strategies. (The guides provide only early users, and surrounding jurisdictions may have implemented the treatment after the guide was completed.) Finally, the user will need an estimate of annual maintenance cost per mile for each treatment to be analyzed. Since maintenance includes “replacement after a crash” in some cases, the user may have to make estimates of the number of expected crashes per year and the amount of expected damage. Again, past users of the treatment can be of assistance here.

Procedure

The general procedure for choosing and targeting treatments with known effectiveness levels was provided in Section III above. The following text will expand that description while focusing on roadway-segment treatments designed to reduce lane-departure crashes. Because the user needs to understand the computerized procedure in order to input the correct values and tailor it for their own jurisdiction, the following provides the details of each step and sub-step.

1. **Specify the types/classes of roadway segments that are potential targets for the treatments.**

Because the choice of treatments, the treatment effectiveness, and the treatment cost per unit length may differ by roadway class/type, the user will need to specify the

types/classes of interest, such as two-lane rural road segments, multi-lane urban segments (perhaps by number of lanes), or rural interstate segments. If desired, these potential treatment segments could be further screened by AADT level (e.g., only “high-traffic” segments).

2. **Develop critical crash frequencies for each candidate treatment type (e.g., shoulder rumble strips) for each roadway class of interest. The “critical frequency” is the frequency of target crashes per mile that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor. In the example presented in the FHWA Sample Plan (24), the target B/C ratio used was 2.0 or greater.**

These “critical frequencies” must be developed for each candidate treatment being examined. If the same treatment is to be used on different roadway classes, it will be necessary to develop different critical frequencies for each treatment by roadway class if the treatment cost per unit length or treatment effectiveness varies by roadway class. The following formula is used:

$$CF = (\text{Ann. Cost})(\text{Target B/C})/(\text{Eff})(\text{Avg. Crash Cost})$$

Where:

- CF = Critical annual frequency of target crashes per unit length to consider the strategy to be cost effective.
- Ann. Cost = The annual cost of the improvement per unit length (e.g., per mile). If it is a construction improvement, it is the construction costs annualized over the expected life of the improvement. Note that if the treatment strategy is related to horizontal curves, then the cost required here is annual cost per unit length of curve (e.g., cost per mile of curve). If the treatment strategy is an education or enforcement treatment, the annual cost can be expressed on a per-unit-length basis if the treatment is to apply to a specific road segment or corridor, but may also cover an entire geographic area or road system to which the treatment is applied (e.g., if the treatment for run-off-road [ROR] crashes is jurisdiction-wide in nature).
- Target B/C = The B/C ratio defined by the user. It is usually between 1.0 and 2.0. In the FHWA Sample Plan (24), a value of 2.0 is used.
- Eff = The estimated effectiveness of the treatment strategy in reducing targeted crashes, expressed as a proportion (i.e., the CRF/100). This can be extracted from the FHWA Sample Plan (24) or from other sources.
- Avg. Crash Cost = The average economic cost per crash for the target crash type that will be affected by this treatment strategy. The following were extracted from Table 10 of *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22) and represent “comprehensive costs” in terms of 2001

Crash Type	Speed Limit Category	Comprehensive Cost/Crash*
Run-off-road crashes involving trees or other roadside objects	≤ 45 mph	\$67,000
	≥ 50 mph	\$107,000
Run-off-road crashes involving rollover as the primary impact type	≤ 45 mph	\$148,000
	≥ 50 mph	\$256,000
Head-on crashes	≤ 45 mph	\$60,000
	≥ 50 mph	\$613,000

* Costs in 2001 dollars

Exhibit IV-3. Crash cost by crash type and posted speed limit (22).

dollars. Comprehensive cost estimates include not only the monetary losses associated with medical care, other resources used, and lost work, but also non-monetary costs related to the reduction in the quality of life. The cost for each crash type is shown in Exhibit IV-3 for two ranges of speed limits – ≤ 45 mph and ≥ 50 mph. The former should be useful for urban crashes, and the latter for rural crashes.

3. Using the inventory file, stratify potentially treatable roadway segments by roadway class.

This stratification will result in a file of roadway segments sorted by route number for each of the roadway classes under consideration for treatment.

4. Link target crashes with roadway segments from the appropriate inventory data file, and then perform a computer screening of all segments on all routes that are potential treatment locations to determine which segments have crash frequencies that exceed the critical crash frequencies calculated above.

This will be done using the network screening program described above, and will be done independently for each of the roadway types under consideration. The network screening program will need to output the route number and beginning and ending milepost for each 1-mile segment that exceeds the critical crash frequency.

Note that if the treatment being considered is for horizontal curves (i.e., the user is searching for a “system” of horizontal curves to correct with, say, improved curve warnings), this step will require that the user’s roadway inventory system can identify the locations (routes and begin/end mileposts) for horizontal curves. If no curve inventory data are available (as will unfortunately be the case in most jurisdictions), then the user will have to use either Procedure 2A or 2B instead of this Procedure 1.

5. Correct the output for “treatment gaps” along the same route resulting from the network screening computer program.

This correction will require that the user manually examine each of the routes under consideration *within each roadway class* to detect possible “treatment gaps.”

Here the user will need to have the network screening program output the locations of the originally chosen treatment sites, enter these sites into some type of spreadsheet – one treatment segment per row, and then sort the rows by route and beginning milepost. By scanning down this listing for each route under consideration, the user can determine where the treatment gaps are located along each route – the missing segments in the listing. (Note that some of these missing segments would result from the fact that the roadway class changed within the route – e.g., from two-lane to four-lane. This determination will have to be made by comparison with information from the inventory file on the route in question.)

This correction for missing segments within the same roadway class will be needed because the network screening will only detect segments along a given route that exceed the critical crash-frequency threshold. In almost all cases, this will leave treatment gaps along a given route within the same roadway class – segments that do not meet the threshold. The user will need to determine whether or not these below-threshold segments should be treated. The logical first answer is “no,” since the segments did not meet the critical threshold. However, there may be times when all or some of these gaps should be included in the treatment program.

First, it may be illogical to leave isolated gaps untreated on a given route *if the gaps have basically the same roadway and roadside characteristics and AADT as the adjacent treatment sites*. The network screening program is examining a certain past period of crashes (e.g., the past 5 years). Crashes, particularly run-off-road and head-on crashes, are usually low-frequency events per mile, and the location of a crash in a given time period may be somewhat random. Thus, if a different 5 years of data were chosen, the chosen treatment locations might be slightly different. These factors will produce such treatment gaps. The user will have to make a judgment concerning whether to treat the gaps, and there are no precise guidelines for making this judgment. As general guidance, if a long section of a route has very few treatment gaps (i.e., most of the segments on the route are identified by the network screening program), and if the user knows that the gaps are very similar to the surrounding treatment sections in terms of AADT and roadway and roadside characteristics, then it would appear logical to treat those gaps also. If there are more “gaps” than “treatments” on a given route but the gaps and treatment segments are similar in terms of AADT and characteristics, then the user might either decide to just treat the originally chosen sections, or not to treat this route at all.

Second, there may also be situations where the logical length of the treatment may be greater than 1 mile. For

example, an agency may decide that shoulder rumble strips will be installed only with repaving, and that repaving is not done in roadway sections of less than X miles (with X greater than 1 mile). The first option here would be to change the length of the window in the network screening program to the minimum project length. However, since the window jumps from point to point along the route (e.g., from the beginning of mile 1 to the beginning of mile 2), the longer the window, the more likely that concentrations of target crashes that fall at the ends and beginnings of adjacent sections will be split into two parts, and thus each part will fall below the critical frequency. An alternative strategy is to use the 1-mile window as originally suggested, and to conduct the same examination as above if there are limited gaps among many treatment segments. The user could also examine the identified treatment sites to see where groups of 1-mile section equal or exceed the minimum project length, and then add additional adjacent segments if their AADT and characteristics are similar to the treatment group sites.

In summary, there are no hard-and-fast guidelines concerning how to correct for treatment gaps within the same roadway class. The decision will have to be made by the user, and the rules for making the decision may change from project to project and treatment to treatment. In general, it would appear that the best decision will be at least partially based on similar AADT and similar characteristics.

6. Estimate the expected crash/injury reductions on all the identified target locations.

The results of this step will be used in Step 9 below to determine whether or not the goal is reached. Here, for each treatment segment within a given roadway class identified at the end of Step 5 (i.e., after correction for treatment gaps), the user will need to determine the number of crashes and injuries that will be reduced by this treatment. This will be done by summing up all pertinent crashes or crash injuries for all segments to be treated, and then multiplying this total by the estimated effectiveness level for the treatment under consideration.

$$\text{CI reduction} = (\text{CI on segments}) \times \text{Eff}$$

Where:

CI = "Goal-related" crashes or crash injuries

Eff = treatment effectiveness

The definition of "goal-related" crashes or injuries is, as implied, based on the nature of the overall goal that has been established. If the goal is oriented to fatal and injury target crashes, then these will be accumulated. If the goal is total target crashes, then these will be accumulated.

The summing of goal-related crashes or injuries will be done by using a computer program to estimate the *annual*

number of such target crashes for all unit-length segments chosen for treatment. Users with full crash and inventory systems who have developed the network screening program will have the ability to link such goal-oriented target crashes to each segment chosen and to sum the total over all segments. The best *annual* estimate will be one based on more than 1 year of past data (usually 3 to 5 years) and then dividing by the number of years used.

7. Repeat the above steps for each potential treatment type.

The above steps are then repeated for the second and subsequent potential treatment types. In each case, critical crash frequencies are calculated for each roadway class, the network screening program is used to identify treatment segments, and corrections are made for treatment gaps. However, a final correction is needed for segments that have been identified for more than one treatment type, as detailed in the following step.

8. Correct for multiple treatments on the same segment.

Since many segment-based treatments affect the same type of target crash (e.g., shoulder rumble strips and shoulder widening both can affect run-off-road crashes), the above procedure will identify the same segment as a potential for treatment in many cases. In these cases, the user has two options: (1) choose only one treatment for each of these segments, or (2) choose to implement two or more treatments on the same segment.

Under Option 1, the user would compare the lists of potential treatment segments (after correction for gaps) from Step 5 above, and would decide which treatment to place on each segment where two or more treatments could be implemented. That segment (and its related goal-oriented crashes or injuries) is then removed from the list of segments for all other treatments.

Under Option 2, the user must develop some measure of *combined effectiveness* for the two or more treatments to be applied to a given segment. Since the combined effectiveness of two treatment strategies on the same location will not be the simple sum of the two effectiveness levels, some correction must be applied for the second and all subsequent treatments that are applied to the same segment. Unfortunately, there is little knowledge available about the combined effects of multiple treatments. Until that knowledge is developed, it is suggested that the effectiveness level (Eff) of the second treatment applied to a given section be reduced by 50 percent, and the effectiveness of the third treatment and subsequent treatments applied to the same segment be reduced to 25 percent of their expected effectiveness when used alone. For example, assume that the first treatment for a given segment has an effectiveness level of 0.2, the second has an effectiveness level of 0.15, and the third has an effectiveness level of 0.10, and the fourth and subsequent treatments add no addi-

tional effectiveness. The estimated *combined effectiveness* of the three treatments applied to the same segment would be $0.2 + 0.15(.5) + 0.1(.25) = 0.3$. Again, this is only an estimate of the true combined effectiveness at best.

9. **Sum all expected crash injury reductions for all chosen treatment types and chosen target locations and compare that total to the established goal.**
10. **Add new treatments, new targets or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.**

Again, the example draft plan presented at the FHWA web site (http://safety.fhwa.dot.gov/roadway_dept/docs/lanedeparture/index.htm) provides additional discussion of this option.

Procedure 2A – Choosing Roadway-Based Treatments and Target Populations When Treatment Effectiveness Is Known and Mileposted Crash Data Are Available, but Detailed Inventory Data Are Not Available

The following text identifies the data needed for conducting Procedure 2A, followed by the individual steps in the procedure. Note again that this procedure requires “mileposted” crash data. If mileposted crash data are not available, refer to Procedure 2B or 3.

Data Needs

The data needed for Procedure 2A are virtually the same as for Procedure 1, except that neither detailed roadway inventory data nor linkable traffic counts are required. (Note that this procedure operates more accurately if the user can not only sort crashes by route and milepost, but also has some inventory information or knowledge that will allow him/her to determine which route-milepost ranges are rural vs. urban, the number of lanes, and whether the roadway is divided or undivided. This will be covered in the steps of the procedure below.) The following are the specific data needed to use Procedure 2A when choosing and targeting roadway-based treatments. A description of each item is provided under Procedure 1 above and will not be repeated here.

- **A specified effectiveness level (CRF or AMF) for each treatment to be examined.**
- **A computerized crash data file that includes sufficient crash details to isolate target crash types (run-off-road, head-on crashes, run-off-road on curves, etc.) and potential target populations that will be affected by each treatment, and which is “mileposted” such that the location of each crash is included.**

As noted in the procedure below, it is also advantageous if the crash data contains information that can be used to define “roadway class or type” – e.g., information on number of lanes, route type, divided vs. undivided, or any other roadway class characteristics. Since no detailed roadway inventory exists in this situation, these data will help in defining potential target locations within different roadway classes or types.

- **A network screening computer program which can read an input file composed of target crash records sorted by route and milepost, and can count the number of target crashes within a given specified length (e.g., 1 mile) that have occurred in the past 3 to 5 years.**

Note that this program is different from the network screening program in Procedure 1, because it is applied to mileposted crash data for which no roadway-segment-based inventory data is available. If such a program does not currently exist in a jurisdiction, it can be developed by a knowledgeable computer analyst familiar with crash data files.

In general, the program will need to accumulate a count each time a target crash is found, the milepost for each crash reached, and the distance from the last crash (e.g., the difference between the two mileposts) for each adjacent pair of crashes. The program will then accumulate the target crash count and cumulative distance until the distance is equal to or greater than the specified window length (e.g., 1 mile). If the accumulated distance is equal to 1 mile, which is unlikely, the program will output the number of target crashes and the milepost of the first and last crashes encountered in that length and the distance between the first and last crash, in this case, 1.0 mile. If the accumulated distance is greater than 1 mile (i.e., the 1-mile limit fell between two adjacent crashes), the counter should subtract the last crash added (i.e., the one outside the 1-mile limit), and should again output the number of target crashes in the window, the milepost for the first crash and last crash remaining in the window, and the distance between the first and last crash, which may be less than 1 mile in this case. A new window would then begin with the current crash being considered (i.e., it would be counted and its milepost recorded) and the process would proceed until the route ends. Each time the specified window length is reached and output is produced, the count will be compared to the critical frequency calculated in Step 2, and will only be retained in the final output file if the count exceeds the critical frequency.

- **Unit cost for each treatment – both original implementation costs and annual maintenance costs**

Procedure

The general procedure for choosing and targeting treatments with known effectiveness levels was provided in Section

III above. The following text will expand that description while focusing on roadway-segment treatments – those designed to reduce lane departure crashes. Because the user needs to understand the computerized procedure in order to input the correct values and tailor it for their own jurisdiction, the following provides the details of each step and sub-step.

1. Develop critical crash frequencies for *each* candidate treatment type and roadway class of interest. The “critical frequency” is the frequency of target crashes per mile that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor.

The same formula and information presented under Step 2 of Procedure 1 above will be used here.

However, if the user is attempting to target horizontal curve treatments without an inventory file that defines the beginning and ending mileposts for each curve, a different “annual cost per unit length” will have to be used. Here, the user will have to estimate the average length of curve in his jurisdiction, and will then estimate the annual treatment cost of that length. It is suggested that if there are different types of terrain in a jurisdiction (e.g., mountainous vs. level terrain) that would significantly affect the average curve length, the user would estimate an average length and cost for curves in each terrain type.

2. Sort crashes by route and milepost in ascending order, and then perform a computer screening of all segments on all routes that are potential treatment locations to determine which segments have target crash frequencies that exceed the critical crash frequencies calculated in Step 2.

This screening will be done using the network screening program described above. If crash-based information is available on roadway class or type (e.g., number of lanes, route type, divided vs. undivided), the target crash definitions should include these variables (e.g., run-off-road crashes on two-lane roads and head-on crashes on divided roads). The screening will then be done independently for each of the roadway types (as defined by crash variables) under consideration. As noted above under “Data Needs,” the network screening program will need to output the total number of target crashes in the specified length, and the route number and mileposts for the first and last crash falling in each “window” for which the total number of target crashes exceeds the critical crash frequency.

Note that if the treatment being considered is for horizontal curves (for example, the user is searching for a “system” of horizontal curves to correct with improved curve warnings), the window length should be defined as the expected maximum (not average) curve length in a given terrain. The use of target crashes that are only curve-

related will lead to acceptable results in this screening effort, even for shorter than maximum-length curves.

3. Correct the output for “treatment gaps” along the same route resulting from the network screening computer program.

If this step is done, the user will follow a “manual review” procedure similar to that described under Step 5 of Procedure 1. The rationale for this step is provided there. As before, this correction will require that the user manually examine each of the routes under consideration *within each roadway class* to detect possible treatment gaps. Here, the user will take the output of the network screening program (i.e., the route and locations of the originally chosen treatment sites), enter these sites into some type of spreadsheet (one treatment window per row), and then sort the rows by route and beginning milepost. By scanning down this listing for each route under consideration, the user can determine where the treatment gaps are located along each route – the missing segments in the listing. (Note that some of these missing segments would result from the fact that the roadway class changed within the route – e.g., from two-lane to four-lane. This determination will have to be made based on the user’s knowledge of where the roadway class changes along a given route.)

However, because there is no inventory data available under this procedure, the user will not have inventory data that provides detailed information on the AADT levels and roadway characteristics of the treatment gaps adjacent to the identified treatment windows. This determination will have to be based on the user’s knowledge of the route in question. If such knowledge is available, the user will identify additional, similar treatment segments for each treatment/road class combination.

4. Estimate the expected crash injury reductions on all the identified target locations.

Just as in Procedure 1, the results of this step will be used in Step 8 below in determining whether or not the goal is reached. Here, for each treatment window identified at the end of Step 3 (i.e., after correction for treatment gaps), the user will need to determine the number of crashes and injuries that will be reduced by this treatment. This will be done by summing up all pertinent crashes or crash injuries for all windows to be treated, and then multiplying this total by the estimated effectiveness level for the treatment under consideration.

$$\text{CI reduction} = (\text{CI on segments}) \times \text{Eff}$$

Where:

$$\begin{aligned} \text{CI} &= \text{Goal-related crashes or crash injuries} \\ \text{Eff} &= \text{treatment effectiveness} \end{aligned}$$

Just as in Procedure 1, the definition of “goal-related” crashes or injuries is, as implied, based on the nature of the

overall goal that has been established. If the goal is oriented to fatal and injury target crashes, then these will be accumulated. If the goal is total target crashes, then these will be accumulated.

The summing of goal-related crashes or injuries will be done by estimating the *annual* number of such target crashes for all segments (windows) chosen for treatment (after correction for treatment gaps). While it was relatively simple to add in the additional crashes from the “gap-filling” segments with a full inventory file in Procedure 1, this is not as simple here, since the network screening program used in this procedure does not output segments other than those meeting the crash frequency threshold. It is suggested that in this case, the annual number of goal-oriented crashes from the identified treatment segments be used to estimate the additional number that would occur on the added treatment gap segments. As noted above, the network screening program can be developed to output the total number of target crashes in each window chosen for treatment and the (approximate) length of each chosen treatment window. The estimate of annual target crashes (or injuries) per mile in these chosen windows is:

$$CI = \frac{\text{Annual Target Crashes}}{\text{Sum of window lengths}}$$

Where:

$$\text{Annual Target Crashes} = \frac{\text{Sum of all target crashes in chosen windows}}{\text{Number of years of crash data used in the sample}}$$

The user can also manually calculate the number of miles of treatment gaps that he or she adds for treatment in Step 3. The number of goal-related target crashes for these segments can be estimated by multiplying the total length of these new segments by CI in the above formula.

5. Repeat the above steps for each potential treatment type.

As in Procedure 1, the above steps are then repeated for the second and subsequent potential treatment types. In each case, critical crash frequencies are calculated for each roadway class, the network screening is used to identify treatment segments, and corrections are made for treatment gaps. However, a final correction is needed for segments that have been identified for more than one treatment type, as detailed in the following step.

6. Correct for multiple treatments on the same segment.

The user will again need to correct for multiple treatments on the same segment. The same rationale and procedure followed in Procedure 1 will be followed here. (See Step 8 of Procedure 1).

7. Sum all expected crash injury reductions for all chosen treatment types and chosen target locations and compare that total to the established goal.

8. Add new treatments, new targets or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.

Again, the example draft plan presented at the FHWA web site (http://safety.fhwa.dot.gov/roadway_dept/docs/lanedeparture/index.htm) provides additional discussion of this option.

Procedure 2B – Choosing Roadway-Based Treatments and Target Populations When Treatment Effectiveness Is Known and Neither Mileposted Crash Data nor Detailed Inventory Data Are Available

The following text identifies the data needed for conducting Procedure 2B, followed by the individual steps in the procedure. Note again that since no mileposted crash data exist, this procedure will only allow the user to identify entire routes within a given jurisdiction as potential treatment routes, but not segments of routes. It will also not allow the user to target the treatments to specific locations along the route.

Data Needs

The data needed for Procedure 2B are less than required in either of the previous two procedures. Major differences include the fact that no inventory or traffic data are required, and that the crashes do not have to be “mileposted” to a specific location on a specific route. However, each crash record must contain information on the county or local jurisdiction and the name of the route/street where the crash occurred.

• **A specified effectiveness level (CRF or AMF) for each treatment to be examined.**

See discussion of this issue under Procedure 1.

• **A computerized crash data file which includes sufficient crash details to isolate target crash types that will be affected by each treatment (run-off-road, head-on crashes and run-off-road on curves), and potential target populations. Each crash record must contain a county or jurisdiction name where the crash occurred, and the name of the route or road where the crash occurred.**

• **“Route length” information that will provide the length in miles of each road or route within a county or local jurisdiction that is a potential target for any treatment, or at least the approximate length.**

If this information is not available in the user’s files, it may be available from other sources including road maintenance records, and can be scaled from maps if necessary.

- **Unit cost for each treatment – both original implementation costs and annual maintenance costs**

See discussion of this issue under Procedure 1.

Procedure

The following steps are those that would be followed for choosing among roadway-segment treatments with known effectiveness and targeting these treatments to entire routes in a jurisdiction.

- 1. Develop critical crash frequencies for each candidate treatment type and roadway class of interest. The “critical frequency” is the annual frequency of target crashes per mile that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor.**

The same formula and information presented above under Step 2 of Procedure 1 will be used here.

- 2. Link target crashes to each route in each jurisdiction (but not to a specific point on the route).**

This will require computer sorting of crashes by each named route. Some manual effort will be required to correct misspelled names and to group routes or streets that have multiple names. The output of this program will be a listing of target crashes sorted by route name. Note that multiple years of crashes can be used, and indeed the procedure will be more accurate if more than 1 year’s crash data (e.g., 3 to 5 years) are used. If multiple years are used, there may be situations where a route was renamed during the period. If so, both crashes with the original and new name should be accumulated under one route name.

- 3. Develop a spreadsheet that contains the count of target crashes for each route (one route per row), along with the mileage for that route.**

It may be possible for the computer program used to sort the crashes in Step 2 to output this count for each route. If not, the counts can be made manually. The final output of this step is a spreadsheet containing a total count of target crashes and the length in miles for each route under consideration.

- 4. Calculate the annual crash frequencies per mile for each potential route.**

If a spreadsheet is used, this is a simple step in which the crash count is divided by the route length times the number of years of crashes used.

- 5. Identify routes to be treated by determining which have calculated annual frequencies per mile that exceed the developed critical crash frequencies per mile.**

This is a comparison of the output of Step 4 with the “critical frequencies” defined in Step 1.

- 6. Estimate the expected crash injury reductions on all the identified target routes.**

Just as in Procedure 1, the results of this step will be used in Step 9 below in determining whether or not the goal for the jurisdiction is reached. Here, for each treatment route identified at the end of Step 5, the user will need to determine the annual number of crashes and injuries that will be reduced by this treatment. This will be done by summing up all pertinent crashes or crash injuries for all routes to be treated, and then multiplying this annual total by the estimated effectiveness level for the treatment under consideration.

$$\text{CI reduction} = (\text{CI}) \times \text{Eff}$$

Where:

CI = Annual “goal-related” crashes or crash injuries on the routes chosen

Eff = treatment effectiveness

Just as in Procedure 1, the definition of goal-related crashes or injuries is, as implied, based on the nature of the overall goal that has been established. If the goal is oriented to “fatal and injury” target crashes, then these will be accumulated. If the goal is total target crashes, then these will be accumulated.

The annual estimate of potentially treatable crashes or injuries can be extracted from the spreadsheet output in Step 3. For the routes chosen, divide the total crashes on each route by the number of years of data, and then sum across all chosen routes.

- 7. Repeat the above steps for each potential treatment type.**

As in Procedures 1 and 2A, the above steps are then repeated for the second and subsequent potential treatment types.

- 8. Correct for multiple treatments on the same route.**

The user will again need to correct for multiple treatments on the same route. In general, the same rationale and procedure followed in Procedure 1 will be followed here. (See Step 8 of Procedure 1.) However, in this case, corrections are made on a route-basis rather than a route-segment basis (i.e., either one treatment is specified for a given route and that route is removed from other treatment groups, or a correction in effectiveness is made for the second and subsequent treatment on the same route).

- 9. Sum all expected crash injury reductions for all chosen treatment types and chosen target routes and compare that total to the established goal.**

- 10. Add new treatments, new targets, or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.**

Again, the FHWA Sample Plan for lane departures (24) provides additional discussion of this option.

Procedure 3 – Choosing Roadway Treatments and Target Locations When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Not Known

As noted in the preceding section, the three procedures described above allow the user to choose roadway-based treatments and treatment targets for a given problem while ensuring that the economic value of the crash/injury reductions will exceed the cost of implementing the program. All three procedures require that the treatments being examined each have a known level of effectiveness expressed in terms of an expected crash/injury reduction – a defined CRF or AMF. Unfortunately, many of the roadway-oriented treatments and many of the non-roadway-oriented treatments (i.e., driver- and vehicle-oriented strategies) in the *NCHRP Report 500* guide series do not have defined levels of effectiveness. Thus, economic analyses like those that are the basis for Procedures 1, 2A and 2B are not possible for these treatments. This Procedure 3 is intended to help the user make an educated choice of which treatments will be most effective in their jurisdiction, and to help the user develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide (e.g., where specific routes or route segments are to be targeted). In general, the choice between alternative roadway-segment treatments will be based on the specific nature of the lane-departure crash problem, and the choice of target locations will be based on the determination of where the crash/injury problem of interest is found. A discussion of this more general procedure is included under the Procedure 3 subheading in Section III, and the reader should review that section.

Procedure 3 is intended for application to tried or experimental treatments for which the analyst has decided that there is likely to be a crash/injury reduction benefit, but for which the analyst does not have sufficient evidence to estimate a specific CRF or AMF value. In a case for which the analyst is able to estimate a specific CRF or AMF value, even if the estimate is only an approximation, it is recommended that Procedure 4 be used rather than Procedure 3.

Data Needs

The only required data for Procedure 3 are crash data that will allow the user to specify target crashes for each roadway-segment treatment under consideration (see Exhibit IV-1 in the “crash data” description under Procedure 1). However, in order to target the treatment to specific routes or route sections, the crash data must be “mileposted” or at least contain information on the county and route. The availability of roadway inventory data that can be linked to the crash data will improve both the treatment choice and the treatment targeting.

Procedure

As described in Section III, Procedure 3 has two basic steps:

- First, choose the best treatments (i.e., the roadway-segment treatments most likely to be applicable in a given jurisdiction) from among the set of all roadway-segment treatments presented in the applicable *NCHRP Report 500* guides.
- Second, choose the routes or route segments to which the selected treatments should be applied.

As described earlier in more detail, the choice of the best treatments from the listing of many potential roadway-segment treatments can be based on the following factors:

- a) The potential treatment judged to be the most effective, given that effectiveness is unknown
- b) The relative magnitude of the crash types and severity levels that the treatment will affect
- c) The cost of the potential treatments per mile
- d) Other technical or policy considerations

These factors must be combined in some fashion to decide which treatment to choose. While there are multiple ways of making this choice, the following represents one such procedure.

1. Prioritize the specific roadway-segment problem(s) to be addressed.

This is related to Factor b in the above list. Here, the issue is whether to treat run-off-road, head-on, tree-related or other roadway segment crash types, and on which roadway systems (e.g., two-lane rural roads, four-lane divided roads, freeways). This prioritization will be based on the frequency and severity of the specific types of lane-departure crashes occurring in a user’s jurisdiction. Target crash types for each roadway-segment treatment were defined under Procedure 1. For each crash type, the user could begin the process by analyzing 3 to 5 years of crash data to determine the frequency of each type. However, since some crash types are more severe than others (e.g., head-on crashes are more severe than run-off-road crashes), total crash frequency alone does not provide the complete answer. While an alternative is to restrict the analysis to only fatal and serious-injury crashes, this will severely limit the crash sample, and will also omit a large component of the crash problem – non-serious injury and no-injury crashes. A better solution is to weight each crash by an economic cost based on its type and severity, and then accumulate the total crash cost within each target crash type. Information on economic cost per

severity level within 22 different crash types including different types of run-off-road and head-on crashes can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). This analysis of total crash cost will provide the user with overall information on which lane-departure crash type is most important.

The user may further refine this analysis by examining crash frequency or total crash cost within roadway classes. If the crash data are mileposted and linkable inventory data are available, details of roadway types can be linked to each crash record (e.g., number of lanes by divided/undivided). If inventory data are not available, there may be variables on the crash record itself which can be used in a less detailed analysis (e.g., number of lanes, rural vs. urban, route type).

This analysis will then produce a listing of potentially treatable roadway-segment crash types (perhaps by road class) that can be sorted by crash frequency or total crash cost, thus providing a ranked listing. For the higher-ranked crash types, the user can then conduct additional analyses to determine more of the specifics of the crash circumstances (e.g., nighttime vs. daytime distributions of total crash cost). These additional “drill-down” analyses should be designed to provide additional information that could lead to the choice of one treatment over another (e.g., raised pavement markers are primarily effective at night or in rainy weather).

2. Identify possible treatments for use for each high-priority crash type.

The user will then review the pertinent *NCHRP Report 500* guides and list treatments that would be most appropriate for each of the high-priority crash types identified in the above step. The choice should be limited to those treatment strategies that are classified as *tried* in the guides. (*Proven* treatments have known effectiveness levels and can be analyzed in one of the three procedures above.) If not already conducted in the “drill-down” analysis in the preceding step, more specific information on the total crash cost related to each potential treatment strategy could be developed by specifying the crash types that are most likely to be affected by each strategy (e.g., nighttime run-off-road-right crashes for raised pavement markers), producing crash frequencies for each specified crash type, and multiplying the frequencies by cost per crash. For some strategies, the *NCHRP Report 500* guide presents information concerning which crash types are most likely affected by that treatment strategy.

3. Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible.

However, for a given set of possible treatments for a particular crash-type/road-class combination, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective. For example, for run-off-road crashes on two-lane rural roads, one would assume that rumble strips on two-lane rural roads would be more effective than wider edge lines or raised delineators. At times, this will clearly be a very difficult judgment to make.

4. Choose “best” treatment(s) by considering estimated effectiveness, cost per mile and other technical and policy considerations.

The user will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost per mile of the treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The user will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined. The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected (e.g., raised delineators will affect run-off-road crashes at night).

The user should be able to work backwards using the number of crashes likely to be affected by a given treatment and the cost of applying that treatment to a given population or location (see items b and c described at the beginning of this procedure) to determine the treatment effectiveness needed to maintain a cost-benefit ratio greater than or equal to one.

$$\frac{B}{C_t} \geq 1.0$$

Where:

- B = economic benefit of applying a selected treatment to a given location or population
- C_t = the cost of applying that treatment to the selected location or population

$$B = N * C_c * \text{Eff}$$

Where:

- N = Number of target crashes for the subpopulation or location where the treatment is to be applied
- C_c = average economic cost per target crash
- Eff = treatment effectiveness, or the percent reduction in target crashes

Since different severity levels have different crash costs, the value used for C_c can be a weighted average of the crash costs associated with the crash types likely to be affected. Solving for the treatment effectiveness, the equation reads:

$$Eff = \frac{C_t}{N * C_c}$$

The analyst can then determine whether the calculated treatment effectiveness required to reach the breakeven point is likely to be achievable.

5. Target the chosen treatments to the roadway segments where the problem is found.

Since this procedure concerns treatment strategies without known effectiveness, it will not be possible to target the treatments based on any type of economic analysis such as those in Procedures 1, 2A and 2B. Instead, the treatment will be targeted to roadway segments or routes showing the highest total crash cost or frequency, coupled with user judgment concerning the nature of the roadway and roadside at potential target locations and technical and political issues. If the crash data are mileposted, the user could (1) link crashes to routes and search for the locations of “clusters” of target crashes for possible treatment, or (2) use a network screening program similar to that described under Procedure 2A to identify 1-mile sections with the highest crash frequency or crash burden (by weighting each crash by its economic cost and summing total crash cost within each window). The windows identified by the network screening program could then be ranked by frequency or total crash cost to identify priority locations. The user would then correct for “treatment gaps” using the same logic provided in Procedure 2A.

If the crashes are not mileposted, but there is information available on jurisdiction and route, the user could link crashes to routes within the jurisdiction and calculate the total crash cost or number of target crashes per mile by dividing the sum of the crash cost or the sum of target crashes on that route by route length. The user can then rank the potential routes for treatment based on this rate per mile, and choose the routes to be treated based on the highest rankings plus other technical and policy factors.

6. Decide what to do with multiple treatments on the same segments/routes.

The above steps could possibly produce roadway locations or routes within a jurisdiction that could be treated with multiple treatments. Unlike the earlier procedures where it was possible to estimate combined effectiveness for multiple treatments on the same segments or routes, since treatment effectiveness is not known here, the user will have to use other factors in the final treatment choice for these locations. If the potential treatment strategies still under con-

sideration are characterized by different target crash types (e.g., tree-related crashes vs. total run-off-road crashes), and if the crash data are mileposted or include route information, the user could use the outputs of Step 5 above in making the targeting decision. Step 5 produced total crash cost or crash frequency of each potential target section or route. For each segment or route where multiple treatments are possible, the user could compare the crash frequency or total crash cost for each of the different possible strategies. Total crash cost will be a much superior criterion if the target crash types being compared differ with respect to crash severity. If total crash cost or frequency for one treatment strategy clearly exceeds total crash cost or frequency for the other, the first would be a logical treatment choice. If the total crash cost or frequency for the different strategies is essentially the same, the user will need to make the decision based on “best judgment” (e.g., which treatment is being used on adjacent roadway segments).

7. Add new treatments, new targets, or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the available funding is used.

In Procedures 1, 2A and 2B, an iterative process is used until sufficient treatment types and locations are selected such that the established crash reduction goal can be reached. In Procedure 3, without effectiveness measures for the treatments, it is not possible to verify whether or not a specific set of treatment types and treatments will meet the established goal. Therefore, the best that can be done is to proceed in selecting treatments types and treatments until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined by evaluations conducted after its implementation.

Procedure 4 – Choosing Treatments and Target Populations in Emphasis Areas for which Some Candidate Treatments Have Known Effectiveness Estimates and Other Treatments Do Not

In many situations, users considering a safety improvement program in a particular emphasis area will need to consider both treatments that have known effectiveness measures and treatments that do not. In this situation, it is recommended that the user give priority to treatments that have known effectiveness measures (*proven* treatments). Treatments that have been used extensively but for which effectiveness measures are not available (*tried* treatments) should then be considered. *Experimental* treatments may have a modest role

in a safety improvement program, particularly if the program is structured to evaluate the effectiveness of the experimental procedure.

The recommended planning approach in this situation is a hybrid of Procedures 1, 2A, 2B, and 3 described above.

Procedure

1. Determine if *proven* treatments can meet the established goal.

Consider treatments with known effectiveness measures (*proven* treatments) using either Procedure 1, 2A, or 2B as appropriate, depending on the types of data available. Determine the crash/injury reduction achieved and compare it to the established crash/injury reduction goal. If the goal has not yet been met, proceed to Step 2.

2. Consider *tried* treatments to supplement the *proven* ones.

This step would involve consideration of treatments without known effectiveness that have been used extensively by highway or driver/vehicle agencies (*tried* treatments). If it is possible to *estimate* the effectiveness of these treatments based on imperfect information, then proceed to Step 3; otherwise, proceed to Step 4.

3. Estimate the effectiveness of *tried* treatments if possible, and analyze them using the appropriate procedure above.

This step involves attempting to estimate the effectiveness of treatments without known CRFs or AMFs. ***Note that estimating treatment effectiveness is very difficult and can lead to poor treatment choices unless the esti-***

mates are realistic. This estimation was not suggested in Procedure 3 for this reason. It is only suggested at this point since the user has already considered all proven treatments before reaching this stage. It is suggested that the following guidelines be used in making such estimates:

- a) In general, be as conservative as possible. Very few treatments can be expected to affect crash frequency by more than 15 to 25 percent.
- b) When possible, formulate an effectiveness estimate that is applicable to particular target crash types only, not to total crashes.
- c) Base estimates for *tried* treatments on CRFs for similar treatments if they exist. For example, a CRF exists for shoulder rumble strips. Other treatments that also try to keep the driver from leaving the roadway by alerting him (e.g., enhanced edgeline marking, raised profile marking) but do not give the same level of warning would be expected to have somewhat similar, but lower, CRFs.

Once effectiveness is estimated, apply Procedure 1, 2A or 2B as appropriate, depending on the types of data available. Determine the crash/injury reduction achieved in Steps 1 and 3 combined and compare it to the established crash/injury reduction goal. If the goal has not yet been met, proceed to Step 4.

4. Consider additional *tried* treatments.

For treatments for which reliable effectiveness measures cannot be estimated in Step 3, apply Procedure 3 to select additional treatment types and target locations until all available funds have been budgeted.

SECTION V

Roadway Junctions

Planning Programs Related to Reducing Crashes at Signalized and Unsignalized Intersections

This section of the guide provides the details of the four levels of treatment choice and targeting procedures described above in the Stage 3 discussion in Section III, but it is oriented to those issues/emphasis areas that are specifically related to at-grade intersections – angle crashes, turning crashes, sideswipe crashes, rear-end crashes, head-on crashes and run-off-road crashes. In most instances, a given procedure will follow the same basic steps, regardless of the crash type being addressed. Where the procedure differs between crash types, this will be noted. In addition, the data needed for the different intersection-oriented crash types will differ and will be specified. The user is *strongly urged* to carefully review the material in each of the pertinent guides before beginning this planning process. These intersection-oriented guides are found within *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. The specific volumes pertinent to this section are:

- *Volume 5: A Guide for Addressing Unsignalized Intersection Collisions* (5)
- *Volume 12: A Guide for Reducing Collisions at Signalized Intersections* (12)

A link to these downloadable guides can be found at <http://safety.transportation.org/guides.aspx>.

Possible Program Types – Spot versus System Programs

Before moving to the specific treatment choice/targeting procedures for these emphasis areas, it is noted that states who were early participants in the AASHTO safety planning process for intersection programs started from two different

perspectives, and the perspective chosen determines the choice and targeting of treatments. Some states chose to try to expand their current “high-crash location (HCL)” program to include more locations to meet their overall goal. Others chose to orient their planning methods to the identification and treatment of “systems” of intersections, not just those locations that fell under the HCL program. Indeed, guidance provided in each of the guides, in companion training courses, and in the FHWA Sample Plan for intersections (25) is that system-based programs will need to be included. If the jurisdiction is really attempting to reach a goal which represents a significant change from the current situation – a stretch goal – it is very unlikely that expansion of the HCL program will suffice. While such an expansion is clearly a component of a stretch-goal plan, large-scale treatment of systems and corridors will also likely be necessary.

Indeed, a jurisdiction can use the following procedure to determine approximately how much the existing HCL program will have to be expanded, which will provide some guidance on whether system programs should also be considered.

1. Examine the most recent listing of HCL projects that were chosen for treatment in your jurisdiction and identify those that were related to intersection crashes.
2. Add the numbers of before-treatment crashes, injuries, and fatalities from each intersection and divide by the number of years of before data to produce a total number of potentially treatable intersection crashes and crash injuries per year.
3. Multiply these totals by 20 percent to get the number of intersection crashes, injuries and fatalities that are expected to be reduced per year by your current program. (This assumes an average Crash Reduction Factor of 20 percent for all intersection strategies. This is probably too high, but in the ballpark of reality, and good enough for this exercise.)

4. Compare these numbers of crashes and injuries reduced and lives saved to your statewide intersection goal and calculate the proportion of your total goal that this represents.
5. To calculate approximately how much you will have to expand the intersection part of your HCL program to meet your goal, divide 1.0 by the proportion from the previous step. For example, if the fatality and injury savings from your current program is 20 percent of your goal, then you will have to identify and treat five times as many intersections in the future (i.e., $1.0 / 0.20 = 5$).

The user will then need to make the determination of whether enough sites with high numbers of intersection crashes can be identified. Usually the HCL program has identified more intersections that can be treated. This full “census” of potential HCL sites can be examined to determine whether enough sites with high numbers of intersection crashes are available. In most cases, if a stretch goal has been set, the answer will be “no.” In that case, the user should consider adding system improvements to the plan.

While all states and some local jurisdictions have procedures in place to identify and treat high-crash locations, it is noted that an improved methodology is currently being developed by FHWA in the *SafetyAnalyst* program described in the preceding section (also see <http://www.safetyanalyst.org>). This set of the software tools for safety management of specific highway sites includes a series of procedures that will allow the user to identify high-crash locations or sites with potential for safety improvement, diagnose potential treatment sites to identify correctable crash patterns, conduct an economic analysis to assure a minimum B/C ratio, and develop a combined treatment program which maximizes the benefits that can be gained from a given total treatment budget. The network-screening tools within *SafetyAnalyst* provide a good approach for applying Procedure 1.

If preliminary analysis indicates that even an enhanced and expanded high-crash location program will not meet the goal, then the users will need to add systems-based treatment programs to the effort. Indeed, the four procedures described earlier and detailed below are developed to assist the user in identifying intersections to treat and to help define

the treatments that should be applied to them. Again, the choice between which procedure is appropriate is defined by three factors – whether or not treatment effectiveness is known, whether the jurisdiction has inventory data that can be linked to their crash data, and whether the crashes are “mileposted” or not. Exhibit V-1 will guide the user to the appropriate procedure.

Procedure 1 – Choosing Intersection Treatments and Target Populations When Treatment Effectiveness Is Known, and Both Crash and Non-Crash Data Are Available

The following text identifies the data needed for conducting Procedure 1, followed by the individual steps in the procedure.

Data Needs

The following are the specific data needed to use Procedure 1 when choosing and targeting intersection treatments.

- **A specified effectiveness level (CRF or AMF) for each treatment to be examined**

The “Treatment Effectiveness” section under each treatment in each *NCHRP Report 500* guide provides a description of what is known about CRFs. It is important that the user review the material in the guides for a given treatment. Valuable information about the stability of the CRF, cautions about the use of the treatment and other essential information is included there, but will not be repeated here.

For a significant proportion of the treatment strategies defined in the six guides covered in this section, a specific AMF is not presented. Since the preparation of some of the earlier guides, additional information on treatment CRFs has been developed in both NCHRP Project 17-25, and in preliminary work for the *Highway Safety Manual*. The AMFs from NCHRP Project 17-25 have been published in *NCHRP Research Results Digest 299 (27)*. The AMFs developed in NCHRP Project 17-27 will be incorporated in the forthcoming *Highway Safety Manual*.

Treatment Effectiveness Known?	Inventory Data Available and Linkable to Crashes?		
	Yes	No	
	Mileposted Crashes	Mileposted Crashes	Unmileposted Crashes
Yes	Procedure 1	Procedure 2A	Procedure 2B
No	Procedure 3	Procedure 3	Procedure 3
Some known, some unknown	Procedure 4	Procedure 4	Procedure 4

Exhibit V-1. Guide to choice of procedures based on knowledge of treatment effectiveness and crash data quality.

- **A computerized crash data file which includes sufficient crash details to isolate target crash types (angle, sideswipe, turning, rear-end, and head-on crashes), and potential target populations that will be affected by each treatment**

Here, the user will need to examine the data formats for variables in their crash file to identify variables and codes within variables that can be used in determining whether or not each crash in the file is a “target crash.” Crash databases often categorize crash data for a given crash into up to three subfiles – general accident/crash variables, variables for each vehicle in the crash, and variables for each occupant in the crash. In general, the analyst will need to first screen to determine if the crash is an intersection or non-intersection crash, and then examine the different crash types within those that are intersection-related. Since “intersection crashes” can include both those in the intersection itself and on the intersection approaches (e.g., rear-end crashes), the analyst will usually have to include those crashes that are coded as both “intersection” and “intersection-related.” The variables needed to determine whether a crash is a “target crash” or not, for intersection crashes, can usually be found in one of the first two subfiles – crash or vehicle data. Crash files differ from jurisdiction to jurisdiction. While certainly not always the case, the following variables (or similar variables) listed in Exhibit V-2 will be used in this determination.

- **Computerized intersection inventory data that can be linked to the crash data by location of the crash**

A few state DOTs have computerized intersection inventory files for the full state highway system that can be linked to crashes, since both the intersections in the inventory file and the crashes are identified by “addresses” – usually route and milepost or GIS coordinates. Most local jurisdictions (i.e., counties, towns, townships, and cities) do not have such an inventory system. For jurisdictions that do not have an inventory file, Procedures 2A and 2B below can be used.

A recommended set of data elements for inclusion in intersection inventories is under development by FHWA

for the Minimum Inventory of Roadway Elements (MIRE).

- **A computer program that will examine each intersection and calculate the number of target crashes (e.g., angle, turning, sideswipe, run-off-road crashes, rear-end, and head-on) that have occurred at each intersection in the past 3 to 5 years.**

This program exists in some jurisdictions, but may not exist in others. If not, a knowledgeable computer analyst can build one. The program will require that counts of target crashes can be made and “attached to” each intersection within an agency’s jurisdiction (or this could be done for all of the intersections on a particular route). The program must then be able to examine each intersection and record the total number of crashes in an output file, along with the route number and an intersection identifier. The process would be repeated for all routes in the system.

- **Computerized traffic count data that can be linked to the intersection inventory data (unless it is contained in that database).**

While the procedure can be operated without computerized count data, these data are often available in state DOT files that have an intersection inventory system. This is not always the case in urban systems. If available, the traffic count information can be used to further target the potential treatment sites in two ways. First, if the user only wishes to treat “high-volume” intersections, these data can be used to screen out “low-volume” intersections prior to running the computer program. Second, after the program has been run, the identified sites can be further screened by a given AADT level, or the sites can be sorted by AADT to assist the user in final site choice.

- **Unit cost for each treatment – both original implementation costs and annual maintenance costs**

The *NCHRP Report 500* guides do not provide treatment costs due to differences between states and expected changes over time. The user will need to obtain information

Crash Type	Variable	Crash Database Subfile
Intersection or Intersection-related	Relation to Junction Location Type	Crash
Angle Crashes	Accident/Crash Type Sequence of Events First Harmful Event Most Harmful Event	Crash Crash or Vehicle Crash Vehicle
Left- and Right-turning Crashes	Same as Angle	Same as Angle
Sideswipe Crashes	Same as Angle	Same as Angle
Run-Off-Road Crashes	Same as Angle plus Number of Vehicles or Units	Crash
Rear-end Crashes	Same as Angle plus Number of Vehicles or Units	Crash
Head-On Crashes	Same as Angle	Same as Angle

Exhibit V-2. Crash variables and subfile location by crash type.

on such costs, either from vendors or from other jurisdictions that have used the treatment. The guides do provide “Information on Agencies or Organizations Currently Implementing This Strategy” that could be contacted for help under each of the treatment strategies. (The guides provide only early users, and surrounding jurisdictions may have implemented the treatment after the guide was completed.) Finally, the user will need an estimate of annual maintenance cost (per intersection or intersection approach) for each treatment to be analyzed. Since maintenance includes “replacement after a crash” in some cases, the user may have to make estimates of the number of expected crashes per year and the amount of expected damage. Again, past users of the treatment can be of assistance here.

Procedure

The general procedure for choosing and targeting treatments with known effectiveness levels was provided in Section III above. The following text will expand that description while focusing on intersection treatments designed to reduce intersection-related crashes. Because the user needs to understand the computerized procedure in order to input the correct values and tailor it for their own jurisdiction, the following provides the details of each step and sub-step.

1. Specify the types/classes of intersections that are potential targets for the treatments.

Because the choice of treatments, the treatment effectiveness, and the treatment cost per intersection may differ by intersection class/type, the user will need to specify the types/classes of interest – e.g., four-leg rural intersections, three-leg urban intersections, rural unsignalized intersections, urban signalized intersections. If desired, these potential treatment sites could be further screened by AADT level (e.g., only “high-volume” intersections).

2. Develop critical crash frequencies for *each* candidate treatment type (e.g., left-turn lane) for each intersection class of interest. The “critical frequency” is the frequency of target crashes per intersection that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor. In the FHWA Sample Plan for intersections (25), the target benefit to cost ratio used was 2.0 or greater.

These “critical frequencies” must be developed for each candidate treatment being examined. If the same treatment is to be used on different intersection classes, it will be necessary to develop different critical frequencies for each treatment by intersection class if the treatment cost per unit length or treatment effectiveness varies by intersection class. The following formula is used:

$$CF = (\text{Ann. Cost})(\text{Target B/C})/(\text{Eff})(\text{Avg. Crash Cost})$$

Where:

- CF = Critical annual frequency of target crashes per intersection to consider the strategy to be cost effective.
 - Ann. Cost = The annual cost of the improvement per intersection. If it is a construction improvement, it is the construction costs annualized over the expected life of the improvement.
 - Target B/C = The B/C ratio defined by the user. It is usually between 1.0 and 2.0. In the FHWA Sample Plan for intersections (25), a value of 2.0 is used.
 - Eff = The estimated effectiveness of the treatment strategy in reducing targeted crashes, expressed as a proportion (i.e., the CRF/100). This can be extracted from *NCHRP Research Results Digest 299* (27) or from other sources.
 - Avg. Crash Cost = The average economic cost per crash for the target crash type that will be affected by this treatment strategy. The following estimates were based on costs from Table 10 of *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22), and represent comprehensive costs in terms of 2001 dollars. Comprehensive cost estimates include not only the monetary losses associated with medical care, other resources used, and lost work, but also non-monetary costs related to the reduction in the quality of life. The cost for each crash type is shown in Exhibit V-3 for two ranges of speed limits: ≤ 45 mph and ≥ 50 mph. The former should be useful for urban crashes, and the latter for rural crashes.
- #### 3. Using the inventory file, stratify potentially treatable intersections by intersection class.
- This stratification will result in a file of intersections for each of the intersection classes under consideration for each treatment.
- #### 4. Link target crashes with intersections from the appropriate inventory data file, and then perform a computer screening of all intersections that are potential treatment locations to determine which intersections have crash frequencies that exceed the critical crash frequencies calculated above.

This will be done using the computer program described above, and will be done independently for each of the intersection types under consideration.

Note that if the treatment being considered is for three-leg intersections (i.e., the user is searching for a “system” of three-leg intersections to correct with, say, left-turn lanes), this step will require that the user’s intersection inventory system can identify the locations of three-leg intersections. If no such data are available, then

Crash Type	Traffic Control	Speed Limit Category	Comprehensive Cost/Crash*
Angle/turning Crashes	Signalized	≤ 45 mph ≥ 50 mph	\$22,000 \$75,000
	Unsignalized	≤ 45 mph ≥ 50 mph	\$32,000 \$96,000
Sideswipe Crashes	Signalized or Unsignalized	≤ 45 mph ≥ 50 mph	\$16,000 \$55,000
	Signalized or Unsignalized	≤ 45 mph ≥ 50 mph	\$24,000 \$33,000
Rear-end Crashes	Signalized or Unsignalized	≤ 45 mph ≥ 50 mph	\$16,000 \$88,000
	Signalized or Unsignalized	≤ 45 mph ≥ 50 mph	\$67,000 \$107,000

* Cost in 2001 dollars (22)

Exhibit V-3. Crash cost by crash type, traffic control and posted speed limit.

the user will have to use either Procedure 2A or 2B instead of this Procedure 1.

5. Review the computer output for “below-threshold” intersections.

The computer program will only detect intersections that exceed the critical crash-frequency threshold. This will leave intersections that do not meet the threshold. The user may desire to manually examine each of the intersections under consideration *within each intersection class* and determine whether or not these “below-threshold” intersections should be treated. The logical first answer is “no,” since the intersections did not meet the critical threshold. However, there may be times when all or some of these intersections should be included in the treatment program.

6. Estimate the expected crash/injury reductions on all the identified target locations.

The results of this step will be used in Step 9 below in determining whether or not the goal is reached. Here, for each treatment location within a given intersection class, the user will need to determine the number of crashes and injuries that will be reduced by this treatment. This will be done by summing up all pertinent crashes or crash injuries for all intersections to be treated, and then multiplying this total by the estimated effectiveness level for the treatment under consideration.

$$\text{CI reduction} = (\text{CI at intersections}) \times \text{Eff}$$

Where:

CI = “Goal-related” crashes or crash injuries

Eff = treatment effectiveness

The definition of “goal-related” crashes or injuries is, as implied, based on the nature of the overall goal that has been established. If the goal is oriented to fatal and injury target crashes, then these will be accumulated. If the goal is total target crashes, then these will be accumulated.

The summing of goal-related crashes or injuries will be done by using a computer program to estimate the *annual* number of such target crashes for all intersections selected for treatment. Users with full crash and inventory systems who have developed the [computer] program will have the ability to link such goal-oriented target crashes to each intersection selected and to sum the total over all intersections. The best *annual* estimate will be one based on more than 1 year of past data (3 to 5 years) and then dividing by the number of years used.

7. Repeat the above steps for each potential treatment type.

The above steps are then repeated for the second and subsequent potential treatment types. In each case, critical crash frequencies are calculated for each intersection class, the computer program is used to identify treatment intersections, and decisions are made whether to treat any “below-threshold” intersections. However, a correction is needed for intersections that have been identified for more than one treatment type, as detailed in the following step.

8. Correct for multiple treatments on the same intersection.

Since many intersection treatments affect the same type of target crash, the above procedure will identify the same intersection as a potential for treatment in many cases. In these cases, the user has two options: (1) choose only one treatment for each of these intersections, or (2) choose to implement two or more treatments at the same intersection.

Under Option 1, the user would compare the lists of potential treatment intersection sites from Step 5 above, and would decide which treatment to place at each intersection where two or more treatments could be implemented. That intersection (and its related goal-oriented crashes or injuries) is then removed from the list of intersections for all other treatments.

Under Option 2, the user must develop some measure of *combined effectiveness* for the two or more treatments

to be applied to a given intersection. Since the combined effectiveness of two treatment strategies at the same location will not be the simple sum of the two effectiveness levels, some correction must be applied for the second and all subsequent treatments that are applied to the same intersection. Unfortunately, there is little knowledge available about the combined effects of multiple treatments. Until that knowledge is developed, it is suggested that the effectiveness level (Eff) of the second treatment applied to a given intersection be reduced to 50 percent of the level shown in the FHWA Sample Plan for intersections (25), and the effectiveness of the third treatment and subsequent treatments applied to the same segment be reduced to 25 percent of the level shown in the draft plan mentioned above. For example, assume that the first treatment for a given segment has an effectiveness level of 0.2, the second has an effectiveness level of 0.15, and the third has an effectiveness level of 0.10, and the fourth and subsequent treatments add no additional effectiveness. The estimated *combined effectiveness* of the three treatments applied to the same segment would be $0.2 + 0.15(.5) + 0.1(.25) = 0.3$. Again, this is only an estimate of the true combined effectiveness at best.

9. **Sum all expected crash injury reductions for all chosen treatment types and chosen target locations and compare that total to the established goal.**
10. **Add new treatments, new targets, or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.**

Again, the FHWA Sample Plan for intersections (25) provides additional discussion of this option.

Procedure 2A – Choosing Intersection Treatments and Target Populations When Treatment Effectiveness Is Known and Mileposted Crash Data Are Available, but Detailed Inventory Data Are Not Available

The following text identifies the data needed for conducting Procedure 2A, followed by the individual steps in the procedure. Note again that this procedure requires “mileposted” crash data. If mileposted data are not available, refer to Procedure 2B or 3.

Data Needs

The data needed for Procedure 2A are virtually the same as for Procedure 1, except that neither detailed intersection inventory data nor linkable traffic counts are required. (Note that this procedure operates more accurately if the user can not only sort crashes by route and milepost, but also has some

inventory information or knowledge that will allow her/him to determine which intersections are rural vs. urban, the number of lanes, the number of legs, and whether the roadway is divided or undivided. This will be covered in the steps of the procedure below.) The following are the specific data needed to use Procedure 2A when choosing and targeting intersection treatments. A description of each item is provided under Procedure 1 above and will not be repeated here.

- **A specified effectiveness level (CRF or AMF) for each treatment to be examined**
- **A computerized crash data file which includes sufficient crash details to isolate target crash types (angle crashes, sideswipe crashes, run-off-road crashes, rear-end crashes, and head-on crashes) and potential target populations that will be affected by each treatment, and which is “mileposted” such that the location of each crash is included**

As noted in the procedure below, it is also advantageous if the crash data contains information that can be used to define “intersection class or type” – e.g., information on number of legs, rural vs. urban, type of traffic control, or any other intersection class characteristics. Since no detailed intersection inventory exists in this situation, these data will help in defining potential target locations within different intersection classes or types.

- **A network screening computer program which can read an input file composed of target crash records sorted by route and milepost, and can count the number of target crashes within a given specified length (e.g., 1 mile) that have occurred in the past 3 to 5 years**

Note that this program is different from the computer program above. It is less likely to currently exist in a jurisdiction, but can be developed by a knowledgeable computer analyst familiar with crash data files.

In general, the program will need to accumulate a count each time a target (i.e., intersection-related) crash is found, the milepost for each crash is reached, and the distance from the last crash (e.g., the difference between the two mileposts) is established for each adjacent pair of crashes. The program will then accumulate the target crash count and cumulative distance until the distance is equal to or greater than the specified window length (e.g., 1 mile). If the accumulated distance is equal to 1 mile, which is unlikely, the program will output the number of target crashes and the milepost of the first and last crashes encountered in that length and the distance between the first and last crash; in this case, 1.0 mile. If the accumulated distance is greater than 1 mile (i.e., the 1-mile limit fell between two adjacent crashes), the counter should subtract the last crash added (i.e., the one outside the 1-mile limit), and should again output the number of target crashes in the window, the milepost for the first crash and last crash

remaining in the window, and the distance between the first and last crash which may be less than 1 mile in this case. A new window would then begin with the current crash being considered (i.e., it would be counted and its milepost recorded) and the process would proceed until the route ends. Each time the specified window length is reached and output is produced, the count will be compared to the critical frequency calculated in Step 2, and will only be retained in the final output file if the count exceeds the critical frequency.

- **Unit cost for each treatment – both original implementation costs and annual maintenance costs**

Procedure

The general procedure for choosing and targeting treatments with known effectiveness levels was provided in Section III above. The following text will expand that description while focusing on intersection treatments – those designed to reduce intersection crashes. Because the user needs to understand the computerized procedure in order to input the correct values and tailor it for his/her own jurisdiction, the following provides the details of each step and sub-step in the procedure.

- 1. Develop critical crash frequencies for each candidate treatment type and intersection class of interest. The “critical frequency” is the frequency of target crashes per intersection that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor.**

The same formula and information presented under Step 2 of Procedure 1 above will be used here.

- 2. Sort crashes by route and milepost in ascending order, and then perform a computer screening of all routes to determine which locations (e.g., 1-mile “windows”) have target crash frequencies that exceed the critical crash frequencies calculated in Step 1.**

This screening will be done using the network screening program described above. If crash-based information is available on intersection class or type (e.g., number of legs, urban vs. rural, type of traffic control), the target crash definitions should include these variables. The screening will then be done independently for each of the intersection types (as defined by crash variables) under consideration. As noted above under “Data Needs,” the network screening program will need to output the total number of target crashes in the specified length and the route number and mileposts for the first and last crash falling in each “window” for which the total number of target crashes exceeds the critical crash frequency.

- 3. Review the computer output for “below-threshold” intersections.**

The computer program will only detect intersections that exceed the critical crash-frequency threshold. This will leave intersections that do not meet the threshold. The user may desire to manually examine each of the intersections under consideration *within each intersection class* and determine whether or not these “below-threshold” intersections should be treated. The logical first answer is “no,” since the intersections did not meet the critical threshold. However, there may be times when all or some of these intersections should be included in the treatment program.

- 4. Estimate the expected crash/injury reductions on all the identified target locations.**

Just as in Procedure 1, the results of this step will be used in Step 9 below in determining whether or not the goal is reached. Here, for each treatment intersection identified in Step 3, the user will need to determine the number of crashes and injuries that will be reduced by this treatment. This will be done by summing up all pertinent crashes or crash injuries for all intersections to be treated, and then multiplying this total by the estimated effectiveness level for the treatment under consideration.

$$\text{CI reduction} = (\text{CI at intersections}) \times \text{Eff}$$

Where:

CI = “Goal-related” crashes or crash injuries

Eff = treatment effectiveness

Just as in Procedure 1, the definition of “goal-related” crashes or injuries is, as implied, based on the nature of the overall goal that has been established. If the goal is oriented to fatal and injury target crashes, then these will be accumulated. If the goal is total target crashes, then these will be accumulated.

The summing of goal-related crashes or injuries will be done by estimating the *annual* number of such target crashes for all intersections selected for treatment.

- 5. Repeat the above steps for each potential treatment type.**

As in Procedure 1, the above steps are then repeated for the second and subsequent potential treatment types. In each case, critical crash frequencies are calculated for each intersection class and the computer program is used to identify treatment intersections. However, a final correction is needed for intersections that have been identified for more than one treatment type, as detailed in the following step.

- 6. Correct for multiple treatments at the same intersection.**

The user will again need to correct for multiple treatments at the same intersection. The same rationale and procedure followed in Procedure 1 will be followed here. (See Step 8 of Procedure 1).

- 7. Sum all expected crash injury reductions for all chosen treatment types and chosen target locations and compare that total to the established goal.**

8. **Add new treatments, new targets, or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.**

Again, the FHWA Sample Plan for intersections (25) provides additional discussion of this option.

Procedure 2B – Choosing Intersection Treatments and Target Populations When Treatment Effectiveness Is Known and Neither Mileposted Crash Data nor Detailed Inventory Data Are Available

The following text identifies the data needed for conducting Procedure 2B, followed by the individual steps in the procedure. Note again that since no mileposted crash data exists, this procedure will only allow the user to identify intersection types within a given jurisdiction as potential treatment sites, but not specific intersection locations. It will also not allow the user to target the treatments to specific locations along the route.

Data Needs

The data needed for Procedure 2B are less than required in either of the previous two procedures. Major differences include the fact that no inventory or traffic data are required, and that the crashes do not have to be “mileposted” to a specific location on a specific route. However, each crash record must contain information on the county or local jurisdiction where the crash occurred, along with the name of the route/street where the crash occurred.

- **A specified effectiveness level (CRF or AMF) for each treatment to be examined.**
- **A computerized crash data file which includes sufficient crash details to isolate crash types that will be affected by each treatment (“target crashes” – e.g., angle crashes, sideswipe crashes, run-off-road crashes, rear-end crashes, and head-on crashes), which includes crashes for all potential target populations. Each crash record must contain a county or jurisdiction name where the crash occurred, and the name of the route or road where the crash occurred.**
- **Route length information that will provide the length in miles of each road or route within a county or local jurisdiction that is a potential target for any treatment, or at least the approximate length.**

If this information is not available in the user’s files, it may be available from other sources including road maintenance records, and can be scaled from maps if necessary.

- **Unit cost for each treatment – both original implementation costs and annual maintenance costs.**

See discussion under Procedure 1.

Procedure

The following steps are those that would be followed for choosing among intersection treatments with known effectiveness and targeting these treatments to entire intersection classes in a jurisdiction.

1. **Develop critical crash frequencies for *each* candidate treatment type and intersection class of interest. The “critical frequency” is the annual frequency of target crashes per mile that, if treated, will result in crash-injury reductions whose economic benefit will exceed implementation costs by some factor.**

The same formula and information presented under Step 2 of Procedure 1 above will be used here.

2. **Link target crashes to each route in each jurisdiction (but not to a specific point on the route).**

This will require computer sorting of crashes by each named route. Some manual effort will be required to correct misspelled names and to group routes or streets that have multiple names. The output of this program will be a listing of target crashes sorted by route name. Note that multiple years of crashes can be used, and indeed the procedure will be more accurate if more than 1 year’s crash data (e.g., 3 to 5 years) are used. If multiple years are used, there may be situations where a route was renamed during the period. If so, both crashes with the original and new name should be accumulated under one route name.

3. **Develop a spreadsheet that contains the count of target crashes for each route (one route per row), along with the mileage for that route.**

It may be possible for the computer program used to sort the crashes in Step 2 to output this count for each route. If not, the counts can be made manually. The final output of this step is a spreadsheet containing a total count of target crashes and the length in miles for each route under consideration.

4. **Calculate the annual crash frequencies per mile for each potential route.**

If a spreadsheet is used, this is a simple step in which the crash count is divided by the route length times the number of years of crashes used.

5. **Identify routes to be treated by determining which have calculated annual frequencies per mile that exceed the developed critical crash frequencies per mile.**

This is a comparison of the output of Step 4 with the “critical frequencies” defined in Step 1.

6. Estimate the expected crash injury reductions on all the identified target routes.

Just as in Procedure 1, the results of this step will be used in Step 9 below in determining whether or not the goal for the jurisdiction is reached. Here, for each treatment route identified at the end of Step 5, the user will need to determine the annual number of crashes and injuries that will be reduced by this treatment. This will be done by summing up all pertinent crashes or crash injuries for all routes to be treated, and then multiplying this annual total by the estimated effectiveness level for the treatment under consideration.

$$\text{CI reduction} = (\text{CI}) \times \text{Eff}$$

Where:

CI = Annual “goal-related” crashes or crash injuries on the routes chosen

Eff = treatment effectiveness

Just as in Procedure 1, the definition of “goal-related” crashes or injuries is, as implied, based on the nature of the overall goal that has been established. If the goal is oriented to fatal and injury target crashes, then these will be accumulated. If the goal is total target crashes, then these will be accumulated.

The annual estimate of potentially treatable crashes or injuries can be extracted from the spreadsheet output in Step 3. For the routes chosen, divide the total crashes on each route by the number of years of data, and then sum across all chosen routes.

7. Repeat the above steps for each potential treatment type.

As in Procedure 1 and 2A, the above steps are then repeated for the second and subsequent potential treatment types.

8. Correct for multiple treatments on the same route.

The user will again need to correct for multiple treatments on the same route. In general, the same rationale and procedure followed in Procedure 1 will be followed here. (See Step 8 of Procedure 1.) However, in this case corrections are made on a route basis rather than an intersection basis (i.e., either one treatment is specified for a given route and that route is removed from other treatment groups, or a correction in effectiveness is made for the second and subsequent treatment on the same route.)

9. Sum all expected crash injury reductions for all chosen treatment types and chosen target routes and compare that total to the established goal.

10. Add new treatments, new targets, or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the goal is met.

Again, the FHWA Sample Plan for intersections (25) provides additional discussion of this option.

Procedure 3 – Choosing Intersection Treatments and Target Locations When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Not Known

As noted in the preceding section, the three procedures described above allow the user to choose intersection treatments and treatment targets for a given problem while ensuring that the economic value of the crash/injury reductions will exceed the cost of implementing the program. All three procedures require that the treatments being examined each have a known level of effectiveness expressed in terms of an expected crash/injury reduction – a defined CRF or AMF. Unfortunately, many of the intersection treatments in the *NCHRP Report 500* guide series do not have defined levels of effectiveness. Thus, economic analyses like those that are the basis for Procedures 1, 2A and 2B are not possible for these treatments. This Procedure 3 is aimed to help the user make an educated choice of which treatments will be most effective in their jurisdiction, and to help the user develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide (e.g., where specific intersections are to be targeted). In general, the choice between alternative intersection treatments will be based on the specific nature of the intersection crash problem, and the choice of target locations will be based on the determination of where the crash/injury problem of interest is found. A discussion of this more general procedure was included under the Procedure 3 subheading in Section III, and the reader should review that section.

Procedure 3 is intended for application to tried or experimental treatments for which the analyst has decided that there is likely to be a crash/injury reduction benefit, but for which the analyst does not have sufficient evidence to estimate a specific CRF or AMF value. In a case for which the analyst is able to estimate a specific CRF or AMF value, even if the estimate is only an approximation, it is recommended that Procedure 4 be used rather than Procedure 3.

Data Needs

The only required data for Procedure 3 are crash data that will allow the user to specify target crashes for each intersection treatment under consideration (see Exhibit V-1 in the “crash data” description under Procedure 1). However, in order to target the treatment to specific intersections, the crash data must be “mileposted” or at least contain information on the county and route. The availability of intersection inventory data that can be linked to the crash data will improve both the treatment choice and the treatment targeting.

Procedure

As described in Section III, Procedure 3 has two basic steps:

- First, choose the best treatments (i.e., the intersection treatments most likely to be applicable in a given jurisdiction) from among the set of all intersection treatments presented in the applicable *NCHRP Report 500* guides.
- Second, choose the routes or route segments to which the selected treatments should be applied.

As described earlier in more detail, the choice of the best treatments from the listing of many potential intersection treatments can be based on the following factors:

- a) The many potential treatments judged to be the most effective, even given that effectiveness is unknown
- b) The relative magnitude of the crash types and severity levels that the treatment will affect
- c) The cost of the potential treatments per mile
- d) Other technical or policy considerations

These factors must be combined in some fashion to decide which treatment to choose. While there are multiple ways of making this choice, the following represents one such procedure.

1. Prioritize the specific intersection problem(s) to be addressed.

This is related to Factor b in the above list. Here, the issue is whether to treat angle, sideswipe, run-off-road, rear-end, head-on, or other intersection crash types, and at which intersection types (e.g., rural three-leg unsignalized intersections, urban four-leg signalized intersections, etc.). This prioritization will be based on the frequency and severity of the specific types of intersection crashes occurring in a user's jurisdiction. Target crash types for each of the intersection treatments were defined under Procedure 1. For each crash type, the user could begin the process by analyzing 3 to 5 years of crash data to determine the frequency of each type. However, since some crash types are more severe than others (e.g., head-on crashes are more severe than sideswipe crashes), total crash frequency alone does not provide the complete answer. While an alternative is to restrict the analysis to only fatal and serious-injury crashes, this will severely limit the crash sample, and will also omit a large component of the crash problem – non-serious injury and no-injury crashes. A better solution is to weight each crash by an economic cost based on its type and severity, and then accumulate the total crash cost (i.e., the total economic cost of crashes) within each target crash type. Information on economic

cost per severity level within 22 different crash types including different types of run-off-road and head-on crashes can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). This analysis of total crash cost will provide the user with overall information on which intersection crash type is most important.

The user may further refine this analysis by examining crash frequency or total crash cost within intersection classes. If the crash data are mileposted and linkable inventory data are available, details of intersection types can be linked to each crash record (e.g., number of legs by type of traffic control). If inventory data are not available, there may be variables on the crash record itself which can be used in a less-detailed analysis (e.g., name of intersecting road, distance from some landmark).

This analysis will then produce a listing of potentially treatable intersection crash types (perhaps by intersection class) that can be sorted by frequency or total crash cost, thus providing a ranked listing. For the higher-ranked crash types, the user can then conduct additional analyses to determine more of the specifics of the crash circumstances (e.g., nighttime vs. daytime distributions of total crash cost). These additional “drill-down” analyses should be designed to provide additional information that could lead to the choice of one treatment over another (e.g., raised pavement markers are primarily effective at night or in rainy weather).

2. Identify possible treatments for use for each high-priority crash type.

The user will then review the pertinent *NCHRP Report 500* guides and list treatments that would be most appropriate for each of the high-priority crash types identified in the above step. The choice should be limited to those treatment strategies that are classified as *tried* in the guides. (*Proven* treatments have known effectiveness levels and can be analyzed in one of the three procedures above.)

3. Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular crash type/intersection class combination, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective. For example, for rear-end crashes on high-speed roads, one would assume that left-turn lanes would be more effective than advance warning signs. At times, this will clearly be a very difficult judgment to make.

4. Choose the “best” treatment(s) by considering estimated effectiveness, cost per intersection and other technical and policy considerations.

The user will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost per intersection of the treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The user will have to choose the final treatments based on “best judgment.” The procedure outlined above will at least ensure that the major factors in the decision are clearly defined. The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected (e.g., left-turn lanes will affect rear-end crashes).

The user should be able to work backwards using the number of crashes likely to be affected by a given treatment and the cost of applying that treatment to a given population or location (see items b and c described at the beginning of this procedure) to determine the treatment effectiveness needed to maintain a B/C ratio greater than or equal to 1.0.

$$\frac{B}{C_t} \geq 1.0$$

Where:

- B = economic benefit of applying a selected treatment to a given location or population
- C_t = the cost of applying that treatment to the selected location or population

$$B = N * C_c * \text{Eff}$$

Where:

- N = Number of target crashes for the subpopulation or location where the treatment is to be applied
- C_c = average economic cost per target crash
- Eff = treatment effectiveness, or the percent reduction in target crashes

Since different severity levels have different crash costs, the value used for C_c can be a weighted average of the crash costs associated with the crash types likely to be affected. Solving for the treatment effectiveness, the equation reads:

$$\text{Eff} = \frac{C_t}{N * C_c}$$

The analyst can then determine whether the calculated treatment effectiveness required to reach the breakeven point is likely to be achievable.

5. Target the chosen treatments to the intersections where the problem is found.

Since this procedure concerns treatment strategies without known effectiveness, it will not be possible to target the treatments based on any type of economic analysis such as those in Procedures 1, 2A and 2B. Instead, the treatment will be targeted to intersections showing the highest total crash cost or frequency, coupled with user judgment concerning the nature of the intersection and technical and political issues. If the crash data are mileposted, the user could (1) link crashes to routes and search for the locations of “clusters” of target crashes for possible treatment, or (2) use a network screening program similar to that described under Procedure 2A to identify 1-mile sections with the highest crash frequency or total crash cost. The windows identified by the network screening program could then be ranked by frequency or total crash cost to identify priority locations. The user would then correct for “treatment gaps” using the same logic provided in Procedure 2A.

If the crashes are not mileposted, but there is information available on jurisdiction and route, the user could link crashes to routes within the jurisdiction and calculate the total crash cost or number of target crashes per mile by dividing the sum of the crash cost or the sum of target crashes on that route by route length. The user can then rank the potential routes for treatment based on this rate per mile and choose the routes to be treated based on the highest rankings plus other technical and policy factors.

6. Decide what to do with multiple treatments at the same intersections/routes.

The above steps could possibly produce intersections or routes within a jurisdiction that could be treated with multiple treatments. Unlike the earlier procedures where it was possible to estimate combined effectiveness for multiple treatments on the same intersections or routes, since treatment effectiveness is not known here, the user will have to use other factors in the final treatment choice for these locations. If the potential treatment strategies still under consideration are characterized by different target crash types (e.g., rear-end crashes vs. sideswipe crashes), and if the crash data are mileposted or include route information, the user could use the outputs of Step 5 above in making the targeting decision. Step 5 produced total crash cost or crash frequency of each potential target section or route. For each intersection or route where multiple treatments are possible, the user could compare the crash frequency or total crash cost for each of the different possible strategies. Total crash cost will be a much superior criterion if the target crash types being compared differ with respect to crash severity. If total crash cost or frequency for one treatment strategy clearly exceeds the total crash cost or frequency for the other, the first would be a logical treatment choice. If the total crash cost or frequency for the different strategies is essentially the

same, the user will need to make the decision based on best judgment.

7. Add new treatments, new targets, or new approaches (e.g., inclusion of safety treatments in normal maintenance or rehabilitation efforts) until the available funding is used.

In Procedures 1, 2A and 2B, an iterative process is used until sufficient treatment types and locations are selected such that the established crash reduction goal can be reached. In Procedure 3, without effectiveness measures for the treatments, it is not possible to verify whether or not a specific set of treatment types and treatments will meet the established goal. Therefore, the best that can be done is to proceed in selecting treatment types and treatments until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined by evaluations conducted after its implementation.

Procedure 4 – Choosing Treatments and Target Populations in Emphasis Areas for which Some Candidate Treatments Have Known Effectiveness Estimates and Other Treatments Do Not

In many situations, users considering a safety improvement program in a particular emphasis area will need to consider both treatments that have known effectiveness measures and treatments that do not. In this situation, it is recommended that the user give priority to treatments that have known effectiveness measures (*proven* treatments). Treatments that have been used extensively but for which effectiveness measures are not available (*tried* treatments) should then be considered. *Experimental* treatments may have a modest role in a safety improvement program, particularly if the program is structured to evaluate the effectiveness of the experimental procedure.

The recommended planning approach in this situation is a hybrid of Procedures 1, 2A, 2B, and 3 described above.

Procedure

1. Determine if *proven* treatments can meet the established goal.

Consider treatments with known effectiveness measures (*proven* treatments) using either Procedure 1, 2A, or 2B as appropriate, depending on the types of data available. Determine the crash/injury reduction achieved and compare it to the established crash/injury reduction goal. If the goal has not yet been met, proceed to Step 2.

2. Consider *tried* treatments to supplement the *proven* ones.

This step would involve consideration of treatments without known effectiveness that have been used extensively by highway or driver/vehicle agencies (*tried* treatments). If it is possible to *estimate* the effectiveness of these treatments based on imperfect information, then proceed to Step 3; otherwise, proceed to Step 4.

3. Estimate the effectiveness of *tried* treatments if possible, and analyze them using the appropriate procedure above.

This step involves attempting to estimate the effectiveness of treatments without known CRFs or AMFs. *Note that estimating treatment effectiveness is very difficult and can lead to poor treatment choices unless the estimates are realistic.* This estimation was not suggested in Procedure 3 for this reason. It is only suggested at this point since the user has already considered all proven treatments before reaching this stage. It is suggested that the following guidelines be used in making such estimates:

- a) In general, be as conservative as possible. Very few treatments can be expected to affect crash frequency by more than 15–25 percent.
- b) When possible, formulate an effectiveness estimate that is applicable to particular target crash types only, not to total crashes.
- c) Base estimates for *tried* treatments on CRFs for similar treatments if they exist.

Once effectiveness is estimated, apply Procedure 1, 2A or 2B as appropriate, depending on the types of data available. Determine the crash/injury reduction achieved in Steps 1 and 3 combined and compare it to the established crash/injury reduction goal. If the goal has not yet been met, proceed to Step 4.

4. Consider additional *tried* treatments.

For treatments for which reliable effectiveness measures cannot be estimated in Step 3, apply Procedure 3 to select additional treatment types and target locations until all available funds have been budgeted.

SECTION VI

Special Road User Populations

Planning Programs Related To Reducing Crashes Involving Older Drivers, Younger Drivers, Pedestrians And Bicyclists

This section of the guide provides the details of choosing treatment strategies for older drivers, younger drivers, pedestrians or bicyclists, and targeting those treatments to subgroups of these populations or to locations where their crashes occur. As indicated earlier, it is assumed at this point that the analyst has chosen his/her other emphasis area or areas (e.g., older drivers and/or pedestrians) and has established a stretch goal. In implementing driver-oriented programs, the estimation of program costs is often challenging. In addition to the direct cost of the program, one-time start-up costs and indirect/administrative costs may be substantial, but are not always addressed in the cost estimation process. Planning of pedestrian and bicycle safety programs is often challenging because of limited crash data. In planning pedestrian safety improvements, opportunities to improve accessibility under the requirements of the Americans with Disabilities Act (ADA) should be addressed.

Four procedures for choosing and targeting treatment strategies were described in the Stage 3 text in Section III. Three of those procedures require that the effectiveness (CRF or AMF) of at least part of the potential treatment strategies be known. However, almost none of the strategies in the guides related to these special road-user populations have known effectiveness. For that reason, only the details of Procedure 3 will be covered in this section. If AMFs are developed for treatments for these populations, or if the analyst is only interested in examining the few treatments with known AMFs, then the economic-based Procedures 1 or 2 can be used. If AMFs exist for some of the treatments of potential interest but not for all (which will likely be the case in the near future), Procedure 4 can be used. While the crash types will differ, details of the use of all three of these

“known-effectiveness procedures” are provided in Section IV on “Roadway Segment Programs.”

Thus, the basic steps in Procedure 3 presented below will be appropriate for all four of the road user populations covered in this section. The data (e.g., variable values used to define older driver crashes and crash types for older drivers vs. pedestrians) will differ, but the basic procedure will remain the same. The analyst is *strongly urged* to carefully review the material in each of the pertinent guides before beginning this planning process. These user-population-oriented guides are found within *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. The specific volumes pertinent to this section are:

- *Volume 9: A Guide for Reducing Collisions Involving Older Drivers* (9)
- *Volume 10: A Guide for Reducing Collisions Involving Pedestrians* (10)
- *Volume 18: A Guide for Reducing Collisions Involving Bicycles* (2008)
- *Volume 19: A Guide for Reducing Collisions Involving Young Drivers* (2007)

A link to these downloadable guides can be found at <http://safety.transportation.org/guides.aspx>.

Procedure 3 – Choosing Roadway User Treatments and Target Subgroups When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Not Known

Again, the assumption here is that there is no known level of effectiveness for the treatment strategies of interest – no defined CRFs or AMFs. Thus, economic analyses like those that are the basis for Procedures 1, 2A and 2B, and 4 are not possible for these treatments. This Procedure 3 is aimed at helping

the analyst make an educated choice of which treatments will be most effective in their jurisdiction, and to help the analyst develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide (e.g., where specific user subpopulations or roadway locations are to be targeted). In general, within each user group, the choice between alternative treatments will be based on the specific nature of the population’s crash problem, and the choice of target subgroups will be based on the determination of where the crash/injury problem of interest is found. A discussion of this more general procedure was included above, and the reader should review that section.

Data Needs

The only required data for Procedure 3 are crash data that will allow the analyst to (1) isolate crashes involving the specific user population of interest (e.g., older drivers) and (2) define crash types for this user population which would suggest strategies and target subgroups. DMV records, and particularly DMV driver history files, may also be useful in planning driver-oriented programs.

To isolate crashes involving the population of interest, the analyst will need to examine the data formats/coding in his/her crash file to identify variables that can be used in determining whether or not a given crash is a “target-population crash.” Crash databases often categorize data for a given crash into up to three subfiles – (1) general accident/crash variables (“crash”), (2) variables for each vehicle in the crash (“vehicle”), and (3) variables for each occupant/person in the crash (“person” or “occupant”). The variables needed to determine whether a crash is a “target-population crash” are usually found in the occupant/person subfile, but could also be found in the general crash subfile (e.g., a “flag” for all pedestrian crashes) or “vehicle” subfile (e.g., driver information included with each vehicle record). Pedestrians or bicyclists are sometimes classed as a “vehicle type” in the vehicle file, and sometimes as a “person type” in the occupant/person file. (If the jurisdiction’s data are compliant with the Model Minimum Uniform Crash Criteria – MMUCC – these data variables will be in the “Person” subfile.) In short, crash files differ from jurisdiction to jurisdiction.

While certainly not always the case, the variables (or similar variables) listed in Exhibit VI-1 will be used in this identification of target-population crashes.

Defining crashes that will guide the *choice of treatment strategy* and the *targeting* of these strategies will require crash data that include specific variables and codes on such items as location of crash (intersection vs. non-intersection), condition of driver or pedestrian, driver/bicyclist/pedestrian action prior to crash, light condition, etc. Again, the names of variables and the specific codes needed to conduct these analyses will vary from jurisdiction to jurisdiction. While not all crash types for all treatment strategies related to all four populations are included here, Exhibit VI-2 provides some guidance concerning where example variables related to some treatment strategies might be found. Note that in MMUCC-compliant databases, the term “non-motorist” will be used for both pedestrians and bicyclists.

Procedure

As described in Section III, Procedure 3 has two basic steps. First, choose the best treatments for the user population of interest (e.g., the older-driver treatments most likely to be applicable in a given jurisdiction) from among the set of all treatments presented in the applicable *NCHRP Report 500* guides. Second, choose the subgroups of users or highway locations to which the selected treatments should be applied. As described earlier in more detail, the choice of the “best treatments” from the listing of many potential user-population treatments can be based on the following factors:

- a) The potential treatment judged to be the most effective, even given that effectiveness is unknown
- b) The relative magnitude of the crash types and severity levels that the treatment will affect
- c) The cost of the potential treatments (either jurisdiction-wide, per-mile or per-location)
- d) Other technical or policy considerations

These factors must be combined in some fashion to decide which treatment to choose. While there are multiple ways of

Population Type	Variable	Crash Database Subfile
Older Drivers or Younger Drivers	Person Type	Person/Occupant
	Driver Age Driver Date of Birth	Person/Occupant or Vehicle Person/Occupant or Vehicle
Pedestrian or Bicyclist	Person Type	Person/Occupant
	Vehicle Type	Vehicle
	Crash Type (First Harmful Event)	Crash

Exhibit VI-1. Crash variables and subfile location by population type.

Crash Type/Issue	Variable	Crash Database Subfile
Intersection vs. Non-intersection	Relation to Junction Type of Intersection Traffic Control Device Type	Crash Crash Crash or Vehicle
Nighttime/Reduced Visibility	Light Condition Weather Roadway Lighting	Crash Crash Crash
Lane Departure (Potentially Related to Pavement Markings)	Accident/Crash Type Manner of Collision Sequence of Events First Harmful Event Most Harmful Event Crash Location (Off-road)	Crash Crash Vehicle Crash Vehicle Crash
Crashes Associated with Medical Conditions	Driver Condition	Person
Occupant Restraint Use	Occupant Protection System Use	Person
Work Zone	Work Zone Related Roadway Condition	Crash Crash
Pedestrian "Walking along Roadway" Crashes	Pedestrian (or Non-Motorist) Action Prior to Crash	Person
Speed-related Crashes	Driver Action Prior to Crash Violation Indicated Contributing Circumstances	Person (or Vehicle) Person (or Vehicle) Person (or Vehicle)
Crash Location (for Targeting Treatments)	County City Route Milepost Longitude/Latitude Block Address	Crash Crash Crash Crash Crash Crash
Speed Limit (for Use in Developing Cost per Crash)	Speed Limit	Crash

Exhibit VI-2. Crash variables and subfile location by crash type/issue.

making this choice, the following represents one such procedure.

1. Prioritize the specific user-population problem(s) to be addressed.

This is related to Factor b in the above list. Here, the initial issue is whether to treat older driver, younger driver, pedestrian or bicyclist crashes. This prioritization will be based on the frequency and severity of the specific types of user-population crashes occurring in an analyst’s jurisdiction. Crashes specific to a given user population were defined in the table above. For each user population, the analyst could begin the process by analyzing 3 to 5 years of crash data to determine the frequency of each population. However, since some crashes for some populations are more severe than others, total crash frequency alone does not provide the complete answer. While an alternative is to restrict the analysis to only fatal and serious-injury crashes, this will severely limit the crash sample, and will also omit a large component of the crash problem – non-serious injury and no-injury crashes. A better solution is to weight each crash for a given user population by an economic cost based on its severity, and then accumulate the total crash cost for each

population. Information on economic cost per crash severity level can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). Here, instead of using severity cost by crash type as is done in roadway-program analyses covered in earlier sections, the analyst will use the basic crash cost by police-reported severity level (i.e., K,A,B,C,O). Exhibit VI-3 below presents those costs per crash. Costs for combinations of crash severity levels (e.g., K+A crashes) are presented in that report (22). This

Crash Severity	Speed Limit Category	Comprehensive Cost/Crash*
Fatal (K)	≤ 45 mph	\$3,622,200
	≥ 50 mph	\$4,107,600
Serious Injury (A)	≤ 45 mph	\$195,700
	≥ 50 mph	\$222,300
Moderate injury (B)	≤ 45 mph	\$62,200
	≥ 50 mph	\$91,600
Minor Injury (C)	≤ 45 mph	\$40,100
	≥ 50 mph	\$49,500
No Injury (O)	≤ 45 mph	\$7,000
	≥ 50 mph	\$7,800

*Crash cost in 2001 dollars

Exhibit VI-3. Crash cost by crash severity and posted speed limit (22).

analysis of total crash cost will provide the analyst with overall information on which user population is most important in his/her jurisdiction.

For the chosen user population, the analyst could then conduct additional analyses of “critical crash types” for that population by producing crash-type distributions and weighting each crash type by the cost per crash. This could be done either by using the costs for the 22 crash types presented in the above report, or by developing severity distributions within each crash type and weighting the individual severity-level frequencies by the cost estimates above. This analysis will then produce a listing of potentially treatable crash types for the chosen user population that can be sorted by crash frequency or total crash cost, thus providing a ranked listing. For the higher-ranked crash types, the analyst can then conduct additional analyses to determine more of the specifics of the crash circumstances (e.g., nighttime vs. daytime distributions of total crash cost). These additional “drill-down” analyses should be designed to provide additional information that could lead to the choice of one treatment over another (e.g., intersection lighting will affect nighttime older-driver crashes at intersections, and traffic calming measures on road sections are more likely to affect locations with higher speeds, as defined by either speed limit or speeding as a contributing factor).

2. Identify possible treatments for use for each high-priority crash type.

The analyst will then review the pertinent *NCHRP Report 500* guides and list treatments that would be most appropriate for each of the high-priority crash types identified in the above step. The choice should be limited to those treatment strategies that are classified as *proven* or *tried* in the guides. If not already conducted in the “drill-down” analysis in the preceding step, more specific information on the total crash cost related to each potential treatment strategy could be developed by specifying the crash types that are most likely to be affected by each strategy (e.g., pedestrian-crossing crashes at higher-speed intersections as targets for intersection traffic calming treatments), producing crash frequencies for each specified crash type, and multiplying the frequencies by cost per crash. For some strategies, the *NCHRP Report 500* series presents information concerning which crash types are most likely affected by that treatment strategy. However, for other user-population strategies, it will not be possible to define one or more specific crash types for a given potential strategy (e.g., education programs for drivers and pedestrians, resource centers to promote safe mobility choices for older drivers). In these cases, the analyst will have to make some judgment concerning the relative size of the crash problem that could potentially be affected by these strategies.

3. Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular user group, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective. For example, strategies related to changing the roadway may be more effective, in general, than strategies related to education (but, of course, will affect only those users at the treated locations). At times, this will clearly be a very difficult judgment to make.

4. Choose “best” treatment(s) by considering estimated effectiveness, cost, and other technical and policy considerations.

The analyst will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost of the treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The analyst will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined. The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected.

5. Target the chosen treatments to the user populations where the problem is found.

In some cases, treatment strategies related to user populations will be implemented jurisdiction-wide. In other cases, it may be desirable to target the treatment to either a subgroup of the user population or to specific locations (e.g., specific counties, route sections, or intersections). If a given strategy can be linked to a specific crash type or types, choosing high-priority subgroups for targeting can be done using similar procedures noted above for choosing treatments. Here, the user-population crashes within each crash type would be divided among all potential user subgroups (e.g., pedestrian crashes would be divided into age groups), and crash frequency or total crash cost would be calculated for each subgroup, producing a ranking based on problem size. If treatment-cost estimates can be made for each subgroup, the total crash cost and treatment cost can be combined to provide an indication of which subgroup might produce the largest payoff per treatment dollar spent.

If targeting is to be done by location, the treatment could be targeted to counties, city areas, or routes/streets showing the highest total crash cost or frequency, coupled with the analyst's judgment of potential differences in cost between locations and technical and political issues. If the crash data are mileposted, the analyst could (1) link crashes to routes and search for the locations of "clusters" of target crashes for possible treatment or (2) use a network screening program similar to that described under Procedure 2A to identify 1-mile sections with the highest crash frequency or total crash cost. The windows identified by the network screening program could then be ranked by crash frequency or total crash cost to identify priority locations. The analyst would then correct for "treatment gaps" using the same logic provided in Procedure 2A (see Section IV). If the crashes are not mileposted, but there is information available on jurisdiction and route, the analyst could link crashes to routes within the jurisdiction and calculate the total crash cost or number of target crashes per mile by dividing the sum of the crash cost or the sum of target crashes on that route by route length. The analyst could then rank the potential routes for treatment based on this rate per mile, and choose the routes to be treated based on the highest rankings plus other technical and policy factors.

6. Decide what to do with multiple treatments for the same subgroup or on the same segments/routes.

The above steps could possibly produce subgroups, geographic areas, roadway locations or routes within a jurisdiction that could be treated with multiple treatments. If the potential treatment strategies still under consideration are characterized by different target crash types (e.g., left-turn intersection crashes vs. angle intersection crashes for older drivers), and if the crash data are mileposted or include route information, the analyst could use the outputs of Step 5 above in making the treatment choice. Step 5 would produce the total crash cost or crash frequency of each potential target subgroup or location. For each subgroup or location where multiple treatments are possible, the analyst could compare the crash frequency or total crash cost for each of the different possible strategies. Total crash cost would be a much superior criterion if the target crash types being compared differ with respect to crash severity (e.g., turning crashes vs. head-on crashes). If total crash cost or frequency for one treatment strategy clearly exceeds total crash cost or frequency for the other, the first would be a logical treatment choice. If the total crash cost or frequency for the different strategies is essentially the same, the analyst will need to make the decision based on best judgment, such

as applying the same treatment used with other user populations.

7. Add new treatments, new targets or new approaches (e.g., inclusion of improved signing and marking in normal maintenance efforts) until the available funding is used.

Without effectiveness measures for the treatments, it is not possible to verify whether or not a specific set of treatment types and treatments will meet the established goal. Therefore, the best that can be done is to proceed in selecting treatment types and treatments until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined by evaluations conducted after its implementation.

Closure – Good Data Produce Better Results

The assumption in this section has been that crash data are available, but not necessarily other data such as roadway inventories. As is obvious in the procedures above, the availability of *mileposted* crash data will result in improved treatment targeting, and the availability of linkable (and thus mileposted) inventory data would further increase the analyst's ability to both choose treatment strategies and to target them. For example, inventory data could provide detailed data not found in crash data files on such items as signal timing, intersection layout, and street width, all of which are related to treatment strategies listed in the guides.

In like fashion, more detailed data on crash types would greatly increase the analyst's ability to choose treatments, particularly for pedestrian and bicycle crashes. Such enhanced data can be developed by a state or local jurisdiction using a tool known as Pedestrian and Bicycle Crash Analysis Tool (PBCAT). For more information on this tool, go to <http://www.walkinginfo.org/pc/pbcats.htm>.

Finally, many of the special user-population strategies covered in this section will be applied in local jurisdictions as well as at the state level. Many local jurisdictions have or are considering officially or unofficially increasing the threshold for crash reporting which means they will be reporting fewer non-injury crashes. It should be noted that such a policy will likely greatly reduce the crash sample available for analysis in local jurisdictions, particularly for older and younger driver programs, since many of the crashes for these two groups will be non-injury crashes. While pedestrian and bicycle crashes may be less affected, their numbers are usually so small in a local jurisdiction that any decrease is problematic. Safety analysts are urged to consider such proposed threshold changes carefully and to bring the expected negative effects to the attention of decision makers.

SECTION VII

Illegal Driver Actions

Planning Programs Related to Reducing Crashes Involving Aggressive Drivers, Alcohol-Impaired Drivers, and Unlicensed or Suspended/Revoked Drivers

This section of the guide presents a strategy for selecting treatment programs that offer maximum potential in reducing crashes involving aggressive drivers, drinking drivers, unlicensed drivers, and drivers with a suspended or revoked driver's license (S/R drivers). As noted earlier, it is assumed that a safety planning team has selected one or more of the above emphasis areas as part of its safety plan and has established a "stretch goal" as described in Section I. Four procedures for choosing treatment strategies and target groups were described in Section III of this guide. Three of these procedures require known estimates of effectiveness (crash reduction and benefit-costs) for some or all of the selected strategies – in other words, that the treatments have known CRFs or AMFs. However, none of the guides considered here identified strategies that completely met this requirement even though many of the strategies are supported by compelling evidence of significant crash reduction. What is generally lacking are precise estimates of the *magnitude* of the crash reduction that could be used in the development of an estimated B/C ratio. The latter, in turn, also requires known estimates of treatment costs and effects on crash severity, which are often lacking. Thus, we know in some cases that the treatment reduces crashes but not by how much or in terms of net cost-benefits.

Procedure 3, as described in Section III, outlined an approach for selecting strategies in the absence of known crash effectiveness estimates (AMFs or CRFs) and B/C ratios. This procedure is designed for use with treatments where crash reduction effectiveness has not been established. Many of the treatments related to illegal driving fall into this category, and that procedure will be presented below. Two additional

treatment-choice procedures will be presented for treatments related to drinking drivers.

The safety planning team is strongly urged to carefully review the material in each of the pertinent guides before beginning the planning process. These user-population-oriented guides are found within *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. The specific volumes pertinent to this section on illegal driving acts are:

- *Volume 1: A Guide for Addressing Aggressive-Driving Collisions.* (1)
- *Volume 2: A Guide for Addressing Collisions Involving Unlicensed Drivers and Drivers with Suspended or Revoked Licenses.* (2)
- *Volume 16: A Guide for Reducing Alcohol-Related Collisions.* (16)

A link to these downloadable guides can be found in <http://safety.transportation.org/guides.aspx>. The planning team is also encouraged to review *NCHRP Report 501 (18)* for a detailed description of an integrated problem identification and safety planning process.

General Strategic Considerations

As noted earlier, data for estimating precise AMFs, CRFs and B/C ratios for many of the driver-oriented strategies do not exist. There are also some other differences between highway-oriented strategies and driver-oriented strategies that need to be recognized in selecting treatment programs and establishing crash-reduction goals. The first relates to the data source and "ownership" of the treatment delivery system. In contrast to many of the highway countermeasures, most of the effectiveness measures for these driver strategies do not relate to crash rates on sections or type of roads. Instead, the safety concern usually relates more to overall crash

rates, perhaps subdivided by severity. The data on which problem driver identification and effectiveness measurements are based (traffic convictions and crashes) usually reside in DMV files. These data may sometimes be added to the state crash file.

It will also be noted that many of the strategies proposed in the guide could require the enactment of legislation, depending on the state in question. Selection of a strategy requiring legislation entails an assessment of the likelihood that the legislation could be enacted in the required time-frame.

Another consideration is cost. An assessment of cost for many of the proposed strategies will require subjective approximations. Some general information on treatment cost is presented for each treatment in each of the three guides (Volumes 1, 2, and 16), and that information should be reviewed by the user. Very costly strategies should be avoided unless supported by proven effectiveness data and an estimated effect size that is sufficient in economic terms (dollar benefits) to be cost-beneficial or cost-effective. Strategies that are judged to have negligible or moderate operational costs (excluding start-up) will usually be cost-beneficial if they produce statistically significant annual crash reductions as small as 5–10 percent over baseline. It is also possible to make statutory sanctions such as ignition interlock, vehicle impoundment, and license suspension self-supporting through administrative fees and fines.

The guides classify strategies into three categories:

1. *Proven*
2. *Tried* but not proven
3. *Experimental* – not tried, effectiveness unknown.

In selecting treatment strategies, priority should be given to strategies rated as *proven*. However, the safety planning team is encouraged to use their own judgment and to independently review the evidence cited in the guides in selecting treatments. The *tried* category includes those treatments that have been used by agencies (in some cases used often), where there is little possibility of negative impacts on crash/injury frequency, and where there is an expectation (but not scientific proof) that the effect of the treatment on safety is likely to be a positive one. The evidence could include poorly designed or executed crash/injury evaluations and indirect or *surrogate* measures that may be related to safety (e.g., behavioral changes that may be related to crash/injury reduction).

The following sections present three methods for choosing and targeting strategies. The first is a modified version of Procedure 3 described in Section III, which is usable when treatment effectiveness (AMF) is unknown. This procedure could be used for any of the illegal-driving strategies found in any of the three guides. The second procedure is a modification of the economic analysis procedures found in Procedures 1, 2A and 2B. It is primarily directed to strategies in the Volume

16 guide concerning alcohol-related (AR) crashes, since effectiveness levels (AMFs) are either given or can be estimated for some of the AR strategies. However, this procedure could also be used for other operator-related strategies if effectiveness is known or becomes known in the future. The third procedure is specific to AR strategies, and is based on advice given in the Volume 16 guide.

Although most of the proposed treatment strategies do not have precise AMFs, a substantial number of the strategies in Volumes 2 and 16 are supported by compelling evidence concerning their efficacy and effectiveness. This is not true for aggressive driving countermeasures (Volume 1). Those who implement strategies for reducing aggressive driving must also contend with definitional ambiguity and the absence of a database for identifying such drivers and initiating appropriate sanctions. These limitations will necessitate use of subjective judgment and indirect methods.

Procedure 3 – Choosing Treatments and Target Subgroups Related To Illegal Driving Actions When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Unknown

The assumption here is that there is no known level of effectiveness for the treatment strategies of interest – no defined CRFs or AMFs. Thus, economic analyses like those that are the basis for Procedures 1, 2A and 2B, and 4 are not possible for these treatments. Procedure 3 is aimed at helping the analyst make an educated choice of which treatments will be most effective in his or her jurisdiction, and to help the analyst develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide or to the “total problem” (e.g., where specific illegal-driver subpopulations or jurisdictions are to be targeted).

However, unlike road user populations covered in other guides (e.g., older drivers, pedestrians), the choice between alternative treatment strategies found in each of these three illegal-driving guides is much less oriented to specific crash circumstances (e.g., different crash types, times of crash, crash location types, etc.). Instead, most of the strategies are related to improvements in programs, such as impounding vehicles of repeat offenders. In addition, for both the guide related to aggressive driving and the guide related to unlicensed, suspended, or revoked drivers, the strategies are related to the full group of such illegal drivers. Thus, while targeting of a chosen strategy can occur based on jurisdiction and selected areas within a jurisdiction, it is not apparent how crash data could be used to further target the strategies. AR crash strategies presented are essentially oriented to three different groups of drivers – young drivers in AR crashes, all drivers in AR crashes, and repeat DUI offenders in AR

crashes. Examination of crash data can provide the analyst with information concerning which of these subgroups are producing the largest AR problem in a given jurisdiction, but virtually none of the strategies within each of the three subgroups are susceptible to further targeting.

For these reasons, the general analysis methods presented under Procedure 3 in other sections of this manual are not as applicable here. For that reason, only a modified Procedure 3 is presented below – one which continues to use relative estimates of the program effectiveness for different alternative treatments, but one that does not include further targeting steps.

Data Needs

Note that Procedure 3 is a “crash-based” procedure. It assumes that the analyst wishes to choose among the alternative strategies and target the treatments based on crash data. It is noted that an alternative way of making such choices is through linking crash data related to problem size to an assessment of the existing *programs* in a jurisdiction, and choosing to implement those strategies which are either missing from the current program or have the least extensive (or least effective) degree of implementation. This *program-deficiency* procedure is described more fully in a later section.

However, if the analyst wishes to choose treatments and targets based on crash data, the revised Procedure 3 described here basically requires crash data that will allow the analyst to (1) isolate crashes involving the specific user population of interest (e.g., drivers involved in alcohol-related crashes) and (2) define crash types or crash characteristics (e.g., AR crashes involving young drivers) for this user population which would suggest strategies and target subgroups.

To isolate crashes involving the population of interest, the analyst will need to examine the data formats/coding in her/his crash files to identify variables that can be used in determining whether or not a given crash is a “target-population crash.” Crash databases often categorize data for a given crash into up to three subfiles – (1) general accident/crash variables

(“crash”), (2) variables for each vehicle in the crash (“vehicle”), and (3) variables for each occupant/person in the crash (“person” or “occupant”). The variables needed to determine whether a crash is a “target-population crash” are usually found in the occupant/person subfile, but could also be found in the general crash subfile (e.g., a “flag” for all alcohol-related crashes) or “vehicle” subfile (e.g., driver information included with each vehicle record). In short, crash files differ from jurisdiction to jurisdiction. While certainly not always the case, the following variables (or similar variables) listed in Exhibit VII-1 will be used in this identification of “target populations.” Note that while such definition is possible from both drivers in AR crashes and drivers with suspended/revoked licenses, there is no clear definition of “aggressive drivers.” Thus, the defining variables will depend on the user’s definition (e.g., speeding well above average traffic speed, multiple violations at the same time, etc.).

Finally, note that identifying alcohol-related crashes involving repeat DUI offenders will be much more difficult since this group is not identified by any combination of variables in the crash file. More information on defining crashes for this group using a “driver history file” is included below.

As noted above, since the strategies described in these three guides are generally applicable to all aggressive or illegal drivers, or to subsets of drivers by age, they do not lend themselves to a great degree of additional *targeting* in many cases. AR strategies could be chosen based on driver age (e.g., strategies of young drivers in AR crashes vs. strategies for all AR crashes). Some of the strategies in Volume 1, the Aggressive Driving Guide (e.g., “Targeted Enforcement”), and Volume 16, the AR Guide (e.g., DUI checkpoints), could be targeted to high-priority locations or high-priority times of day based on crash occurrence. (They could also be targeted based on citation data that includes location of the offense, assuming that such enforcement is somewhat “random” across the jurisdiction.) The names of crash variables and the specific codes needed to conduct these targeting analyses will vary from jurisdiction to jurisdiction. While not all relevant crash variables are

Population Type	Variable	Crash Database Subfile
Drivers Involved in Alcohol-Related Crashes	Alcohol Involvement	Crash
	Law Enforcement Suspect	Person/Vehicle
	Alcohol Use	Person/Vehicle
	Alcohol Test Violation Codes	Person/Vehicle
Drivers with Suspended/Revoked Licenses	Driver License Jurisdiction	Person/Vehicle
	Driver License Class	Person/Vehicle
	Driver License Status Violation Codes	Person/Vehicle
Aggressive Drivers	(Depends On User Definition of Aggressive Driving)	

Exhibit VII-1. Crash variables and subfile location by population type.

presented here, Exhibit VII-2 provides some guidance concerning where example variables related to some treatment strategies might be found.

Procedure

As described in Section 3, Procedure 3 has two basic steps. First, choose the best treatments for the user population of interest (e.g., the treatments related to AR crashes most likely to be applicable in a given jurisdiction) from among the set of all treatments presented in the applicable *NCHRP Report 500* guides. Second, choose the subgroups of users (e.g., young AR or aggressive drivers), highway locations, or times of day to which the selected treatments should be applied.

As described earlier in more detail, the choice of the “best treatments” from the listing of many potential user-population treatments can be based on the following factors:

- a) The potential treatment judged to be the most effective, even given that effectiveness is unknown
- b) The relative magnitude of the crash types and severity levels that the treatment will affect
- c) The cost of the potential treatments (either jurisdiction-wide or per-mile or per-location)
- d) Other technical or policy considerations

These factors must be combined in some fashion to decide which treatment to choose. While there are multiple ways of making this choice, the following represents one such procedure.

1. Prioritize the specific user-population problem(s) to be addressed.

An initial issue may be whether to treat one, two or all three of the groups covered in these guides – aggressive drivers, drivers involved in AR crashes, and/or unlicensed and S/R drivers. This decision can be based on the

frequency and severity of the specific types of user-population crashes occurring in an analyst’s jurisdiction. Crashes specific to a given user-population were defined in Exhibit VII-1. For each user population, the analyst could begin the process by analyzing 3 to 5 years of crash data to determine the frequency of each crash population – either total crashes or some subset (e.g., fatal and serious-injury crashes). However, since the severity distribution may differ between some populations, and since restricting the analysis to only fatal and serious-injury crashes will severely limit the crash sample and will omit a large component of the crash problem – non-serious injury and no-injury crashes – a better solution is to weight each crash for a given user population by an economic cost based on its severity, and then accumulate the total crash cost for each population. Information on economic cost per crash-severity level can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). Here, instead of using severity cost by crash type as is done in roadway-program analyses covered in earlier sections, the analyst will use the basic cost per crash categorized by police-reported crash-severity level (i.e., K,A,B,C,O). Exhibit VII-3 below presents those costs per crash. Costs for combinations of crash severity levels (e.g., K+A crashes) are presented in that report (22). This analysis of total crash cost will provide the analyst with overall information on which of these three illegal driver populations is most important in his/her jurisdiction. If only one of the illegal driver populations is being examined, the analysis can provide useful data for public information programs concerning the total cost of such crashes.

2. Prioritize the specific alcohol-related subpopulations to be addressed.

Once one or more populations are identified, the second step involves the identification of subgroups in most need of treatment. In general, the strategies in the guides

Crash Type/Issue	Variable	Crash Database Subfile
Driver Age	Driver Age	Person/Occupant or Vehicle
	Driver Date of Birth	Person/Occupant or Vehicle
Time of Crash	Light Condition	Crash
	Hour of Day	Crash
Speed-Related Crashes (for Aggressive Driving)	Driver Action Prior to Crash	Person (or Vehicle)
	Violation Indicated	Person (or Vehicle)
	Contributing Circumstances	Person (or Vehicle)
Crash Location (for Targeting Treatments)	County	Crash
	City	Crash
	Route	Crash
	Milepost	Crash
	Longitude/Latitude	Crash
	Block Address	Crash
Speed Limit (for Use in Developing Cost per Crash)	Speed Limit	Crash

Exhibit VII-2. Crash variables and subfile location by crash type/issue.

Crash Severity	Speed Limit Category	Comprehensive Cost/Crash*
Fatal (K)	≤ 45 mph	\$3,622,200
	≥ 50 mph	\$4,107,600
Serious injury (A)	≤ 45 mph	\$195,700
	≥ 50 mph	\$222,300
Moderate injury (B)	≤ 45 mph	\$62,200
	≥ 50 mph	\$91,600
Minor injury (C)	≤ 45 mph	\$40,100
	≥ 50 mph	\$49,500
No injury (O)	≤ 45 mph	\$7,000
	≥ 50 mph	\$7,800

* Crash Costs in 2001 dollars

Exhibit VII-3. Crash cost by crash severity level and posted speed limit (22).

for aggressive and unlicensed/suspended drivers are aimed at the entire population of such drivers. However, the strategies in the AR guide are essentially oriented to three different groups of illegal drivers – young drivers in AR crashes, all drivers in AR crashes, and repeat DUI offenders in AR crashes. The problem size (or total crash cost) for the first two groups can be calculated using the procedures in the above paragraph in combination with the “Driver Age” variable in the crash file. However, the isolation of alcohol-related crashes involving repeat DUI offenders will be much more difficult unless this group is identified by variables in the crash file. In a limited number of crash files, information will be added concerning whether a crash-related AR citation is the “first” or a “subsequent” offense. Those AR crashes coded as having a “subsequent” AR citation would be the target crashes. However, if this information is not available, then the analyst will have to rely on other data sources. If the analyst has a usable “driver history file” (see Section II) and if that file includes information on *crashes* (in addition to convictions), then he/she could use those data to estimate the number of crashes related to repeat offenders. (Note that the crashes counted should occur after or at the same time as the second or subsequent DUI offense.) If that driver-history file does not contain AR *crash* information, then the process will be much more difficult. The analyst will have to use the driver-history file to identify the population of repeat offenders based on the number of past AR convictions. This group would then have to be matched to the crash files for the time period under examination (say, by driver license number, which is usually found on both files), and specifically to crashes that occur either after or at the same time as the second or subsequent AR offense. The identified crashes would then have to be further screened to determine which are alcohol-related before the estimate could be made. Finally, if the state has a citation tracking system that includes information on crash occurrence in conjunction with an AR citation, this could provide the needed crash-related counts. If the number of

repeat-offender crashes cannot be calculated, then the analyst could not use this modified Procedure 3 to choose between AR groups, but could use the *program-deficiency* procedure described following this procedure later in this section to make AR treatment choices.

Note that the number of crashes involving a repeat offender will almost always be a very small part of all AR crashes in any jurisdiction. Thus, if the choice of AR strategies is to be based primarily on the size (or economic harm) of the crash problem, the AR strategies related to total AR crashes or AR crashes involving young drivers will always be the choice. However, calculating the number of repeat-offender crashes when possible will provide the analyst (and the public) with solid information on the relative size of that part of the AR crash problem.

3. Identify possible treatments for use for each high-priority illegal driver group.

The analyst will then review the pertinent *NCHRP Report 500* series guides and list treatments that would be most appropriate for each of the high-priority illegal driver groups identified in the above step. The choice should be limited to those treatment strategies that are classified as *proven* or *tried* in the guides.

4. Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular user group, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective. This judgment will be most difficult for the aggressive-driver strategies, where there is essentially no information on crash-related effectiveness. The judgment will be somewhat easier for the strategies in the other two guides since they contain some information on estimated effectiveness for some of the strategies.

5. Choose best treatment(s) by considering estimated effectiveness, cost and other technical and policy considerations.

The analyst will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost of the treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The analyst will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined.

The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected.

6. Target the chosen treatments to the user populations where the problem is found.

In some cases, treatment strategies related to illegal drivers will be implemented jurisdiction-wide. In other cases, it may be desirable to target the treatment to either a subgroup (e.g., young AR drivers), to specific locations (e.g., specific counties, route sections, or intersections), or to specific time periods (e.g., DUI checkpoints at night). However, unlike most strategies in other guides, the strategies described in these three guides do not lend themselves to a great degree of additional targeting in many cases. Some of the strategies in Volume 1, the Aggressive Driving Guide (e.g., “Targeted Enforcement”), and Volume 16, the AR Guide (e.g., DUI checkpoints), could be targeted to high-priority locations or high-priority times of day based on crash occurrence. (They could also be targeted based on citation data that include the location of the offense, assuming that such enforcement is somewhat “random” across the jurisdiction.)

If targeting is to be done by location, the treatment could be targeted to counties, city areas, or routes/streets showing the highest total crash cost or frequency, coupled with the analyst’s judgment of potential differences in cost between locations and technical and political issues. If the crash data are mileposted, the analyst could (1) link illegal driving crashes to routes and search for the locations of “clusters” of target crashes for possible treatment, or (2) use a network screening program similar to that described under Procedure 2A to identify 1-mile sections with the highest crash frequency or total crash cost. The windows identified by the network screening program could then be ranked by crash frequency or total crash cost to identify priority locations. The analyst would then correct for “treatment gaps” using the same logic provided in Procedure 2A (see Section IV). If the crashes are not mileposted, but there is information available on jurisdiction and route, the analyst could link crashes to routes within the jurisdiction and calculate the total crash cost or number of target crashes per mile by dividing the sum of the crash costs or the sum of the number of target crashes on that route by route length. Then rank the potential routes for treatment based on this rate per mile. The analyst could then choose the routes to be treated based on the highest rankings plus other technical and policy factors.

Note again that the lack of treatment effectiveness data means that the analyst will not be able to verify whether or not a specific set of implemented strategies can be expected to meet the established crash-reduction goal. In these cases, the best that can be done is to proceed in selecting strategies and

target subgroups, times or locations until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined by conducting a sound evaluation after its implementation.

Where quantitative estimates or approximations of treatment effectiveness can be made, it may be possible to provide estimates of net impact (number of crashes prevented) by multiplying the unit treatment effects by the number of drivers or roadway segments treated. This should be possible for many of the alcohol and unlicensed/suspended/revoked driver treatments but would appear unfeasible for aggressive driver treatments due to lack of treatment effect estimates and absence of data on the population volume of such drivers.

Alternative Economic Analysis Procedure – Choosing Treatments and Target Subgroups for Alcohol-Related Crash Strategies When Treatment Effectiveness in Terms of Alcohol-Related Crash/Injury Reduction Can Be Estimated

This second procedure for AR crash strategies is a modification of the economic analysis procedures found in Procedures 1, 2a and 2b. However, the emphasis here is not on mileposted vs. un-mileposted crashes, or on the presence or absence of roadway inventory data. While programs related to illegal driving could be targeted based on crash location (e.g., to roadways around alcohol outlets which might generate increased AR crashes), the more likely targeting is to subpopulations of drivers (e.g., young drinking drivers or repeat offenders). The procedure here assumes that effectiveness factors for the strategies are known or can be estimated. Close review of the “Effectiveness” sections for strategies in *Volume 16: A Guide for Reducing Alcohol-Related Collisions* indicates that estimates of AR crash reductions are possible for some of these treatments. (Indeed, it may also be possible to estimate the crash-related effectiveness of some of the strategies found in *Volume 2: A Guide for Addressing Collisions Involving Unlicensed Drivers and Drivers with Suspended or Revoked Licenses*.) If those treatments for which effectiveness can be estimated are being analyzed, the following procedure can be used. Additional estimates of reductions may result from future research efforts.

Data Needs

The data needed for this procedure will be the same as described in the modified Procedure 3 above – data that will allow the analyst to (1) isolate crashes involving the specific user population of interest (e.g., young drivers involved in alcohol-related crashes) and (2) define the specific crash types involving drivers in each subgroup of interest (Exhibit VII-4).

Population Type	Variable	Crash Database Subfile
Drivers Involved in Alcohol-Related Crashes	Alcohol Involvement	Crash
	Law Enforcement Suspect	Person/Vehicle
	Alcohol Use	Person/Vehicle
	Alcohol Test Violation Codes	Person/Vehicle
Young Drivers Involved in Alcohol-Related Crashes – Use “Driver Age”	Driver Age Driver Date of Birth	Person/Occupant or Vehicle
Repeat DUI Offenders Involved in Alcohol-Related Crashes	The isolation of alcohol-related crashes involving repeat DUI offenders might require a usable “driver history file.” See discussion above under Procedure 3 concerning how this might be accomplished.	

Exhibit VII-4. Crash variable and subfile location by population type for alcohol-related crashes.

Additional data related to economic cost associated with different crash types and program costs will be described below.

Procedure

1. Specify the AR target groups of interest – young drivers, all drivers, repeat offenders.

Note that some of the strategies in Volume 16 are only appropriate for certain subgroups. It is suggested that the analyst consider all three subgroups in the initial analysis.

2. Estimate the annual number of affectable AR crashes for the target group or groups of interest.

This can be done by defining group-specific crashes (e.g., AR crashes involving young drivers or all drivers) using the crash variables in the table above and analyzing 3 to 5 years of crash data. Averaging over this longer time period will provide a more stable estimate of annual crashes. As noted in the discussion under Procedure 3 above, the difficulty will be in isolating AR crashes involving repeat DUI offenders unless the crash file contains information on prior violations. Once identified, a crash-based file should be developed for each subgroup of interest (i.e., one analysis record per AR crash).

As indicated in the Procedure 3 discussion above, an alternative to using the crash file might be an analysis of DUI violation and crash data in the driver history file. This would be particularly true if one is estimating effectable AR crashes for repeat offenders. As noted there, this would only be possible if the driver history file (or a citation-tracking system) contains information on crashes that can be linked to specific DUI violations. If so, multiple years of the driver history file could be used in this analysis.

3. Categorize the AR crashes for each target group of interest into specific crash types.

This step can be omitted, using only total counts of crashes for each subgroup of AR drivers. However, much more precision in the economic estimates of crash costs

will be gained by this crash-type categorization. Here, the crashes should be categorized using the 22 crash types shown in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). This categorization will allow calculation of the economic cost of these crashes in the steps below. Note that even greater precision can be gained by further categorizing each crash type by speed limit (i.e., 45 mph and lower vs. 50 mph and greater) and by crash severity (i.e., K+A, B+C, no injury), since crash cost estimates are provided for those breakdowns in the same reference.

4. Estimate the number of AR crashes that can be reduced annually by each potential treatment.

This will be done by multiplying the annual number of AR crashes for each subgroup by the estimated percent reduction due to the treatment. These effectiveness estimates will be made by the user based on information found under the “Expected Effectiveness” section of the guide. If the crashes for each subgroup were further categorized by crash type (or crash type within speed limit and injury categories), calculate the reductions for each crash type in the same manner.

Care must be exercised in maintaining consistency in the unit of analysis. If the effectiveness data and treatments are in terms of drivers treated, the crash reductions represent number of crashes per, say, 100 drivers treated. If the effectiveness data are in terms of percentage of crashes reduced over some prior period or historical crash time series baseline, the net number of crashes reduced can be computed directly.

5. Convert the crash reductions to “economic benefits.”

This will be done by multiplying each calculated crash frequency reduction from the previous step by the appropriate crash cost from Council, et al. (22)

6. Calculate the total “economic benefit” for each subgroup.

If the analyst used only total counts of crashes for each subgroup of AR drivers in Step 2 (and skipped Step 3), then the total economic benefit will be calculated in Step

5, and this step may be skipped. If the analyst has used individual crash types (or crash types by severity and speed limit) in the above steps, those individual estimates within each subgroup must be summed to calculate the total economic benefit for each subgroup.

7. Define the annual cost for treating all drivers in each subgroup.

This will be an estimate of total program cost for each treatment under study and for each subgroup being considered. This assessment will require subjective approximations. Some general information on treatment cost is presented for each treatment in the guide, and that information should be reviewed by the user. Depending on the treatment, this cost may include start-up cost and cost per driver (i.e., all drivers that would need to be treated without knowing who will subsequently be involved in an AR crash). For other treatments, this may simply be an annual cost (e.g., for public information programs). Note that the total cost over the expected life of the project will need to be amortized to an “annual cost” basis, since the benefit calculations are in annual numbers [see *NCHRP Report 501 (18)*].

8. Calculate “net benefits” for each treatment by subtracting cost from benefits.

9. Choose the treatments (and thus treatment subgroups) with the greatest net benefit.

10. Decide whether to use multiple treatments.

After reviewing the prioritized listing of treatments and estimated costs, the analyst may decide to further determine whether multiple treatments would be beneficial. If the treatment combinations being considered affect *different* driver subgroups (e.g., one affects young AR drivers while the second affects [older] multiple offenders), then the net benefit of that combination will be the sum of the individual calculations from Step 8. However, this is not usually the case. Multiple treatment combinations will often affect the same subgroup even if they are aimed at different subgroups. In this case, Steps 2–8 will need to be repeated for each combination under study. Thus the potentially affected driver groups will be specified first, then the AR crashes will be calculated, etc.

Note, however, that one cannot expect that two treatments with estimated levels of effectiveness A% and B% will produce a reduction of A% + B% if applied to the same driver group. The combined effect would be expected to be less. Unfortunately, since we do not have good data on the effectiveness of individual treatments, we have even less knowledge about the effectiveness of combined treatments. In the absence of such knowledge, it is suggested that the effectiveness level of the second treatment applied to a given driver subgroup be reduced to 50 percent of the level originally estimated for that

treatment, and the effectiveness of the third treatment applied to the same driver subgroup be reduced to 25 percent of the original level. (Assume that any additional treatments after the third will have no additional effect.) For example, assume that the first treatment for a given AR subgroup has an effectiveness level of 20 percent, the second has an effectiveness level of 15 percent, and the third has an effectiveness level of 10 percent. The estimated *combined effectiveness* of the three treatments applied to the same segment would be $20\% + 15\% (.5) + 10\% (.25) = 30\%$. Again, this is only an estimate of the true combined effectiveness at best.

Alternative Procedure – Choosing Treatments and Target Subgroups for Alcohol-Related Crash Strategies Based On Existing DWI Program Needs

The above two procedures for choosing treatments and subgroups have been based on the size of the alcohol-related crash problem among different target subgroups of drivers and, in the second procedure, on estimated treatment effectiveness. Both are based on crash data, which make them the recommended procedures to follow. However, in the absence of crash data, a third alternative procedure that is advocated in Volume 1, the AR Guide, is to conduct a *careful assessment of the nature of the jurisdiction’s drinking-driving problem and how the DWI countermeasure system is currently functioning*. The choice of AR treatment strategies from those listed in the guide (and thus the choice of target subgroups) would be based primarily on “current AR program needs” – strategies that are not currently being implemented, or whose implementation can be significantly improved. This assessment of current program needs requires a multidisciplinary team, since the system for dealing with alcohol-impaired driving may be the most complex and involve the greatest number of disciplines and state agencies of any traffic safety issue. States frequently use a task force that represents all the key elements of this system. Without such an approach, a fragmented and incomplete understanding of the problem is likely and progress will be difficult.

The National Highway Traffic Safety Administration (NHTSA) works with highway safety offices within states to facilitate such an assessment procedure using outside experts. A brief description of NHTSA’s program assessment process can be found at <http://www.nhtsa.dot.gov>. A more detailed description of this process for impaired driving and recent findings from such assessments can be found at <http://www.nhtsa.dot.gov/cars/rules/regrev/evaluate/809815/index.html>.

Finally, it is strongly recommended that the findings of an assessment of program needs be combined with crash-based information on the size of the AR problem attributable to

each of the three subgroups of AR drivers (i.e., young AR drivers, all AR drivers, and repeat offenders) using the analyses defined in Step 1 of Procedure 3 above. This would provide information on not only which program components need strengthening, but also the size of the AR crash problem that might be affected by different improvements.

The above approach could also be applied to the unlicensed/suspended/revoked driver problem. A large percentage of suspended/revoked drivers have been suspended or revoked for driving under the influence and there is considerable overlap in the proposed treatment strategies.

Closure

Choosing treatments and targeting those treatments to the three illegal driving populations covered in this section is difficult. The programs are complex, there is limited crash-based information on treatment effectiveness for the strategies covered in the three guides, and there is limited information on program costs. However, choices have to be made given that available budgets will always be limited to some degree. It is hoped that the procedures presented in this section at least provide some insight into how such choices can be made.

SECTION VIII

Unsafe Driver Actions

Planning Programs Related to Reducing Crashes Involving Distracted and Fatigued Drivers and Unbelted Vehicle Occupants

This section of the guide presents a strategy for selecting treatments to reduce crashes involving distracted and fatigued drivers and unbelted vehicle occupants. As noted earlier, it is assumed that a safety planning team has selected one or more of the above emphasis areas as part of its safety plan and has established a “stretch goal” as described in Section I. Four procedures for choosing treatment strategies and target groups were described in Section III of this guide. Three of these procedures require known estimates of effectiveness (crash reduction and benefit-costs) for some or all of the selected strategies – in other words, that the treatments have known CRFs or AMFs. However, in general, the two guides considered here identified strategies that do not completely meet this requirement even though many of the strategies are supported by compelling evidence of significant crash reduction. The major exceptions to this situation are a subset of proposed strategies related to distracted and fatigued drivers, strategies related to improving the roadway to prevent lane departure, and intersection crashes involving these drivers. Some of these strategies could be analyzed using procedures 1, 2, and 2A since AMFs are known. The user is referred to Sections IV and V if analyzing those strategies with known effectiveness. What is generally lacking for other strategies in these two guides are precise estimates of the *magnitude* of the crash reduction that could be used in the development of an estimated B/C ratio. The latter, in turn, also requires known estimates of treatment costs and effects on crash severity, which are often lacking. Thus, we know in some cases that the treatment reduces crashes but not by how much or in terms of net cost-benefits.

It should be noted that some strategies aimed at drowsy drivers are also beneficial for impaired drivers. For example,

edgeline and centerline rumblestrips may help alert the drowsy driver and also may help keep impaired drivers from leaving their travel lane. The traffic engineer should use his or her judgment to determine which subset of crashes or driver population may be affected by each treatment application being considered. The benefits of a given treatment may be greater, and therefore worth more investment, when other target populations or crash types are also positively impacted.

Procedure 3, as described in Section III, outlined an approach for selecting strategies in the absence of known crash effectiveness estimates (AMFs or CRFs) and B/C ratios. This procedure is designed for use with treatments where crash reduction effectiveness has not been established. Many of the treatments related to unsafe driver actions fall into this category, and that procedure will be presented below.

The safety planning team is strongly urged to carefully review the material in each of the pertinent guides before beginning the planning process. These user-population oriented guides are found within *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan*. The specific volumes pertinent to this section on illegal driving acts are:

- *Volume 11: A Guide for Increasing Seatbelt Use (11)*
- *Volume 14: A Guide for Reducing Crashes Involving Drowsy and Distracted Drivers (14)*

A link to these downloadable guides can be found in <http://safety.transportation.org/guides.aspx>. The planning team is also encouraged to review *NCHRP Report 501 (18)* for a detailed description of an integrated problem identification and safety planning process.

General Strategic Considerations

As noted earlier, data for estimating precise AMFs, CRFs and B/C ratios for many of the driver-oriented and vehicle-

occupant-oriented strategies do not exist. There are also some other differences between highway-oriented strategies and driver-oriented strategies that need to be recognized in selecting treatment programs and establishing crash-reduction goals. The first relates to the data source and “ownership” of the treatment delivery system. In contrast to many of the highway countermeasures, most of the effectiveness measures for these driver and vehicle occupant strategies do not relate to crash rates on sections or type of roads. Instead, the safety concern usually relates more to overall crash rates, perhaps subdivided by severity. The data on which problem driver identification and effectiveness measurements are based (traffic convictions and crashes) usually reside in DMV files. The information on previous convictions may sometimes be added to crash files.

It will also be noted that some of the strategies proposed in the guides could require the enactment of legislation, depending on the state in question. For example, increasing seat belt usage may require upgrading from secondary to primary enforcement legislation. Selection of a strategy requiring legislation entails an assessment of the likelihood that the legislation could be enacted in the required time-frame.

Another consideration is cost. An assessment of cost for many of the proposed strategies will require subjective approximations. Some general information on treatment cost is presented for each treatment in both of the guides, and that information should be reviewed by the user. Very costly strategies should be avoided unless supported by proven effectiveness data and an estimated effect size that is sufficient in economic terms (dollar benefits) to be cost-beneficial or cost-effective. Strategies that are judged to have negligible or moderate operational costs (excluding start-up) will usually be cost-beneficial if they produce statistically significant annual crash reductions as small as 5–10 percent over baseline.

The guides classify strategies into three categories:

1. *Proven*
2. *Tried* but not proven
3. *Experimental* – not tried, effectiveness unknown

In selecting treatment strategies, priority should be given to strategies rated as proven. However, the safety planning team is encouraged to use their own judgment and to independently review the evidence cited in the guides in selecting treatments. The *tried* category includes those treatments that have been used by agencies (in some cases used often), where there is little possibility of negative impacts on crash/injury frequency, and where there is an expectation (but not scientific proof) that the effect of the treatment on safety is likely to be a positive one. The evidence could include poorly designed or executed crash/injury evaluations and indirect or

surrogate measures that may be related to safety (e.g., behavioral changes that may be related to crash/injury reduction).

As noted earlier, if the user is considering roadway-related strategies for drowsy and distracted drivers described in the related guide, and if the considered strategies have known effectiveness measures, then Procedures 1, 2A, and 2B in Sections IV and V should be used. The issue here will be defining the proportion of all drivers involved in lane-departure crashes or intersection crashes who are drowsy and distracted. Some guidance on defining such drivers will be given under “Data Needs” below. For the remaining strategies which do not have known effectiveness (AMF) measures, the recommended method for choosing and targeting strategies is a modified version of Procedure 3 described in Section III. This procedure could be used for any of the unsafe driving strategies found in either of the two guides.

Procedure 3 – Choosing Treatments and Target Subgroups Related To Unsafe Driving Actions When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Unknown

The assumption here is that, for the majority of the strategies, there is no known level of effectiveness – no defined CRFs or AMFs. Thus, economic analyses like those that are the basis for Procedures 1, 2A and 2B, and 4 are not possible for these treatments. Procedure 3 is aimed at helping the analyst make an educated choice of which treatments will be most effective in his or her jurisdiction, and to help the analyst develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide or to the “total problem” (e.g., where specific unsafe-driver subpopulations or jurisdictions are to be targeted).

However, unlike road user populations covered in other guides (e.g., older drivers or pedestrians), the choice between alternative treatment strategies found in each of these two unsafe-driving guides is much less oriented to specific crash circumstances such as different crash types, crash location (except for the roadway-based strategies), and times of crash (except perhaps for drowsy drivers). Instead, most of the strategies are related to improvements in programs, such as increasing seatbelt usage. In addition, for both the guide related to drowsy and distracted driving and the guide related to increasing seatbelt usage, the strategies are related to the full group of such drivers and vehicle occupants who undertake such unsafe actions. Some limited subpopulation-targeting is possible for the occupant restraint strategies (children vs. other occupants) and for the drowsy and distracted driver strategies (i.e., teen drivers, adult drivers, and heavy truck drivers). Some additional targeting of a chosen strategy can occur based on jurisdiction and selected areas

within a jurisdiction. However, additional targeting based on crash types and other crash data are not generally applicable with these strategies.

For these reasons, the general analysis methods presented under Procedure 3 in other sections of this manual are not as applicable here. For that reason, only a modified Procedure 3 is presented below – one which continues to use relative estimates of the program effectiveness for different alternative treatments, but one that does not include further targeting steps based on crash circumstances.

Data Needs

Note that Procedure 3 is a “crash-based” procedure. It assumes that the analyst wishes to choose among the alternative strategies and target the treatments based on crash data. It is noted that an alternative way of making such choices is through linking crash data related to problem size to an assessment of the existing *programs* in a jurisdiction, and choosing to implement those strategies which are either missing from the current program or have the least extensive (or least effective) degree of implementation. This *program-deficiency* procedure is described more fully in a later section.

However, if the analyst wishes to choose and target treatments based on crash data, the revised Procedure 3 described here basically requires crash data that will allow the analyst to (1) isolate crashes involving the specific user population of interest (e.g., drivers involved in fatigue-related crashes or crashes involving unbelted vehicle occupants), and (2) define crash types or crash characteristics (e.g., crashes involving unbelted occupants in specific age ranges) for this user population which would suggest strategies and target subgroups.

To isolate crashes involving the population of interest, the analyst will need to examine the data formats/coding in their crash file to identify variables that can be used in determining whether or not a given crash is a “target-population crash.”

Crash databases often categorize data for a given crash into up to three subfiles – (1) general accident/crash variables (“crash”), (2) variables for each vehicle in the crash (“vehicle”), and (3) variables for each occupant/person in the crash (“person” or “occupant”). The variables needed to determine whether a crash is a “target-population crash” are usually found in the occupant/person subfile, but could also be found in the general crash subfile (e.g., a “flag” for head-on and run-off-road crashes in general) or “vehicle” subfile (e.g., driver information included with each vehicle record). In short, crash files differ from jurisdiction to jurisdiction. While certainly not always the case, the variables (or similar variables) listed in Exhibit VIII-1 will be used in this identification of “target-populations.” Thus, the defining variables will depend on the user’s definition of fatigue-related crashes (e.g., late-night crash involvement with no indication of DUI, especially head-on or run-off-road crashes). Drivers involved in nighttime crashes, especially those who are not under the influence of alcohol, are a logical subpopulation to consider for fatigue involvement, although fatigue involvement can also clearly occur during other time periods as well, and treatments that help drowsy drivers may also help drivers who are under the influence of alcohol. Research on human circadian rhythms indicates that early afternoon is also a period when drowsiness is likely. Since there is no broadly accepted definition of distracted driving crashes, defining specific crash types related to distracted driving may be difficult or impossible. Some crash files may include a variable on “distraction.” Indeed, the MMUCC guidelines for crash variables include such variables (i.e., P16. “Driver Distracted By”). Narratives written by the investigating officer may include driver and witness reports and the officer’s own impressions about possible distractions or fatigue. While reading narratives on every crash report can be much more time-consuming than simply scanning for a coded “distraction” variable, these statements can provide a wealth of information on the

Population Type	Variable	Crash Database Subfile
Drivers Involved in Fatigue-Related Crashes	Fatigue Involvement Captured under “Driver Condition” (If Available)	Person/Vehicle
	Alcohol Involvement	Person/Vehicle/Crash
	Time of Day	Crash
	Violation Codes	Person/Vehicle
	Driver Action Prior to Crash	Person (or Vehicle)
	Violation Indicated	Person (or Vehicle)
Distracted Drivers	Contributing Circumstances	Person (or Vehicle)
	Driver Distracted By	Person
	Driver Condition	Person/Vehicle
	Driver Action Prior to Crash	Person (or Vehicle)
Unbelted Vehicle Occupants	Contributing Circumstances	Person (or Vehicle)
	Seatbelt Usage	Person
	Injury Severity	Person/Vehicle
	Crash Type	Crash

Exhibit VIII-1. Crash variables and subfile location by population type.

circumstances surrounding the crash. It must be noted that “distraction” variables are very likely less reliable than other police collected variables since they must be based either on information provided by the driver (which can be self-serving) and/or on very difficult conclusions drawn by the investigating police officer who was not on the scene or in the vehicle at the time of the crash. However, this may be the only data available, unless the user can define distraction/inattention in some alternative manner. Seatbelt usage for vehicle occupants can be based on data from the officer’s investigation of a crash. However, like distraction/inattention data, such data will not always be as accurate as we would hope because the officer has to base his/her judgments on after-crash observations and occupant/witness statements. Some occupant statements may be untrue, particularly in states with mandatory belt usage laws.

As noted above, some of the strategies described in these two guides are directed to specific driver/occupant ages and types of drivers. The roadway-related strategies noted for fatigued and distracted drivers can be targeted to specific roadway location if Procedures 1, 2A, and 2B are used, but are difficult to target under this modified Procedure 3. For this limited additional targeting, the names of crash variables and the specific codes needed to conduct these targeting analyses will vary from jurisdiction to jurisdiction. While not all relevant crash variables are presented here, Exhibit VIII-2 provides some guidance concerning where example variables related to some treatment strategies might be found.

Procedure

As described in Section III, Procedure 3 has two basic steps. First, choose the “best treatments” for the user population of interest (e.g., the treatments related to fatigue-related crashes

or crashes involving unbelted vehicle occupants most likely to be applicable in a given jurisdiction) from among the set of all treatments presented in the applicable *NCHRP Report 500* guides. Second, where appropriate, choose the subgroups of users (e.g., young drivers or older drivers), highway locations, or times of day to which the selected treatments should be applied.

As described earlier in more detail, the choice of the “best treatments” from the listing of many potential user-population treatments can be based on the following factors:

- a) The potential treatment judged to be the most effective, even given that effectiveness is unknown
- b) The relative magnitude of the crash types and severity levels that the treatment will affect
- c) The cost of the potential treatments (either jurisdiction-wide or per-mile or per-location)
- d) Other technical or policy considerations

These factors must be combined in some fashion to determine which treatment to choose. While there are multiple ways of making this choice, the following represents one such procedure.

1. Prioritize the specific user-population problem(s) to be addressed.

An initial issue may be whether to treat one, two or all three of the groups covered in these guides – drowsy drivers, distracted drivers, and unbelted vehicle occupants. This decision can be based on the frequency and severity of the specific types of user-population crashes occurring in an analyst’s jurisdiction. Crashes specific to a given user-population were defined in the table above. For each user population, the analyst could begin the process by

Crash Type/Issue	Variable	Crash Database Subfile
Driver Age	Driver Age Driver Date of Birth	Person/Occupant or Vehicle Person/Occupant or Vehicle
Occupant Age (for Child Restraint Strategies)	Occupant Age	Person/Occupant
Time of Crash	Light Condition Hour of Day	Crash Crash
Vehicle Type (to Identify Large Truck Drivers)	Vehicle Type Motor Vehicle Body Type Category Commercial Motor Vehicle Configuration	Vehicle Vehicle Vehicle
Crash Location (for Targeting Treatments)	County City Route Milepost Longitude/Latitude Block Address	Crash Crash Crash Crash Crash Crash
Speed Limit (for Use in Developing Cost per Crash)	Speed Limit	Crash

Exhibit VIII-2. Crash variables and subfile location by crash type/issue.

analyzing 3 to 5 years of crash data to determine the frequency of each crash population – either total crashes or some subset (e.g., fatal and serious-injury crashes). However, since the severity distribution may differ between some populations, and since restricting the analysis to only fatal and serious-injury crashes will severely limit the crash sample and will omit a large component of the crash problem – non-serious injury and no-injury crashes – a better solution is to weight each crash for a given user population by an economic cost based on its severity, and then accumulate the total cost of crashes for each population. Information on economic cost per crash severity level can be found in *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). Here, instead of using severity cost by crash type as is done in roadway-program analyses covered in earlier sections, the analyst will use the basic cost per crash categorized by police-reported severity level (i.e., K,A,B,C,O). Exhibit VIII-3 below presents those costs per crash. Costs for combinations of crash severity levels (e.g., K+A crashes) are presented in that report (22). This analysis of total crash cost will provide the analyst with overall information on which of these three unsafe driver/occupant populations is most important in his/her jurisdiction. If only one of the unsafe driver/occupant populations is being examined, the analysis can provide useful data for public information programs concerning the economic cost of such crashes.

2. Prioritize the specific subpopulations to be addressed.

Once one or more populations are identified, the second step involves the identification of subgroups in most need of treatment. Some strategies in each of the two guides can be applied to all drivers or occupants, and thus all crashes involving the population of illegal drivers are treatable. However, certain strategies in each of these two guides are only applicable to certain user subgroups (e.g., child vs. adult restraint strategies or fatigue strategies for passenger car drivers vs. heavy truck drivers). In order to analyze the possible benefit of these strategies, crashes in-

Crash Severity	Speed Limit Category	Comprehensive Cost/Crash*
Fatal (K)	≤ 45 mph	\$3,622,200
	≥ 50 mph	\$4,107,600
Serious injury (A)	≤ 45 mph	\$195,700
	≥ 50 mph	\$222,300
Moderate injury (B)	≤ 45 mph	\$62,200
	≥ 50 mph	\$91,600
Minor injury (C)	≤ 45 mph	\$40,100
	≥ 50 mph	\$49,500
No injury (O)	≤ 45 mph	\$7,000
	≥ 50 mph	\$7,800

* Crash Cost in 2001 dollars

Exhibit VIII-3. Crash cost by crash severity and posted speed limit (22).

volving only the applicable subpopulations must be identified and analyzed. Here, just as in Step 1, the prioritization of subpopulations can be based on the frequency and severity of the specific types of user-subpopulation crashes occurring in an analyst's jurisdiction. Crashes specific to a given user-subpopulation can be defined using variables in the table above (e.g., occupant age for child restraint programs or vehicle type for heavy-truck driver programs). For each user subpopulation, the analyst could analyze 3 to 5 years of crash data to determine the frequency of each crash population. Again, either total crashes or some subset (e.g., fatal and serious-injury crashes) could be used, but the economic cost of crashes is a better measure since crash severity may differ. The same cost figures presented above could be used.

Note that using these crash costs to develop the economic harm of crashes involving unbelted children will likely result in conservative estimates of that economic cost. These cost-per-crash estimates in Council, et al. (22) were based on standardized populations of vehicle occupants by age and belt usage. Components of these costs related to lost wages and other factors would be greater for fatally injured children than for older populations. However, it is felt that even though perhaps conservative, they are suitable for this use.

3. Identify possible treatments for use for each high-priority unsafe driver group.

The analyst will then review the pertinent *NCHRP Report 500* guides and list treatments that would be most appropriate for each of the high-priority unsafe driver groups identified in the above step. The choice should be limited to those treatment strategies that are classified as *proven* or *tried* in the guides.

4. Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular user group, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective. The judgment will be somewhat easier for the strategies in these two guides since there is some information available on estimated effectiveness for some of the strategies.

5. Choose best treatment(s) by considering estimated effectiveness, cost and other technical and policy considerations.

The analyst will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost of the treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to

“weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The analyst will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined. The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected. The roadway-oriented treatments for drowsy and distracted drivers (e.g., shoulder and centerline rumble strips) are also included in the *NCHRP Report 500* guides discussed in Section IV of this guide and are best addressed with the procedures presented there.

6. Target the chosen treatments to the user populations where the problem is found.

If targeting is to be done by location, the treatment could be targeted to counties, city areas, or routes/streets showing the highest total crash cost or frequency, coupled with the analyst’s judgment of potential differences in cost between locations and technical and political issues. Mileposted crash data could be used as discussed in Section III for Procedure 2A to target specific roadways for enforcement related to fatigued drivers. However, for enforcement related to unbelted occupants, targeting of communities identified from crash data as having the most crashes involving unbelted occupants (per person, per road mile, or per vehicle-mile of travel) may provide the best targeting method. Crash data may also be useful in targeting specific age groups that are being injured as unbelted occupants. Targeting information might also be extracted from observational seatbelt use studies done within specific states.

Note again that the lack of treatment effectiveness data means that the analyst will not be able to verify whether or not a specific set of implemented strategies can be expected to meet the established crash-reduction goal. In these cases, the best that can be done is to proceed in selecting strategies and target subgroups, times or locations until the available budget

for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined if a sound evaluation is conducted after its implementation.

Where quantitative estimates or approximations of effectiveness can be made for treatments aimed at distracted or fatigued drivers, it may be possible to provide estimates of net impact (number of crashes prevented) by multiplying the unit treatment effects by the number of drivers or roadway segments treated. Since passenger restraint strategies will not prevent crashes, and because it is difficult to estimate the increase in belt use as a result of any specific program or to translate that increase into a well-defined reduction in injury severity, providing estimates of net impacts for these treatments is more difficult. Seatbelt strategies are most effective in communities and among populations where usage rates are the lowest and there is the greatest room for improvement. And because the proper use of restraint systems is so effective at reducing injury level in crashes, it is important to continue to develop and implement effective programs aimed at increasing restraint use in these communities and among these populations.

Closure

Choosing treatments and targeting those treatments to the unsafe driving populations covered in this section are difficult. The programs are complex, there is limited crash-based information on treatment effectiveness for the strategies covered in the two guides, and there is limited information on program costs. However, choices have to be made given that available budgets will always be limited to some degree. Because programs aimed at these targeted populations are much more focused on driver behavior, they often deal with educational and enforcement-related programs more than traditional engineering treatments. The application of these types of programs is usually more flexible in nature and costs for implementation can be more easily adapted to a budget of any size. It is hoped that the procedures presented in this section at least provide some insight into how budgetary choices can be made.

SECTION IX

Special Vehicles

Planning Programs Aimed at Reducing Crashes Involving Large Trucks and Motorcycles

This section of the guide provides the details of choosing treatment strategies for reducing crashes involving special vehicle types, such as large trucks and motorcycles. As indicated earlier, it is assumed at this point that the analyst has chosen his or her emphasis area or areas (e.g., large trucks or motorcycles) and has established a stretch goal for crash reduction. Four procedures for choosing and targeting treatment strategies were described in the Stage 3 text in Section III. Three of those procedures require that the effectiveness of at least some of the potential treatment strategies be known – that the treatments have a known CRF or AMF. However, almost none of the strategies in the guides related to these special vehicle types have known effectiveness. For that reason, only the details of Procedure 3 will be covered in this section. If AMFs are developed for treatments for these populations, or if the analyst is only interested in examining the few treatments with known AMFs, then the economic-based Procedures 1 or 2 can be used. If AMFs exist for some of the treatments of potential interest but not for all (which will likely be the case in the near future), Procedure 4 can be used. While the crash types will differ, details of the use of all three of these “known-effectiveness procedures” are provided in Section IV on “Roadway Segment Programs.”

Thus, the basic steps in Procedure 3 presented below will be appropriate for all four of the special vehicle types covered in this section. The data will differ, but the basic procedure will remain the same. The analyst is *strongly urged* to carefully review the material in each of the pertinent guides before beginning this planning process. These user-population-oriented guides are found within the *NCHRP Report 500* guide series. The specific volumes pertinent to this section are:

- *Volume 13: A Guide for Reducing Collisions Involving Heavy Trucks (13)*

- *Volume 22: A Guide for Reducing Collisions Involving Motorcycles (pending)*

A link to these downloadable guides can be found at <http://safety.transportation.org/guides.aspx>.

Procedure 3 – Choosing Treatments and Target Subgroups for Crashes Involving Special Vehicle Types When Treatment Effectiveness in Terms of Crash/Injury Reduction Is Not Known

Again, the assumption here is that there is no known level of effectiveness for the treatment strategies of interest – no defined CRFs or AMFs. Thus, economic analyses like those that are the basis for Procedures 1, 2A, 2B, and 4 are not possible for these treatments. This Procedure 3 is aimed at helping the analyst make an educated choice of which treatments will be most effective in his or her jurisdiction, and to help the analyst develop a targeting strategy for the treatment in cases where it is not to be applied jurisdiction-wide (e.g., where specific vehicle subpopulations or roadway locations are to be targeted). In general, within each user group, the choice between alternative treatments will be based on the specific nature of the population’s crash problem, and the choice of target subgroups will be based on the determination of where the crash/injury problem of interest is found. A discussion of this more general procedure was included under the Procedure 3 subheading in Section III, and the reader should review that section.

Data Needs

The only required data for Procedure 3 are crash data that will allow the analyst to (1) isolate crashes involving the specific vehicle types of interest (e.g., large trucks or motorcycles), and (2) define crash types for these vehicle types that would suggest strategies and target subgroups.

To isolate crashes involving the vehicle types of interest, the analyst will need to examine the data formats/coding in his or her crash file to identify variables that can be used in determining whether or not a given crash is a “target-population crash.” Crash databases often categorize data for a given crash into up to three subfiles – (1) general accident/crash variables (“crash”), (2) variables for each vehicle in the crash (“vehicle”), and (3) variables for each occupant/person in the crash (“person” or “occupant”). The variable needed to determine whether a crash involves a specific vehicle type is, by definition, found in the vehicle subfile. Trucks and motorcycles are nearly universally among the vehicle types identified explicitly in the vehicle subfile data. There are state-to-state variations in the number and nature of truck type categories that are explicitly identified in crash data. Motorcycles are virtually never categorized into separate motorcycle types in crash data. Example variables used to identify these two vehicle types are shown in Exhibit IX-1 below.

Defining crashes that will guide the *choice of treatment strategy* and the *targeting* of these strategies will require crash data that includes specific variables and codes on such items as location of crash (intersection vs. non-intersection, ramp vs. mainline); condition of driver (e.g., impaired, fatigued); driver action prior to crash; driver license status (e.g., motorcycle license or endorsement); condition of vehicle, etc. Again, the names of variables and the specific codes needed to conduct these analyses will vary from jurisdiction to jurisdiction. Exhibit IX-2 provides some guidance concerning where example variables related to some treatment strategies might be found.

Procedure

As described in Section III, Procedure 3 has two basic steps. First, choose the “best treatments” for the user population of interest (e.g., the large truck or motorcycle treatments most likely to be applicable in a given jurisdiction) from among the set of all treatments presented in the applicable *NCHRP Report 500* guides. Second, choose the subgroups of highway locations to which the selected treatments should be applied. As described earlier in more detail, the choice of the “best treatments” from the listing of many potential user-population treatments can be based on the following factors:

- a) The many potential treatments judged to be the most effective, even given that effectiveness is unknown
- b) The relative magnitude of the crash types and severity levels that the treatment will affect
- c) The cost of the potential treatments (either jurisdiction-wide or per-mile or per-location)
- d) Other technical or policy considerations

These factors must be combined in some fashion to decide which treatment to choose. While there are multiple ways of making this choice, the following represents one such procedure.

1. Prioritize the specific user-population problem(s) to be addressed.

Here, the initial issue is whether to treat large truck crashes, motorcycle crashes or both. This prioritization will be based on the frequency and severity of the specific types of crashes by vehicle type occurring in an analyst’s jurisdiction. For each vehicle type, the analyst could begin the process by analyzing 3 to 5 years of crash data to determine the frequency of each population. However, since some crashes for specific vehicle types may vary in severity, total crash frequency alone does not provide the complete answer. While an alternative is to restrict the analysis to only fatal and serious-injury crashes, this will severely limit the crash sample, and will also omit a large component of the crash problem – non-serious injury and no-injury crashes. A better solution is to weight each crash for a given user population by an economic cost based on its severity, and then accumulate the total crash cost for each population. In the preceding sections of this guide, information on economic cost per crash severity level was extracted from *Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries* (22). Exhibit IX-3 presents those costs per crash. Costs for combinations of crash severity levels (e.g., K+A crashes) are presented in that report (22). This analysis of total crash costs per year will provide the analyst with overall information on which vehicle types are most important in his/her jurisdiction.

Note that the total crash cost calculated using these severity-based figures may not be as accurate for motorcycle

Population Type	Variable	Crash Database Subfile
Drivers of Heavy Trucks	Vehicle Type	Vehicle
	Motor Vehicle Body Type	Vehicle
	Commercial Motor Vehicle Category	Vehicle
	Commercial Cargo Body Type	Vehicle
Motorcycle Operators	Vehicle Type	Vehicle
	Motor Vehicle Body Type Category	Vehicle

Exhibit IX-1. Crash variables and subfile location by population type.

Crash Type/Issue	Variable	Crash Database Subfile
Intersection vs. Non-intersection; Ramp-related	Relation to Junction Type of Intersection Traffic Control Device Type	Crash Crash Crash or Vehicle
Lane Departure (Potentially Related To Pavement Markings)	Accident/Crash Type Manner of Collision Sequence of Events First Harmful Event Most Harmful Event Crash Location (Off-road)	Crash Crash Vehicle Crash Vehicle Crash
Vehicle Equipment Problems	Vehicle Defect Contributing Circumstances, Motor Vehicle	Vehicle Vehicle
Fatigue-related Crashes	Fatigue Involvement Captured under "Driver Condition" (If Available)	Person/Vehicle
Alcohol-involved Crashes	Alcohol Involvement Law Enforcement Suspect Alcohol Use Alcohol Test Violation Codes	Crash Person/Vehicle Person/Vehicle Person/Vehicle
Speed-related Crashes	Driver Action Prior to Crash Violation Indicated Contributing Circumstances	Person (or Vehicle) Person (or Vehicle) Person (or Vehicle)
Work Zone Crashes	Work Zone Related Roadway Condition	Crash Crash
Driver Age	Driver Age Occupant Age Seating Position	Person (or Vehicle) Person Person
Motorcycle Helmet Use	Occupant Protection System Used	Person (or Vehicle for Driver)
Driver License Status/ Motorcycle Endorsement	Driver License Class Driver License Status Violation Codes	Person (or Vehicle) Person (or Vehicle) Crash or Vehicle
Driver Clothing	Driver Protective Equipment (maybe)	Person or Vehicle
Crash Location (for Targeting Treatments)	County City Route Milepost Longitude/Latitude Block Address	Crash Crash Crash Crash Crash Crash
Speed Limit (for Use in Developing Cost per Crash)	Speed Limit	Crash

Exhibit IX-2. Crash variables and subfile location by crash type/issue.

Crash Severity	Speed Limit Category	Comprehensive Cost/Crash*
Fatal (K)	≤ 45 mph	\$3,622,200
	≥ 50 mph	\$4,107,600
Serious Injury (A)	≤ 45 mph	\$195,700
	≥ 50 mph	\$222,300
Moderate Injury (B)	≤ 45 mph	\$62,200
	≥ 50 mph	\$91,600
Minor Injury (C)	≤ 45 mph	\$40,100
	≥ 50 mph	\$49,500
No Injury (O)	≤ 45 mph	\$7,000
	≥ 50 mph	\$7,800

* Crash Cost in 2001 dollars (22)

Exhibit IX-3. Crash cost by crash severity and posted speed limit.

and truck crashes as for crashes covered in other sections. The costs per crash in Council, et al. (22) were based on the full distribution of crashes and vehicles in crashes, and thus are predominately weighted by passenger vehicles. They are not based exclusively on truck or motorcycle crashes. Thus, they are based to some extent on the expected number of occupants in all crash-involved vehicles who might be injured or killed in a crash of a given severity. Since heavy truck and motorcycle crashes involve a different mix of “occupants” than passenger cars, these figures may not be totally accurate. In the absence of other crash-cost figures, it is suggested that these be used for motorcycle crashes. They could also be used for truck crashes for consistency with other vehicle types. However, a second study by Zaloshnja and Miller (28) presented costs specific to truck-involved crashes. Exhibit IX-4 presents cost-per-crash by crash-severity level for “all large trucks” from that report. The Zaloshnja and Miller report (28) does not categorize the cost by crash types or speed limits, but does categorize them by different large truck types (e.g., straight trucks, bobtail, truck-tractor with one trailer). Note also that crash costs shown here are converted from Year 2000 costs in Zaloshnja and Miller to Year 2001 costs to be consistent with other costs in this guide. The conversion was based on changes in the Consumer Price Index and followed procedures recommended in that report.

2. Prioritize the specific subpopulations to be addressed.

Once one or more populations are identified, the second step involves the identification of subgroups in most need of treatment. Most of the strategies in the heavy truck guide are applicable to all truck crashes. Thus all crashes involving heavy trucks are treatable with these strategies. However, there are three truck strategies that appear to be more applicable to only selected crash types. The strategy related to truck rollover on interchange ramps is focused on this type of crash at this type of location. Strategies related to truck mechanical failure might be targeted to crashes involving truck defects, and the parking-related strategies might be considered applicable to fatigue-related truck crashes.

Many of the strategies in the motorcycle guide are also applicable to all motorcycle crashes. In the cases of the roadway-related strategies presented there, it is difficult to define specific crash types that might be analyzed since many of these are suggestions for changing roadway design and

maintenance problems (e.g., minimize roadway irregularities such as potholes and lower manhole covers, reduce roadway debris, reduce or eliminate use of low traction materials in roadway markings). It does not appear that examining only crashes related to poor road condition would capture all applicable motorcycle crashes. However, one could examine motorcycle crashes occurring in work zones to determine the possible problem size for the strategies related to those zones. It would also be possible to identify alcohol-related motorcycle crashes and crashes involving motorcycle operators who are either unlicensed or not licensed to operate a motorcycle. With respect to strategies related to protective equipment, it will be difficult to identify crashes where more protective or more reflective clothing might be needed, but will be much easier to identify crashes in which the motorcycle operator was not wearing a protective helmet.

In order to analyze the possible benefit of those truck or motorcycle strategies targeted to specific crash types or user subpopulations, crashes involving only the applicable subpopulations can be identified using variables in the table above (e.g., motorcycle operators not licensed to operate a motorcycle) and can be analyzed. Here, just as in Step 1, the prioritization of subpopulations can be based on the frequency and severity of the specific types of user-subpopulation crashes occurring in an analyst’s jurisdiction. For each user subpopulation or crash type, the analyst could analyze 3 to 5 years of crash data to determine the frequency of each crash population. Again, either total crashes or some subset (e.g., fatal and serious-injury crashes) could be used, but the economic cost of crashes is a better measure since crash severity may differ. The cost figures presented above could be used.

3. Identify possible treatments for use for each high-priority crash type.

The analyst will then review the pertinent *NCHRP Report 500* guides and list treatments that would be most appropriate for each of the high-priority crash types identified in the above step. The choice should be limited to those treatment strategies that are classified as *proven* or *tried* in the guides.

4. Rate the possible treatments based on “estimated effectiveness.”

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular vehicle type, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective. For example, strategies related to changing the roadway may be more effective, in general, than strategies related to education (but, of course, will affect only those users at the treated locations). At times, this will clearly be a very difficult judgment to make.

Crash Severity	Comprehensive Cost/Truck Crash*
Fatal (K)	\$3,370,648
Serious Injury (A)	\$138,841
Moderate Injury (B)	\$62,779
Minor Injury (C)	\$52,412
No Injury (O)	\$10,713

* Converted to 2001 dollars (28)

Exhibit IX-4. Truck crash cost by crash severity.

5. Choose best treatment(s) by considering estimated effectiveness, cost and other technical and policy considerations.

The analyst will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost of the treatment and other technical and policy considerations. Unfortunately, there are no good guidelines for how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The analyst will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined. The output of this step will be one or more chosen treatments, with the nature of the treatment defining the specific crash types more likely to be affected.

6. Target the chosen treatments to the vehicle types and crash types where the problem is found.

In some cases, treatment strategies related to these vehicle types will be implemented jurisdiction-wide. In other cases, it may be desirable to target the treatment to specific locations. If targeting is to be done by location, the treatment could be targeted to counties, city areas, or routes/streets showing the highest total crash cost or frequency, coupled with the analyst’s judgment of potential differences in cost between locations and technical and political issues. Most of the strategies in these two guides are related to treating the driver or vehicle, rather than the roadway, and this targeting to jurisdiction would appear to be the most appropriate. It would be difficult to target further by crash type or other factors. If the analyst is considering the roadway-related strategies, and if the crash data are mileposted, the analyst could (1) link crashes to routes and search for the locations of “clusters” of target crashes for possible treatment, or (2) use a network screening program similar to that described under Procedure 2A to identify 1-mile sections with the highest crash frequency or total crash cost. The identified windows could then be ranked by frequency or total crash cost to identify priority locations. The analyst would then correct for “treatment gaps” using the same logic provided in Procedure 2A (see Section IV). If the crashes are not mileposted, but there is information available on jurisdiction and route, the analyst could link crashes to routes within the jurisdiction and calculate the total crash cost or number of target crashes per mile by dividing the sum of the crash costs or the sum of the number of target crashes on that route by route length. The analyst could then rank the potential routes for

treatment based on this rate per mile, and choose the routes to be treated based on the highest rankings plus other technical and policy factors.

An excellent example of location-specific targeting that can be done if crashes are mileposted to specific roadway locations involves ramp treatments to prevent or reduce truck rollovers. If ramp-related crashes (based on “relation to junction”) are mileposted, even if just to the interchange mainline, the analyst can determine which specific interchanges and ramps exhibit the largest problem.

Note again that the lack of treatment effectiveness data means that the analyst will not be able to verify whether or not a specific set of implemented strategies can be expected to meet the established crash-reduction goal. In these cases, the best that can be done is to proceed in selecting strategies and target subgroups, times or locations until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined if a sound evaluation is conducted after its implementation.

Where quantitative estimates or approximations of treatment effectiveness can be made, it may be possible to provide estimates of net impact (number of crashes prevented) by multiplying the unit treatment effects by the number of drivers or roadway segments treated.

Closure – Good Data Produce Better Results

Choosing treatments and targeting those treatments to the vehicle populations covered in this section is difficult. The programs are complex, there is virtually no crash-based information on treatment effectiveness for the strategies covered in the two guides, and there is limited information on program costs. However, choices have to be made given that available budgets will always be limited to some degree. It is hoped that the procedures presented in this section at least provide some insight into how such choices can be made.

The assumption in this section has been that crash data are available, but not necessarily other data such as roadway inventories. As is obvious in the procedures above, the availability of *mileposted* crash data will result in improved treatment targeting for roadway-related strategies (and perhaps enforcement strategies), and the availability of linkable (and thus mileposted) inventory data would further increase the analyst’s ability to both choose treatment strategies and to target them. For example, inventory data could provide detailed data not found in crash data files on such items as signal timing, intersection layout, and street width, all of which are related to treatment strategies listed in the guides.

SECTION X

Reducing Crashes in Work Zones

The FHWA rule on work zone safety and mobility (31) specifies that each agency “develop and implement systematic procedures to assess work zone impacts in project development and to manage safety and mobility during project implementation.” This rule states that agencies “shall continually pursue improvement of work zone safety and mobility by analyzing work zone crash and operational data from multiple projects” (31).

Strategies to reduce work zone accidents can cover a broad spectrum of the roadway system. Every freeway, rural road or city street will at sometime in its life cycle be in a work zone. These work zones can vary in duration from a 1-hour crack sealing location, to a complete reconstruction lasting months or years. Exposure of road users to work zones is extremely difficult to measure and has been the subject of several research projects.

The work zone crash history is often similar to the crash experience of the roadway prior to work. It is recommended that the crash history of the roadway be reviewed as part of the work zone design process. While all crashes that occur during a work operation may be termed “work zone” crashes, it may be beneficial to examine other guides for reducing crashes in a specific area. For example, if there are a large number of single vehicle run-off-road crashes, the guide for reducing run-off-road crashes should be consulted.

Many agencies specify that project engineers collect data on work zone crashes that occur on their projects. While this procedure ensures that project personnel are aware of crashes taking place on their project, and analyses of these crashes may supplement other analysis, they do not involve the crash records system and therefore are not discussed in this guide.

In the FHWA rule on work zone safety and mobility the definition of work zone crash is as follows:

Work zone crash means a traffic crash in which the first harmful event occurs within the boundaries of a work zone or on an approach to or exit from a work zone, resulting from an activity, behavior, or control related to the movement of the traffic units

through the work zone. This includes crashes occurring on approach to, exiting from or adjacent to work zone that are related to the work zone (31).

Analysis of work zone crashes will be discussed in terms of the existence of three items or data files.

1. The existence of an item on the crash record that identifies the crash as a work zone crash. It is recommended that this work zone crash identifier be an explicit item that must be completed, if applicable, for each crash, rather than being one of many possible contributing circumstances that might be noted in a field such as “roadway defects.”
2. A work zone or project file that lists the location and dates of various work zones. This file may only contain data on construction projects of long-term duration, or may also include short-term maintenance and utility work zones.
3. Computerized roadway inventory data including traffic count data that can be linked to the crash data by location of the crash.

As discussed in Appendix 9 of *A Guide for Reducing Work Zone Collisions* (17), the Model Minimum Uniform Crash Criteria (MMUCC) recommends that four fields be collected on work zone crashes as follows:

1. Was the crash in or near the construction, maintenance, or utility work zone? If yes collect fields 2–4.
2. Location of the crash:
 - a. Before the first work zone sign
 - b. Advance warning area
 - c. Transition area
 - d. Activity area
 - e. Termination area
3. Type of work zone:
 - a. Lane Closure
 - b. Lane shift/crossover

- c. Work on shoulder or median
 - d. Intermittent or moving work
 - e. Other
4. Workers present?

Crash reduction strategies in work zones must first of all be effective for the type of road being worked on. Crash reduction factors are not known for work zone crash reduction strategies, but can be estimated for no-work zone conditions. For example, if shoulder rumble strips have a 0.80 CRF outside of work zones (i.e., result in a 20 percent reduction in run-off-road crashes), then a rough estimate of their effectiveness in work zones is the same 0.80 CRF.

Different levels of analysis can be undertaken depending on the types of crash, roadway, and work zone information available. Four levels of analysis are discussed based on data availability as follows:

- *Level 1 Analysis* – crash data include a work zone flag/variable, a complete highway inventory is available, and the location and date of all work zones from construction, maintenance and permits (utility) sections are available to link with the highway inventory.
- *Level 2 Analysis* – crash data include a work zone flag/variable and a roadway inventory is available, but there is no work zone file.
- *Level 3 Analysis* – crash data include a work zone flag/variable, but there is no work zone file or highway inventory.
- *Level 4 Analysis* – crash data do not include a specific variable indicating a work zone crash, but other fields such as a traffic control device or object struck contain information that can infer that the crash is a work zone crash. No work zone file or highway inventory is available.

Level 1 Analysis

The Level 1 analysis can be the most complete because data is available on the boundaries and duration of each work zone, the highway inventory can be searched for physical characteristics of the road where the work zone was located, and crashes identified as work zone crashes can be analyzed and compared to total accidents.

This analysis also can be used to compute exposure numbers for work zones and to compare crash rates for work zone and non-work zone conditions. The list below shows the types of analyses that can be completed for Level 1.

Summarize the following types of crashes:

- Crashes by road type
- Crashes by type of work (construction, maintenance, and utility)
- Crashes by crash type

- Crashes by project type (paving, bridge work, night work, etc.)
- Crashes by work zone type (lane closure, diversion, shoulder work, etc.)

Once these summaries are available, the following comparisons should be made:

- Work zone rates to non-work zone rates for road type and type of work.
- Work zone rates to non-work zone rates for work zone type
- All fatal crashes to work zone fatal crashes
- Total crashes to work zone crashes
- All fatal and injury crashes to work zone fatal and injury crashes

In addition to these comparisons, the following analysis should be completed for a sample of the construction projects completed in the current year:

- Number of crash reports coded as work zone crashes versus the number of crashes found by query using location and date
- Determine the number of crashes that were related to work activity

One type of analysis that is done by the Ohio DOT is shown in Exhibit X-1. This exhibit shows 15 long-term interstate projects, the duration and length of each project, and an average AADT for the project. The projects were constructed during 2002.

With this information, crash rate is determined for each project and an average crash rate is computed for all 15 projects (1.68 crashes/mvm as shown in Exhibit X-1). Fatality and fatal plus injury rates can also be computed. A free-flow comparable rate is also computed for 15 projects using crash data from 1999 to 2002. While details for each project are not available from Exhibit X-1, the free-flow projects should be comparable in road type and they could be the same roadway before construction. The AADTs listed would normally come from the highway inventory file, but the work zone AADTs should be determined from counts made during the work zone operations.

At this level of analysis, crash rates for sections within a project can be computed by using the work zone file. Exhibit X-2 compiled by the Ohio DOT shows comparison of work zone sections versus pre-work zone 3-year averages for the same section. Note that 3-year averages were taken for the same months (4/15–11/15) in order to remove seasonal effects of crashes from any comparisons.

The results of the Level 1 analysis should be detailed enough to point to crash reduction strategies. Road types

Work Zone Crash Summary - 2002															
CO	RTE	Project No.	Begin SLM	End SLM	Length	Begin Month	End Month	Time Period (Days)	Average ADT	Work Zone Crashes	Work Zone Rate	Work Zone Cost	Fatal	Injury	PDO
HAM	275	32(02)	28.08	32.20	4.12	03	12	304	113,108	174	1.23	\$1,979,748	0	26	148
		3012(00)	32.20	35.40	3.20	04	12	274	84,947	163	2.19	\$1,908,468	0	26	137
CLE	275	3012(00)	0.00	4.29	4.29	04	12	274	86,397	134	1.32	\$1,523,880	0	20	114
		2(02)	4.29	9.79	5.50	03	12	304	71,116	140	1.18	\$1,923,318	0	31	109
		172(02)	9.79	13.58	3.79	06	12	213	60,257	100	2.06	\$1,336,338	0	21	79
MIA	75		4.94	10.84	5.90	01	12	365	63,656	212	1.55	\$3,012,660	0	50	162
MED	71		15.80	26.38	10.58	01	12	365	46,761	272	1.51	\$4,317,401	1	48	223
STA	77	3008(00)	11.59	12.76	1.17	06	12	207	85,111	84	4.08	\$1,265,436	0	22	62
ASD	71	151(00)	2.30	6.30	4.00	05	11	213	41,470	48	1.36	\$769,932	0	14	34
			6.30	9.00	2.70	05	08	122	41,192	23	1.70	\$1,327,205	1	6	16
SUM	77		24.19	28.37	4.18	01	11	335	63,032	117	1.33	\$1,839,834	0	33	84
RIC	71	166(01)	13.40	16.40	3.00	01	04	122	41,865	21	1.37	\$2,197,408	2	3	16
			16.40	18.90	2.50	04	11	243	41,487	43	1.70	\$540,864	0	8	35
LUC	280		0.36	5.78	5.42	01	12	365	55,334	125	1.14	\$1,695,006	0	27	98
SUM	76	323(00)	15.06	17.98	2.92	04	10	213	60,681	55	1.46	\$815,292	0	14	41
								3,918		AVE.	1.68	\$26,452,790			Ave Cost / Day \$6,752

Free Flow Comparable									Cost Difference	Hot Spot	Congested	HSP - I	HSP - NI
Comp. Crashes	Comp Year	Comp Year ADT	Comp. Rate	Percent Difference	Free Flow Cost	Fatal	Injury	PDO					
130	00	109,353	0.95	23%	#####	1	35	94	-\$991,379	Y	19	52	124
120	00	79,835	1.72	22%	#####	1	30	89	-\$833,969				
82	00	92,180	0.76	43%	#####	0	17	65	\$435,294	Y	242	336	348
129	00	75,107	1.03	13%	#####	0	32	97	\$38,502				
76	00	60,990	1.54	25%	#####	0	16	60	\$319,410				
103	99	58,161	0.82	47%	#####	1	25	77	\$544,273	N	229	403	--
166	99	49,156	0.87	42%	#####	0	34	132	#####	N	--	607	424
53	99	82,379	2.66	35%	\$703,998	0	11	42	\$561,438	Y	96		187
17	99	42,730	0.47	66%	\$175,716	0	2	15	\$594,216	N	--	--	--
10	99	40,989	0.74	56%	\$163,134	0	3	7	#####				
99	00	59,128	1.20	10%	#####	0	26	73	\$346,086	Y	--	--	488
10	01	43,035	0.64	54%	\$163,134	0	3	7	#####	N	--	--	--
17	02	43,360	0.64	62%	\$339,606	0	7	10	\$201,258				
57	00	52,601	0.55	52%	\$965,466	0	17	46	\$729,540	N	261	377	449
32	99	52,915	0.97	33%	\$404,028	0	6	26	\$411,264	N	265	--	557
		AVE.	1.04	39%	#####	Ave Cost/Day \$4,791			Ave Difference \$512,103				

Exhibit X-1. Historical crash data analysis (Ohio DOT).

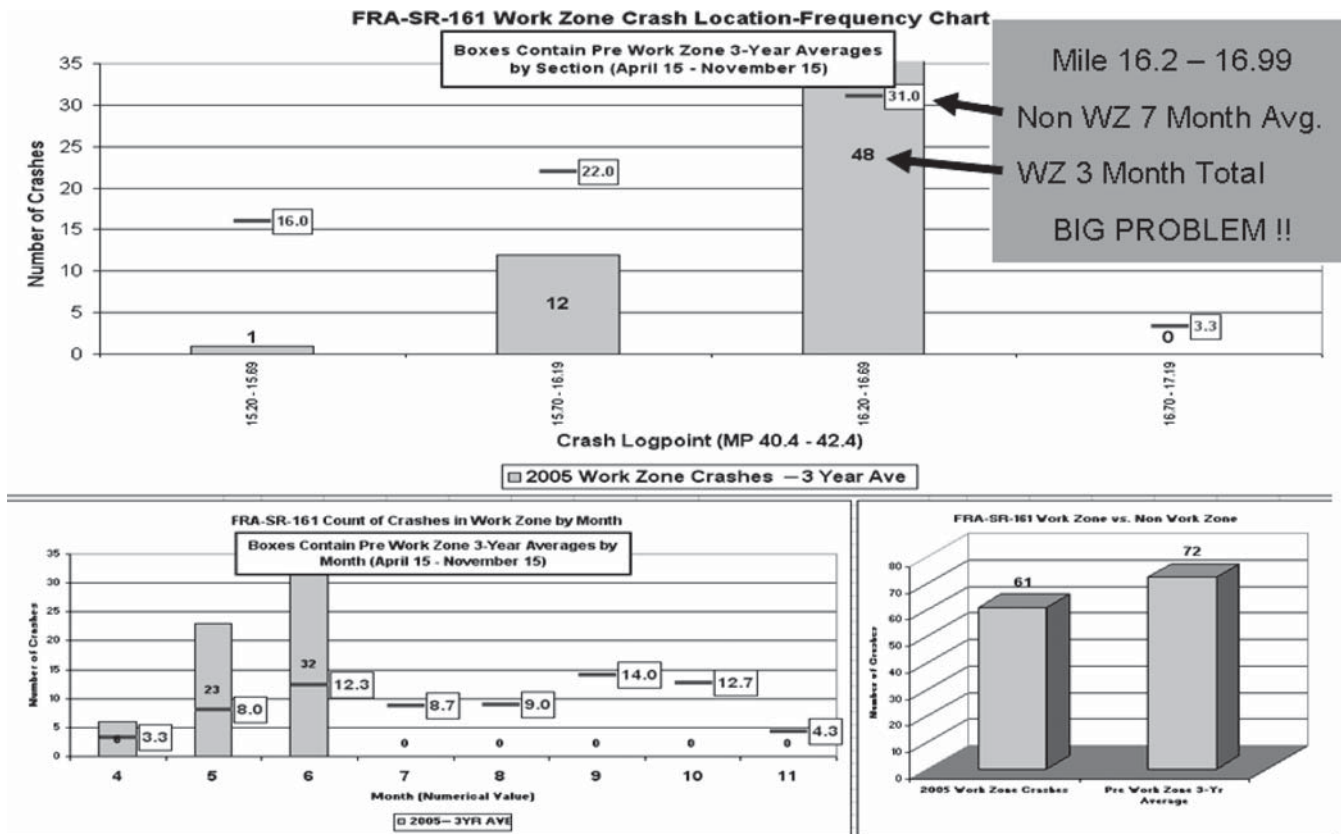


Exhibit X-2. Application outputs (Ohio DOT).

when work zone rates are 50 to 100 percent greater than pre-work zone rates should be examined on a project-by-project basis. In Ohio, analyses of work zone crashes revealed that many safety problems involved Interstate work zones with severe congestion levels. If work zones on high volume roadways are a specific problem, then strategies aimed at reducing the number, duration and impact of work zones should be examined. Project level reviews of crash data revealed numerous crashes near on- and off-ramps. This result pointed to Strategy 19.1 C1 – establish work zone design guidance, and Strategy 19.1 A1 – improved maintenance and construction practices. Specific details were added to Ohio’s contract documents to reduce these crashes. There was also greater use of night and weekend work schedules to minimize congestion in work zones as discussed in Strategies 19.1 A4 – use nighttime work zones, and 19.1 F2 – improve coordination, planning, and scheduling of work activities.

Level 2 Analysis

In a Level 2 analysis, work zone crashes are flagged, and a highway inventory is available that can be linked to crash data. However, there is no file of work zone dates and locations. Without the work zone file, it is not possible to categorize work zone crashes by type of work, project type, or work zone

type. Since it is not possible to determine work zone locations and dates, it is not possible to determine exposure or to compute work zone crash rates.

An example of a Level 2 analysis conducted by a state highway agency is shown in Exhibit X-3. This exhibit shows the frequency of work zone crashes by severity level and road type. Severity of work zone crashes can be compared to the severity of all crashes. Also the severity of work zone crashes by road type can be compared to the severity of all crashes by road type.

Other computations are possible in the Level 2 analyses including the type of crash for work zone crashes, the month, day of the week, and time of day that work zone crashes occur. The greatest weakness of this analysis is the lack of exposure information. This means that statistics, such as 85 percent of work zone crashes occur during daytime, are difficult to interpret without knowing what percent of work is being done during daytime, or the percent of vehicle miles of travel that take place in daytime work zones. It is also not possible to examine a portion of a work zone to find crash concentrations such as shown in Exhibit X-2.

At any analysis level other than Level 1, the Strategy 19.1 F1-develop/enhance agency level work zone crash data systems should be considered. To enhance this Level 2 analysis, an agency would need to establish a work zone file that contains



**IOWA WORK ZONE CRASHES
(BY HIGHWAY SYSTEM AND CRASH SEVERITY)**

07/03/08

Year	Interstates			State Highways			County Roads			City Streets			Crash Type Totals			TOTAL CRASHES
	F	I	PDO	F	I	PDO	F	I	PDO	F	I	PDO	F	I	PDO	
1978	0	5	16	2	47	71	0	11	15	0	35	51	2	98	153	253
1979	0	5	51	0	33	64	0	11	19	0	38	79	0	87	213	300
1980	1	9	20	1	19	49	1	11	19	0	38	79	3	77	167	247
1981	2	5	15	1	38	52	0	10	18	0	28	57	3	81	142	226
1982	1	7	19	1	36	40	0	14	15	0	19	30	2	76	104	182
1983	3	12	25	2	49	57	0	6	9	1	27	43	6	94	134	234
1984	2	36	56	3	67	88	2	7	14	0	27	42	7	137	200	344
1985	2	17	42	4	58	81	0	10	12	0	24	39	6	109	174	289
1986	0	32	76	0	42	64	1	12	16	0	32	51	1	118	207	326
1987	5	21	7	0	57	101	1	10	16	0	17	35	6	105	159	270
1988	2	44	100	2	44	71	1	11	19	1	22	63	6	121	253	380
1989	0	43	110	2	38	85	2	11	18	0	20	51	4	112	264	380
1990	2	29	89	1	61	90	0	8	14	1	31	51	4	129	244	377
1991	5	32	101	3	50	88	0	11	16	0	30	62	8	123	267	398
1992	3	43	79	3	48	63	1	12	14	1	23	48	8	126	204	338
1993	3	55	76	1	35	65	0	13	19	0	32	49	4	135	209	348
1994	10	58	77	1	76	63	1	12	8	0	23	55	12	169	203	384
1995	2	47	77	1	51	53	0	12	15	0	29	53	3	139	198	340
1996	1	34	47	1	71	82	1	14	14	0	30	66	3	149	209	361
1997	5	49	61	5	56	69	0	14	10	0	31	55	10	150	195	355
1998	4	30	39	4	61	64	1	12	17	0	18	34	9	121	154	284
1999	4	45	69	13	85	89	0	12	12	0	31	56	17	173	226	416
2000	1	40	44	5	68	62	0	12	19	0	31	45	6	151	170	327
2001	1	n/a	n/a	7	n/a	n/a	0	n/a	n/a	0	n/a	n/a	8	n/a	n/a	n/a
2002	3	n/a	n/a	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a	3	n/a	n/a	n/a
2003	5	n/a	n/a	0	n/a	n/a	0	n/a	n/a	0	n/a	n/a	5	n/a	n/a	n/a
1991 to 2000 Totals	38	433	670	37	601	698	4	124	144	1	278	523	80	1436	2035	3551
1991 to 2000 Average	3.8	43.3	67.0	3.7	60.1	69.8	0.4	12.4	14.4	0.1	27.8	52.3	8.0	143.6	203.5	355.1

Note: F = Fatality (Number of Actual Fatalities)
 I = Injury (Number of Injury Crashes)
 PDO = Property Damage Only (Number of PDO Crashes)

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 Office of Construction
 Data From : Office of Traffic and Safety
 Highway Division
 Iowa Department of Transportation

Exhibit X-3. Example of a statewide work zone crash summary.

the dates and locations of all work zones. This file could be started considering only long-term construction projects on Interstates and state highways.

If results of this analysis show that most work zone fatalities are occurring on Interstates, then crash reduction strategies such as 19.1 A2-utilize full-time roadway closure for construction operations, or 19.1 F4-implement work zone quality assurance procedures could be implemented.

If work zone crashes are concentrated in the daytime or weekdays, Strategy 19.1 A4-use nighttime road work could be considered. Strategy 19.1 F2-improve coordination, planning and scheduling of work activities may also be effective in work zone crash reduction.

If the percentage of pedestrian, bicyclists or motorcyclists crashes is larger than for total crashes, then Strategy 19.1 C3-improve work zone safety for pedestrians, bicyclists and motorcyclists should be considered. A large number of pedestrian crashes may also indicate worker crashes that are traffic crashes, as opposed to worker occupational injuries. This pattern would point to Strategy 19.1 B4-reduce flagger exposure to traffic, or Strategy 19.1 C2-implement measures to reduce work space intrusions and limit consequences of intrusions.

Level 3 Analysis

In Level 3 analysis, work zone crashes are flagged but there is no work zone file or highway inventory. This analysis is dependent on crashes being flagged and how much information is obtained once they are flagged. If four fields are collected as recommended by the MMUCC then the Level 3 analysis can be expanded to consider the type of work zone, the location within the work zone, and if workers are present at the time of the crash. If the crash is simply flagged as a work zone crash with no further details, the Level 3 analysis will be limited to a determination of the frequency and severity of work zone crashes versus all crashes in an agency.

Exhibit X-4 is taken from *A Guide for Reducing Work Zone Collisions* (17). While this exhibit contains only fatal crash data, it is representative of the types of comparisons that can be made in the Level 3 analysis. Results are typical of work zone crash characteristics.

Results from this exhibit are outlined in *A Guide for Reducing Work Zone Collisions* and are typical of fatal work zone accidents:

- Almost 30 percent of fatal work zone crashes occurred on urban or rural interstates, and this is more than double the percentage of all fatal crashes.
- Rear-end fatal crashes were over 2.5 times more common in work zones than in all fatal crashes.

- Work zone fatal crashes are more common in the summer months than all fatal crashes.
- Almost 60 percent of work zone fatal crashes occurred on roads with posted speed limits of 55 mph or greater.
- Work zone fatal crashes are more likely to involve more than 2 vehicles than all fatal crashes.

This analysis is limited by the available data and many of the results from Exhibit X-4 could be related to exposure. In other words, more work zones occur in summer months and therefore the proportion of work zone crashes is higher in summer months than all crashes.

At this level, Strategy 19.1 F1-develop/enhance agency level work zone crash data systems should be considered. The addition of a highway inventory that is linked to crash data and a work zone file that gives dates and locations of work zones would enable a much more comprehensive analysis.

If rear-end and multiple-vehicle crashes are more predominant in work zones than for all crashes, Strategy 19.1 B2-improve visibility of work zone traffic control devices and Strategy 19.1 D2-improve credibility of signs should be implemented.

If work zone crashes are concentrated in the daytime or weekdays, then Strategy 19.1 A4-use nighttime road work and Strategy 19.1 F2-improve coordination, planning and scheduling of work activities may be effective in work zone crash reduction.

A large proportion of single vehicle crashes in work zones may be a trigger to consider Strategy 19.1 B2-improve visibility of work zone traffic control devices (particularly barriers), Strategy 19.1 B3-improve visibility of work zone personnel and vehicles, and Strategy 19.1 C2-implement measures to reduce work space intrusions (and limit consequences of intrusions).

Level 4 Analysis

If there is no flag for indicating a work zone crash, then it may be impossible to determine the nature of work zone crashes or if they are even a problem that should receive a priority treatment. Some crash forms do include fields that might indicate crashes related to work zones such as an item for “barricade” under traffic control, or “under repair” item in the road condition field. It may also be possible to manually request the reports for recent major projects, and examine these crashes to determine the nature of the work zone crash problem. Strategy 19.1 F1-develop/enhance agency level work zone crash data systems should be a priority if no flag is available on the crash data form to indicate a work zone crash.

Factor	All Fatal Crashes (Percent)	Work Zone Fatal Crashes (Percent)
<i>Time of Day</i>		
Night	49	47
Day	50	52
Unknown	1	1
<i>Day of Week</i>		
Weekend	34	31
Weekday	66	69
<i>Season</i>		
Winter	22	16
Spring	24	26
Summer	27	31
Autumn	27	27
<i>Roadway Function</i>		
Rural, Interstate	7	13
Rural, Other	51	39
Urban, Interstate	6	15
Urban, Other	35	32
Unknown	1	1
<i>Speed Limit</i>		
1–50 mph	44	38
55–75 mph	52	58
Unknown	4	4
<i>Number of Vehicles Involved</i>		
One	57	53
Two	36	35
More Than Two	7	12
<i>Manner of Two-vehicle Collision</i>		
Rear-end	13	35
Head-on	26	21
Angle	32	22
Side-swipe, Opposite Direction	21	15
Side-swipe, Same Direction	6	7
Other or Unknown	2	1

Exhibit X-4. Comparison of factors: percentages of work zone and non-work zone fatal crashes (data from FARS, 2003).

SECTION XI

Reducing Death and Injury Consequences Through Improved Rural EMS Services

This section of the guide provides general details on the process of choosing treatments that will improve Emergency Medical Services (EMS) in rural areas, thereby minimizing the effects of injuries sustained from motor vehicle crashes. The process of choosing treatments and target populations is generally performed through the use of one of four procedures:

- Procedure 1 – Choosing treatments and target populations when treatment effectiveness is known, and both crash and non-crash data are available.
- Procedure 2 – Choosing treatments and target populations when treatment effectiveness is known and crash data are available, but detailed inventory data are not available.
- Procedure 3 – Choosing treatments and target populations when treatment effectiveness in terms of crash/injury reduction is not known.
- Procedure 4 – Choosing treatments and target populations for which some candidate treatments have known effectiveness estimates and other treatments do not.

Choosing treatments to improve rural EMS will generally be done using Procedure 3, primarily because the treatments identified in the *Guide for Enhancing Rural Emergency Medical Services* (15) do not have defined levels of effectiveness expressed in terms of well defined CRFs or AMFs. (Like seatbelt strategies, EMS strategies will not result in an overall reduction in crashes, but will hopefully reduce the level of injury of the most severe crashes.) Thus, Procedures 1 and 2 cannot be specifically applied to this emphasis area, and Procedure 4 is a hybrid of the first three procedures so it is not applicable to this emphasis area either.

Data Needs

There are three types of data recommended for choosing treatments to improve rural EMS. The first type of data that

is desirable is crash data. Crash data can be used to identify high crash locations. Identifying areas of high concentration of serious injury and fatal crashes can be useful for prioritizing the allocation of funds to implement EMS treatments in specific areas of the state (or within a local jurisdiction) with the highest concentrations of crashes.

The second type of data that is desirable for improving rural EMS is data for evaluating the efficacy and effectiveness of EMS systems. The evolution and establishment of an EMS data collection system from which outcome measures can be derived has progressed slowly and sporadically. A compounding factor is the lack of standard nomenclature within EMS to describe patient conditions or to document patient care. However, a national standard on nomenclature is being developed to address this issue under the National Emergency Medical Services Information System (NEMSIS – see <http://www.nemsis.org/>). It is also desirable to supplement the EMS data with trauma center data concerning the actions of patient treatment after reaching the hospital.

The third type of data would include coverage area for EMS agencies, types of equipment available, and capabilities of responders, as well as response times.

Procedure

The two basic steps for Procedure 3 are as follows:

1. Choose the “best treatments” from among the set of all treatments presented in the applicable *NCHRP Report 500* guides.
2. Choose the routes or locale where the selected treatments should be applied.

When applying Procedure 3 to enhance EMS in rural areas, the general order of the steps should probably be reversed. The first step should be identifying the location or locations (i.e., geographical area) with the greatest potential for making

improvements. The most logical areas for improving rural EMS are those rural areas with the highest concentration of injuries resulting from motor vehicle crashes. This step can be performed at all levels of administration (i.e., state, regional, county, and local).

Having identified the locations (i.e., geographical areas) with the greatest potential for making improvements to the rural EMS system, the next step is to choose the “best treatments” applicable for the area. The choice of the best treatments as listed in the *Guide for Enhancing Rural Emergency Medical Services* (15) can be based on the following factors:

- The potential treatments judged to be the most effective, even given that the effectiveness is unknown
- The costs of implementing the potential treatments
- Other technical or policy considerations

These factors must be combined in some fashion to decide which treatment to choose.

The general procedure for deciding which treatment to choose can be divided into two phases. The first phase relates to identifying areas for improvement within your local EMS system. The second phase relates to selecting treatments that improve deficiencies in (a) system integration, (b) quality of care, and/or (c) response time.

Phase I – Identify Areas for Improvement in Your Local EMS System

The primary purpose of this phase is to identify potential ways to improve your local EMS system. One of the objectives for improving EMS in rural areas in the *Guide for Enhancing Rural Emergency Medical Services* (15) provides guidance on how to achieve this goal. The objective is to provide or improve management and decision-making tools to enable system managers to make more informed decisions on ways to improve their services. The logical steps in this process are provided below.

Step 1. Evaluate the status of your current system and develop resource and performance standards unique to your local rural EMS system.

To make an informed decision on how best to improve your local rural EMS system, it is necessary to understand how your current system operates. This can be done either through an internal evaluation or an expanded evaluation which may include perspectives from other stakeholders such as area hospitals and medical assistance facilities, governing bodies, schools, service clubs, the business community, and the public at large. This process can help evaluate the place of the EMS agency in the community.

The next level of this step is to develop resource and performance standards unique to your local rural EMS system. It must be recognized that the primary measures used to determine the success of an EMS system (i.e., the response to patients in cardiac arrest prior to biological death and the transport of trauma patients to the appropriate level of trauma center) are based upon national standards, and in most cases these national standards do not account for the barriers and challenges facing rural EMS systems compared to their counterparts in urban areas. Therefore, it is critical for local rural EMS agencies to determine realistic resource and performance standards for their given area, taking into consideration the standards set by the various national organizations.

This first step can be viewed as an evaluation process, or in another way, it can be viewed as a planning process. First, an agency needs to assess the status of their current system. Second, an agency needs to assess where they ought to be by establishing resource and performance standards for the future.

Step 2: Identify, provide, and mandate efficient and effective methods for collection of necessary EMS data.

A complete assessment of any EMS system requires that an analysis be completed on the performance of the system. All personnel at EMS agencies need to understand the importance of consistent, long-term collection of data for system evaluation and improvement. National standards have been developed in regards to collection of EMS data. Each agency has the responsibility to collect the minimum set of data. A minimum data set must support analyses of response standards, patient care, treatments administered, and patient outcomes.

Step 3: Identify and evaluate model rural EMS operations.

The purpose of this step is to evaluate several peer systems (i.e., those having similar demographics and service demands) to learn from their experiences. This should provide better access to information about procedures/strategies/treatments that have worked well, and others that have been less successful. Therefore the new system can provide guidance for jurisdictions that are faced with enhancing their current system, or in some cases, developing a comprehensive EMS program. This step will provide a better basis for establishing resource and performance standards as well as guidelines for improving the operation of your local rural EMS system.

Step 4: Provide evaluation results to elected and administrative officials at the county and local levels.

Rural EMS systems often operate with minimal oversight, control, or responsibility to governing bodies. Given the lack of direct control of EMS systems in many rural areas, the representatives of the citizens may not be aware of response issues and problems until a tragic event is cov-

ered by the media. Providing elected and administrative officials with measures and standards that have been developed from evaluations would give them a better understanding of the levels of service offered in their community, and the nature of any improvements needed. By understanding the myriad of issues, community leaders will be able to determine the gap between the actual level of service provided in the community, what level of service they desire for their community, and the issues related to meeting that level of response.

In many ways these four steps pertaining to Phase I are long-term procedures/steps for choosing the best treatments applicable for an area. In the short-term, it may be desirable for an agency to perform an initial internal evaluation as part of Step 1 and to identify deficiencies in (a) system integration, (b) quality of care, and/or (c) response time. Thus, in the short-term an agency can begin the Phase II process of selecting treatments that improve deficiencies in the selected areas. However, agencies should have a longer-term goal to develop a more systematic approach to system evaluation and identifying areas for improvement within their local EMS system.

Phase II – Select Treatments That Improve Deficiencies in System Integration, Quality of Care, and/or Response Time

The primary purpose of this phase is to choose the best treatments applicable for improving deficiencies in system integration, quality of care, and/or response time. Three of the four objectives in the *Guide for Enhancing Rural Emergency Medical Services (15)* pertain to deficiencies in system integration, quality of care, and response time. By implementing strategies/treatments related to the respective objective, EMS agencies in rural areas will be able to work more efficiently toward their goal of providing the best available care for injured patients involved in motor vehicle crashes in the following ways:

- By integrating services, EMS agencies will be able to utilize capabilities of other organizations and be able to streamline processes and develop new and unique functionality that previously did not exist.
- Providing better educational opportunities will improve the life-saving skills of EMS personnel and others who may not have previously been involved in EMS.
- By reducing the time from injury to appropriate definitive care, many patients will have a greater probability of survival. Reduction of the time required for notification, dispatching, travel time to the crash site, time spent at the crash site, and travel time from the crash site to the

hospital can all reduce the elapsed time until definitive care begins.

While there are multiple ways of selecting the best treatments for implementation, the following represents one such procedure.

Step 5: Prioritize the type of deficiencies to be improved.

EMS systems around the country exist at various levels of sophistication and in various stages of development. State EMS Directors, system managers, and policy makers at the local level are best suited to determine which objectives are best to pursue, based on their existing levels of service and resources. State EMS Directors and local EMS system managers should also work with State and local highway agencies during the process of prioritization. In making these decisions, State EMS Directors, system managers, and policy makers should try to answer the following questions, based upon the current levels of services and resources:

- Where are the bottlenecks in existing processes?
- Does the existing level of life-saving skills negatively impact the quality of service provided to injured patients?
- Is the average time from injury to appropriate definitive care acceptable?

By answering these questions, State EMS Directors, system managers, and policy makers can judge the magnitude of the problems/deficiencies and judge the room for improvement in each area.

Step 6: Identify possible treatments for each high priority problem/deficiency.

The user will review the *Guide for Enhancing Rural Emergency Medical Services (15)* and list treatments that would be most appropriate for each of the high priority problem areas identified in the above step. The choice should be limited to those treatment strategies that are classified as *tried* in the guides.

Step 7: Rate the possible treatments based on estimated effectiveness.

Since this procedure deals with treatment strategies with unknown effectiveness, this appears to be impossible. However, for a given set of possible treatments for a particular problem/deficiency, it may be possible to make a judgment concerning which treatment strategy would be expected to be most effective.

Step 8: Choose the best treatment(s) by considering the estimated effectiveness, cost of implementation, and other technical and policy considerations.

The user will then combine the output of the steps above with at least two other factors in making a final decision on which treatment(s) to implement – the cost of implementation and other technical and policy considerations. Unfortunately, there are no good guidelines for

how to “weight” the different factors. While problem size (total crash cost) and assumed treatment effectiveness are key factors, there may be technical, policy, and cost considerations that will remove certain treatments from consideration even if they are felt to be effective. The user will have to choose the final treatments based on best judgment. The procedure outlined above will at least ensure that the major factors in the decision are clearly defined.

Step 9: Target the chosen treatments to areas with high crash concentrations.

Since this procedure concerns treatment strategies without known effectiveness, it will not be possible to target the treatments based on any type of economic analysis such as those in Procedures 1, 2A and 2B. Instead, the treatment will be targeted to EMS agencies and communities located in geographical areas with the highest total crash cost or frequency, coupled with user judgment concerning other characteristics of the potential target groups, and technical and political issues.

Step 10: Repeat the process for each problem/deficiency.

Step 11: Add either new treatments or new target areas until the available funding is used.

Without effectiveness measures for the treatments, it is not possible to verify whether or not a specific set of treat-

ment types and treatments will meet the established goal. Therefore, the best that can be done is to proceed in selecting treatment types and treatments until the available budget for safety improvement has been fully committed. The total benefit of the selected program will not be forecastable, but the success of the program can be determined if a sound evaluation is conducted after its implementation.

Closure

Choosing treatments and targeting those treatments to the unsafe driving populations covered in this section is difficult. The programs are complex, there is limited crash-based information on treatment effectiveness for the strategies covered in the two guides, and there is limited information on program costs. However, choices have to be made given that available budgets will always be limited to some degree. Because programs aimed at improving EMS responsiveness are not traditional engineering treatments, the application of these types of programs is usually more flexible in nature and costs for implementation can be more easily adapted to a budget of any size. It is hoped that the procedures presented in this section at least provide some insight into how budgetary choices can be made.

SECTION XII

Data Improvements and What They Can Do for You

In this section, the case is made for improving the timeliness, accuracy, completeness, and accessibility of traffic records information. In general, more reliable data means that users can make better quality decisions – they can be more certain of the facts and of achieving the desired outcome from any action.

Throughout this guide, a data-driven, decision-making approach has been described as the most effective way to identify and address highway and traffic safety problems. The method is aimed at identifying opportunities to improve traffic safety, where an opportunity is defined as something that is a *real* problem that there is a *real* way to address. Using data helps define opportunities in three important ways:

- By describing a problem numerically, we know how large it is relative to other highway traffic safety problems we may be facing; ideally, we will know when and under what conditions the problem occurs and the risk posed by the problem for specific portions of the public. In many ways, numerically describing the problem in detail will often suggest the appropriate solutions.
- By numerically evaluating countermeasures, we know which ones work, to what extent and under what conditions, and at what cost. This provides the decision maker with a proven set of tools to use in situations where the data show there is a problem. Together, proven countermeasures along with well-described problems give the decision maker a more complete idea of where the opportunities lie to improve highway and traffic safety.
- Knowing the problem and the effectiveness of available countermeasures, a decision maker also knows what to expect either if nothing is done or if various countermeasures are applied. Setting numeric targets for each problem area allows decision makers to understand if the target is achievable given the size of the problem and the countermeasures available. It also helps to ensure that realistic targets are established in the first place.

In Section I of this guide, a three-step process is presented for data-driven highway and traffic safety decision-making. The usefulness of data for defining opportunities applies to those same three stages:

1. Define/choose issue(s)/emphasis areas.
2. Set a crash, injury or death reduction goal for that issue.
3. Define the series of treatments and the target subpopulation (drivers, highway corridors, intersections, etc.) for each treatment that will be required to meet your goal.

Section II of this document presents the various data types that are used in highway and traffic safety decision making. It also presents the problems associated with each of the data types, including poor timeliness, accuracy, completeness, and accessibility. The implications of these problems for data-driven decision making are numerous, and yet each section of this guide includes the advice that poor data or missing data are not excuses for ignoring the data altogether when making decisions. This final section goes further by presenting a list of options for what to do to improve the data, and why improving the data is important.

Advice on what can be done will be drawn from two primary sources and from other supplemental sources:

- DeLucia and Scopatz. *NCHRP Synthesis 350: Crash Records Systems*. NCHRP Project 20-5, Synthesis Topic 35-03 (29).
- Council and Harkey. *Traffic Safety Information Systems International Scan: Strategy Implementation White Paper* (30).

The advice is divided into sections that relate to the organizational structure responsible for planning traffic records improvements and the practical data improvement strategies that can be considered when developing a plan of action.

Organizational Issues

In Section II (and elsewhere), the point has been made that ownership (custodial responsibility) of files that make up a

traffic records system is distributed among a variety of agencies at the state and sometimes the local levels of government. Federal databases rely almost exclusively on state data, which in turn depends almost exclusively on data collected (and perhaps stored) locally. These dependencies place the most emphasis on quality improvement on the agencies that are furthest from the money and other resources that are available for data quality improvement. To obtain grants, local agencies typically have to show that they have a numerically large highway traffic safety problem, and that they have a valid solution to those problems, and that the benefits of improving their traffic records information outweigh the costs of the programs they are hoping to fund.

The other barrier to traffic records improvement is that most of the core databases that make up a state's traffic records system exist to serve some other primary purpose. The crash data are there specifically to support highway and traffic safety decision-making, but other components of the system such as roadway files, driver and vehicle files, court files and health-care files all serve a different primary mission. The owners of these datasets are responsible for meeting their primary mission and the continued existence of these files depends on the funding and resources devoted to meeting their primary missions. In that context, raising the highway traffic safety "consciousness" of the leadership in each of the custodial agencies is crucial. This is accomplished through the following initiatives:

- *Establish a strong, two-tiered Traffic Records Coordinating Committee (TRCC).* Ideally, the TRCC will have an executive level made up of key stakeholders, especially the leadership (or IT directors) from the traffic records custodial agencies. This executive group should then empower a working-level TRCC to oversee improvements to the traffic records system and to make recommendations to the custodial agencies on how best to meet the needs of collectors, managers and users of traffic records data. A TRCC is required by law to maintain eligibility for some portions of federal transportation dollars. NHTSA has well-established guidelines for what makes an effective TRCC. They can be found in *Traffic Records: A Highway Safety Program Advisory* (see <http://www.nhtsa.dot.gov/people/perform/pdfs/Advisory.pdf>). Note that in their discussions of improving roadway inventory, traffic, and other non-crash safety data, Council and Harkey (30) recommended a separate "data user/owner" committee within the state highway department because of the multiple owners and users of the inventory and traffic data. This group would serve as an expert subcommittee to the TRCC.
- *Conduct a Traffic Records Assessment in accordance with the NHTSA Traffic Records Program Advisory.* The Advisory and Assessment are powerful tools for a state to learn where its traffic records system is deficient. The Assessment, in

particular, is an opportunity to get expert advice from a neutral third party (a panel of peers/practitioners in various traffic records disciplines). An up-to-date assessment is also required to maintain eligibility for some federal funds. (See <http://www.nhtsa.dot.gov>.)

- *Develop and maintain a Strategic Plan for Traffic Records Improvement.* A Strategic Plan serves as a roadmap to get from the current system (with all its shortcomings) to the desired traffic records system – one that meets the defined needs of its users. The TRCC should take the lead in developing and maintaining the plan, and the plan itself should include a detailed series of actions that are assigned to specific agencies and staff within agencies. Milestones and clear performance metrics are key to achieving the goals of this (or any) strategic plan. Section 408 of the SAFETEA-LU legislation outlines the requirements for a strategic plan in order for a state to become eligible for federal funds available for traffic records improvement (see <http://www.nhtsa.dot.gov/people/perform/pdfs/SAFETEA-LU.pdf>). NHTSA has also published official rules for this grant funding in the Federal Register (see http://www.nhtsa.dot.gov/people/perform/pdfs/Federal_Register.pdf).

Ultimately, the organizational issues come down to inter-agency cooperation. If the state and local agencies can work together to solve the data quality and access problems, they will find ways to do so more efficiently than if they operate in isolation. In particular, cooperation means that opportunities for sharing resources and avoiding duplication are more likely to be identified and implemented. Since traffic records systems are costly to build and costly to operate, and since the resources available to devote to the systems are limited, it makes sense to coordinate action among the various stakeholders in order to meet as many needs as possible with the available resources.

The TRCC, by virtue of its broad participation among representative stakeholders, gives the state a valuable resource in the improvement and promotion of traffic records for use by decision makers. By establishing a forum for coordination and cooperation among collectors, managers and users, the TRCC can assist the state's decision makers in identifying the barriers to data improvement and suggesting ways to overcome them. The TRCC can be the focal point for needs assessments, quality control monitoring, and planning.

Data Improvement Strategies

In this sub-section, practical advice identifying data improvement strategies is listed. These items should not be viewed in isolation, but rather as a set of potential actions that could be included in a *Strategic Plan for Traffic Records Improvement*. The selection of which of these actions to pursue, and in what sequence, is best made as part of an overall

strategic planning process undertaken by the TRCC. Specific actions include:

- *Develop a formal Performance Assessment program for all components of the Traffic Records System.* This program should be overseen by the TRCC, in cooperation with the custodial agencies that would take primary responsibility for implementation and regular reporting of performance measures. The program should include measures of timeliness, accuracy, and completeness of the data, and these measures should be available to data system managers on a continual basis to assist them in day-to-day monitoring of the health of their data system. Summary, aggregate data should be available to the system managers and the TRCC to aid in tracking improvements on some regular basis (monthly, quarterly, and/or annually). Proposals for data quality improvement programs should be tied to the Performance Assessment program by reference to the performance measures that will be affected by the proposed program, and the costs and benefits of the proposed improvements should be weighed against other competing proposals to ensure that traffic records improvement dollars are spent in a cost-effective manner.
- *Improve crash data consistency through adoption of national standards and guidelines.* The national standards include ANSI D-16.1 and ANSI D-20. The *Model Minimum Uniform Crash Criteria* (MMUCC) guidelines define a recommended minimum data set and data definitions for crash reporting. When states adopt these standards and guidelines, they are able to use the pre-defined data elements and, in many cases, improve the quality of their system documentation at very little cost. Training manuals, edit checks, and data users guides can also be tied to the standards and guidelines making it much easier for data collectors, system managers, and data users to understand the contents and limitations of each data file.
- *Create or improve roadway, intersection, and interchange inventory data.* Data on the characteristics of the roadway system including the locations, lengths, geometrics, traffic control features, and traffic volumes for specific roadway elements can serve a vital role in safety management and safety planning. Most state highway agencies have a computerized inventory of roadway segment characteristics, although many local agencies do not. Very few state or local agencies have computerized inventories of the intersections or interchanges under their jurisdiction. The development of such inventories would enhance safety planning. There are currently no uniform criteria for roadway inventory data, but FHWA is currently developing a set of criteria known as the Minimum Inventory of Roadway Elements (MIRE).
- *Promote the use of “high-end” automated field data collection and electronic transfer systems.* There is a wide variety

of field data collection software in use for crash data collection throughout the country. The advantages of the state-of-the-art systems in supporting data quality improvement are, by now, well-documented. A good field data collection system will incorporate methods for validation of data as it is entered by the law enforcement personnel, thus helping to ensure that the information meets pre-defined accuracy and completeness standards. Methods such as GPS, map-based, and pick-lists for street names can help to standardize location data collection for crash (and other) data thus making it much more likely that the events can be tied to specific locations defined in the roadway database. Electronic data transfer from local agencies to the statewide crash database helps to ensure that the data are more timely as well. Some states have chosen to standardize on one software vendor’s product, while others have chosen to set standards for the quality of the data that are forwarded to the state and thus accommodate the varying needs and resources of the local agencies. Both methods have shown good results – the most important determinant of success is the quality of the software and the training that the data collectors receive.

- *Promote data sharing and linkage among the key components of the traffic records system.* Data sharing, including “data-for-data partnerships,” is a way to maximize the efficiency of the data collection and data entry efforts of agencies involved with similar datasets (e.g., law enforcement and courts, law enforcement and the state-wide crash data system, and courts and the driver history database). Data linkage is the merger of elements from two or more datasets for the purpose of expanding the support for data analysis. Automating the links between datasets also offers the opportunity to improve data quality by cross-checking information, and by automatically filling in some portions of a data record from validated information already contained elsewhere.
- *Establish a data clearinghouse (data warehouse) to support user access to system documentation, analytic tool and support, and linked datasets.* Data users, especially high-level decision makers, cannot be expected to spend the time and effort required to obtain the data they need, research its proper use, link it accurately to other data, and conduct analyses in a valid manner without some form of assistance. In recent years, the concept of a data warehouse that provides necessary support for users has gained popularity. The concept involves creation of a central point where users can obtain the data they need, along with current documentation (user guides, data element definitions, and a statement of known limitations of the data) and support from data experts. In an ideal setting, the data warehouse would also include a set of simple-to-use analytic tools available to all authorized users. Some warehouses are also able to provide analytic support to users, including help in

using the analytic tools as well as conducting analyses on request. A data warehouse is also an ideal place for creation and management of merged datasets resulting from the linkage between various traffic records components. Where necessary, the warehouse staff can help to control access to restricted information while still ensuring that the data are available to legitimate users.

- *Promote the use of GIS and other advanced technologies that add value to the information.* The mapping capabilities of GIS are an example of *value added* data management and analysis. Mapping implies the ability to locate events (e.g., crashes, citations, EMS runs, etc.) in a way that is also compatible with other location-based datasets (such as state and local roadway inventory files, traffic data, population and demographics). By layering the maps of safety-related events with roadway, traffic and other data, a rich picture of the safety problems for a state or local area can emerge. This information, when shared with decision makers in the agencies responsible for data collection, can provide them with a powerful resource that helps them do their job. These decision makers, in turn, are more likely to appreciate the value of collecting and reporting high-quality data in a timely fashion. This is but one example of how an inter-agency partnership and returning data-for-data can help to improve cooperation and help to make the case for improved data quality. Ensuring that the local agencies have access to data and analytic resources (as in the case of a data warehouse) is another way to give them an incentive to improve data quality.
- *Establish web-based data entry/editing and analysis facilities for use by agencies that cannot afford field data collection systems.* Data collectors (especially in law enforcement, the courts, and EMS) include some very small and not-well-funded organizations. Many of these smaller agencies do not contribute a large amount of data individually, but taken as a group may be responsible for a meaningful portion of the overall highway and traffic safety information available in a state. Under current conditions, it is rare for these agencies to be able to justify or afford field-data collection or other advanced systems. Even if the software is provided free of charge, the cost of the equipment and training required to make use of the software may be prohibitive. In states facing this situation, one solution is to provide web-based access for data entry, data editing, and analysis to support these users. While the initial intent may be to support the small departments/agencies, the availability of a web-based system may appeal to medium and even large agencies as an alternative to implementing a system locally.

The selection of strategies for improving traffic records in a state is best accomplished in the context of an overall

strategic-planning effort. The TRCC should have the lead in such an effort and the custodial agencies should be strong participants and backers of the initiatives. While it is true that federal grant dollars can be used in the initial stages of these efforts, experience has shown that a dependency on grant funding does not bode well for the long-term viability of a system. Budgeting for the life-cycle costs of a system and finding ways to ensure that the system is self-sufficient (for both funding and other resources) are the keys to sustainability for the foreseeable future. The TRCC is an ideal group for making recommendations about the long-term health of the system, but ultimately the funding to support this coordinated long-term effort must come from the state (and perhaps local) agencies with custodial responsibility over a portion of the traffic records system. These agencies are not likely to spend their money on other agencies' systems unless there is some obvious benefit to them in completing their own primary mission. In addition, the decision to share information technology resources may have to be taken at a higher level than even the custodial agencies' leadership. A consortium of data owners, collectors, and users is the best way to make the case for the eventual pooling of resources. The TRCC and Executive TRCC are viewed as a good starting point for developing the argument in favor of shared resources.

Closure – Good Data Produce Better Results

The use of highway safety data is integral to safety decisions. The better and more complete the data, the better the resulting decisions. This guide has provided analytical methods that can assist the safety analyst in choosing and targeting safety improvement strategies in the 22 different emphasis areas of the AASHTO Strategic Highway Safety Plan. Alternative methods have been presented for different levels of available safety data – from crash data only to mileposted and linked crash, inventory, and traffic data. However, the consistent message presented throughout the guide is that the “full” safety data systems will allow for more detailed analysis and more precise answers. Such systems do not currently exist in all state and local jurisdictions that are tasked with the responsibility for these safety decisions. This final section has provided a discussion of ways to improve existing data systems, including recommendations concerning how to better coordinate the various organizations involved in collecting and using the various forms of safety data and what specific data-improvement strategies have proven to be successful in the past. It is hoped that these recommendations will result in improvements in data that will lead to decisions that will help solve one of the largest public health problems faced by the United States – highway crashes.

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Abbreviations and acronyms used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI-NA	Airports Council International-North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
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	Air Transport Association
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
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
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation