NCHRP
REPORT 546

NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

Incorporating Safety into Long-Range Transportation Planning

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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Incorporating Safety into Long-Range Transportation Planning

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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FOREWORD

By Ronald D. McCready
Senior Program Officer
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This report describes the transportation planning process and discusses where and how safety can be effectively addressed and integrated into long-range planning at the state and metropolitan levels. This guidance manual should be especially useful to federal, state DOT, MPO, and local transportation planners, as well as other practitioners and stakeholders concerned with addressing safety within transportation systems planning, priority programming, and project development planning.

National transportation policies and programs emerging out of the Intermodal Surface Transportation Efficiency Act (ISTEA) and the Transportation Equity Act for the 21st Century (TEA-21) require transportation plans and decisions at the state and metropolitan levels to take safety into account more directly. While safety is often mentioned in plan policies and goals, the short- and long-range planning and programming processes rarely include safety initiatives and commitments in a comprehensive manner. Further, the data collection, analytical support methods, performance monitoring, and decision collaboration normally carried out as part of the planning process for facilities and services do not adequately include safety.

Presently, within long-range transportation planning at the state and metropolitan levels, current conditions, performance, and impacts can be assessed as the basis for predicting future implications of plan alternatives in terms of system capacity, travel demand, system condition, economic conditions, population, and land use. We can predict the impacts of pavement preservation and the future condition of highway congestion and capacity deficiencies. Regarding safety, we can describe the current accident and fatality rates and project them into the future; however, we cannot accurately predict future safety implications associated with transportation system improvements. Similarly, while we can estimate, if not accurately predict, future effectiveness of various safety countermeasures, we are not able to assess their collective implications or performance expectations on a systemwide basis. Thus, long-range transportation planning processes at the state and metropolitan levels need better analytical tools to identify current and likely future safety deficiencies and methods to address those deficiencies. Further, processes to create and promote communication and collaboration between safety and transportation planning practitioners are essential in order to integrate safety into long-range transportation planning and decision making. This need is particularly acute because current national policy requires these long-range planning processes to improve the safety and security of the transportation system for motorized and non-motorized users.

The objective of this research was to develop a guidance manual for practitioners that identifies and evaluates alternative ways to more effectively incorporate and integrate safety considerations in long-range statewide and metropolitan transportation planning and decision-making processes. The research encompasses the full range of safety implications of facility and geometric improvements, capacity improvements, operational improvements, population growth and other demographic issues, land use decisions, and human behavior-related issues associated with all surface transportation modes. It also includes recommendations for improvements to the tools, methods, and procedures that support systems, corridor, and project planning.

Under NCHRP Project 8-44, "Incorporating Safety into Long-Range Transportation Planning," researchers at the University of Arizona and the Georgia Institute of Technology focused on safety issues within the long-range transportation planning processes of state DOTs and metropolitan planning organizations (MPOs) and included the following: (1) a comprehensive review of recent literature on safety and how it is addressed in long-range transportation planning; (2) a review of federal regulations and guidance on safety issues in the planning process; and (3) case studies to synthesize notable current practice in safety planning. A planning process was developed that describes how and when various methods can best be applied in developing systems-level transportation plans. The process addresses decision-making relationships; technical requirements (e.g., data and analytical methods); necessary staffing capabilities; public involvement; interagency coordination; financial commitments; and methods for tying the systems-planning considerations to more detailed processes such as corridor planning, subarea planning, modal development planning, priority programming, and project development. The guidance manual presents descriptions of a variety of analytical tools and software applications for conducting various safety analyses. It also describes PLANSAF, a tool developed as part of the research to forecast safety effects at the traffic analysis zone (TAZ) level or higher. Appropriate applications of the tool are discussed in this appendix. Finally, guidance is provided for MPOs or DOTs to develop their own set of safety forecasting models at the TAZ level.

The guidance manual, contained on the accompanying *CRP-CD-62*, is presented in an interactive electronic format for easy use as a tool for planning practitioners.

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CRP-CD-62

National Cooperative Highway Research Program: NCHRP 8-44

Guidance: Incorporating Safety into Long-Range Transportation Planning

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LIST OF EXHIBITS

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SUMMARY

This guidance manual is targeted to personnel in DOTs, MPOs, and other agencies and stakeholder groups involved in statewide and regional transportation planning. The manual provides an overview as well as details on how to integrate safety as an explicit consideration in the transportation-planning process. The term 'safety' is cast rather broadly and is meant to include all externalities of the transportation system that result in personal harm—including both physical and emotional—such as minor and severe injuries and fatalities, and for all system users such as pedestrians, bicyclists, transit riders, motorists, and commercial vehicle operators. Although the transportation-planning process can be long and arduous, as this manual illustrates, there are ample opportunities in the process to consider safety.

After providing the motivation for this guidance (Chapter 1), the manual begins with a discussion of safety as it relates to the transportation-planning process (Chapter 2). Chapter 3 illustrates why safety should receive greater visibility and explicit treatment in the transportation-planning process, while Chapter 4 provides the institutional context in which transportation-planning activities are conducted. Chapter 5 describes the transportation-planning process and provides a flowchart of the process whose elements are the fundamental building blocks of any planning process—local, regional, or state.

The elements, or steps, that constitute the planning process provide unique opportunities for incorporating safety into the planning process (Chapter 6). Starting from the visioning step of the process, which can be a top-down or bottom-up approach (or some combination thereof), through the development of the transportation plan, strategies for including safety into the process are provided. Chapter 6 serves as the primary contribution of the manual in terms of planning guidance as it relates to safety considerations and provides numerous examples from various DOTs and MPOs throughout the U.S. on how to accomplish successful integration of safety. Each of the elements or steps in the transportation process (7 are described) makes use of a set of questions to help assess how 'well' safety is incorporated into that step. While each step of the transportation-planning process is discussed, suggested strategies for making safety integral into each step are provided. Chapter 7 is a condensed version of chapter 6, and provides a succinct 'road map' for integrating safety into the 7 transportation-planning steps or elements. This chapter serves well individuals wanting to get a sense of how safety is considered in the transportation-planning process in overview fashion, and serves well also as a roadmap of the integrated process.

The appendix of this manual is extensive. It is meant to provide supporting documentation for many of the activities described in the body of the manual. Because the appendix materials are time sensitive, some of the materials will become outdated as time progresses. For example, new legislation may be enacted that replaces existing legislation. Also, some of the software and analytical tools described will undoubtedly be replaced with improved versions with greater capabilities. Thus, the user should be careful to seek the most current information provided through links and references provided in the appendix. With that said, the appendix provides a wealth of information with the aim to support activities associated with the integration of safety into planning.

Appendix A provides a host of example safety initiatives in various state agencies within the U.S.. It is not meant to be an exhaustive list of all safety initiatives, but instead provides a flavor of the breadth of agencies and programs that have been successfully implemented throughout the U.S.

Appendix B provides details of the Federal Highway Safety Program. It describes alcohol-related guidelines, alcohol-related incentive grants, and passenger restraint related guidelines and grants.

Appendix C describes a variety of analytical tools and software for conducting various kinds of safety analyses. The appendix begins with a convenient summary table describing the range of capabilities, expertise, and data requirements for each of the tools. Then, each of the tools are described in fair detail, so that a person wishing to conduct a certain type of safety analysis can determine first if an appropriate tool is available, what is required to use and apply the tool, and what information requirements and in-house expertise are required.

The final tool described in this appendix—PLANSAFE—has been developed as part of this NCHRP research effort. The intent of this tool is to enable the forecasting of safety at the traffic analysis zone (TAZ) level or higher (e.g., a group of TAZs affected by a proposed project). Appropriate and inappropriate uses of the tool are described, and example applications of the tool are provided. Numerous predictive models are discussed for crashes at the TAZ level.

Finally, Appendix D provides the details necessary for an MPO or DOT to develop their own set of safety forecasting models at the TAZ level. This appendix is useful for a DOT or MPO with sufficient GIS resources and capabilities and motivation to develop models specific to their region or state (instead of using coefficients based on Arizona and Michigan data).

CHAPTER 1. INTRODUCTION

Travel safety is repeatedly identified in surveys as being one of the most important characteristics of transportation system performance. It is thus not surprising that transportation and enforcement agencies at all levels of government emphasize the importance of safety with respect to their responsibilities in providing and managing transportation infrastructure. Given this emphasis on a safe transportation system, one would expect safety to be well integrated into all aspects of an agency's planning and decision-making processes. In many instances, such is not the case.

Project NCHRP 8-44, "Incorporating Safety Into Transportation-planning" found through surveys and case studies that safety is often considered by transportation officials to be a concept that is best handled during the project design process or left to enforcement agencies. Relatively little thought was given to how safety could be considered early in the planning process so that resulting plans, operations strategies, policies, and institutional partnerships would incorporate safety not as an afterthought, but rather as an integral part of an agency's capital investment, operations, and daily management programs. However, several state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) have begun to develop an approach for integrating safety considerations into plan and program development that hold great promise[1,2]. The results of this research indicate that a more comprehensive and effective consideration of safety in transportation-planning can indeed occur and result in outcomes that are beneficial for safety.

The purpose of this guidebook is to provide overall direction on how safety is integrated into the transportation-planning process. The audience for the guidebook is primarily transportation practitioners and decision makers who want to know what approaches and tools can be used to increase the consideration of safety in transportation-planning. The guidebook first discusses the concept of safety, what safety means, and who should be involved in safety planning. The guidebook next recognizes that incorporating safety into transportation-planning presupposes that one knows what is transportation-planning. This section of the guidebook presents a generic framework for a transportation-planning process that highlights major elements and tasks associated with developing and delivering the many different products that result from a typical planning effort. The next section of the guidebook presents information on the different types of analysis tools and methods that can be used in the transportation-planning process and to understand better the role that safety considerations have in affecting transportation system performance. The final section presents a checklist of questions that transportation officials can ask themselves to gauge the level to which their planning process is considering safety in a serious and significant way.

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CHAPTER 2. WHAT IS MEANT BY SAFETY AS IT RELATES TO TRANSPORTATION-PLANNING?

At first glance, the answer to the question above seems self-evident. Safety, as traditionally defined, means achieving a trip purpose without incurring personal harm or damage to property. In order to achieve this, transportation planners and engineers have focused on fatalities, injuries, crashes resulting in property damage, assaults on transit facilities, truck crashes, crashes at railroad crossings, pedestrian and bicycle involved crashes, etc. Historically, this concern has led to improvements in the geometric design or operations of transportation facilities, a traditional responsibility of transportation agencies. Over the past 40 years, however, government policies with respect to safety have been defined much more broadly than simply calling for improved project designs. Efforts have also focused on enforcement, education, and emergency services (which along with "engineering" constitute the four E's of the safety challenge).

Incorporating safety into transportation-planning often means integrating safety into all aspects of an agency's operations.

Incorporating safety into transportation-planning often means integrating safety into all aspects of an agency's operations. For example, the Federal Highway Administration conducted a program review in 2001 of the Highway Safety Improvement Program (HSIP) in the states of Delaware, Oregon, Connecticut, Florida, Ohio, and Iowa. The main objective of this review was to identify best practices in implementing the safety program. The practices listed below were determined to constitute best practices by the FHWA, and for the purposes of this guidebook, provide some guidance on the characteristics of effectively incorporating safety into transportation-planning.

- Identify safety as a major goal of the agency, with commitment to it at the highest levels. In several of the states visited, the governor played an active role in promoting safety; support by the state transportation secretary was also critical.
- Develop a good multi-disciplinary safety management process, with a strong emphasis on roadway safety. A safety management system is a systematic process that has the goal of reducing the number and severity of traffic crashes by ensuring that all opportunities to improve highway safety are identified, considered, implemented as appropriate, and evaluated in all phases of highway planning, design, construction, maintenance, and operation. It does so by providing information for selecting and implementing effective highway safety strategies and projects. Having a good system provides a focus on safety and enables the various disciplines to work together to comprehensively address highway safety problems.
- Emphasize safety on all projects. Although much of the emphasis has been on remedial efforts, highway safety enhancements are implemented in conjunction with new or with other roadway improvement projects. Under the TEA-21, safety must be incorporated as part of the state and metropolitan transportation-planning processes.
- Designate a Safety Engineer/Coordinator and/or a designated safety division within the State DOT as the focal point for the HSIP. For the larger states with regional structures, each region's office must have Safety Engineers/Coordinators and/or designated safety sections.
- Assist local governments. Many localities do not have staff solely dedicated to highway safety and as a result may not have the expertise to address their highway safety problems and needs.

- Use current technologies (e.g., GIS and web-based systems). These technologies help to provide more timely and accurate information, especially in the areas of data collection and analysis.
- Develop community-based traffic safety programs. Community-based programs help to elevate the importance of safety at the community and higher levels.
- Create a traffic records coordinating committee. These committees help to ensure the timeliness, accuracy, and linkage of data and help to avoid duplication of efforts.
- Develop systematic and well-documented processes. Employee turnover and/or lateral transfers can devastate existing momentum towards safety programs; thus, detailed documentation can help to preserve the momentum and institutional memory of such programs.
- Collect and use timely and accurate crash data. This need is critical for determining where efforts should be focused. Considerable efforts are being made to reduce the period of time between when crashes occur and when the data are made available for use in automated systems.
- Select hazardous locations for corrective action based on several factors. While there were a number of variations for selecting 'sites with promise', the most common factors were combinations of crash frequency, rate, and severity.

An impressive number of innovative safety programs have been implemented throughout the U.S. that include a wide range of enforcement, education, and engineering initiatives

Given the focus of this review, it is not surprising that emphasis was given to fatal and major injury road crashes and the corresponding types of infrastructure strategies that could reduce fatalities and crash-related injuries. However, as noted previously, safety includes more than just infrastructure-related strategies. An impressive number of innovative safety programs have been implemented throughout the U.S. that include a wide range of enforcement, education, and engineering initiatives including (see appendix A for more detail on these and other initiatives):

- Booze It & Lose It: Law enforcement officers conduct sobriety tests at roadside checkpoints in a state or region.
- Please Be Seated: Through public education and increased awareness, this initiative is designed to reduce child injuries and deaths caused by motor vehicle crashes. Those observing an unrestrained child in a moving vehicle can inform the Please Be Seated program by completing and mailing a card. Once a card is received, the vehicle owner is mailed a friendly letter from the Please Be Seated program stressing the importance of using a child safety seat or seat belt to protect children.
- Bus Safety Program: Law enforcement officers monitor school bus routes to enforce a state's "no stopped bus passing" law and to ensure safety for children.
- Graduated Driver Licensing (GDL): The GDL law is designed to help teenagers learn how to drive safely by giving them more experience behind the wheel in a step-by-step process until they "graduate" to a full license. Various versions of GDL are available.
- Community Traffic Safety Teams (CTSTs): These teams are locally based groups of highway safety advocates who are committed to solving traffic safety problems through a comprehensive, multi-jurisdictional, and multi-disciplinary approach.
- Get the Picture, Listen to the Signs: Educational and marketing efforts are made to promote the importance of highway signs and the need for motorists to understand a sign's meaning.

- Traffic Safety Almanac Program: Detailed roadway-based problem analyses and reports are prepared that link problem identification and countermeasure data, conveyed on a routine, systematic basis to traffic safety activists.
- Highway Work Zone Safety: A series of training videos were developed that document the dangers of the work zone and the safety considerations critical for all workers.
- Campus BLAST (Building Local Alternatives for Safe Transportation): A total of 75 local bars in two towns agreed to distribute campaign materials, including more than 20,000 identification tags and brochures with a "don't drink and drive" message to college students during campus enrollment.
- Governor's Center for Teen Leadership (GCTL): This program provided students from 4th to 12th grades with team-based traffic safety/leadership retreat training.
- Operation Lifesaver: Safety is enhanced at highway/railway crossings through the purchase and distribution of public information materials.
- Safe Routes to School: Programs throughout the U.S. promote walking and bicycling to school through education and incentives. In particular, the program focuses on safety by encouraging greater enforcement of traffic laws, educating the public, and exploring ways to create safer streets.

Many safety initiatives are led by groups and organizations that are independent of transportation agencies, although transportation planners and engineers have often played key roles in their development

This list presents a small sample of the many different safety-related programs and initiatives implemented throughout the U.S. and in many other countries (see Exhibit 1 for an international perspective on safety). Many of these initiatives have been led by groups and organizations that are independent of transportation agencies, although transportation planners and engineers have often played key roles in their development and implementation. Because many of these efforts do not originate from transportation agencies or from the transportation-planning process, some believe (as evidenced in the survey results and case studies for this project) that these programs do not constitute major concerns within the transportation-planning process. Such programs in some cases are believed to be better suited for safety organizations, schools, and enforcement agencies.

The rationale for this position is neither surprising nor unexpected. Statutory limits on the use of funds, an historical focus on the programming of projects (as in facilities), and a methodological framework that lends itself more to transportation capacity-related analysis than driving behavioral analysis all lead to a position that safety behavioral strategies should be someone else's responsibility. However, this research identified several instances where state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) have played lead roles in many of the types of programs listed above. In others, although such agencies have not held lead roles, they have played critically important collaborative roles in implementing the programs. Which organization takes the lead role for a particular program will depend on local institutional history, legal mandates, and organizational capabilities. It is important to note, however, that the guidance developed in subsequent sections of this guidebook assumes that:

Incorporating safety considerations and strategies into the transportation-planning process includes not only a consideration of safety-related capital projects and system operations strategies, but also a concern for public education, enforcement, and emergency response to incidents.

Exhibit 1: Aspects of safety from an international perspective

Aspects of Safety from an International Perspective [World Bank, 2004, http://www.worldbank.org/transport/roads/safety.htm#developing]

1. *Designing Roads to Improve Road Safety (Safety Engineering)*
   Introduction of self-enforcement techniques in roadway design is likely to have more favorable short-term results than improving vehicle standards and driver testing requirements. Road accidents can be prevented by better planning and greater emphasis on safety-conscious designs of the road network. Systematic identification and treatment of hazardous locations can improve road safety substantially.

2. *Data Systems and Analysis*
   Data are the cornerstone of all road safety activities and are essential for the diagnosis of the road accident problem and for monitoring road safety efforts. It is important to identify which categories of road users are involved in accidents, which maneuvers and behavior patterns lead to accidents, and under what conditions accidents occur, in order to focus on safety activities.

3. *Road Safety Research*
   Research and development are important elements of transportation safety and should be incorporated into road safety programs. Road safety research aims to improve knowledge about factors contributing to road accidents, to understand the effects of different countermeasures, and to develop innovative and more effective safety measures. It forms the framework of knowledge against which better policy and resource allocation decisions are made to ensure the most effective use of available resources.

4. *Road Safety Audits*
   Road safety audits are the systematic checking of the safety aspects of highway and traffic management schemes and facilities, including modifications to existing infrastructure. The main aim for new projects is to counteract safety problems through proactive design from the beginning and to reduce the potential for future problems. Safety audits should be included during the design, construction, and maintenance phases of transportation projects. As part of resurfacing projects, such audits can be used to incorporate safety more comprehensively into standard agency operations.

5. *Publicity Programs*
   Road user education and the raising of safety awareness is an important part of any road safety strategy. To be effective, these activities must be based on analysis of data and should be designed, targeted, and monitored in a systematic and appropriate way to ensure success.

6. *Children's Traffic Education*
   Teaching safety skills to children can provide lifelong benefits to society but is a long-term intervention strategy. Children may remember the messages in the short term, but effective and sustainable development of positive attitudes towards road safety are best achieved by inclusion in the core education curriculum, either as a compulsory subject or as a cross-curricular theme.

Aspects of Safety from an International Perspective

7. *Driver Training and Testing*
With road user error contributing to the vast majority of road accidents, the development of safe drivers who are skilled in defensive driving techniques is an important objective in any road safety program. Driving examiners should receive specialized training.

8. *Traffic Law and Enforcement*
Effective, consistent, and continuous traffic law enforcement plays an important role in reducing traffic accidents.

6. *Vehicle Safety Standards*
Improvements in vehicle design, occupant protection, and vehicle maintenance have made significant contributions to accident reductions. Occupants are protected by safety features such as seat belts, headrests, air bags, and special seats for children. Safety related components need regular maintenance, which is achieved by periodic vehicle inspections combined with frequent random inspections of vehicles on the road. Overloading of heavy duty vehicles is a serious safety hazard for all road users and should be regulated and enforced.

7. *Emergency Medical Services*
Timely and proper treatment of road casualties is essential for reducing the severity of motor vehicle related injuries. Driver education on first aid procedures and correct transportation of accident victims is also vital. A single emergency telephone number (for example, "911") can facilitate the simultaneous alerting of police, ambulance, and other rescue services and help to reduce emergency medical service response times.

8. *Monitoring and Evaluation*
A simple but effective monitoring and evaluation system is required to track progress of road safety activities and to estimate the safety impacts. Monitoring and evaluation systems established as part of implementing action plans and safety initiatives must therefore , where appropriate, be able to indicate progress towards achievement of institutional impact and developmental objectives.

9. *The Role of NGOs*
Road safety cannot be the responsibility of government alone. The commercial sector, service organizations, and non-governmental organizations (NGOs) play important roles in increasing road safety awareness.

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CHAPTER 3. WHY IS SAFETY AN IMPORTANT ISSUE FOR THE TRANSPORTATION-PLANNING PROCESS?

The basic point of departure for this guidebook is that safety, broadly defined, should be engrained in the planning processes undertaken by state DOTs, MPOs and regional planning agencies. The reasons for this are many:

- Similar to other issues that are linked to the construction and operation of transportation facilities (e.g., air quality, economic development, etc.), travel safety is clearly an issue that can be affected by how the transportation system is designed, constructed, operated, and maintained. Accordingly, given that transportation-planning leads to changes in this transportation system, safety should be thoroughly integrated into an agency's planning process.
- The costs associated with motor vehicle-related fatalities and vehicle accidents are staggering. The National Safety Council estimates the cost to society of a fatality to be just over $3 million. In the Houston-Galveston metropolitan area between 1998 and 2000, motor vehicle crash costs to society were estimated to be $11.9 billion….just in this one metropolitan area!
- Motor vehicle fatalities and crashes are a leading public health problem in the U.S., and indeed, in the world. Over 40,000 people are killed each year on the U.S. road system; over two million are injured. In 1998 the U.S. Department of Health and Human Services declared that motor vehicle fatalities were the leading cause of death in the U.S. for those under the age of 34 and was a top 10 cause for all other age groups (for the most recent national and state statistics for safety, see http://nhtsa.gov/people/Accident/crashstatistics/index.htm).

Evidence from around the world and throughout the U.S. suggests that many accidents are preventable

- For states and metropolitan areas struggling with congestion on freeways and other major roads, crashes represent a major source of congestion (referred to as "non-recurring" congestion). In busy rush hours, the time it takes police and/or emergency services to reach a site, clear the vehicles from the travel lanes, collect any relevant crash-related data, and remove disabled vehicles from the roadway can lead to monumental traffic delays on critically important roads. Indeed, some estimates blame between 50 and 70 percent of urban congestion on crash-related incidents.
- Evidence from around the world and throughout the U.S. suggests that many crashes are preventable. In the U.S., approximately 30 percent of motor vehicle fatalities and 72 percent of the motor-vehicle-related injuries involve speeding. Collisions with fixed objects were a characteristic of 27 percent of fatalities and 15 percent of injuries. Just over 39 percent of fatalities involved drugs or alcohol. A comprehensive program or strategy dealing with the causes of motor vehicle crashes could have a significant benefit to society.

A comprehensive safety program includes a range of strategies and actions and involves many different agencies and groups

- A comprehensive safety program includes a range of strategies and actions and involves many different agencies and groups. Comprehensive safety strategies require the combined efforts of many of these participants to be effective (e.g., a speed limit that is not enforced is unlikely to influence driver behavior). Thus, there is a need for the many different agencies and groups responsible for safety-related programs and efforts to coordinate their activities and to exchange information to make safety program activities more successful. An important forum for fostering safety program collaboration at the state and metropolitan levels could be through the transportation-planning process.

- Finally, statewide and metropolitan transportation-planning in the U.S. reflects federal mandates on what such planning should consist of. In both cases, safety has been identified by Congress as a national issue that needs to be considered.

The importance of safety in the U.S. is highlighted by inspection of several figures. There are approximately 42,000 motor vehicle traffic related fatalities each year in the United States (see Exhibit 2), or about 1.5 crashes per 150 million vehicles miles of travel.

Pedestrians are particularly vulnerable transportation system users who account for about 12 percent of total fatalities (see Exhibit 3). Pedestrian crashes tend to be severe, involve high costs, and require comprehensive efforts to address.

Alcohol-involved crashes claim the lives of about 17,000 Americans each year, and represent a behavioral problem that involves numerous agencies (e.g., health and human services, judicial and courts, law enforcement, department of transportation, governor's office of highway safety, etc.) and represent a significant federal issue (see Exhibit 4).

These two trends alone illustrate the multidisciplinary nature of the transportation safety problem, the magnitude of the transportation system-related deaths, and the justification for a coordinated and comprehensive remediation approach.

Exhibit 2: Total number and rate of U.S. motor vehicle traffic-related fatalities

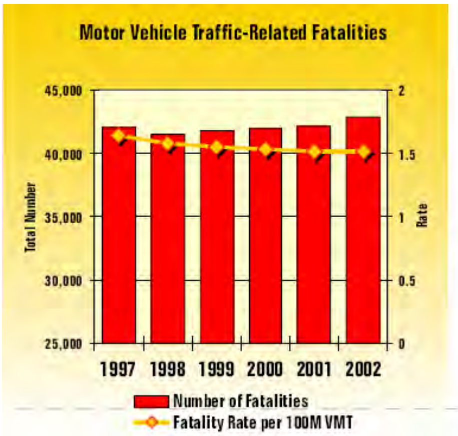


Exhibit 3: Total number and percentage of U.S. pedestrian fatalities

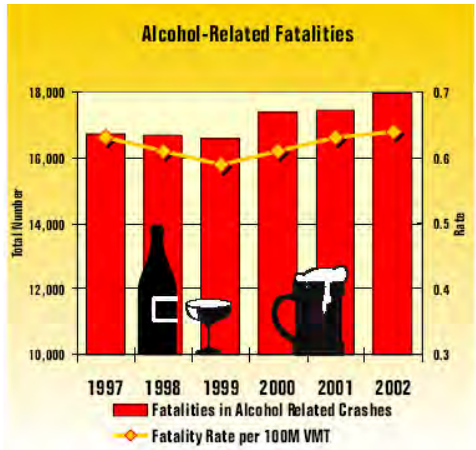


Exhibit 4: Total number and rate of U.S. alcohol-related fatalities

Roadway departure fatalities (defined as run-off-the-road, head-on, opposite direction sideswipes and opposite direction front-to-side-related fatalities) accounted fo 59% of total fatalities, or about 25,400 deaths in 2002. Designing safe roadside environments, increasing driving control through signing, striping, and high design standards, and reducing impaired driving all serve as potential remedies for such types of crashes.

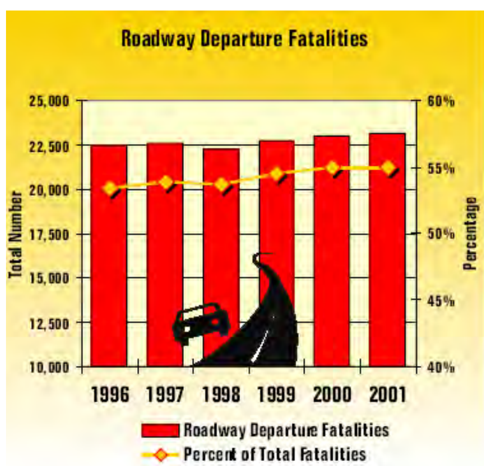
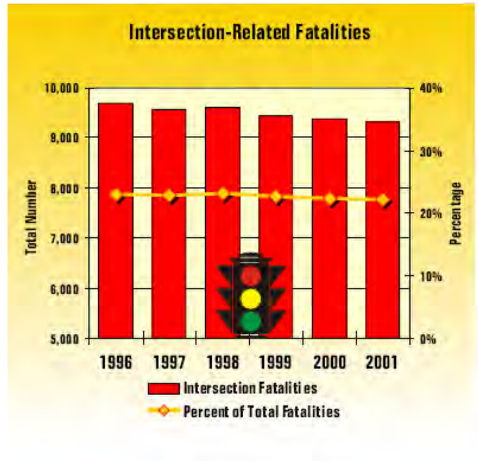


Exhibit 5: Total number and percent of U.S. roadway departure fatalities

Intersection-related fatal crashes (see Exhibit 6) account for about 22% of total fatalities or about 8,500 nationally. Engineering and/or operational characteristics that are important include signal timing and phasing, channelization, and intersection geometry. Behavioral problems such as running through red lights and speeding may play vital roles in these types of crashes as well.

Exhibit 6: Total number and percent of U.S. intersection-related fatalities



Motorcycle-related fatal crashes (see Exhibit 7) account for about 3,000 fatalities nationally, and the number is steadily climbing. The rate of fatal crashes for motorcycles (per 100 million vehicles miles of travel) is about 15 times higher than the rate of fatal crashes for motor vehicles, reflecting the inherently greater risk associated with high speeds and lack of body protection and safety features on motor cycles compared to motor vehicles. In addition, motor cycles have become more popular and have become significantly higher performing over recent years.

Exhibit 7: Total number and rate of U.S. motorcycle-related fatalities

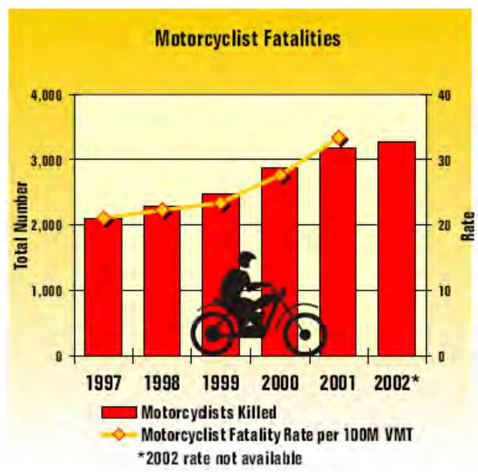


Exhibit 8: Total number and percentage of U.S. speeding-related fatalities

Speeding-related fatalities (see Exhibit 8) account for about 13,800 fatalities nationally (or about 32% of fatalities). Speeding is both a behavioral and engineering issue: enforcement and adjudication affect speeding as well as engineering design considerations such as design speeds, posted speed limits, lane widths, pavement surface, striping, and other factors.

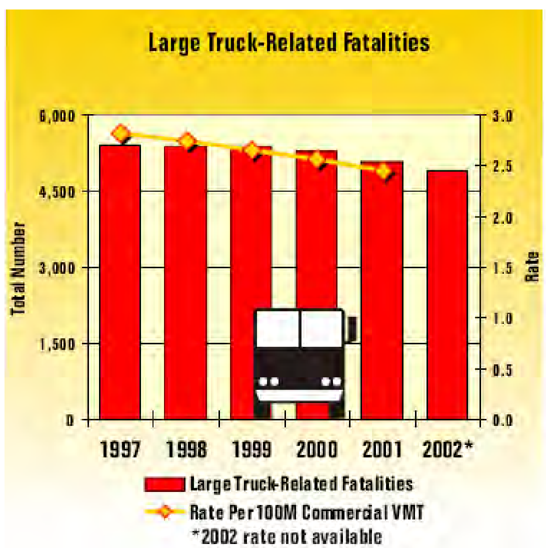


Exhibit 9: Total number and percentage of U.S. large truck-related fatalities

Fatalities associated with heavy duty or large trucks (see Exhibit 9) account for about 4,900 nationally or about 2.5 fatalities per 100 million commercial vehicle miles of travel. Because of the significant mass, lack of maneuverability (compared to an average passenger vehicle), and reduced visibility of adjacent motor vehicle drivers, crashes associated with large trucks tend to be severe. Pedestrians and bicyclists are particularly vulnerable to large vehicles due to poor driver visibility in large trucks and the large roadway space large trucks consume.

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CHAPTER 4. INSTITUTIONAL CONTEXT FOR INCORPORATING SAFETY INTO TRANSPORTATION-PLANNING

Two aspects of the institutional context for incorporating safety into transportation-planning merit special attention. The first relates to legislative and government programmatic requirements to consider safety in a systematic way. The second reflects the large number of stakeholders and participants that could be part of a comprehensive safety program for a state or metropolitan area.

Legislative and Program Requirements

Transportation agencies focus on the many different aspects of providing and operating a transportation system. One of the most important reasons for doing so is that enabling legislation or other related legislative acts direct such action. In many states, for example, state legislation directs the state DOT to provide a safe transportation system or provide special funds or enforcement powers to foster increased safety. State legislation, however, often does not directly link a concern for safety with the transportation-planning process. This linkage has most recently occurred through federal legislation.

TEA-21 emphasizes safety consciousness in a more comprehensive, system-wide, and multi-modal context

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 is, in many ways, a benchmark of federal transportation legislation. Along with the subsequent Transportation Efficiency Act for the 21st Century (TEA-21) in 1998, it defined the post-Interstate transportation program, and broadened the types of issues considered as part of the transportation-planning process. By mandating the consideration of a broader range of issues in planning, it was assumed that the projects and strategies resulting from the planning and programming processes would relate to these issues. ISTEA reinforced this broadening of focus with the requirement for state DOTs and MPOs to develop management systems relating to six different performance characteristics of the transportation system, one of which targeted safety. The intent of these management systems was to provide a systematic process of identifying system deficiencies, analyzing and evaluating prospective improvement strategies, and monitoring implemented projects/strategies to determine whether projected effects actually occurred. The requirement for these management systems, except in the case of congestion management systems for transportation management areas, was made optional by Congress in the National Highway System Designation Act of 1995.

TEA-21 was the first federal law that required state DOTs and MPOs to incorporate safety and security as one of several priority factors into their respective transportation-planning processes and activities. It emphasized that safety should be considered in a more comprehensive, system-wide, and multi-modal context. Given such a requirement, the consideration of safety issues by the planning process became one criterion used by the Federal Highway Administration and the Federal Transit Administration when statewide- and metropolitan-planning processes are reviewed and certified for compliance with federal law.

Although both ISTEA and TEA-21 are important legislative foundations for considering safety in the transportation-planning process, in fact, the federal government had been emphasizing the importance of safety for many years. For example, the Federal Highway Administration issued a series of regulations in the late 1970s and early 1980s (again modified in 1991 and 1998) commonly known as the Highway Safety Improvement Program (HSIP). As part of the HSIP, the FHWA requires each state to develop and implement on a continual basis a HSIP that has the overall objective of reducing the number and severity of crashes and decreasing the potential for crashes on all highways. The requirements for a HSIP include:

- Planning: a process of collecting and maintaining a record of crash, traffic and highway data; analyzing available data to identify hazardous highway locations; conducting engineering study of those locations; prioritizing implementation; conducting benefit-cost analysis; and paying special attention to railway/highway grade crossings.
- Implementation: a process for scheduling and implementing safety improvement projects and allocating funds according to the priorities developed in the planning phase.
- Evaluation: a process for evaluating the effects of transportation improvements on safety including the cost of the safety benefits derived from the improvements, the crash experience before and after implementation, and a comparison of the pre- and post-project crash numbers, rates, and severity.

Projects resulting from this process are to be developed by the states and approved by the FHWA (see Appendix B for other federal programs relating to safety).

Additional federal requirements for safety are incorporated into 23 U.S.C. Section 402, which required the creation of a state highway safety program. This program, administered by the National Highway Traffic Safety Administration requires that "the Governor of the State be responsible for the administration of the [State Highway Safety Program] through a Governor's Highway Safety office, which shall have adequate powers and be suitably equipped to carry out… such program" [23 U.S.C. § 402 (b1A)]. The governor is responsible for administering Section 402 funds under this law. To encourage jurisdictions within a state to adopt highway safety programs, the governor may also approve safety programs administered by political subdivisions of the state, provided that these programs are in accordance with the minimum guidelines prescribed by the Secretary of Transportation. This law specifies that at least 40 percent of all federal allocations under Section 402 shall be allocated to the political subdivisions of the state. NHTSA may not approve a state's annual work program if at least 40 percent of a state's political subdivisions do not receive such allocations.

This law also requires states seeking funding under Section 402 to develop an annual performance plan containing measurable transportation goals and objectives aimed at addressing safety problems. An annual highway safety plan, approved by the Governor's Representative for Highway Safety, is required to describe Section 402 program activities and costs. The law further requires that each state submit an annual report that describes the state's progress towards its highway safety goals, as well as how the funding allocated under Section 402 contributed towards meeting these goals. This process is illustrated in Exhibit 10.

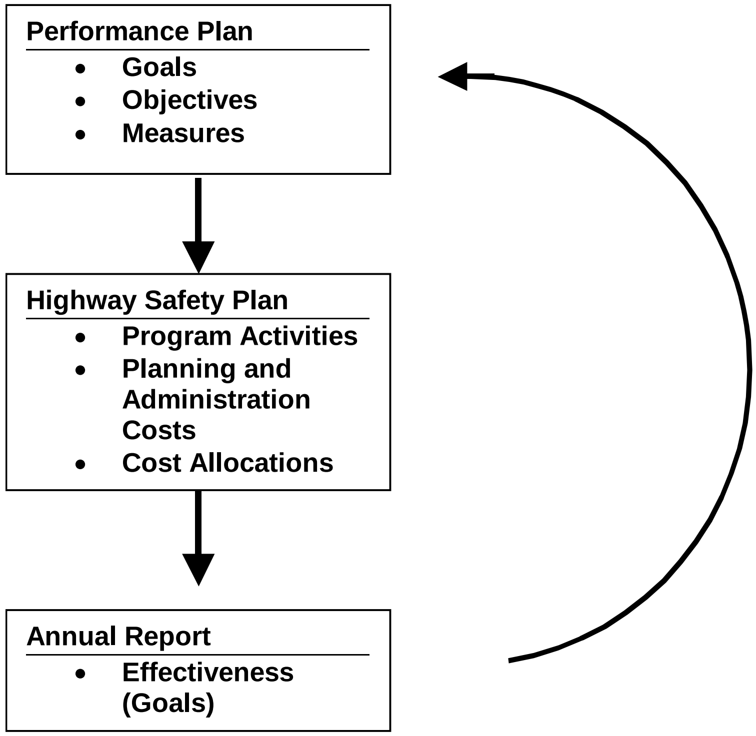


Exhibit 10: Annual state section 402 safety planning process

The majority of activities undertaken by the Governors' Highway Safety Offices are oriented towards encouraging the use of passenger restraint systems, minimizing dangers associated with individual's driving under the influence of drugs and alcohol, and encouraging safe behavior in school and construction zones. While these activities are associated with behavioral aspects of transportation system usage, it is clear that the substantive safety issues these programs are seeking to address are of great interest to transportation-planning efforts aimed at increasing transportation system safety. The relationship between highway safety offices and their safety programs and the planning efforts of transportation agencies is one that needs to be strengthened and strategies found to better integrate these processes.[3]

Stakeholders in Transportation-planning and Safety

The effective integration of safety considerations into transportation-planning requires the collaborative interaction of numerous groups. In most cases, who is involved will depend on what issue is being addressed. For example, a bicycle safety program focused on child safety might involve enforcement agencies, governor highway safety representatives, local public works agencies, school administrators, parent organizations, churches, local store owners and business associations, emergency response providers, and civic associations. It is therefore difficult to identify in a generic sense who should be involved in safety conscious planning. The key, however, is collaboration; and the key to successful collaboration is identifying for each participant what benefit each receives through participation.

Exhibit 11 presents the results of a survey that sought to identify the agencies that MPO and state DOT officials consider to have the most influence in transportation-planning. The MPO respondents indicated that the state DOT was the most influential of the 12 organizations listed; local police agencies were ranked as fifth most influential. The state DOT respondents said that other members of their own DOT have the most influence on the issues addressed in the statewide transportation-planning process, and the Governor's Office of Highway Safety ranks third.

Exhibit 11: Agency Influence in transportation-planning process issues as ranked by MPOs and state DOTs

Agency	MPO Rank	DOT Rank
Governor's Office of Highway Safety	10	3
Metropolitan Planning Organization	2	4
State Department of Transportation	1	1
Local departments of transportation	4	6
Departments of Public Health	8	11
Departments of Public Safety	6	8
Local police agencies	5	5
Department of Education/School Boards	9	9
Federal Highway Administration	3	2
Federal Transit Administration	7	7
Area Agency on Aging	11	12
American Automobile Association (AAA)	12	10

All of the agencies listed in Exhibit 12are potentially important participants in a transportation-planning process with greater emphasis on safety. A list of additional participants is provided in Exhibit 12.

Exhibit 12: List of potential participants in safety conscious transportation-planning process

- Citizen's transportation advisory committees
- Special transportation authorities
- Transit agencies
- Insurance companies
- School districts and universities
- Business community
- Civic groups
- Local media
- Contractors
- Special advocacy groups, such as motorcycle, pedestrian and bicycle organizations
- Private transit providers
- Traffic engineers
- Engineering design consultants
- Hospitals
- Emergency service responders
- Homeowners' Associations
- Parents' groups
- Elderly groups
- Local lobby groups

One of the key characteristics of effective comprehensive safety programs at the state and metropolitan levels is the successful collaboration of many different participants

To be effective, a core group must be involved if the transportation-planning process is to incorporate safety considerations in a serious way. This core group will likely include the planning organization, transportation agencies, enforcement organizations, emergency responders, and the Governor's Highway Safety Representative. One of the key characteristics of effective comprehensive safety programs at the state and metropolitan levels has been the successful collaboration of many different participants. Such success partly rests on understanding what role each participant plays in the broader perspective of transportation safety.

The *Governors' Highway Safety Offices* (GHSOs) are typically involved in the behavioral and human aspects of transportation safety. Typical programs initiated or administered by GHSOs include driver licensing and education programs, drunken driving and driver impairment-related programs, educational campaigns and programs, helmet use and driver restraint programs, and special population programs such as youth and senior driver programs.

Transportation infrastructure agencies are typically involved in the project design or engineering aspects of transportation safety, as well as in the operations of the transportation system. Although state DOTs have primary responsibility for roads carrying the most traffic, county and local jurisdictions almost always have their own staff or organizations with responsibility for a community's transportation program. Programs often initiated or administered by DOTs include roadway safety management systems, identifying 'sites with promise', maintaining and improving roadway design standards, implementing traffic engineering projects and strategies, and evaluating system safety. In some cases, state DOTs house motor vehicle divisions and are responsible for motor vehicle safety inspection programs. In addition, DOTs are often the repository for databases relating to the physical characteristics of the road network. The extent and quality of roadway and roadside data (e.g., pavement condition, pavement width, lighting conditions, signal phasing, etc.) are critical for subsequent safety analysis of transportation system performance.

Transportation service providers are concerned about passenger safety in that feeling safe and secure is an important characteristic of a service that is necessary to attract and maintain ridership. A transit agency or operating authority is a good example of this type of agency. Most large transit agencies have their own police force and provide surveillance of key locations on their transit system. Most recently, the threat of terrorist attacks have heightened the concern for personal safety on transit systems (the largest number of terrorist attacks in the world over the past 10 years has been on public transit services).

The *metropolitan planning organization (MPO)* is the agency responsible for developing a regional transportation plan and a transportation improvement program (TIP). As part of this responsibility, the MPO engages in planning studies, program development, and policy formulation leading to improved transportation system performance. Similar to state DOTs, MPOs collect a large amount of data on the condition and operational performance of the transportation system. They are also most often the developers and users of regional models that are used to analyze transportation system performance. For both activities, that is, data collection and analysis, the MPO will have an important role in efforts to consider safety more comprehensively in the transportation-planning process.

Emergency medical services (EMS) agencies play an important role in transportation safety. Both the quality and expediency of care that are provided at a crash scene followed by the quality of care provided at the hospital are critical factors that influence the survivability of a motor vehicle-related crash. In addition, the quality and extent of EMS data are critical for assessing the safety characteristics of the transportation system.

Departments of public safety (DPS) or *police agencies* play a critical role in enforcing traffic laws. These agencies typically carry out routine enforcement activities, and in addition, apply for assistance from GOHSs for special programs such as driving impairment enforcement. In addition, police agencies play a vital role in the collection and accuracy of motor vehicle crash data.

Elected and appointed officials such as state and local legislators, mayors, judges, and city and county attorney's offices are very important to the overall success of a jurisdiction's safety efforts. Legislatures pass laws that greatly influence transportation safety, such as primary safety restraint laws, motorcycle helmet laws, and child bicycle helmet laws. Judges also play vital roles when and how they determine sentences and fines for various traffic violations, whereas city and county attorneys (prosecutors) decide which 'cases' to bring to court. Importantly, some of the more effective strategies for reducing fatalities are those that most directly affect individual behavior, something that is often difficult to legislate. Thus, elected and appointed officials are critically important to initiatives that have potential to achieve safety goals through behavior modification.

Federal government agencies such as the U.S. Department of Transportation (DOT), Federal Highway Administration (FHWA), Federal Transit Administration (FTA) and National Highway Traffic Safety Administration (NHTSA) play important roles in national, state, metropolitan, and local transportation safety through the provision of special programs targeted at safety improvement, as well as through their monitoring of the statewide and metropolitan transportation-planning process. Numerous opportunities exist for federal matching funds to support safety-related projects and strategies.

Non government organizations (NGOs) and *lobby groups* play vital roles in getting safety legislation passed and laws enforced. For example, Mothers Against Drunk Driving (MADD) has provided a major impetus at both the national level and in many states for initiatives aimed at reducing the incidence of drunk driving. In some metropolitan areas and states, the American Automobile Association (AAA) has been aggressively working with state and local governments to improve the safety record. At the local level, citizen advocacy groups for pedestrian, bicycle, and road safety often attempt to influence the priorities and direction of governmental transportation programs.

Incorporating safety into the transportation-planning process in a substantive and comprehensive way depends upon the participation of many if not all of these groups and organizations. As noted previously, the collaborative nature of this participation is an important precursor to success.

CHAPTER 5. THE TRANSPORTATION-PLANNING PROCESS

Before one can identify the types of strategies or investments that can improve safety, the safety challenge must first be understood. This means not only understanding the "big picture" from the perspective of numbers and incidence of road-related fatalities and major injuries, but also becoming knowledgeable about some of the leading contributing factors.[4] Thus, the best examples of safety conscious planning have begun with a comprehensive collection and analysis of data, which often includes conducting research on what factors are most important with respect to fatalities or personal injuries. For example, some states have found through detailed analysis of crash data that a disproportionate number of crashes involve pedestrians and bicyclists, and that a large percentage of these involve elderly individuals who are involved in crashes close to their homes.[5,6,7] This finding has led these agencies to emphasize pedestrian-oriented safety measures in their safety programs.

The transportation vision reflects the interaction between desired states of prosperity, environmental quality, and social equity/community quality of life

In other cases analysis of crash data showed that in rural areas, run-off-the-road crashes were by far the most significant type of fatality crashes, while in urban areas, side impacts were at the top of the list. In addition, the high incidence of alcohol-related fatal crashes and excessive speeding have led to targeted enforcement measures that have had important impacts.

The significance of an initial "fact-finding" effort is that it will guide transportation and safety officials to the kinds of strategies that are most appropriate for the types of safety problems being faced.[see, for example, 8,9,10,11,12] Some of these problems may not be appropriately addressed in the transportation-planning process, and thus are the focus of other agency efforts. Many comprehensive safety-planning efforts, for example, are undertaken by the leadership of the local enforcement agency or the Governor's Highway Safety Office. In yet other cases, safety problems are addressed by transportation agencies, and thus are incorporated into the transportation-planning process. Once it has been determined what kinds of safety strategies sit squarely in the transportation arena, one can begin the process of integrating safety concerns within the transportation-planning process.

As shown in Exhibit 13, transportation systems planning begins with the creation of a vision. The vision reflects the interaction between desired states of prosperity, environmental quality, and social equity/community quality of life. This vision can consist of general statements of desired end-states, or can be as specific as a defined transportation system scenario. For example, most planning visions discuss the need for a safe and secure transportation system that provides mobility and accessibility. Although this sounds rather general, the process of developing the vision relies on extensive public outreach and is often one of the most interactive steps of the systems planning process. Thus, the "visioning process" can be a very important means of raising critical issues, such as safety, as one of the important topics addressed in the planning process as it proceeds through the subsequent steps.

Although important for establishing a community's overall desired direction, visions and vision statements can often be very general and full of statements that are hard to disagree with. More specific information on what the planning process is to accomplish is needed. This is typically accomplished by defining goals and objectives. Goals and objectives serve to direct subsequent planning activities for assessing the relative contribution of different alternatives or strategies in achieving desired outcomes. Importantly, goals also lead later in the planning process to the identification of criteria for evaluating different transportation system options and alternatives. Thus, for example, if safety is to be an important consideration in evaluating different transportation projects, or a specific definition of safety is desired as part of this evaluation, one needs to start with safety being part of the definition of goals and objectives.

Goals and objectives lead to the identification of system performance measures. This is a relatively new concept in transportation-planning, although performance measures are used in other fields (such as enforcement). The primary purpose of these measures is to target key data collection (and resulting information needs) on those aspects of performance that decision makers determine to be important for their state or region. For example, many performance measures have been defined that monitor whether traffic safety, congestion, average speeds, system reliability, and mobility options have changed over time. Presumably, the results of this monitoring--system performance defined along the dimensions as identified by the individual measures--is then used to influence the types and magnitudes of investments that need to be made in the transportation system.

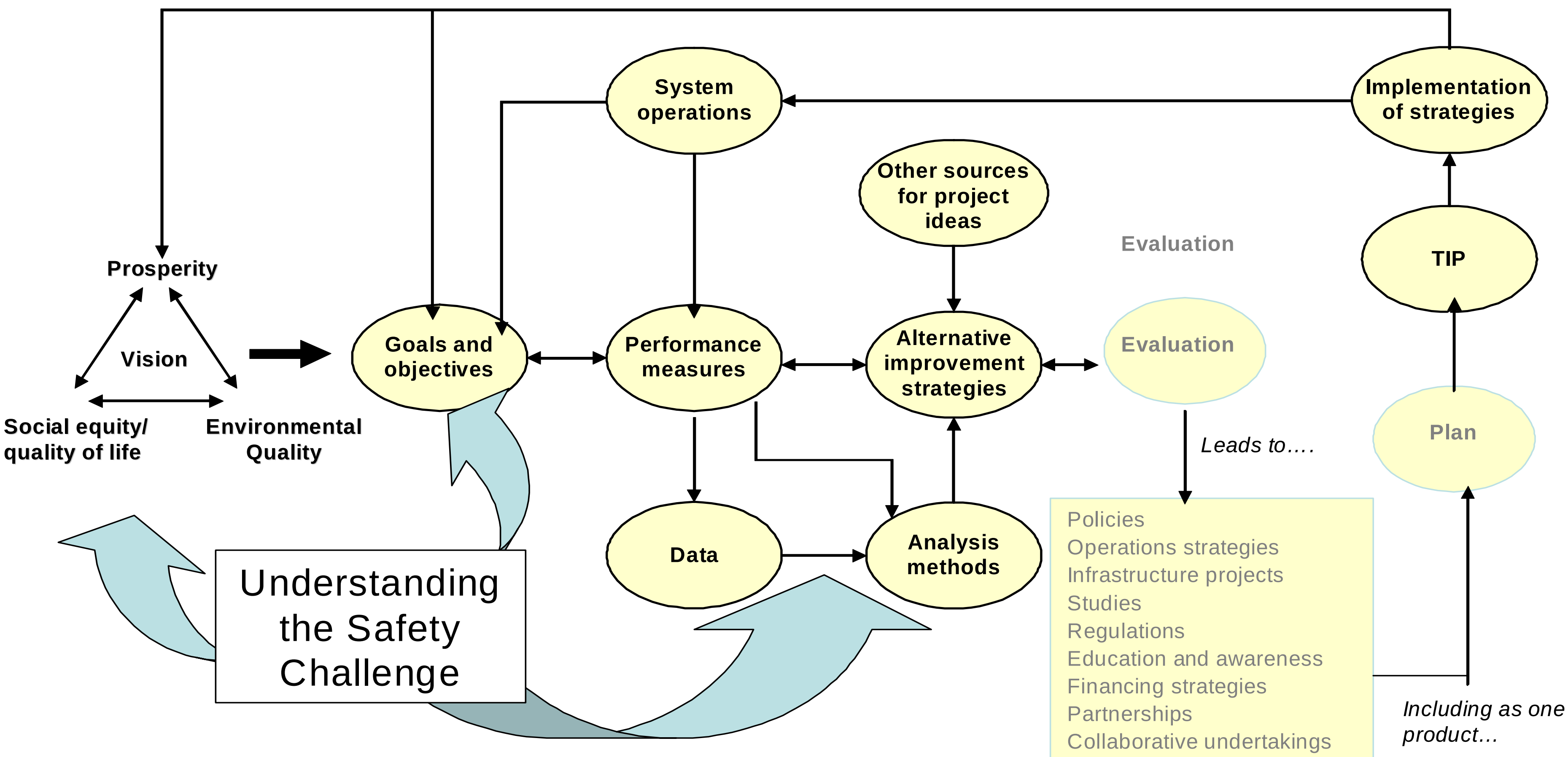
Data collection and analysis methodologies are key to any planning process for understanding the underlying phenomena of interest and the challenges likely to be faced in the future. The ***analysis*** process focuses on understanding how a transportation system and its components work, and consequently how changes to that system will alter its performance. The analysis step includes the identification of alternative strategies or projects that meet the objectives of the study. Analysis tools, ranging from simple data analysis to more complex simulation models, are used to produce the information that feeds the next step of the process, which is evaluation. Many helpful analysis tools are described in Appendix C of this guidance.

Evaluation is the process of synthesizing the information on the benefits, costs, and impacts generated by analysis so that judgments can be made concerning the relative merits of alternative actions. One of the most common ways of making sure that the results of evaluations are linked closely to the needs of decision makers is through the definition of evaluation criteria that reflect important decision-making concerns. These criteria provide important guidance to planners and engineers on what type of data and analysis tools must be available in order to produce the desired information.

Transportation-planning, or for that matter any planning process, can result in a variety of ***products***. Planning may produce new policies and regulations, operations strategies, proposed projects, additional studies, efforts to educate and inform key constituencies, new finance strategies, enhanced partnerships with different groups in a state or region, and additional collaborative undertakings. However, federal regulations require that the transportation-planning process produce a plan. The statewide plan can range from simply a statement of investment policies and strategies to a detailed master plan that outlines specific investments to be made over the plan's life (usually 20 years). For metropolitan transportation-planning, the plan is typically targeted on specific projects or transportation corridors where improvements are necessary.

The program of projects that will be constructed in the near term, referred to as the transportation improvement program (TIP) for the metropolitan area, and the state transportation improvement program (STIP) for a state, is connected to the plan through a process called ***programming***. This process of matching desired actions with the available funds requires a priority-setting process. Vital at this stage of the planning process with respect to focusing more attention on transportation safety are the relationships with safety stakeholders in the region. Usually, this priority-setting process is undertaken with contributions from a multitude of stakeholders interested in a wide variety of issues. **Safety advocates need to be part of the priority setting process.**

Exhibit 13: The transportation-planning process (Adapted from Meyer and Miller, 2001)



Once the planning process is complete, recommended projects or actions need to be further refined. For projects that need some form of construction activity, a project ***development*** process is followed. The three major steps in project development include developing project concepts, planning the project in finer detail than what would ordinarily occur in systems planning, and preliminary and final engineering. Again, the inclusion of safety stakeholders in the planning of local projects is an important catalyst to make sure safety is appropriately addressed.

The final component of the framework is ***system monitoring***. System monitoring provides a feedback loop to goals and objectives and the use of performance measures. Poor system performance leads to further planning analysis so that additional action is taken.

Exhibit 13 depicts the different components of a transportation-planning process. In reality, this description is suitable for any type of planning effort. For example, an agency interested in focusing efforts on safety or developing a comprehensive safety plan can use this framework to develop a systematic approach for doing so. The vision focuses on transportation safety; the goals and objectives are oriented toward desired safety targets; safety data and analysis tools assess the relative value of one approach versus another; the different approaches are evaluated on the basis of safety-oriented criteria; a set of strategies or actions are adopted; and finally these strategies are implemented.

Given the major components of transportation-planning as shown in Exhibit 13, answering the questions in Exhibit 14 should provide a good point of departure in assessing whether the transportation-planning process currently in place within a state or metropolitan area considers safety in meaningful and substantive ways.

If any of the answers to the questions in Exhibit 14 are "no", then safety issues should be given additional priority and greater emphasis in the transportation-planning process. The following sections will provide the user of this guidebook with strategies for developing a more safety-conscious planning process.

It should be noted at the outset, that in some cases, states and metropolitan areas have developed a separate safety comprehensive plan that focuses exclusively on safety improvements to the transportation system. In such cases, the linkages between this planning effort and the development of the comprehensive transportation plan are critical. For example, the safety-related goals and performance measures should be common to both. The strategies identified as being important to the state or region should be consistent if not the same. The monitoring system should feed into both efforts. Having a state or metropolitan comprehensive safety plan in no way diminishes the need to incorporate safety into the transportation-planning process. Indeed, in some cases, transportation-planning could very well be the implementing process for some of the strategies recommended by the safety-planning effort. The development of a comprehensive safety plan should be viewed as complementing the safety-oriented activities of those involved in the transportation-planning process.

Exhibit 14: Questions for assessing the planning process

Assessing The Planning Process…..	*See*
1. Does the vision statement for the planning process include safety?	Exhibit 15
2. Are there at least one planning goal and at least two objectives related to safety?	Exhibit 17
3. Are safety-related performance measures part of the set being used by the agency?	Exhibit 21
4. Are safety-related data used in problem identification and for identifying potential solutions?	Exhibit 24
5. Are safety analysis tools used regularly to analyze the potential impacts of prospective strategies and actions?	Exhibit 35
6. Are evaluation criteria used for assessing the relative merits of different strategies and projects including safety-related issues?	Exhibit 39
7. Do the products of the planning process include at least some actions that focus on transportation safety?	Exhibit 46
8. To the extent that a prioritization scheme is used to develop a program of action for an agency, is safety one of the priority factors?	Exhibit 46
9. Is there a systematic monitoring process that collects data on the safety-related characteristics of transportation system performance, and feeds this information back into the planning and decision-making process?	Exhibit 50
10. Are all of the key safety stakeholders involved in the planning process?	Chapter 4

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CHAPTER 6. INCORPORATING SAFETY CONSIDERATIONS INTO TRANSPORTATION-PLANNING

Incorporating safety into the transportation-planning process can occur at many different steps of the planning process. Doing so will result in greater decision-making emphasis placed on safety-related strategies and projects. Seriously considering safety will entail the incorporation of safety considerations throughout the planning process. However, it is likely that even incorporating safety considerations into one or two elements of the planning process (for example, in the evaluation and priority-setting components) could influence final decisions. This chapter discusses how safety can be included in each step of the planning process. Questions that serve as tools for assessing the safety-related status of an individual step in the planning process are provided at the beginning of each section. If it is found that safety is not considered in a rigorous way in a particular planning step, suggested actions for so doing are recommended at the end of each section.

Step 1: Incorporating Safety into the Vision Statement

Questions for assessing the vision statement of the region, DOT, or MPO are provided in Exhibit 15.

Exhibit 15: Questions for assessing the vision statement

Questions to be asked…

- Is safety incorporated into the current vision statement of your jurisdiction's transportation plan? If not, why not?
- Is safety an important part of the mandates and enabling legislation of key agency participants in the planning process?
- Is safety an important concern to the general public and planning stakeholders? If not, should it be?
- How is safety defined by community stakeholders?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system?

A vision statement describes what a community would like to be in the future, including desired characteristics of its transportation system. These might include general descriptions of community character and transportation system performance or targeted statements concerning desired transportation performance. The vision statement is usually developed through extensive outreach efforts to the community. Thus, the process of developing a vision statement is very much a "bottom-up" process, although, in most cases, vision statements should be consistent with and support stated policies. The following vision statement for the California statewide transportation-planning process illustrates a typical vision statement for a state. The vision for California is to have:

> *"a safe sustainable transportation system that is environmentally sound, socially equitable, economically viable, and developed through collaboration; it provides for the mobility and accessibility of people, goods, services, and information through an integrated, multimodal network."[Caltrans, California Transportation Plan, 2025, Sacramento, CA, March 2004].*

The following two vision statements from the San Francisco Bay area and Orlando, FL illustrate similar types of vision statements for metropolitan transportation-planning processes:

> *"The highest aim of the Metropolitan Transportation Commission is to plan for, deliver and manage a safe, efficient, integrated, multimodal transportation system for the San Francisco Bay Area".* [Metropolitan Transportation Commission, *2001 Regional Transportation Plan, Chapter 3: RTP Goals*, Oakland, CA: 2001].

> *"By the year 2020, have a regional, integrated, multi-modal transportation system that safely and efficiently moves people and goods to, through and within our urban area, and which enables the Central Florida community to flourish in the global marketplace.* "[Orlando MetroPlan, *Year 2020 Long Range Transportation Plan Update,* Orlando, FL, Dec. 2000]

Note that in each of the vision statements "safety" is a desired characteristic of the future travel experience.

Although many vision statements turn out to be generalized statements on community desires and wishes, they often are the result of extensive community outreach and reflect community input. Developing vision statements (referred to as the "visioning process") to guide a planning process is one of the first efforts to engage a community in a discussion of desired community characteristics and importantly of what role the transportation system can play in achieving these desired states. Thus, the visioning process is important to this guidebook not only because it represents one of the first comprehensive efforts to seek input from and educate a community on what constitutes important transportation system performance, but also because it represents an important "point of departure" for the many planning activities that follow. Furthermore, it sets the tone for the overall focus of the planning process and what needs to be considered when analyzing and evaluating different transportation options. Transportation safety should be part of the transportation system performance element of vision statements. Exhibit 16 presents steps that can be taken to insert safety considerations in the vision statement.

Exhibit 16: Suggested steps for including safety in the vision statement

Suggested steps…..

- Prepare and present background information on transportation safety in the state or jurisdiction. This information can perhaps be best presented via video or DVD. Illustrate how significant the safety problem is not only on the personal level, but also to society as a whole. Describe safety for all modes: motor vehicles, pedestrians, bicycles, and transit.
- Prepare and present information on what benefits are likely to occur to this safety situation with the implementation of a comprehensive safety strategy in the state or community.
- Prepare prototypical vision statements that include safety as part of the vision (or identify such statements used by others in the U.S.). Present these statements at public meetings, board meetings, or in other forums where the visioning process is taking place to raise awareness toward the safety challenge.

Step 2: Incorporating Safety into the Set of Goals and Objectives

The goals and objectives for a region are derived from the vision statement. Questions to help assess how and/or whether safety is effectively and appropriately included in goals and objectives are provided in Exhibit 17.

Exhibit 17: Questions for assessing goals and objectives

Questions to be asked…..

- Is safety incorporated into the current goals and objectives set of your jurisdiction's transportation plan? If not, why not? If so, what, if anything, needs to be changed in the way safety is represented?
- How does the safety goal relate to the community understanding of safety as discovered through the vision development process?
- Does the safety goal lead only to recommended project construction and facility operating strategies, or does it also relate to strategies for enforcement, education, and emergency service provision?
- Does the safety goal reflect the safety challenge of all modes of transportation that is, is it defined in a multi-modal way?
- Are there goal-related objectives that provide more specific directions of how the goal is going to be achieved? Are these objectives measurable?
- Do the objectives reflect the most important safety-related issues facing your jurisdiction?
- Can the desired safety-related characteristic of the transportation system be forecasted or predicted? If not, is there a surrogate measure or characteristic that will permit one to determine future safety performance?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system as it relates to planning goals and objectives?
- If target values are defined in objective statements (for example, fatal accidents will be reduced by 20%), have these targets been vetted through a technical process that shows that the target value can be reached?

Goals and objectives provide more specific guidance for the planning process. Not only do goals and objectives convey to the community a sense of what the transportation-planning process and planning products are striving to achieve, they provide important "directions" to the development of the criteria that will be used later to analyze and evaluate different projects and strategies. As with the development of a vision statement, the creation of a goals and objectives statement is undertaken with many opportunities provided for public input.

Similar to a vision statement, goals and objectives are sometimes stated in general terms; however, they do provide more specific guidance than what is found in a vision statement. For example, the following goals and objectives were defined for the San Francisco Bay area transportation-planning process:

Mobility:	Improve mobility of persons and freight
Safety:	**Improve safety for system users**
Equity:	Promote equity for system users
Environment:	Enhance sensitivity to the environment
Economic Vitality:	Sustain the economic vitality of the region
Community Vitality:	Promote vital and livable communities

For the safety goal, the following, more specific, objectives were identified:

1) Ensure key transportation facilities are capable of withstanding a major earthquake
2) Ensure MTC, Caltrans, and the Bay Area transit operators can effectively coordinate their services following a major earthquake or other significant emergency that disrupts Bay Area transportation
3) Help ensure the safety of motorists using Bay Area freeways
4) Help ensure the safety and security of transit system users
5) Assist local jurisdictions in their efforts to implement effective strategies to reduce serious injuries and loss of life for pedestrians and bicyclists

Exhibit 18 and Exhibit 19 show different goals statements from several metropolitan areas.

Safety goals and objectives can also be more specific and include targets, such as:

1) Reduce fatal accidents in the region by 10% over the next three years
2) Reduce accidents that occur in the traffic build-up after an initial accident by 20% over the next two years
3) Reduce fatal and serious injury accidents by drivers aged 16 to 23 by 30%
4) Reduce drug and alcohol-related accidents by 25%
5) Reduce pedestrian- and bicycle-related injuries and fatalities by 50%
6) Reduce red-light running violations by 30%
7) Reduce emergency response times to motor vehicle accidents so that 90% of all accidents are attended to within 6 minutes of the accident
8) Reduce school-zone-related accidents by 75%

Specific safety targets such as these may serve to provide guidance and motivation to engineers and planners to achieve regional safety goals. If from the assessment of a plan's goals and objectives it is determined that safety is not incorporated in a complete way, Exhibit 20 describes some steps that can be taken to include safety explicitly in the goals and objectives of a region.

Goals and Objectives for the Houston-Galveston Area Council

Goal 1 - Reduce congestion and improve access to jobs, markets and services.

Goal 2 - Preserve and maintain the existing transportation infrastructure.

Goal 3 - Improve transportation safety and security.

Goal 4 - Be environmentally responsible.

Achieve the safety and security goal by….

- Increasing funding to reduce high accident levels in the region.
- Undertaking safety studies throughout the region.
- Mitigating 344 major accident hot spots at a cost of $172 million but with an annual benefit of $392 million.
- Supporting traffic safety education and traffic enforcement efforts.
- Building an information system that will identify crime incidents on transportation facilities to support strategic safety and security investments.

Exhibit 18: Goals and objectives for the Houston-Galveston area council

Suggested steps…..

- Prepare prototypical safety-related goals and objectives for the safety problems identified through the public involvement process. Present and refine these goals and objectives given public and decision maker feedback.
- If objectives are to be defined with recommended achievement targets (e.g., reduce fatalities by 20 percent over 10 years), conduct an analysis to determine if such a target can reasonably be achieved with 1) existing strategies, 2) by enhancing existing strategies, or 3) only be implementing significantly more draconian strategies.
- Use the information material prepared in the visioning process to educate stakeholders and decision makers about safety as it relates to goals and objectives.

Exhibit 19: Safety goals for Columbus, Ohio, and Southeast Michigan

Safety Goal in Columbus, OH

Goal: Enhance the safety of the regional transportation system.

- Remedy dangerous highway, transit, and pedestrian facilities.
- Enhance pedestrian safety through the minimization or elimination of conflicts among pedestrians, bicycles, automobiles especially between transit stops, residential and schools, shopping, and recreational areas.

Safety Goal and Objectives in Southeastern Michigan

Goal: Promote a safe and secure transportation system

- Reduce traffic accidents, especially between modes
- Increase transit safety and security for riders and employees
- Improve identification and clearance of roadway incidents
- Develop pedestrian-friendly communities and roadways.
- Local communities should define safety needs and strategies

Exhibit 20: Suggested steps for including safety in regional or statewide goals and objectives

Step 3: Incorporating Safety into System Performance Measures

Evaluation of system performance has traditionally relied on measures of congestion, travel delay, traffic volumes, and measurements of the condition of such things as pavements and bridges. Safety performance can be monitored as well. Exhibit 21 lists questions for assessing the role of safety in defining system performance measures for a region.

Exhibit 21: Questions for assessing role of safety in system performance measures

Questions to be asked…

- What are the most important safety-related characteristics of the transportation system that resulted from community outreach efforts to date? If performance measures are used, are these characteristics reflected in the articulated set of performance measures?
- Will the safety performance of the transportation system (as defined in the performance measures) likely respond to the types of strategies and projects that will result from the planning process? That is, are the performance measures sensitive enough to discern changes in performance that will occur after program implementation?
- Is the number of safety performance measures sufficient to address the safety concerns identified in the planning process? Alternatively, are there too many safety measures that could possibly "confuse" one's interpretation of whether safety is improving?
- Does the capability exist to collect the data that are related to the safety performance measures? Is there a high degree of confidence that the data and the data collection techniques will produce valid indicators of safety performance? Who will be responsible for data collection and interpretation?
- Can the safety performance measures be linked to the evaluation criteria that will later be used in the planning process to assess the relative benefits of one project or strategy over others? If so, can the safety performance measures be forecasted or predicted for future years?

Performance measures are used to monitor the characteristics of transportation system performance and to determine the extent to which desired goals and objectives are being achieved. The use of performance measures is a relatively new phenomenon in transportation-planning, and thus there is little consistency from one jurisdiction to another of how safety is monitored. For example, the following measures from a Texas comprehensive safety plan show how performance measures can relate to specific goals,

GOAL — Decrease traffic deaths and injuries

<u>Performance Measures</u>

- Mileage death rate (deaths per 100 million VMT)
- Vehicular traffic accident rate/100 million VMT
- Traffic accident injury rate/100 million VMT

GOAL — Stabilize the increase in the frequency and percentage of all speed-related accidents

Performance Measures

- Frequency of speed-related accidents

Another example of the role of safety performance measures in transportation-planning is found in the Minnesota Statewide Transportation Plan. This plan is divided into ten policies aimed at improving the performance of the state's transportation system. One of these policies is, "Increase the safety and security of transportation systems and users." Five specific measures define what is meant by increased safety:

- Reducing the number of accidents per vehicle-mile traveled
- Reducing the number of general aviation accidents
- Reducing the number of accidents between cars and trains at railroad crossings
- Reducing the total number of roadway fatalities
- Reducing the number of general aviation fatalities.

The Minnesota DOT analyzed the impacts of different safety policies in achieving safety goals. Exhibit 22 shows the results of this analysis. Using a trend-based projection, that is, with little intervention from transportation and enforcement agencies, the number of motor vehicle fatalities would increase from approximately 640 fatalities per year to 735 fatalities per year. With moderate enforcement and transportation interventions, fatalities are projected to decrease to 600, while an aggressive policy results in a projected decrease in fatalities to 550.

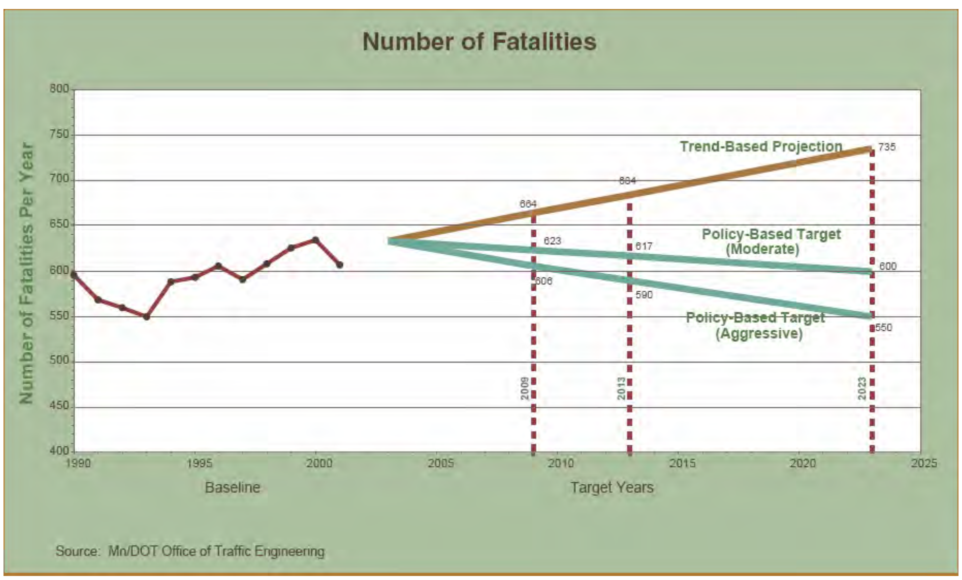


Exhibit 22: Minnesota DOT analysis of fatality performance goals

To be useful, performance measures need to be understood by transportation and enforcement professionals as well as decision makers and the general public. In most cases, multiple metrics are needed to assess the full range of safety problems and of the programs designed to address them. However, the number of safety-related performance measures should be limited to a critical few so that the consequences of implementing safety programs can be identified and monitored in a meaningful way. The measures should rely on existing data and methods to the extent possible and preferably be monitored continuously over time.

A range of possible safety performance measures for use in transportation-planning includes crash count-related performance measures (e.g., fatal crashes), normalized accident rate performance measures (e.g., fatal crashes per million vehicle miles of travel), unit costs and cost-effectiveness measures (e.g., dollars invested in countermeasure), alcohol and drug involved crashes (e.g., number of intoxicated young drivers) and some other measures (e.g., restraint usage rates).

Transportation officials often do not agree as to whether performance measures that incorporate driver exposure through rates (e.g., crashes per 100 million vehicle miles traveled) or those that simply reflect the overall magnitude of the problem (e.g., total fatalities) are more appropriate. The lack of consensus stems from the fact that crash rates on some facilities will decrease with increasing traffic volumes without safety interventions, thus making comparison across sites problematic—a lower crash rate could merely reflect a site with greater traffic volumes. Conversely, crash frequencies by themselves lack an accounting of exposure at a site to the level of risk associated with the amount of traffic present. The most widely acceptable approach is to determine the expected crash count for a site using a comparison group of sites with similar traffic volumes and other features, or to account for the non-linear relationship with exposure by calibrating a count-based regression model (i.e., Poisson or Negative Binomial); however, this approach requires analysis capability and understanding. It is highly recommended that this approach be adopted for conducting detailed safety analyses. For some planning purposes, however, it may be prudent to examine both crash rates and frequencies. In fact, this approach is widely practiced, and rests upon the logic that examining a problem from multiple 'angles' will lead to greater problem insight.

Exhibit 23 provides a short list of suggested steps for including safety in system performance measures. These steps provide important information regarding a range of strategies and specific measures for monitoring safety performance.

Exhibit 23: Suggested steps for including safety in system performance measures

Suggested steps…..

- Review safety-related performance measures used by similar agencies in the U.S. (see Appendix E).
- Prepare a set of prototypical safety-related performance measures that reflect the goals and objectives in your planning effort. This set should be limited in number to only those measures that provide critical information on the safety performance of the transportation system and that could presumably be affected by the types of strategies that will result from the planning process.
- Discuss the proposed set of performance measures with those in the agency responsible for collecting the data to ensure feasibility of collection and data accuracy. In addition, discuss the measures with transportation modelers in the region or state to determine if the measures can be predicted in future years.

Step 4: Incorporate Safety into Technical Analysis

Technical analysis is one of the most important steps in the overall planning framework. Through a systematic and comprehensive process, this step identifies problems and opportunities for improvement in the transportation system, and analyzes the relative effectiveness of different projects or strategies in terms of the goals and objectives established earlier in the planning effort. In one sense, this step of planning is really a "breaking down" of transportation problems into components that are used to pinpoint where critical leverage is applied to solve these problems. Two aspects of this technical analysis process merit special attention when considering a closer integration of safety into systems planning—safety-related data and their use, and analysis models/tools. Exhibit 24 lists some questions for assessing the availability, quality, and need for safety data in the planning process.

Safety-Related Data

Exhibit 24: Questions for incorporating safety-related data in the planning process

Questions to be asked…..

- Given the definition of safety that resulted from the visioning and goals/objectives phases of the planning process, what types of data are needed to support the safety desires of the community?
- Are these data available currently? If not, who should collect these data? Are there ways of collecting the data, or are there surrogate data items that can be used to reduce the costs and burdens of data collection?
- Does the state (or region) have a systematic process or program for collecting safety-related data? If not, who should be responsible for developing one?
- Is there a quality assurance/quality control strategy in place to ensure the validity of the data collected? If not, who should develop one?
- Are there opportunities to incorporate data collection technologies into new infrastructure projects or vehicle purchases (e.g., surveillance cameras or speed sensors)?
- Does the safety database include safety data for all modes of transportation that are relevant to the planning process (e.g., pedestrians, bicyclists, transit, intermodal collisions, etc.)? If not, what is the strategy for collecting such data? Who should be responsible?
- What types of database management or data analysis tools are available to best use the data (e.g., a geographic information system)? Are such tools available to produce the type of information desired by transportation decision makers?
- Are there other sources of data in your state or region that might be relevant for safety-related planning (e.g., insurance records, hospital admissions, non-profit organizations, etc.)? If yes, who should approach these groups to negotiate the sharing of data?
- Are there any liability risks associated with the collection and/or reporting of accident data? If so, how can your agency be protected against such risk?

Effective technical analysis relies on the availability and use of valid and high quality data. Data are used in a variety of ways. In the context of safety-related planning, they are used to better understand the nature and complexity of safety problems. For example, an analysis might be used to determine whether road fatalities are related more to high driving speeds or to driving while intoxicated. Analysis will also inform to what extent pedestrian injuries and fatalities are related to school activities. These insights are important for gaining a better appreciation of the safety challenges facing a jurisdiction. Analyzing data collected by numerous transportation, enforcement, and health agencies could result in important knowledge for answering these questions.

Data are also important for identifying where different types of safety problems exist in a state or metropolitan area. Exhibit 25 through Exhibit 33 illustrate how the combination of quality data and the use of a geographic information system (GIS) in the Houston metropolitan area can pinpoint potential safety problem areas or "hotspots" for a variety of different problem types, which can then be further examined with critical analysis. Notice that with useful visualization and analytical tools, transportation officials can identify potential sites for safety-related infrastructure improvements (and further detailed analysis and site investigations), where to target enforcement activities (e.g., location of illegal running of red lights), and where to emphasize safety education (e.g., at schools with high pedestrian/bicycle/motor vehicle crashes). Capitalizing on GIS tools and portraying crash-related data in such a manner provides useful information to those deciding where to allocate limited safety resources and where additional detailed analyses and investigations are warranted.

As shown in Exhibit 25, both MPOs and DOTs rate vehicle crash data as the most important type of data for safety-related planning. Every state has a formal approach for collecting crash data, as do many local jurisdictions. The U.S. Department of Transportation and the National Highway Traffic Safety Administration (NHTSA) also collect and disseminate crash data by state via the internet. Crash data are most often collected for each incident and thus include identifiers relating to the location, date/time, roadway characteristics (e.g., alignment, work zone, weather, light conditions, number of lanes, and road surface), crash characteristics (e.g., "manner of collision" and "first harmful event" such as hit object or vehicle rollover), contributing factors, emergency management service (EMS) arrival times, and vehicles and persons involved, and hospital information (e.g., medical injuries and procedures, costs, treatments). At the vehicle/driver level, data can include vehicle type and identification (e.g., make/model, axles, body type, use of a trailer, vehicle identification number (VIN) and state of registration), vehicle crash involvement (e.g., contributing factors and pre-crash travel speed), hazardous material cargo, vehicle crash results (e.g., fire/explosion/spill, rollover, deformation, jackknife) and driver characteristics (e.g., license state, license restrictions and license history).

Although crash data are critical for conducting safety-related transportation-planning, planners and engineers often face difficulties in obtaining such data in a comprehensive manner and in a timely fashion. Although crash databases do exist, there is likely to be significant undercounting of the total number of crashes that occur in a state or metropolitan area, especially for non-serious injury and property damage-only crashes. Many agencies that have some responsibility for reporting crash data often use different referencing systems, thus creating a challenge when all of the safety-relevant data for crashes across an entire state or region need to be combined. In many cases, although police agencies have standardized police accident report (PAR) forms that request data on a wide range of crash-related factors, filling out such forms often receives very little priority from police agencies, especially at the crash scene. Finally, crash data that are routed to central databases are often not available to transportation planners for two (and sometimes more) years after they are reported.

Exhibit 25: Importance of data for safety-related transportation-planning source as determined through project survey

Data source	MPO	State DOT
Vehicle crashes	1	1
DUIs	14	12
Injury/fatality	4	3
Property damage	7	8
Vehicle miles traveled	2	4
Air quality/emissions	8	9
Water navigation crashes	10 (tie)	15
Air transport crashes	9	10 (tie)
Transit/paratransit incidents	10 (tie)	10 (tie)
Roadway inventories	3	2
Emergency medical response	13	16
Accident investigation	16	12
Safety belt/restraint use data	12	14
Bicycle crashes/injuries	6	7
Pedestrian crashes/injuries	5	6
Rail crashes	15	5

With increasing attention paid to the importance of safety in the transportation-planning-process, and given new network and vehicle technologies that make data collection less onerous, several of the problems with data collection may be solved in future years. Transportation officials should seek opportunities to incorporate more efficient and effective data collection capabilities when new projects or changes to services are implemented.

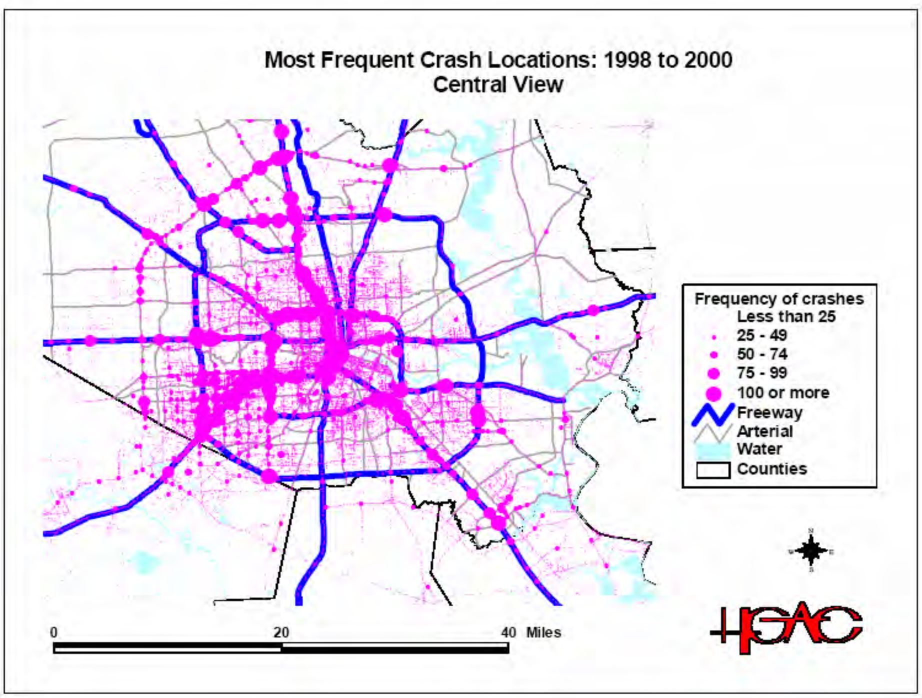


Exhibit 26: GIS map of accident frequencies on a transportation network

Exhibit 27: GIS map of crashes on a small road network

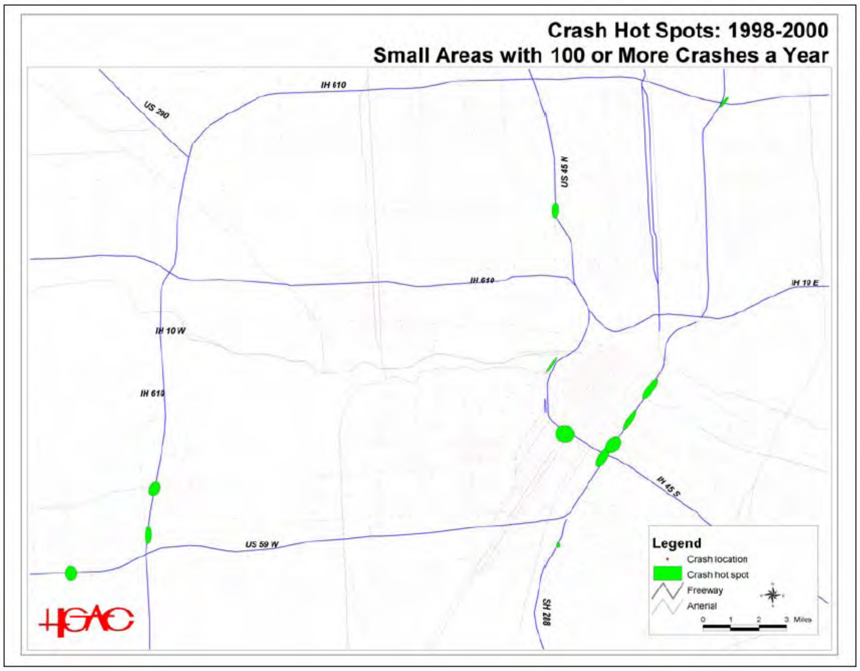
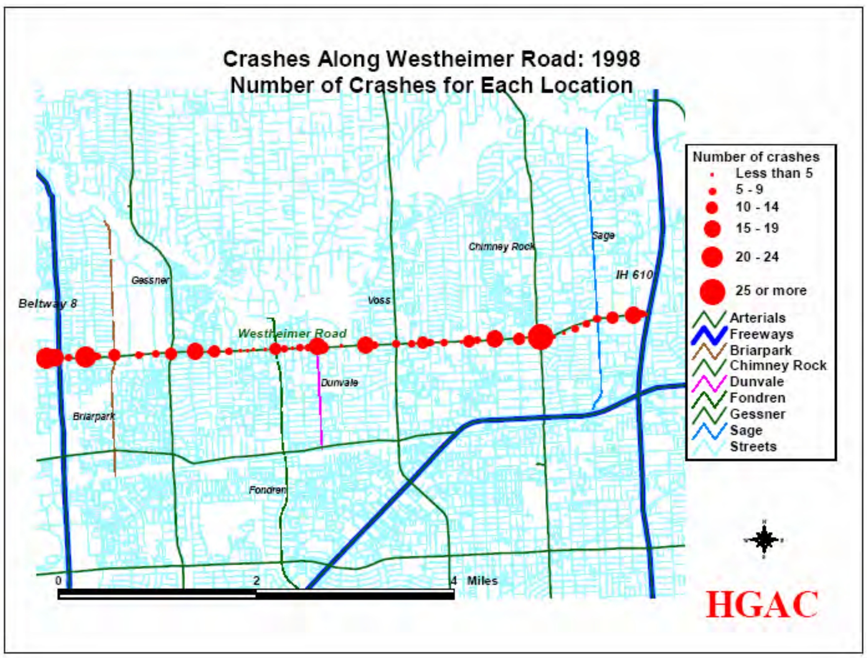


Exhibit 28: GIS map of crashes along a corridor



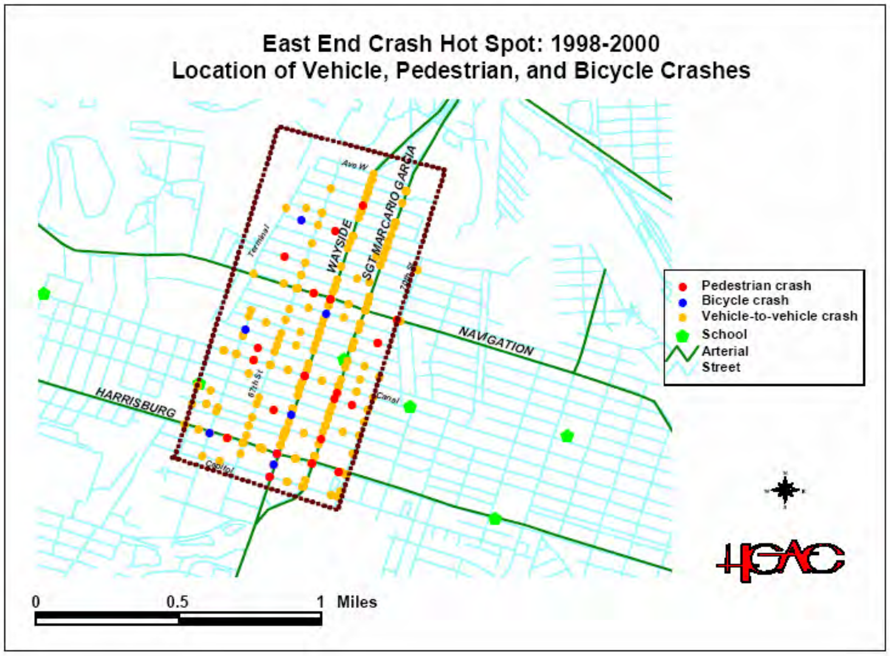


Exhibit 29: GIS map of bicycle and pedestrian crashes at the neighborhood scale

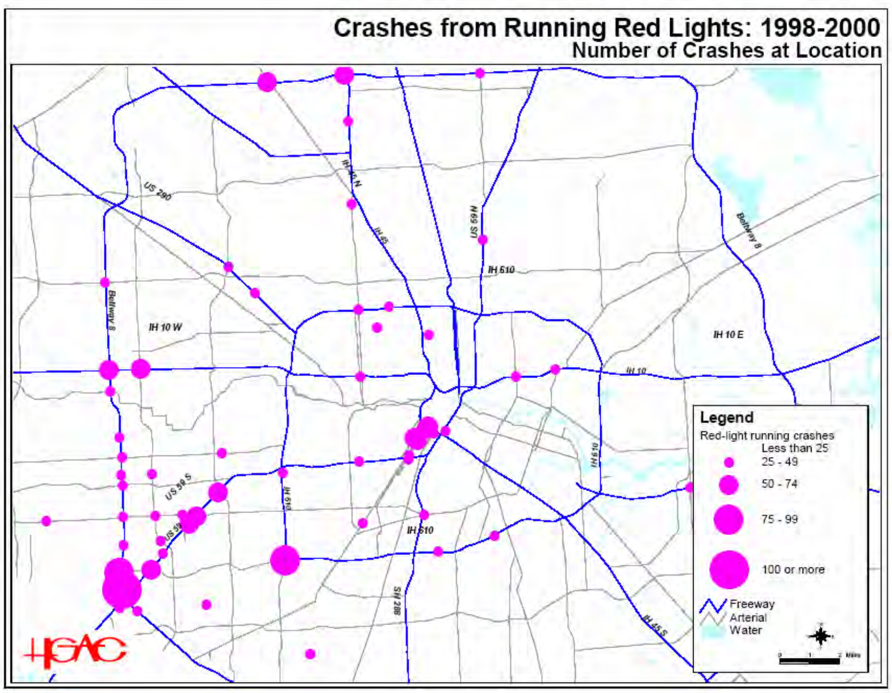


Exhibit 30: GIS map of red-light-running-related crashes on a transportation network

Exhibit 31: GIS map of bicycle and pedestrian crashes in a transportation network

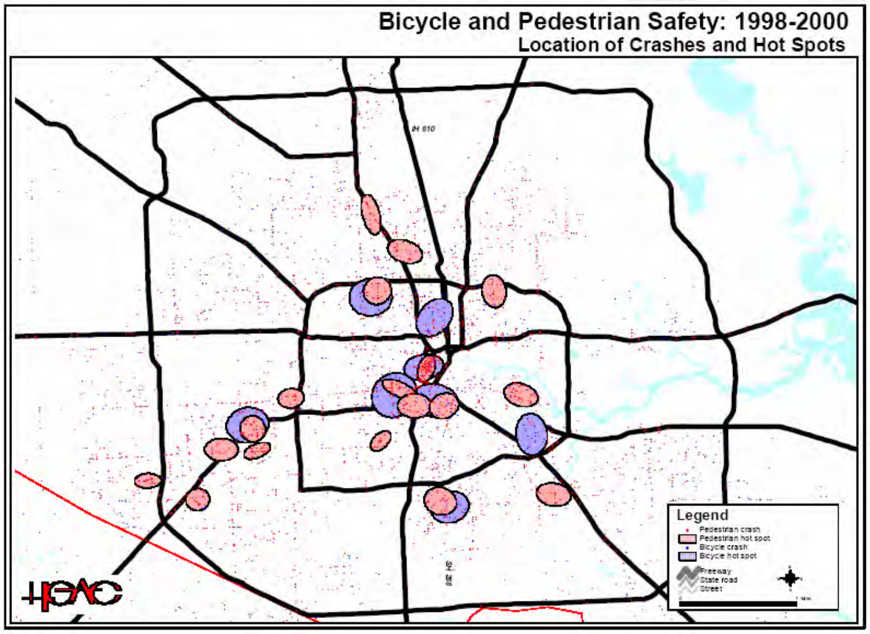
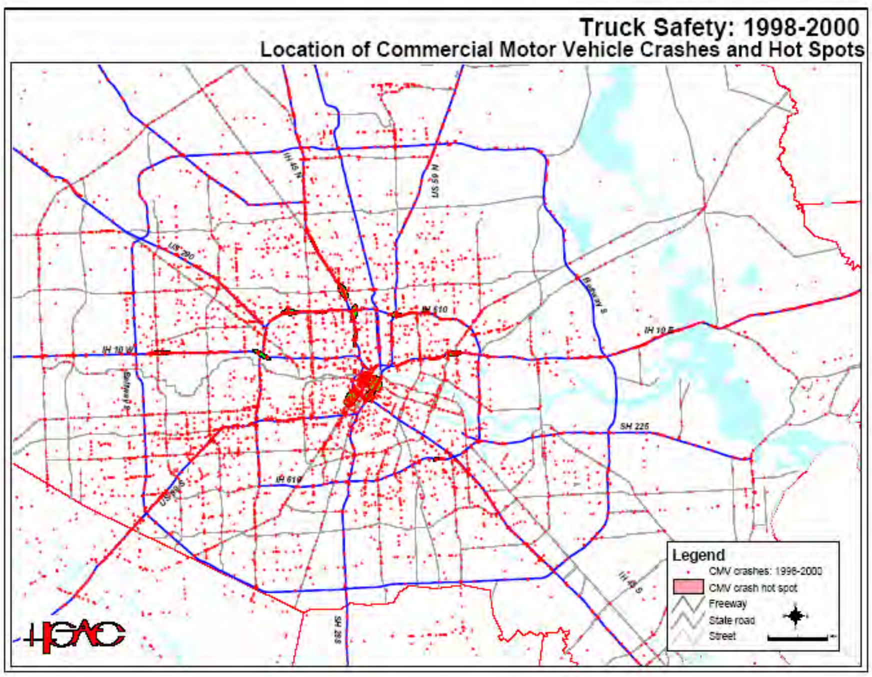


Exhibit 32: GIS map of commercial motor vehicle crashes in a transportation network



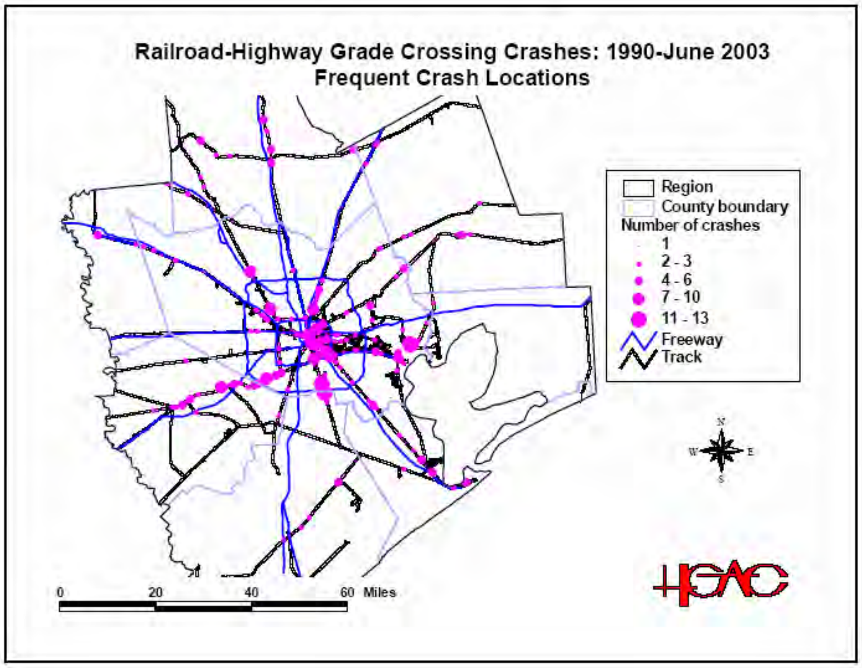


Exhibit 33: GIS map of railroad-highway crossing crashes

Exhibit 34 describes steps than can be taken to establish a regional safety database that can be used to support detailed safety analysis in a region. While a GIS system is not necessary, it can be helpful to manage data, to store data, and to combine data from numerous sources that are increasingly becoming available in GIS format. [14]

Exhibit 34: Suggested steps for developing a regional safety database

Suggested steps…

- For each of the goals, objectives and performance measures identified in the planning process, define the types of data that will be necessary to produce the desired information. Develop a data collection strategy…what are the sources of relevant data? Who is responsible for collecting this data? Who is responsible for putting this data into useable form?
- Investigate sources of data that currently exist (e.g., collected by federal agencies) that could be used to illustrate the safety challenges facing the state, metropolitan area or community.
- Develop a memorandum of understanding or some other form of agreement with relevant agencies for developing a safety database.
- Develop a plan for how safety-related data will be poresented, both for internal agency purposes and public presentations. Test this template with public groups to assess its effectiveness.
- Involve staff members who are responsible for data collection and data management in decisions relating to the overall strategy for safety-related database management. If a geographic information system is to be used, have these staff members identify what steps must be taken to develop a fully operational system

A host of safety analysis tools are available for planners and engineers [see, for example, 15, 16, 17, 18, 19]. Exhibit 35 provides a list of questions that can be asked to help foster the identification of appropriate tools.

Analysis Tools

Exhibit 35: Questions to guide the selection of appropriate safety analysis tools

Questions to be asked…..

- What is the scale of the safety problem being faced? Regional? Corridor? Site-specific? What tools are available to analyze safety problems at the appropriate scale of analysis?
- What information is needed and desired by decision makers? Can existing analysis tools produce this information with reasonable levels of validity?
- What are the possible types of strategies that could be implemented to deal with this safety problem? Are there analysis tools currently available in the agency or in partner agencies that can be used to determine the effectiveness of these types of strategies? If not, are there analysis tools available elsewhere?
- Is the safety-planning challenge one that requires predicting or forecasting the future safety characteristics of a transportation system or facility? If so, what approach will be taken to predict such future performance? What are the underlying assumptions in this approach (e.g., future accident rates are the same in the future as they are today)? Or, in other terms, what are the sources of uncertainty associated with safety predictions?
- Can existing analysis tools, or if necessary, the process of developing new ones, be undertaken in the timeframe associated with when decisions have to be made? If not, is there a more timely analysis procedure that can be used to produce information that is relevant to decision makers?
- If the safety challenge includes problems associated with multiple modes of transportation, and if so, what tools can address multimodal or mode specific safety issues? For example, most available analysis tools focus on road safety. If the state or region is facing safety problems with pedestrian, bicycle, transit, or freight trip-making, what analysis tools will be used to analyze these types of problems? If available analysis tools are not used, how are these problems addressed in the safety-related planning effort?

Appendix C provides descriptions of many tools to aid the analyst in answering the questions posed in Exhibit 35. The tools are designed to address a range of specific safety-related issues, and the reader is encouraged to become familiar with the tools available. An excellent summary of the available tools is provided in Exhibit 53 in Appendix C. The table provides the name of the tool, the primary purpose of the tool, the level of detail required to run the tool (data requirements), and the required level of expertise. The remainder of Appendix C provides detailed descriptions of the tools, how to contact the vendors, what specific data and expertise are required, etc. The safety analysis tools available include roadway design, planning-level safety forecasting, hot spot identification, pedestrian, bicycle, multimodal, intersection analysis, road segment analysis, database management, safety level of service, and data linkage tools.

The level of analytical rigor applied in safety-related planning efforts will depend upon many factors; the demand for safety analysis in the region, the cooperation and coordination with other stakeholder agencies in the region, the allocation of safety responsibility in the region, the level of personnel resources available to conduct such analyses (which typically depends on agency size), and the level of technical expertise available within the agency. Because of the nature of safety problems, analysis tools will be needed that assess problems and the consequences of alternative strategies for different time spans—short-, medium- and long-range perspectives—as well as at different scales—individual project, corridor, sub-area and regional levels. Project and corridor-level safety tools have been available for some time and are used in many safety studies. Regional level planning tools, however, are not as readily available. One tool has been developed as part of this research and is described in Appendix C of this document.

At this point, it is worthwhile to discuss some fundamental concepts in safety that will serve as useful concepts for individuals not typically involved in safety analysis. These concepts are important because some difficult lessens have been learned over the years in the study of transportation system safety, and some of these lessons have yielded counter-intuitive results.

1. <u>System safety is not accurately measured by one-time crash counts</u>. When looking at intersections, road segments, ramps, crosswalks, etc., crash counts across multiple observation periods (e.g., each day, month, or year) will fluctuate above and below the underlying mean crash rate—or true underlying safety. In other words, a crash count in any given observation period may be significantly above or below the expected crash count for the site due simply to random fluctuations in crashes (crashes are by their very nature due in part to random events). Thus, a high crash count for one particular observation period is not sufficient by itself to define an underlying safety problem; it merely indicates the potential for one. By analyzing the data and crash circumstances more carefully—such as the crash history of a location, greater confidence can be attained in understanding whether a safety problem exists, and if so, what remedial measures might be necessary.
2. <u>Countermeasures typically affect specific types of crashes—called target crashes</u>. Safety countermeasures rarely show beneficial effects on all crash types and more often affect only certain crash outcomes. For example, red-light-running cameras will have an effect mostly on angle and rear-end crashes at intersections. It thus follows that certain crash types have greater safety improvement potential with specific types of countermeasure treatments.
3. <u>Crash trends increase and decrease without interventions or countermeasures</u>. Many factors beyond control of the planner or engineer will affect crashes, such as weather, catastrophic events (e.g., earthquakes, hurricanes), changes in road users, aging of the driving population, changes in crash reporting over time, changes in surrounding land uses, etc. Thus, a robust analysis will try to account for changes that are due to factors other than the countermeasure of interest.
4. <u>Safety performance relative to underlying safety is critical</u>. The expected long run (or underlying) safety of an entity (e.g., young driver, vehicle type, road segment, intersection, etc.) needs to be estimated in order to determine the safety performance of an individual or group of entities. For example, a rural intersection should not be compared to the average urban intersection, because these intersection types perform differently (e.g., different drivers, traffic volumes, speeds, driving environment, etc.). What matters more is how the rural

intersection performs relative to an appropriate comparison group of rural intersections and how the intersection performs over time. The same holds true when comparing crosswalks, road segments, younger drivers, etc.

5. Safety performance functions are not typically straight lines. For a fairly homogenous group of transportation system components (signalized intersections, segments of interstate, etc.), increases in traffic volumes will result in increases in associated crashes until an inflection point is reached, whereby crashes then may begin to level off or decline. This means that crash or crash rates may also decline with increasing traffic volumes after a certain inflection point is reached, making crash rate comparisons across sites with different traffic volumes problematic. For example, fatal crashes tend to decrease as congestion increases, since higher traffic volumes tend to reduce travel speeds, a primary factor in crash severity. Multi-vehicle crashes also tend to increase as volumes increase, until a 'saturation' point is reached, at which these crashes level off or even decline as speeds are reduced.
6. Accident modification factors are used to quantify countermeasure effectiveness. An accident modification factor (AMF) is usually estimated for a countermeasure so that its effectiveness is known.[20, 21] The accident modification factor is multiplied by the count of target crashes (see point #2) before the countermeasure is applied to obtain an estimate of the count of target crashes expected after the countermeasure is applied.

Exhibit 36 presents an example of accident modification factors from the Denver metropolitan area. Note that these factors are developed for different types of improvement categories.

Exhibit 36: Accident modification factors for highways in the Denver metropolitan area [Source: Denver Regional Council of Governments, 2002]

Improvement Characteristics	Percentage Reduction in Relevant Accidents (Accident Modification Factor)	Target Accident Types
Curve Reconstruction	0.50	Run off road, head-on
Vertical Re-Alignment	0.45	Head-on, limited sight
Median Barriers	0.60 fatal, 0.10 injury	Head-on
Climbing/Passing Lane	0.15	Passing, rear-end
Lane Widening	0.20	Sideswipe (multi-lane)
Widen from 2-lane to 4-lane Road	0.30	Rear-end, head-on
Continuous Center-Left Turn Lane	0.30	Rear-end

Exhibit 36 presents one set of AMFs for highway countermeasures. Countermeasures, of course, exist for many applications, including both behavioral- and engineering-related programs and/or investments. Exhibit 37 presents a list of sources for obtaining information regarding countermeasure effectiveness for both behavioral- and engineering-related improvements.

Exhibit 37: Sources of information on countermeasure effectiveness: behavioral and engineering countermeasures

Source	Behavioral Countermeasures
AASHTO	Strategic Highway Safety Plan Guides (NCHRP Report 500)
Centers for Disease Control & Prevention	Guide to Community Preventive Services (sections on highway safety)
Jones and Lacey	Systematic Reviews of Strategies to Prevent Motor Vehicle Injuries
U.S. DOT	State of Knowledge of Alcohol-Impaired Driving: Research on DWI Offenders, DOT HS 809 027
U.S.DOT	Alcohol and Highway Safety 2001: A Review of the State of Knowledge DOT HS 809 383
American Journal of Preventative Medicine	Reviews of behavioral safety countermeasures/interventions
U.S. DOT	Highway Safety Grant Management Manual, Highway Safety Program Guidelines
U.S.DOT/NHTSA	Traffic Tech-Technology Transfer Series: 1995 – 2004; Traffic Safety Digest: 1996 – 2004
U.S.DOT/NHTSA	Crash Outcome Data Evaluation System (CODES)
IACP	Nifty 50: Fifty ways to promote traffic safety 2003 IACP Law Enforcement Challenge Submissions

Source	Engineering Countermeasures
Transportation Research Record	Numerous journal articles relating to safety, e.g., TRR 1865, 1818, etc.
Accident Analysis & Prevention	Numerous journal articles relating to behavioral aspects of safety
NCHRP/TRB	Reports on highway safety, committee activities such as Highway Safety Manual
Federal Highway Administration	Various activities on safety, including IHSDM, SafetyAnalyst, PedSafe, etc.
Elvik, E. and Truls Vaa.	The Handbook of Road Safety Measures, (2004)
Evans, L.	Traffic Safety. Science Serving Society, (2004)

Different types of safety analysis tools and methods are available to address different kinds of safety problems.[see, for example, 22, 23, 24, 25, 26, 27] Those interested in solving specific types of safety problems are encouraged to conduct a web search on that topic. The breadth of safety issues and the different types of tools available to address them is so large that this report cannot hope to recommend a set of tools for all safety problems.

Exhibit 38 presents steps that can be taken to improve the safety-related analysis capabilities in a state or metropolitan region. The steps include conducting peer reviews, developing lists of current capabilities, research needs, and developing data analysis plans.

Exhibit 38: Suggested steps for improving safety related analysis capabilities

Suggested steps…

- Inventory the types of safety analysis tools that exist in the state or metropolitan area's safety-related agencies. Relate those that exist to the types of safety problems that are being faced. If analysis tools do not exist for the identified types of problems, develop a strategy for developing or acquiring this type of analysis capability.
- Starting with the tools listed in Appendix C, conduct a peer review of the existing safety analysis capabilities. Invite representatives from peer agencies who have experience with safety-related planning to assess the capabilities that currently exist in the state or metropolitan region. Have this peer review produce specific steps that need to be taken to improve the analysis capability for safety-related planning.
- Develop a long term and coordinated data-collection and safety analysis strategy for the state and/or metropolitan area. This strategy would include a description of current capabilities, likely future safety problems, and the steps needed to put in place an analysis capability for dealing with such problems. This strategy should be developed cooperatively with all of the safety partners in the state or metropolitan area.
- If not already available, the state, in cooperation with metropolitan planning organizations, should develop a table of accident reduction factors and their associated likely reductions in accidents and fatalities for different types of safety improvements (numerous sources are available for this). Some analysis may be necessary to complete this table; whereas some information may be obtained from prior research and experience. These factors need to be carefully reviewed for accuracy and relevance to the specific safety needs and conditions a planner is attempting to address. Many reduction factors were developed for locations with conditions that may or may not be transferable to the conditions in another metropolitan area or state. Such information on countermeasure effectiveness is critical for determining the benefits associated with safety-related improvements and for prioritizing investments.
- For non-infrastructure or non-traffic operations strategies, such as safety education, marketing campaigns, and emergency management services, regions should work closely with safety partner organizations to determine a methodology for assessing the effectiveness of such strategies. This might include targeted before and after studies on selected programs, or simply anecdotal evidence of what impacts such programs have had on public attitudes and behavior.

Step 5: Evaluating Alternative Projects and Strategies

Exhibit 39 provides a set of questions that can be used to assess the safety-related evaluation capabilities within a region. These questions focus on issues of evaluation capabilities, roles of organizations in the evaluation process, and the validity and completeness of evaluation inputs.

Exhibit 39: Questions regarding evaluation methodologies

Questions to be asked…..

- For the types of evaluation decisions that need to be made, is an evaluation methodology in place that produces useful information for decision making? Will this methodology deal effectively with assessing tradeoffs among many different types of projects and strategies?
- Is a simple rating sufficient to provide the type of information desired, or are multiple measures needed?
- How will non-infrastructure-related strategies and actions be evaluated? For example, if dollars are expended on safety education programs, how will the relative effectiveness of these programs be evaluated, if at all?
- Does the state or metropolitan area have reliable estimates of the costs to society of different accident types and/or severities? If not, where can these estimates be obtained?
- Who will be conducting evaluations, that is, who will be assigning the points in a scoring scheme or estimating discounted benefits in a cost--benefit methodology? Does the capability exist to undertake such efforts in a fair and unbiased way?
- Are there computer-based tools that can help the evaluation process in an efficient manner? (see Appendix C)
- How are the underlying assumptions in the evaluation process (such as value of life, discount factors, etc.) best explained to decision makers and to the general public?
- Will the evaluation results be sufficiently sensitive to the collection of various inputs? Should sensitivity analyses be conducted?
- What is the best way of presenting evaluation results to decision makers?

Once safety-related strategies and projects have been evaluated for their safety effects (using tools discussed in the previous section), the next step in the planning process is to determine which actions result in greater benefits to society. The process of determining the desirability of different courses of action and presenting this information to decision makers in a comprehensive and useful form is called evaluation. Assessing the desirability of a course of action (i.e., investment in a countermeasure) includes determining how costs and benefits are to be measured, estimating the source and timing of the benefits and costs of the proposed actions, and comparing these benefits and costs to determine which action is preferred.

Most safety-related evaluation efforts use one of three methods, 1) simply listing the evaluation criteria and show how the alternatives compare, 2) assigning weights or scores to the evaluation factors, or 3) conducting cost--benefit analysis.

Ranking by Evaluation Criteria: A common approach for evaluating numerous factors when comparing transportation projects is simply developing a list of the impacts associated with different evaluation criteria. For example, the following evaluation criteria are used in the Southeastern Michigan Council of Governments (SEMCOG) process for determining the relative benefits of projects that go into the region's transportation plan. As shown in the list, many different factors are important to decision makers in this region when considering which projects are most beneficial. In this case, the safety criterion, defined as accident locations per mile, is one of the important considerations when project comparisons are made.

- Bridge deficiencies per mile
- High accident locations per mile
- Percent congestion along corridor
- Pavement needs
- Freight characteristics
- Transit ridership
- Non-motorized characteristics
- Traffic volumes
- Population and household density
- Proximity to activity centers
- Proximity to special population groups

Decision makers presented with this information choose projects based on their consideration of what is important to their agency or jurisdiction. Tradeoffs among the many different evaluation factors are explicitly made. Often, however, the information presented to decision makers does not indicate the "best" alternative. As shown in the above list, it is very likely that among the hundreds of projects that are typically considered by state DOT and MPO officials, the relative impacts of one project versus another would vary among the different criteria. In one case, a project would show good improvement in bridge condition, but not show as much improvement in safety as other projects. In such an evaluation scheme, the judgement of which projects are better than others rests with the decision makers.

In some situations, where funding programs are set aside for specific categories and thus effectiveness can be measured with one evaluation criterion, such as safety, air quality, economic development, etc., the selection of the "best" alternative becomes much easier…it is simply the one that shows the greatest benefit. Thus, for example, if funds have been set aside for improving road safety, and benefits are measured as the reduction in the number of crashes, the most desired projects will be those that show the greatest reduction in crashes. In comprehensive transportation-planning, however, reducing project selection decisions to a single criterion seldom happens.

Assigning Scores to Projects: One approach for providing more information to decision makers assigns points to individual projects in relation to how they perform against a given set of criteria and then sums these points to assign a score for each project. Exhibit 40 illustrates this concept as applied in Denver. In the Denver region, roadway operational improvement projects can receive up to 35 priority points, a maximum of 16 points is given for the most severely congested roads, up to 4 points if a project is in a corridor receiving emphasis in the regional transportation plan, and up to 9 points is assigned to the most heavily used roads. The number of safety points relates to the relative benefit (that is, reduction in crashes) expected if the project were implemented, and the severity of the problem (that is, the crash record compared to multiples of the statewide average for that type of road). This example illustrates a points-based system that includes safety as well as other considerations (mobility, congestion, etc.)

Exhibit 40: Assigning points as an evaluation methodology in Denver [Source: Denver Regional Council of Governments, 2003]

Evaluation Criteria	Points	Scoring*
Congestion	0-16	Up to 16 points based on the current degree of congestion (V/C ratio) on the existing roadway
RTP Emphasis Corridors	0-4	4 points to projects on emphasized freeways or major regional arterials. 2 points to projects on emphasized principal arterial segments
Safety	0-7	Up to 7 points based on weighted accident rate compared to statewide average and estimated accident reduction.
Usage	0-9	Current AWDT/lane > 11,000 = 9 points; < 2,500 = 0 points

	Estimated Number of Accidents per Mile Eliminated per Three Years			
	Low 0-14 fewer	Medium 15-35	High 36-59	Very High 60+
Accident Range	**Safety Points To Be Awarded**			
State Average	0	1	3	4
1-2 x State Average	1	2	4	5
2-3 x State Average	2	4	5	6

Exhibit 41 illustrates the same concept for pedestrian and bicycle projects in the Denver region. In this case, projects can receive up to 39 points, a maximum of 4 points if a project is in a regional transportation plan designated corridor, 12 points for having the best safety benefits, and up to 23 points for a project's effectiveness in addressing the non-motorized transportation needs of the region. Safety points are awarded based on crash history, level of conflict (in this case indicated by differential speed between pedestrians and bicyclists and adjacent motor traffic), and on the existence of lighting.

Exhibit 41: Scoring for pedestrian and bicycle projects in the Denver region

Evaluation Criteria	Points	Scoring*
RTP Priority Corridors	0-4	4 points for bike projects on RTP Regional Bicycle Corridors 2 points for bike projects on Community Bicycle Corridors 4 points for pedestrian projects along RTP major regional arterials 2 points for pedestrian projects along RTP principal arterials
Safety	0-12	Projects evaluated on the anticipated improvement of existing safety problems
Potential Need	0-23	Up to 23 points for specific project attributes which address existing local or regional needs of non-motorized travel

The points awarded for safety for each evaluated project are broken down as follows:

- **Crash History**
  1 point award for each applicable injury accident, up to a maximum of 5

- **Conflict Factor**
  1 point if < 25 mph
  2 points if 26-34 mph
  3 points if 35-44 mph
  4 points if 45-54 mph
  5 points if > 55 mph

- **Facility Lighting**
  2 points to projects that facilitate non-motorized travel, if lighting is not available now

The challenge associated with this approach with respect to project evaluation is first determining the relative maximum points to be awarded in the different categories (which explicitly assigns priority across objectives), and then actually conducting a project-by-project assignment of points. The relative number of points among the different evaluation categories is usually determined by the decision-making body through an iterative process of determining the relative importance of different evaluation factors (e.g., "if you had a total of 100 points, how many would you give to safety? congestion relief? environmental quality? etc.) . The actual assigning of points in each category is usually done by technical staff, although in some cases, advisory committees of stakeholders and public representatives participate in this process.

Using Benefit-Cost Analysis: The incremental benefit-cost analysis is one of the most common methods of comparing the relative worth of projects. This evaluation method assesses the relative incremental benefit of a project compared to all other projects on the basis of additional dollars spent to build the next most expensive project. For example, if one is facing a choice between two projects and the budget only allows one project to be built, the best decision will be the one that maximizes the benefit received per dollar expended. To illustrate, assume that the benefits of project A and B are $100 and $150 respectively, while the costs are $80 and $125 respectively. One can see that the benefit to cost ratio for each project is calculated as:

Project A: $100/$80 = 1.25
Project B: $150/$125 = 1.20

However, a higher B/C ratio for project A as compared to project B does not mean that project A is the better choice, since $45 is available for investing in other opportunities. The initial B/C calculation simply determines whether the benefits for an individual project are greater than the respective costs for that project. In order to determine the "best" choice, one must determine the incremental benefit associated with additional costs. In this case, for the additional costs of $125 - $80 = $45 that will be spent to implement project B, the additional benefit will be $150 - $100 = $50. Therefore, the incremental B/C ratio is $50/$45 = 1.11, which is greater than 1. Stated simply, this reveals that for each dollar spent to construct project B over the cheaper project A, $1.11 in benefits will accrue. All else being equal, it is clearly beneficial to select project B (Note: that the "correct" decision in this case was not the one that had the highest initial individual project B/C ratio).

Using the benefit-cost methodology creates several challenges that must be addressed if the method is to be used correctly. These challenges are briefly presented below. Readers are encouraged to seek additional information regarding benefit-cost analysis methods [see 28, 29, 30, 31].

How are benefits defined? Benefit-cost analysis assumes that all benefits and costs can be assigned dollar values.[28] This is not a significant obstacle for project costs, which are estimated in dollars. However, estimating the monetary value of benefits is a challenge. The typical application of the benefit-cost method for road projects assumes that three major components of benefits are possible—a reduction in travel time, a reduction in vehicle operating costs, and a reduction in crash costs (fatalities, injuries, and property damage). Through the analysis process, estimates should be available on the number of minutes saved, the reduction in vehicle miles traveled and the reduction in crashes. In order to assign dollar values to these benefits, the evaluation methodology must include the value of time, a value of vehicle operating costs (per mile), and values for various crash severities.

With respect to a value of crashes, the federal government and many states have conducted economic studies to determine the cost to society of different types of crashes. Exhibit 42 shows the estimated costs to society of different types of crashes. Exhibit 43 illustrates the same concept for North Carolina, and Exhibit 44 shows similar estimates for transit accidents in Los Angeles. These estimates are based on expected medical, time lost, employer, and emergency services costs associated with a crash-related injury or fatality. Notice in Exhibit 43 that a quality of life cost is also included in the overall estimate. This cost reflects the stress and related disturbances to family and civic life associated with someone no longer able to participate in day-to-day life activities.

Exhibit 42: Federal Highway Administration estimates of cost to society of accidents

Urban Functional System	Death	Cost/Nonfatal Injury	Property Damage Cost/Accident
Interstate		$27,047	$5,148
Other freeway/expressway		$35,002	$6,435
Other principal arterial	$3 million	$28,638	$6,435
Minor arterial		$39,775	$6,435
Collector		$31,820	$5,148

Exhibit 43: North Carolina estimates of cost to society of accidents

	Fatal Injury	Incapacitating Injury	Moderate Injury	Minor Injury	PDO
Medical	$18,676	$14,656	$3,209	$1,721	$137
Emergency Services	$1,184	$292	$190	$123	$60
Lost Work	$1,020,469	$22,535	$6,917	$3,345	$366
Employer Cost	$8,055	$1,199	$493	$272	$88
Traffic Delay	$488	$212	$205	$174	$251
Property Damage	$11,064	$4,350	$3,697	$2,794	$2,505
Monetary Cost	$1,059,936	$43,245	$14,710	$8,431	$3,406
Quality of Life	$1,865,164	$101,551	$22,776	$8,431	$3,406
Comprehensive Cost	$2,925,100	$144,796	$37,486	$17,916	$3,904

Exhibit 44: Los Angeles estimates of cost to society of transit accidents

	Bus and Rail (per Million Vehicle Miles)		
Type of Accident	Bus Rate	Rail Rate	Cost per Event
Fatal	0.162	1.161	$2,710,000
Injury	25.800	11.600	$65,590

The safety benefits associated with a particular project are thus the expected reduction in the number of crash types (resulting from the analysis process) multiplied by related crash benefit values similar to those shown in the previous exhibits. National cost estimates can be used when local, regional, or state costs estimates are lacking; however, 'local' and 'recent' cost estimates should be used when available.

Are costs and benefits defined consistently? Some outcomes are not easy to tally in the cost or benefit column. For example, is an increase in travel time resulting from a project a negative benefit or a positive cost? This at first may seem trivial, but it is not. An impact identified as a negative cost will result in a different B/C ratio than if the impact is identified as a benefit (and vice versa). For example, assume a B/C ratio of 1.5 is estimated for a project costing $1 million, but yielding $1.5 million in estimated benefits. In addition, suppose travel time is increased as a result of the project, with the net negative benefit of travel time savings estimated to be -$250,000. If this additional impact is treated as a negative benefit then the B/C ratio becomes 1.25, whereas treating the travel time increase as an additional cost results in a B/C of 1.2. Thus, an inconsistent treatment of costs and benefits across projects being compared can result in unfair comparisons. The solution to this problem is careful and consistent tallying of costs and benefits across projects.

What does one do about benefits and costs that accrue at different times over the life of the project? Most projects have benefits and costs that will occur at different times in the future. For example, a new road will likely incur its major costs in the initial construction period and then experience an increasing level of benefits over time. Another type of project, one that requires enforcement or operations costs continually over the life of the project, would show a very different stream of costs. In comparing benefits and costs of different projects, it is important that this comparison be done in a way that fairly reflects the differing circumstances of each project. This is done in one of two ways. Either all benefits and costs are discounted to the present time (using a governmentally defined discount factor and assuming that all projects have equal project lives) or all benefits and costs are annualized into benefits and costs (i.e., benefits and costs each year). Again, the specifics of how one does this are beyond the scope of this guidebook; readers are encouraged to consult a variety of widely available references on the use of discount factors.

With benefits and costs defined and discounted, the decision criterion for determining the best project is simply to conduct an incremental benefit-cost analysis that satisfies the following equation:

$$\geq 1.0 \quad \frac{\Sigma(\text{pwf})(\text{benefits})_b - \Sigma(\text{pwf})(\text{benefits})_a}{\Sigma(\text{pwf})(\text{costs})_b - \Sigma(\text{pwf})(\text{costs})_a}$$

where:

- pwf = present worth factor (the discount factor for the different years that benefits and costs occur)
- $(\text{benefits})_b$ = benefits for project b, which is the higher cost project
- $(\text{benefits})_a$= benefits for project a, which is the lower cost project

This equation says that if the incremental B/C ratio between two projects yields a ratio greater than or equal to one, then the higher cost project is preferred. If the ratio is less than one then the lower cost project is preferred.

Exhibit 45 provides suggested steps for incorporating an evaluation methodology into a safety conscious planning process.

Suggested steps…

- Define early in the planning process what evaluation criteria will likely be used so that the data collection and analysis tool development and selection will be directly related to the information desired and needed. This effort would most likely be subject to community and decision maker involvement. It is best to define a limited number of critically important criteria that will be of overarching concern to decision makers.
- Inventory the different safety-related evaluation methods currently in use in the state or metropolitan area. Determine gaps in evaluation capability that might affect the production of desired evaluation information. Select an appropriate/acceptable methodology for the region.
- Periodically update (or develop, if not available) accident cost to society data. This is important in that the other benefit values used in a benefit cost analysis, those relating to reduced operating costs and reduced travel time, are usually updated on a periodic basis. Safety benefit values need to keep pace.
- While the transportation-planning process is underway, develop methods and approaches that will be used when the evaluation process is undertaken. Do not wait until late in the planning process to do so!
- Think carefully about how the definition of evaluation criteria will lead to the selection of the best projects or strategies. Is there any bias introduced into this selection process by the way evaluation criteria are defined?
- Prepare prototypical presentation templates for safety information and obtain feedback from decision makers and from the general public on the level to which they effectively convey information.

Exhibit 45: Suggested steps for incorporating an evaluation methodology into the safety conscious planning process

Step 6: Develop Plan and Program

Exhibit 46 lists questions regarding the inclusion of safety-related projects in the transportation plan. The questions aim to raise awareness as to the role of safety in the Transportation Plan and Improvement Programs, as well as other planning activities undertaken by both state DOTs and MPOs.

Exhibit 46: Suggested steps for including safety in the transportation plan and program

Questions to be asked…..

- Does the transportation plan and program include safety-related projects and strategies? Are they appropriately identified in the documents?
- If other comprehensive safety plans exist for the state or region, are the transportation plan and program consistent with the goals, performance measures, actions and strategies as indicated in these comprehensive plans?
- If some form of prioritization scheme is used to rank projects in the programming process, is safety included in this scheme? If so, what is the relevant weight of safety compared to other factors?
- Are key safety stakeholders involved in the final development of the transportation plan and program?
- Are safety-related tasks or analysis included in the MPO's Unified Planning Work Program (UPWP) or the state DOT's State Planning and Research (SPR) work program?

As noted previously, the transportation-planning process can result in many different products. The Unified Planning Work Program (UPWP), the MPO's annual program of planning tasks and the State Planning and Research (SPR) work program, the comparable work program for the state DOT's planning bureau, are important indicators of the priorities found in the planning process. Each provides an excellent opportunity to advance safety planning activities and strategies. If one wants to see a stronger emphasis given to safety, these task programming documents are an important means of doing so.

Certainly, how safety is incorporated into a transportation plan and program is a critical characteristic of the degree to which safety is fully integrated into the transportation-planning process. However, especially for safety issues, the planning process needs to do more than just have safety mentioned in the transportation plan. Targeting specific groups for education efforts, enhancing traffic enforcement activities, providing improved data collection and data management efforts, conducting further studies on specific urban corridors or parts of a state where safety is of particular concern, and considering additional regulations to promote transportation safety are all valuable results of the transportation-planning process. Exhibit 47 presents the results of the survey of MPOs and state DOTs conducted for this research. The question asked was, to what extent are the safety-related issues shown included in the long-range transportation plan? The MPOs predominantly include pedestrian and bicyclist safety in their transportation plans and more generally traffic management strategies, as well as presenting the results of traffic safety studies. For DOTs, not surprisingly, traffic management, pedestrian and bicycle safety strategies, and safety at intermodal crossings (e.g., railroad grade crossings) received considerable attention. Although many of the other topics were not considered as important by the majority of respondents with respect to transportation plans and programs, it is interesting to note that some MPOs and state DOTs did consider these issues to be important enough to be included in the transportation plan.

Exhibit 47: Inclusion of concepts in long-range transportation plans

	Yes (%)	No (%)	Not included, but discussed in planning (%)	Yes (%)	No (%)	Not included, but discussed in planning (%)
Safety Education Programs						
Motor-Vehicle Safety Education	13.4	**60.8**	25.8	20.6	**58.8**	20.6
Safety Publicity	26.8	**48.5**	24.7	26.5	**50.0**	23.5
Bicyclist/Pedestrian Safety Education	**59.8**	15.5	24.7	**47.1**	23.5	29.4
Transit Safety Education	19.6	**50.5**	29.9	2.9	**82.4**	14.7
Work Zone Safety Education	8.2	**77.3**	14.4	35.3	**38.2**	26.5
Education Policy	14.4	**71.1**	14.4	11.8	**73.5**	14.7
Elderly Driver Evaluation Programs	7.2	**81.4**	11.3	11.8	**76.5**	11.8
Mature Driver Education	5.2	**80.4**	14.4	8.8	**76.5**	14.7
Engineering and Operations						
Traffic Management	**88.5**	2.1	9.4	**73.5**	17.6	8.8
Safety Audits of Existing/Rehabilitated/New Roadways	25.0	**42.7**	32.3	23.5	**55.9**	20.6
Traffic Safety Studies	**55.2**	14.6	30.2	**41.2**	32.4	26.5
Traffic Safety Measures in Construction Zones/"Work Zones"	7.3	**59.4**	33.3	29.4	**47.1**	23.5
Personal Vehicle Safety						
Seat Belt / Restraint Use	4.2	**80.0**	15.8	25.0	**53.1**	21.9
Child Safety Seat Use	1.1	**86.3**	12.6	18.8	**68.8**	12.5
Aggressive Driving	6.3	**70.5**	23.2	15.6	**71.9**	12.5
Distracted Driving (i.e. Cell Phones While Driving)	5.3	**75.8**	18.9	12.5	**75.0**	12.5
Older Driver Safety and Mobility	13.7	**63.2**	23.2	25.0	**46.9**	28.1
Winter (Snow and Ice) Driving	1.1	**80.0**	19.0	15.6	**65.6**	18.8
Drinking and Driving / DWI Prevention / Impaired Driving	5.3	**75.8**	19.0	21.9	**56.3**	21.9
Graduated Driver Licensing / Restricted Driving	3.2	**87.4**	9.5	15.6	**78.1**	6.3
Multi-modal Safety Programs						
School Bus Safety	8.4	**72.6**	19.0	6.3	**75.0**	18.8
Motorcycle Safety	3.2	**90.5**	6.3	12.5	**75.0**	12.5
Commercial Truck Safety	24.2	**44.2**	31.6	**34.4**	31.3	**34.4**
Bicyclist Safety	**70.5**	9.5	20.0	**62.5**	21.9	15.6
Pedestrian Safety	**69.5**	8.4	22.1	**59.4**	25.0	15.6
Intermodal Junction Safety (i.e. Roadway/Railway Crossings)	**46.3**	26.3	27.4	**59.4**	18.8	21.9
Alternative Transportation Education Programs						
Information Kits on How to Use Public Transportation	20.0	**46.3**	33.7	12.5	**75.0**	12.5
Information/Call Centers with Comprehensive Information on Safety/Incidents	28.4	**50.5**	21.1	15.6	**68.8**	15.6
Enforcement and Other Programs						
Speeding	16.8	**60.0**	23.2	16.1	**64.5**	19.4
Legislation	27.4	**48.4**	24.2	**41.9**	25.8	32.3
Safe Communities	17.9	**63.2**	18.9	9.7	**74.2**	16.1
Emergency Medical Services	18.9	**61.1**	20.0	16.1	**61.3**	22.6

The Minnesota DOT provides a good example of how a state DOT identifies safety-related projects and strategies in the statewide transportation plan. According to the plan, the following strategies and actions will be undertaken by the DOT:

"<u>Safety Strategies</u>

- Monitor the safety characteristics of the current systems (highways, intersections, rail crossings, airports) to determine overall accident and fatality trends and causes so that improvements can be targeted to eliminate the root causes and to address the highest risk locations and/or segments.
- To achieve the aggressive targets for fatality reduction, MnDOT will work with the Department of Public Safety and the public and private sector agencies (e.g., medical sector, emergency response services, insurance sector) to consider legislative initiatives to reduce the number of fatalities and accidents and to achieve the aggressive targets sought (e.g., primary seatbelt law, 0.08 percent blood alcohol content, graduated drivers licenses for teens, sobriety check points, automated red light enforcement).

- Support the Department of Public Safety and sheriff's offices in identifying high-accident locations that may benefit from additional enforcement (e.g., speeding, DWI, seatbelt usage).
- Work with local units of government to raise awareness of fatalities on local transportation systems and establish task force groups to identify potential programs and to target problem areas.
- Work with the Department of Public Safety and private sector interests to identify educational initiatives that will help improve driver skills and promote better driving behavior (e.g., incentives for web-based driver education). Focus is given to high risk driving populations (e.g., young and elderly drivers). In addition, explore knowledge of current traffic rules and laws to determine potential benefits of requiring periodic updates of the written driver's test. Explore use of refresher courses offered on the Web, with automatic submission to insurance companies for possible credit.
- Develop and implement communication strategies to increase awareness of safety issues and practices for vehicle operators (e.g., excessive speed, seat belt use, defensive driving, driver inattention, driving under the influence, lack of sleep).
- Ensure that all planning and corridor studies include system safety analysis to identify potential safety problem areas as well as potential access and safety improvements that will reduce the number and severity of accidents.
- Conduct railroad corridor analyses to address issues such as unsafe at-grade crossings and to identify potential crossing consolidation or closures, selected replacement with over/underpasses, improved warning/safety systems to reduce accidents and fatalities.
- Improve information available to freight carriers and pilots (e.g., weather, road and water conditions, training, regulations).
- Consider implementing innovative safety systems (e.g., centerline rumble strips, wider pavement markings, wider shoulders, cable barriers separating two-lane traffic) to reduce the number of run-off road accidents and/or vehicles crossing centerlines into oncoming traffic. These accidents tend to be on higher speed roadways and result in more severe injuries and fatalities.

Security Strategies

- Work with the Federal Motor Carrier Safety Administration, carriers and shippers of hazardous materials and other associations representing trucking companies/truckers that transport high-risk commodities that may pose a threat to the safety and security of the transportation infrastructure and the users of the transportation system.
- In response to the terrorist events of September 11, 2001, MnDOT has created two teams to pursue transportation security issues. One team will focus on internal issues such as the security of MnDOT buildings and staff. Another, external security team will focus on the security of external assets such as bridges, roadways, and transit facilities. The objectives for these teams are as follows:
  - Identify critical highway assets and their potential vulnerabilities.
  - Develop action plans/countermeasures to enhance existing capability to detect, deter and/or minimize the consequences of disasters.

- o Revise existing emergency response plans so MnDOT can effectively carry out coordinated response duties and sustain core businesses during and after a crisis.
- o Prioritize and estimate the costs of putting MnDOT plans into action.
- o Liaison and coordination with national, state and local security agencies/task forces/transportation industry representatives (public and private)."

Note in this list of strategies and actions the emphasis placed on collaborative undertakings with other agencies and organizations relevant to the safety challenge in Minnesota.

Another example of the types of strategies and actions that can be considered by a state is shown in Exhibit 48. This table lists the "tools" that are available in the safety management system used by Iowa officials to enhance safety on its transportation system.

Exhibit 48: Contents of Iowa's safety management system toolbox

- Increasing Driver Safety Awareness
- Increasing Safety Belt and Child Restraint Usage
- Preventing Drowsy and Distracted Driving
- Curbing High-Risk Driving Behaviors
- Ensuring Drivers Are Fully Licensed, Competent, and Insured
- Reducing Impaired Driving
- Education and Licensing for Young Drivers
- Sustaining Safe Mobility in Older Drivers
- Making Walking and Street Crossing Safer
- Ensuring Safer Bicycle Travel
- Making School Bus Travel Safer
- Making Public Transit Travel Safer
- Improving Motorcycle Safety and Increasing Motorcycle Awareness
- Making Large Truck Travel Safer
- Reducing Farm Vehicle Accidents
- Improving the Design and Operation of Roadway Intersections
- Keeping Vehicles on the Roadway and Minimizing the Consequences of Leaving the Road
- Reducing Head-On and Across-Median Accidents
- Improving Work Zone Safety
- Accommodating Older Drivers
- Reducing Train-Vehicle Accidents
- Reducing Vehicle-Animal Accidents
- Implementing Road Safety Audits
- Enhancing Emergency Response Capabilities to Increase Survivability
- Improving Information and Decision Support Systems
- Using Intelligent Transportation Systems (ITS) to Improve Highway Safety
- Creating More Effective Processes and Safety Management Systems
- Developing and Encouraging Multidisciplinary Safety Teams

One aspect of transportation-planning and the resulting safety characteristics of the transportation system that is often overlooked by transportation planners and engineers is the relationship between land use/urban design and safety. This is a particularly critical issue because the manner in which communities develop establishes the long-term urban form of a metropolitan area. The land use-safety relationship is most noticeable in the types of development that occur adjacent to roads. Development decisions, almost always under the governmental review of local governments, can result in poor roadway design, additional intersections or driveways (that is, additional conflict points), and/or land use patterns that do not provide easy and safe transit access to adjacent sites. When state agencies and MPOs conduct corridor studies leading to roadway reconstruction, having to deal with access rights and right of way demands of abutting private property can have a significant impact on final roadway design.[32]

One of the most successful strategies of providing access to abutting land in the safest possible manner is the adoption of an access management policy. Several studies have shown that the crash rates rise with more signalized intersections, more driveways and more pedestrian motor vehicle conflict points.[33] The range of safety benefits of an access management policy falls between 30% to 60% reduction in crashes, depending on the type of access controls used. A long range transportation plan that addresses the land use/transportation linkage or a state policy on access management can be an important effort at improving the safety of a road network. In many cases, MPOs have developed guidance to local communities that focuses on the consequences of development on already congested roads and on the important transit benefit of providing safe access to transit stops or stations.

In many ways, the development of a transportation plan that is sensitive to safety concerns can represent an opportunity to change the way agencies design and operate the transportation system. For example, a planning process could lead to a decision to use a design manual with standards that positively affect crash rates. Or the process could result in a recommendation to conduct a safety evaluation for each proposed project alternative prior to final design selection. In other words, although transportation-planning often focuses on infrastructure-related solutions, a much broader perspective on how the planning process can affect transportation system safety would include recommended policies, processes, studies, and budget priorities.

With respect to the transportation program, many of the projects placed in the transportation improvement program (TIP) or statewide transportation improvement program (STIP) are the result of negotiations that invariably characterize such deliberations. However, in many cases, project prioritization schemes similar in approach to those used in evaluation are part of setting priorities for project inclusion in the programming document as well as the timing of project implementation. Steps for including safety in transportation plans and programs are shown in Exhibit 49.

Exhibit 49: Suggested steps for including safety in transportation plans and programs.

Suggested steps…

- Include safety stakeholders in the culminating planning steps leading to the approval of a transportation plan and program.
- Develop safety priority factors that can be used to give safety-beneficial projects more priority in programming decisions.
- Highlight the safety-related strategies and projects that are identified in the transportation plan and program. This might include a separate safety chapter or appendix in the transportation plan and an indication in the program of which projects are primarily safety-related.
- Develop public marketing materials that highlight the safety benefits of the plan and program.

Step 7: Monitoring System Performance

System performance should be monitored to evaluate the effectiveness of various strategies, programs, and policies. Exhibit 50 lists questions that can be asked to assess how this monitoring process occurs with respect to safety.

Questions to be asked…..

- Is there a systematic program or strategy for monitoring the safety performance of the transportation system? If so, is it effective? If such a program does not exist, how can it be developed?
- Is the feedback provided by the monitoring system used for refining goals, objectives, performance measures, problem identification, project analysis and evaluation? Is this feedback provided in a timely manner?
- Are there new vehicle or system management technologies that can be used to provide the desired data more cost effectively? Can such data collection be integrated into other efforts by the state or region to collect system performance data? For example, if the state has an intelligent transportation system (ITS) architecture, is safety an important feature of this strategy?
- Who are the major players in a safety management system? What are their responsibilities? Is there a need to define in more formal terms these responsibilities and inter-relationships?

Exhibit 50: Questions for assessing the role of safety in monitoring system performance.

Once projects and strategies have been implemented, it is important to monitor the safety performance of the transportation system, and feed this information back into the original vision, goals and objectives, and selected performance measures. This feedback is then used in the subsequent planning cycle to highlight failures (or deficiencies) and successes with respect to system safety. This monitoring can occur as part of the normal data collection program of an agency, or a special data management system can be developed specifically targeted at monitoring the safety performance of the transportation system.

Exhibit 51 shows such a targeted management system. The Safety Management System for Phoenix uses a safety goal and safety performance measures to drive the collection of safety-related data and the identification of projects and strategies. These projects and strategies reflect the planning, engineering, education and enforcement aspect of the safety challenge in that metropolitan area.

Many states have similar types of safety management systems, although they are often not closely tied to the transportation plan. To all intents and purposes, safety data management systems are crash databases that enable the identification of high risk locations, and depending upon system capabilities, aid in the selection of appropriate countermeasures

Exhibit 52 lists some suggested steps for including safety explicitly in the performance monitoring activities of a transportation-planning process.

Exhibit 51: Phoenix safety management system

Phoenix Safety Management System

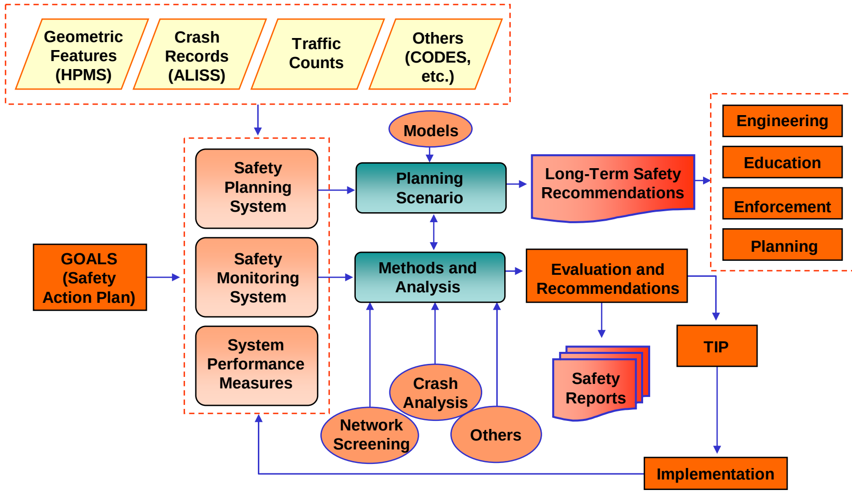


Exhibit 52: Suggested steps for including safety in the monitoring of transportation system performance

Suggested steps…

- Analyze the current flow of safety information from the monitoring of transportation system performance to its use in analyzing and evaluating safety-related projects and strategies. Identify components of this information flow that can be improved.
- Identify the major sources of safety data in the state and/or region. Conduct a forum that illustrates the importance of this data, and that identifies steps that can be taken to improve the process and substance of agency efforts.
- Develop a state or regional strategy for monitoring the safety of the multimodal transportation system. This monitoring should not only include the identification of current hazardous locations, but it should also proactively identify areas of potential hazard that can be addressed now rather than wait for the safety problem to occur.

CHAPTER 7. PUTTING IT ALL TOGETHER

This guidebook describes a transportation-planning process that integrates safety into key planning steps. Clearly, how a state DOT or MPO considers safety in its planning and decision-making processes will depend on numerous factors. In some cases, a separate comprehensive-safety-planning process or safety management system might already be in place, and thus there is no need for a rethinking of how planning is undertaken. In other situations, the state DOT or MPO might already be following many of the recommendations made in this guidebook.

This chapter is intended to provide the user of the guidebook with one location where all of the assessment questions can be found. Exhibit 14 is repeated below as a guide of how this report can be used. The questions on the left side of this exhibit focus on important components of the transportation-planning process. The right side of the exhibit provides a reference on where additional information can be obtained on how safety can be integrated into that particular aspect of transportation-planning.

Assessing The Planning Process…..	*See*
Does the vision statement for the planning process include safety?	Exhibit 15
Are there at least one planning goal and at least two objectives related to safety?	Exhibit 17
Are safety-related performance measures part of the set being used by the agency?	Exhibit 21
Are safety-related data used in problem identification and for identifying potential solutions?	Exhibit 24
Are safety analysis tools used regularly to analyze the potential impacts of prospective strategies and actions?	Exhibit 35
Are evaluation criteria used for assessing the relative merits of different strategies and projects including safety-related issues?	Exhibit 39
Do the products of the planning process include at least some actions that focus on transportation safety?	Exhibit 46
To the extent that a prioritization scheme is used to develop a program of action for an agency, is safety one of the priority factors?	Exhibit 46
Is there a systematic monitoring process that collects data on the safety-related characteristics of transportation system performance, and feeds this information back into the planning and decision-making process?	Exhibit 50
Are all of the key safety stakeholders involved in the planning process?	Chapter 4

The assessment questions that were listed in front of each section are repeated below. This combined list of questions can be used as a baseline assessment of the degree to which a transportation-planning process fully integrates safety into its key components. Not only will these questions allow the user to determine where improvements can be made, but they provide a means of identifying the types of steps that might be taken to provide a greater sensitivity to safety concerns.

ASSESSMENT OF THE INTEGRATION OF SAFETY INTO TRANSPORTATION-PLANNING

Vision

- Is safety incorporated into the current vision statement of the jurisdiction's transportation plan? If not, why not?
- Is safety an important part of the mandates and enabling legislation of key agency participants in the planning process?
- Is safety an important concern to the general public and planning stakeholders? If not, should it be?
- How is safety defined by community stakeholders?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system?

Goals and Objectives

- Is safety incorporated into the current goals and objectives of the jurisdiction's transportation plan? If not, why not? If so, what, if anything, needs to be changed in the way safety is represented?
- How does the safety goal relate to the community understanding of safety as discovered through the vision development process?
- Does the safety goal lead only to recommended project construction and facility operating strategies, or does it also relate to strategies for enforcement, education and emergency service provision?
- Does the safety goal reflect the safety challenge of all modes of transportation that is, is it defined in a multi-modal way?
- Do goal-related objectives provide sufficiently specific directions on how the goals are achieved? Are these objectives measurable?
- Do the objectives reflect the most important safety-related issues facing a jurisdiction?
- Can the desired safety-related characteristic of the transportation system be forecasted or predicted? If not, is there a surrogate measure or characteristic that will permit one to determine future safety performance?
- What type of information is necessary and desired to educate the community on the importance of a safe transportation system as it relates to planning goals and objectives?
- If target values are defined in objective statements (for example, fatal accidents will be reduced by 20%), have these targets been vetted through a technical process that shows that the target value can be reached?

Performance Measures

- What are the most important safety-related characteristics of the transportation system that resulted from community outreach efforts to date? If performance measures are used, are these characteristics reflected in the articulated set of performance measures?
- Will the safety performance of the transportation system (as defined in the performance measures) likely respond to the types of strategies and projects that will result from the planning process? That is, are the performance measures sensitive enough to discern changes in performance that will occur after program implementation?
- Is the number of safety performance measures sufficient to address the safety concerns identified in the planning process? Alternatively, are there too many safety measures that could possibly "confuse" one's interpretation of whether safety is improving?
- Does the capability exist to collect the data that are related to the safety performance measures? Is there a high degree of confidence that the data and the data collection techniques will produce valid indicators of safety performance? Who will be responsible for data collection and interpretation?
- Can the safety performance measures link to the evaluation criteria that will be used later in the planning process to assess the relative benefits of one project or strategy over others? If so, can the safety performance measures be forecast or predicted for future years?

Analysis--Data

- Given the definition of safety that resulted from the visioning and goals/objectives phases of the planning process, what types of data are needed to support the safety desires of the community?
- Are these data available currently? If not, who should collect these data? Are there ways of collecting this data, or are there surrogate data items that can be used to reduce the cost and burdens of data collection?
- Does the state (or region) have a systematic process or program for collecting safety-related data? If not, who should be responsible for developing one?
- Is there a quality assurance/quality control strategy in place to ensure the validity of the data collected? If not, who should develop one?
- Are there opportunities to incorporate data collection technologies into new infrastructure projects or vehicle purchases (e.g., surveillance cameras or speed sensors)?
- Does the safety database include safety data for all modes of transportation that are relevant to the planning process (e.g., pedestrians, bicyclists, transit, intermodal collisions, etc.)? If not, what is the strategy for collecting such data? Who should be responsible?
- What types of database management or data analysis tools are available to best use the data (e.g., a geographic information system)? Are such tools available to produce the type of information desired by transportation decision makers?
- Are there other sources of data in your state or region that might have relevant data for safety-related planning (e.g., insurance records, hospital admissions,

non-profit organizations, etc.)? If yes, who should approach these groups to negotiate the sharing of data?

- Are there any liability risks associated with the collection and/or reporting of accident data? If so, how can your agency be protected against such risks?

Analysis—Tools

- What is the scale of the safety problem being faced? Regional? Corridor? Site-specific? What tools are available to analyze safety problems at the appropriate scale of analysis?
- What information is needed and desired by decision makers? Can existing analysis tools produce this information with reasonable levels of validity?
- What are the possible types of strategies that could be implemented to deal with this safety problem? Are there analysis tools currently available in the agency or in partner agencies that can be used to determine the effectiveness of these types of strategies? If not, are there analysis tools available elsewhere?
- Is the safety-planning challenge one that requires predicting or forecasting the future safety characteristics of a transportation system or facility? If so, what approach will be taken to predict such future performance? What are the underlying assumptions in this approach (e.g., future accident rates are the same in the future as they are today)? Or, in other terms, what are the sources of uncertainty associated with safety predictions?
- Can existing analysis tools, or if necessary, the process of developing new ones, be undertaken in the timeframe associated with when decisions have to be made? If not, is there a more timely analysis procedure that can be used to produce information that is relevant to decision makers?
- If the safety challenge includes problems associated with multiple modes of transportation, and if so, what tools can address multimodal or mode specific safety issues?

Evaluation

- For the types of evaluation decisions that need to be made, is an evaluation methodology in place that produces useful information for decision making? Will this methodology deal effectively with assessing tradeoffs among many different types of projects and strategies?
- Is a simple rating sufficient to provide the type of information desired, or are multiple measures needed?
- How will non-infrastructure-related strategies and actions be evaluated? For example, if dollars are expended on safety education programs, how will the relative effectiveness of these programs be evaluated, if at all?
- Does the state or metropolitan area have reliable estimates of the costs to society of different accident types and/or severities? If not, where can these estimates be obtained?
- Who will be conducting evaluations, that is, who will be assigning the points in a scoring scheme or estimating discounted benefits in a cost--benefit methodology? Does the capability exist to undertake such efforts in a fair and unbiased way?

- Are there computer-based tools that can help the evaluation process in an efficient manner? (see Appendix C)
- How are the underlying assumptions in the evaluation process (such as value of life, discount factors, etc.) best explained to decision makers and to the general public?
- Will the evaluation results be sufficiently sensitive to the collection of various inputs? Should sensitivity analyses be conducted?
- What is the best way of presenting evaluation results to decision makers?

Plan and Program Development

- Does the transportation plan and program include safety-related projects and strategies? Are they appropriately identified in the documents?
- If other comprehensive safety plans exist for the state or region, are the transportation plan and program consistent with the goals, performance measures, actions and strategies as indicated in these comprehensive plans?
- If some form of prioritization scheme is used to rank projects in the programming process, is safety included in this scheme? If so, what is the relevant weight of safety compared to other factors?
- Are key safety stakeholders involved in the final development of the transportation plan and program?
- Are safety-related tasks or analysis included in the MPO's Unified Planning Work Program (UPWP) or the state DOT's State Planning and Research (SPR) work program?

System Monitoring

- Is there a systematic program or strategy for monitoring the safety performance of the transportation system? If so, is it effective? If such a program does not exist, how can it be developed?
- Is the feedback provided by the monitoring system used in refining goals, objectives, performance measures, problem identification, project analysis and evaluation? Is this feedback provided in a timely manner?
- Are there new vehicle or system management technologies that can be used to provide the desired data more cost effectively? Can such data collection be integrated into other efforts by the state or region to collect system performance data? For example, if the state has an intelligent transportation system (ITS) architecture, is safety an important feature of this strategy?
- Who are the major players in a safety management system? What are their responsibilities? Is there a need to define in more formal terms these responsibilities and inter-relationships?

Similar to the list of questions presented above, the suggested steps found at the end of each section of the guide are summarized below to act as an overall guide on the types of actions transportation officials can take to integrate safety more effectively into the transportation-planning process.

SUGGESTED STEPS TO INTEGRATE SAFETY MORE EFFECTIVELY INTO TRANSPORTATION-PLANNING

Vision

- Prepare and present background information on transportation safety in the state or jurisdiction. This information can perhaps be best presented via video or DVD. Illustrate how significant the safety problem is not only on the personal level, but also to society as a whole. Describe safety for all modes: motor vehicles, pedestrians, bicycles, and transit.
- Prepare and present information on what benefits are likely to occur to this safety situation with the implementation of a comprehensive safety strategy in the state or community.
- Prepare prototypical vision statements that include safety as part of the vision (or identify such statements used by others in the U.S.). Present these statements at public meetings, board meetings, or in other forums where the visioning process is taking place to raise awareness toward the safety challenge.

Goals and Objectives

- Prepare prototypical safety-related goals and objectives for the safety problems identified through the public involvement process. Present and refine these goals and objectives given public and decision maker feedback.
- If objectives are to be defined with recommended achievement targets (e.g., reduce fatalities by 20 percent over 10 years), conduct an analysis to determine if such a target can reasonably be achieved with 1) existing strategies, 2) by enhancing existing strategies, or 3) only be implementing significantly more draconian or costly strategies.
- Use the information material prepared in the visioning process to educate stakeholders and decision makers about safety as it relates to goals and objectives.

Performance Measures

- Review safety-related performance measures used by similar agencies in the U.S.
- Prepare a set of prototypical safety-related performance measures that reflect the goals and objectives that have been adopted for the planning effort. This set should be limited in number to only those that provide critical information on the safety performance of the transportation system, and that could presumably be affected by the types of strategies that will result from the planning process.
- Discuss the proposed set of performance measures with those in the agency responsible for collecting the data that will be used in assigning values to these measures. In addition, discuss the measures with transportation modelers in the region or state to determine if the measures can be predicted in future years?

Analysis—Data

- For each of the goals, objectives and performance measures identified in the planning process, define the types of data that will be necessary to produce the desired information. Develop a data collection strategy…what are the sources of relevant data? Who is responsible for collecting this data? Who is responsible for putting this data into useable form?

- Investigate sources of data that currently exist (e.g., collected by federal agencies) that could be used to illustrate the safety challenges facing the state, metropolitan area or community.
- Develop a memorandum of understanding or some other form of agreement with relevant agencies for developing a safety database.
- Develop a template on how safety-related data will be portrayed, both for internal agency purposes as well as for public presentations. Test this template with public groups to assess its effectiveness in conveying safety information.
- Involve staff members who are responsible for data collection and data management in the decisions relating to the overall strategy for safety-related database management. If a geographic information system is used, have staff members identify what steps must be taken to develop a fully operational system (e.g., developing consistent referencing systems among the different data sources).

Analysis--Tools

- Inventory the types of safety analysis tools that exist in the state or metropolitan area's safety-related agencies. Relate those that exist to the types of safety problems that are being faced. If analysis tools do not exist for the identified types of problems, develop a strategy for developing or acquiring this type of analysis capability.
- Starting with the tools listed in Appendix C, conduct a peer review of the existing safety analysis capabilities. Invite representatives from peer agencies who have experience with safety-related planning to assess the capabilities that currently exist in the state or metropolitan region. Have this peer review produce specific steps that need to be taken to improve the analysis capability for safety-related planning.
- Develop a long term and coordinated data-collection and safety analysis strategy for the state and/or metropolitan area. This strategy would include a description of current capabilities, likely future safety problems, and the steps needed to put in place an analysis capability for dealing with such problems. This strategy should be developed cooperatively with all of the safety partners in the state or metropolitan area.
- If not already available, the state, in cooperation with metropolitan planning organizations, should develop a table of accident reduction factors and their associated likely reductions in accidents and fatalities for different types of safety improvements (numerous sources are available for this). Some analysis may be necessary to complete this table; whereas some information may be obtained from prior research and experience. These factors need to be carefully reviewed for accuracy and relevance to the specific safety needs and conditions a planner is attempting to address. Many reduction factors were developed for locations with conditions that may or may not be transferable to the conditions in another metropolitan area or state. Such information on countermeasure effectiveness is critical for determining the benefits associated with safety-related improvements and for prioritizing investments.
- For non-infrastructure or non-traffic operations strategies, such as safety education, marketing campaigns, and emergency management services, regions should work closely with safety partner organizations to determine a methodology for assessing the effectiveness of such strategies. This might include targeted before and after studies on selected programs, or simply

anecdotal evidence of what impacts such programs have had on public attitudes and behavior.

Evaluation

- Define early in the planning process what evaluation criteria will likely be used so that the data collection and analysis tool development and selection will be directly related to the information desired and needed. This effort would most likely be subject to community and decision maker involvement. It is best to define a limited number of critically important criteria that will be of overarching concern to decision makers.
- Inventory the different safety-related evaluation methods currently in use in the state or metropolitan area. Determine gaps in evaluation capability that might affect the production of desired evaluation information. Select an appropriate/acceptable methodology for the region.
- Periodically update (or develop, if not available) accident cost to society data. This is important in that the other benefit values used in a benefit cost analysis, those relating to reduced operating costs and reduced travel time, are usually updated on a periodic basis. Safety benefit values need to keep pace.
- While the transportation-planning process is underway, develop methods and approaches that will be used when the evaluation process is undertaken. Do not wait until late in the planning process to do so!
- Think carefully about how the definition of evaluation criteria will lead to the selection of the best projects or strategies. Is there any bias introduced into this selection process by the way evaluation criteria are defined?
- Prepare prototypical presentation templates for safety information and obtain feedback from decision makers and from the general public on the level to which they effectively convey information.

Plan and Program Development

- Include safety stakeholders in the culminating planning steps leading to the approval of a transportation plan and program.
- Develop safety priority factors that can be used to give safety-beneficial projects more priority in programming decisions.
- Highlight the safety-related strategies and projects that are identified in the transportation plan and program. This might include a separate safety chapter or appendix in the transportation plan, and an indication in the program of which projects are primarily safety related.
- Develop public marketing materials that highlight the safety benefits of the plan and program.

System Monitoring

- Analyze the current flow of safety information from the monitoring of transportation system performance to its use in analyzing and evaluating safety-related projects and strategies. Identify components of this information flow that can be improved.
- Identify the major sources of safety data in the state and/or region. Conduct a forum that illustrates the importance of this data, and that identifies steps that can be taken to improve the process and substance of agency efforts.

- Develop a state or regional strategy for monitoring the safety of the multimodal transportation system. This monitoring should not only include the identification of current hazardous locations, but it should also proactively identify areas of potential hazard that can be addressed now rather than wait for the safety problem to occur.

By conducting a process assessment with the questions found at the beginning of this chapter, and by implementing the suggested steps suggested above, the user of this guidebook will go a long way toward developing a transportation-planning process that is more sensitive to safety concerns. Additional material that will be helpful to the user of the guidebook is found in the appendices. In particular, Appendix C provides a brief description of many tools that are available to transportation planners and engineers for the analysis and evaluation of the safety aspects of project and system performance. Research and tool development for safety conscious planning will certainly continue in future years. Guidebook users are encouraged to keep abreast of these developments in that they will likely provide important capabilities to transportation practitioners.

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33. Gluck, J., H. Levinson, and V. Stover, " Impacts of Access Management Techniques," *Report 420*, National Cooperative Highway Research Program, Transportation Research Board, Washington D.C., 1999.

Important Web Sites for Safety and Transportation-planning

American Association of State Highway and Transportation Officials:
www.transportation.org/aashto/home.nsf

AASHTO's Strategic Safety Plan : www.safety.organization.org

American Public Tranportation Association: www.apta.com

American Traffic Safety Services Association: www.atssa.com

Association of Metropolitan Planning Organizations: www.ampo.org

Bureau of Transportation Statistics, U.S. DOT: www.bts.gov

Centers for Disease Control National Bicycle Safety Network:
www.cdc.gov/ncipc/bike/default.htm

Federal Highway Administration: www.safety.fhwa.dot.gov

FHWA Safety Conscious Planning: www.fhwa.dot.gov/planning/scp/scpflfrm.htm

Federal Motor Carrier Safety Administration:
www.fmcsa.dot.gov/safetyprogs/saftprogs.htm.

Federal Transit Administration: www.fta.dot.gov

FTA Safety and Security: www.transit-safety.volpe.dot.gov

Governors Highway Safety Association: www.statehighwaysafety.org

Institute of Transportation Engineers: www.ite.org

Insurance Institute for Highway Safety: www.hwysafety.org

International Society of Highway Safety Data Professionals, Traffic Records Committee: www.traffic-records.org

National Association of Regional Councils: www.narc.org

National Highway Institute: www.nhi.fhwa.dot.gov

National Highway Traffic Safety Administration: www.nhtsa.dot.gov

National Transit Institute: www.ntionline.com

National Transportation Safety Board: www.ntsb.org

Pedestrian and Bicycle Information Center: www.walkinginfo.org and www.bicyclinginfo.org

Traffic Safety Digest: www.nhtsa.dot.gov/people/outreach/safedige/

Traffic Techs: www.nhtsa.dot.gov/people/outreach/traftech/

Transportation Research Board: www.trb.org

APPENDIX A EXAMPLE STATE SAFETY INITIATIVES

ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

- Public Involvement in Transportation-planning - Public meetings are frequently held around the state on transportation-planning issues. Most of these meetings deal with specific plans or projects directly affecting the community and are scheduled by the responsible project manager within the DOT & PF.

ARKANSAS STATE HIGHWAY AND TRANSPORTATION DEPARTMENTS

- Technology Transfer - T2 - The Technology Transfer Program is responsible for assisting cities and counties in implementation of transportation-related technologies. The objective is a safer, more efficient, and more economical road and street program. Targeted operations include construction and maintenance, materials, administration, and computer programs.

FLORIDA DEPARTMENT OF TRANSPORTATION

- Click It or Ticket: This paid campaign reinforces a statewide enforcement effort. Many community events and local media stories publicize the targeted enforcement and the necessity for it.
- Occupant Protection (Including Child Passenger Protection Programs)
- Florida's Community Traffic Safety Teams (CTSTs): These teams are locally based groups of highway safety advocates who are committed to solving traffic safety problems through a comprehensive, multi-jurisdictional, multi-disciplinary approach. Members include local city, county, state and occasionally federal agencies, as well as private industry representatives and local citizens.
- Florida's Safety Management System (SMS): SMS is broadly defined as the integration of the vehicle, driver, and roadway elements into a comprehensive approach to solving highway safety problems. The intent of the SMS is to provide the safest roadway system possible through the combined efforts of engineering, enforcement, emergency services and education, the "4-E's" of safety.
- Use of Seat Belts (Including Innovative Seat Belt Programs)
- Highway Safety Data Improvements
- Pedestrian/Bicycle Safety Program: The Florida Pedestrian and Bicycle Program promotes safe walking and bicycling in Florida by improving the environment for safe, comfortable, and convenient walking and bicycling trips as well as improving the performance and interaction among motorists, bicyclists, and pedestrians.
- Alcohol-Impaired Driving Countermeasures
- Transportation Safety Engineering section: Transportation safety engineering is engineering the prevention of driver conflicts on the roadway into project design, thereby reducing roadway problems leading to traffic accidents, and giving clear information to assist drivers to make safe driving decisions.

IOWA DEPARTMENT OF TRANSPORTATION

- Put the Brakes on Fatalities Day: The campaign's message - "Drive as if your life depends on it." - emphasizes the fact that people need to be fully alert when they are driving.
- Iowa Campaign: The Iowa DOT and Governor's Traffic Safety Bureau are using this national event to launch their own yearlong highway safety campaign aimed at reducing the number of highway fatalities in the state. Once each month during the year, the DOT will distribute safety information and related Iowa facts pertaining to a specific highway safety topic to highway safety organizations and local jurisdictions for them to share with the public.
- Iowa safety management system (SMS): This program is a diverse partnership of highway safety practitioners in engineering, enforcement, education, and emergency services dedicated to reducing the number and severity of accidents on Iowa's roadways.
- Highway Work Zone Safety: A series of training videos were developed that present an honest, true-story, documentary look at the dangers of the work zone and the safety considerations critical for all workers.
- Work Zone Educational Material: The Iowa Department of Transportation has developed new work zone safety curriculum materials for use in Iowa classrooms. Copies of materials aimed at third, fifth and eighth grade students and driver education students have been mailed to Iowa schools.

KANSAS DEPARTMENT OF TRANSPORTATION

- Give 'Em A Brake: The Kansas Department of Transportation launched the "Give 'Em A Brake" traffic safety campaign in 1993 to increase awareness of the dangers highway workers face in construction and maintenance projects.
- Get the Picture, Listen to the Signs: This campaign promotes the importance of all highway signs and the need for motorists to read each one and be prepared to respond while driving.
- Kansas Identification Stickers (KIDS): This system is used because at times it becomes critical to identify a child and obtain permission to administer medical care.
- Child Passenger Safety Act: Children under age four must be in a federally approved child safety seat. All children under 14 years of age must be protected by a safety belt. Children under the age of 14 are prohibited from riding in any portion of the vehicle not intended for passengers; this includes riding in the back of pickup truck.
- Safety Belt Use Act: This Act is a secondary law. Drivers are cited for this violation only in combination with a separate moving violation.

KANSAS BUREAU OF TRAFFIC SAFETY

- Campus BLAST (Building Local Alternatives for Safe Transportation): This ongoing program is aimed at reaching college-age students. The initiative was successful at the University Of Kansas (KU) in Lawrence and was piloted at Kansas State University (KSU) in Manhattan. A total of 75 local bars in both towns agreed to distribute campaign materials. KU and KSU distributed more than 20,000 ID holders and brochures with a "don't drink and drive" message to students during campus enrollment.

- Kansas Drunk Driving Prevention Project (KDDPP): This project delivers public information and education about alcohol awareness to all age groups statewide.
- STOP Underage Drinking Campaign: This was piloted in four Kansas counties in FY 2000. Counties continue to participate in the comprehensive initiative, which includes the following components: Responsible Alcohol Service Workshops, Cops in Shops, Victim Impact Panels for High School Driver Education Students, and the Kansas High School Days manual.
- Take a Stand Campaign: Targeted at 14- to 18-year-olds, “Take a Stand” is a unique integrated media campaign. The Youth Alcohol Media Campaign strived to empower teens within five Kansas counties to be involved in DUI prevention by not drinking and driving and by intervening to keep someone they know from drinking and driving.
- Governor's Center for Teen Leadership (GCTL): This project addressed the need for and provided students from 4th to 12th grade with team-based traffic safety/leadership retreat training. Students were encouraged to return to their schools to implement action plans developed during the training.
- Wichita U.S.D 259 Teen Court Project: Providing a mechanism for holding youthful offenders accountable, this project utilizes peer pressure and influence to encourage positive choices and safe and appropriate behavior.
- Kansas Network of Employers for Traffic Safety (NETS): This is an employer-led public/private partnership dedicated to improving the safety and health of employees, their family members, and members of communities in which they work and live by reducing the number of traffic accidents that occur on and off the job.
- Sobriety Checkpoint Program: The Kansas Highway Patrol (KHP) coordinated the Sobriety Checkpoint Program, conducting 95 checkpoints covering 64 percent of the state's population.
- KDOT Safety Belt Education Office (KSBEC), including Safe KIDS and Safe Communities.
- Kansas Clicks STEP: This campaign was initiated in Kansas during 2000 to provide financial support to law enforcement agencies for overtime occupant protection enforcement. The STEP program is dedicated to increasing enforcement of the state's safety belt and child safety seat laws during peak holiday travel times throughout the year.
- Kansas Bicycle/Pedestrian Public Information and Education Program: This program encourages the safe use of bicycles through the distribution of two fact-filled brochures aimed at educating the bicycle rider.
- Sedgwick County Safe Communities Coalition: Established in 1997, data collection, merging, and linking analysis components help the community identify particular traffic safety issues. The main strategies for the coalition have been to strengthen the coalition; collect, merge, link, and analyze injury data; access existing injury prevention activities; and develop and introduce new interventions based on the data analysis.
- Assistance Services for Kansas (TASK) and Traffic Engineering Assistance Programs (TEAP): TASK trains state and local officials with workshops and training sessions. TEAP processes requests from local agencies in 30 areas of concern.
- Operation Lifesaver: Operation Lifesaver promotes safety at highway/railway crossings through the purchase and distribution of public information materials.

LOUISIANA HIGHWAY SAFETY COMMISSION

- Pedestrian Safety: Attempt to reduce pedestrian death rate from 3.1 to 2.0 per 100,000 population by year 2003 for metropolitan areas with a population of 300,000 or more; The LHSC, in cooperation with the Safe Community - New Orleans, implemented a pedestrian safety program in the Central Business District.
- Roadway Safety: Support statewide use of traffic signs which comply with the Manual for Uniform Traffic Control Devices (MUTCD); Each year LHSC provides a limited number of grants to communities in support of MUTCD compliance.
- In cooperation with LaDOTD and the Federal Highway Administration, LHSC posted thousands of Buckle Up Louisiana signs along the interstate and state highway system.
- LHSC, in cooperation with LaDOTD and the Federal Highway Administration, posted hundreds of You Drink, You Drive, You Loose DWI signs along the state rest areas.
- LHSC works closely with LaDOTD on the hazard elimination program, designed to identify and eliminate construction hazards.
- LHSC works closely with LaDOTD and LSP on the Incident Management Team (Highway), which is designed to facilitate safety of motorists and expeditious restoration of traffic flow stemming from major traffic accidents.
- Safety Management Systems
- Prevent and reduce the number and severity of traffic accidents.
- Ensure that all opportunities to improve highway safety are considered.
- Develop a cooperative effort with state, regional, local agencies, and citizen associations and groups in selecting and implementing an effective SMS.
- School Buses: Reduce the number of school bus accidents by 25 percent by the year 2003. The LHSC continues to work through the Louisiana Department of Education to provide the Caution At Bus Stops (CABS) program. This program is designed to create safety awareness among school bus transportation officials and bus drivers regarding safety practices for school children while entering or exiting school buses.
- LHSC supports the National Highway Traffic Safety Administration / National Safety Council School Bus & Pedestrian Safety Training programs.
- LHSC supports the National Highway Traffic Safety Administration's School Bus Driver In-Service Training program.
- Traffic Records: To provide for increased accuracy, accessibility, and timeliness of traffic records data; The revised State of Louisiana Uniform Motor Vehicle Accident Report has been in place since January 1999. Revision of the report was accompanied by a complete revision of the accident file database. Law enforcement agencies entering accident data on the DPS-secured web application receive the data back the next business day. Other agencies have invested in stand-alone applications and transfer the data to the state electronically; In 2000, the LHSC began monitoring accident data and providing feedback to police agencies. Cooperation of the various police agencies to correct reports and provide supervision to accident investigators had been phenomenal. Providing feedback to the law enforcement agencies is the key to improved data quality, timeliness, and accident investigations; LHSC formed a permanent Traffic Records Committee (LaTRC) in 1998. This committee has a broad-based

representation of information services specialists, policy makers, data providers, and data users from around the state. Louisiana is establishing a network that links accident files with roadway files, GIS data, EMS data, driver licensing and vehicle registration data, prosecution, and courts.

- LaTRC supported linking the LADOTD headquarters and district offices to LHSC image files. This linkage provides ready access to information and data used in the development of safety programs. The data are used to identify traffic safety hazards and respond in a timely fashion.
- Youth: LHSC, in cooperation with the Louisiana Alliance to Prevent Underage Drinking, created a program for citizens to report violations of Louisiana's 0.02 BAC law. The Alliance has established a new toll-free number to report the sale of alcohol to those under 21.

NEBRASKA DEPARTMENT OF ROADS

- Risk Management Section: This group is responsible for analysis of accident data. These data include the production of standard reports; the “Standard Summaries of Nebraska Motor Vehicle Traffic Accidents”; the production of specialized reports from the database when requested by sources within the Department of Roads, other agencies, or the general public; and the completion of accident studies at specific locations. The Location Analysis Unit conducts accident studies for all highway projects and regularly monitors the state highway system to identify potential accident trouble spots. This information is used by department engineers to develop highway projects and safety improvements.
- Fatality Analysis Reporting System (FARS) The Nebraska Department of Roads uses FARS extensively in safety assessments. This system was developed by the National Highway Traffic Safety Administration to help identify and measure national safety problems and to provide an objective basis to evaluate the effectiveness of motor vehicle safety standards and highway programs.
- Safenet: The Nebraska Department of Roads uses Safenet extensively in safety assessments, which provides commercial truck accident data for the Federal Highway Administration’s SAFETYNET database, oversees the State Property Damage System, and maintains the Department of Roads’ Employee Accident Reporting System.

NEW MEXICO TRAFFIC SAFETY BUREAU

- Traffic Safety Problem Identification and Information Program (Traffic Records): Use advanced data analysis and data merging techniques to identify problem locations and conditions and to provide critical planning, management, and evaluation of priority traffic safety initiatives.
- Traffic Safety Almanac Program (Pedestrian, Bicycle, and Roadway Safety): Provide detailed roadway-based problem analyses and reports linking problem and countermeasure data, presented clearly and conveyed on a routine, systematic basis to traffic safety activists in New Mexico's communities. Utilize traffic records review, engineering analysis, field data collection, key informant interviews, and community involvement to improve traffic engineering in local communities.
- Traffic Safety Information Coordination (Traffic Records): Improve traffic safety management information systems in order to increase access by activists to critical financial, traffic safety, evaluation, and programmatic information.

- Community Programs Coordinator (DWI Prevention & Safe Communities): Develop and implement strategies to help communities implement effective DWI prevention. Train communities to apply the safe communities approach.
- Public Information and Education Coordinator (DWI Prevention): Develop and implement strategies to increase public awareness of alcohol-related traffic problems.
- Traffic Safety Prevention Programs Management (DWI Prevention): Oversee all programs related to DWI prevention and coordinate activities with Operation Buckle Down.
- Traffic Safety Program Management (Safe Communities): Assess the informational and training needs of community-based traffic safety programs. Develop and implement training and technical assistance for local- and state-level traffic safety programs to enable New Mexico to meet its performance goals. Provide ongoing participation by state and local traffic safety advocates in training events.
- Quality Assessment Program Management (Planning & Administration): Coordinate processes for grant compliance, technical assistance, and documentation of procedures and processes.
- Financial Management System Coordination (Planning & Administration): Coordinate efficient processes for the financial management of grants.
- Community Motorcycling Safety Program (Motorcycle Safety): Operate a strong motorcycle training program that includes interaction with community traffic safety initiatives.

NORTH CAROLINA GOVERNOR'S HIGHWAY SAFETY PROGRAM

- Booze It & Lose It: As part of the "Booze It & Lose It" campaign, law enforcement officers conduct sobriety checkpoints in every county of the state.
- Education: A coordinated public information campaign continues to remind people that in North Carolina, drunk drivers lose their license on the spot. Not only do driving while under the influence (DWI) offenders lose their license or even lose their lives in needless accidents, they pay a large fine for their offense.
- Child Safety: Like many states, North Carolina mandates that children buckle up. According to state law, children less than age 16 must be buckled up in a motor vehicle regardless of their seating position, and children less than age 5 and less than 40 pounds must be properly secured in a correctly installed safety seat – in the back seat – if the vehicle has an active front passenger-side airbag.
- Click It or Ticket: This program not only focuses on getting adults buckled up, but children as well. This initiative includes a strong effort to educate parents and children about child passenger safety and especially air bag safety.
- Please Be Seated: North Carolina has joined many states in an effort to encourage proper use of child safety seats and seat belts. Please Be Seated is designed, through public education and awareness, to reduce child injuries and deaths caused by motor vehicle accidents. Anyone who observes an unrestrained child in a moving vehicle can inform the Please Be Seated program by completing and mailing a card. Once the card is received, the vehicle owner is sent a friendly letter from Please Be Seated. The letter will stress the importance of using a child safety seat or seat belt to protect their children. The individual will also receive information on how to obtain a child safety seat.
- School Bus Safety: Law enforcement officers across North Carolina are monitoring school bus routes to enforce the state's no passing law and to ensure

safety for children. North Carolina law states that any motorist approaching a stopped school bus from any direction must come to a complete stop while that bus is displaying its mechanical stop arm or flashing red stoplights and is stopped for the purpose of receiving or discharging passengers.

- Graduated driver licensing (GDL): North Carolina's new graduated driver licensing (GDL) law is designed to help teenagers learn how to drive safely by giving them more experience behind the wheel in a step-by-step process until they "graduate" to a full license. This program is designed to reduce accident risks for young new drivers by systematically providing them with more practical experience, gained under the safest possible conditions, before allowing them to drive on their own.
- No-Zone: The "No-Zone" represents danger areas around trucks where accidents are more likely to occur. North Carolina is helping to educate motorists about the No-Zone. The Governor’s Highway Safety Program (GHSP) urges North Carolina motorists to pay special attention to driving in these blind spots.
- Safe Communities: Safe Communities programs are grounded in two basic principles: reduce traffic injuries in local communities, and include a diverse group of partners in their implementation and ultimate success.

OREGON DEPARTMENT OF TRANSPORTATION

- Bicyclist Safety: This is a program about safety and the idea that a bicycle is a reasonable and valid mode of transportation, especially when compared to other options.
- Commercial Motor Vehicle program: The Motor Carrier Transportation Division (MCTD) has overall responsibility for Commercial Motor Vehicle programs in the state of Oregon. The Transportation Safety Division's Commercial Motor Vehicle Safety Program supplements the MCTD mission and goals by providing additional funding to increase identification and reduction of Commercial Motor Vehicle (CMV) traffic accidents. The Roadway Safety Initiatives program focuses on short-term, high cost-benefit engineering, enforcement, and educational projects to improve CMV Safety on Oregon’s Highways.
- Driver Education: Basic education on rules of the road and safety
- Employer Safety: This is an employer-led public/private partnership dedicated to improving the safety and health of employees, their family members and members of communities in which they work and live by reducing the number of traffic accidents that occur on and off the job.
- Impaired Driving: State drug prevention, law enforcement, and transportation officials warn teens and parents about the consequences of drug use at raves.
- Motorcycle Safety: The TEAM OREGON Motorcycle Safety Program is targeted at motorcyclists for safety.
- Pedestrian Safety Program: This program creates awareness among pedestrians about safety.
- Law Enforcement for Traffic Safety committee: The committee is charged with assisting the Safety Division in the review of a variety of statewide law enforcement issues including: Review of accident data and statistics, making recommendations for law enforcement projects and equipment purchases, legislation, and other issues of interest to the Traffic Law Enforcement Program.
- Roadway Safety: Typical actions taken in safety corridors to increase safety include more frequent enforcement, low cost engineering improvements, and education efforts such as media events, brochures, and poster distribution.

Drivers are asked to pay extra attention and carefully obey all traffic laws when driving in these areas.

- Safety Belts: The "booster seat" law, passed by the 2001 Legislature, requires drivers who transport children to use approved devices that elevate small children to make standard safety belts fit properly.
- Safe Communities: The main strategies are to collect, merge, link, and analyze injury data; access existing injury prevention activities; and develop and introduce new interventions based on the data analysis.
- Work Zone Safety: This program increases awareness of the dangers that highway workers face in construction and maintenance projects.
- Youth Safety: If students drink alcohol and do not show up for their MIP (minor in possession) court hearing, they will immediately lose their driving privileges. The courts are required to suspend their licenses.
- Governors Advisory Committees: Governors Advisory Committees advise the ODOT Transportation Safety Division (TSD) and the GHSA Representative on safety issues in a variety of disciplines.

WASHINGTON STATE

- WST2 - Safety Management: Transportation safety in emergency services, law enforcement, and education within local agencies has been organized into a single system with the help of the safety management system. It reduces the incidence of response-driven safety improvements in favor of planned, prioritized, and system-driven improvements.
- WST2 Newsletter: This newsletter is a quarterly periodical produced by the Washington State Technology Transfer Center. It is dedicated to covering a wide range of technical topics to assist Washington State communities and local governmental agencies in management, construction, safety, and maintenance of their transportation infrastructure.
- Local Agency Safety Management System: This manual provides an overview and description of the Washington Local Agency Safety Management System (SMS). It covers such topics as the benefits of implementing SMS, the SMS process, the individual elements of a local agency SMS, and specific tools to assist in making an SMS work.

TEXAS TRAFFIC SAFETY SECTION

- Texas Traffic Safety Program
- Police Traffic Services and Speed Control: Enforce the law and check speeds.
- Alcohol and Other Drug Countermeasures/Youth Alcohol: Deliver public information and education about alcohol awareness to all youths statewide.
- Emergency Medical Services (EMS): Provide immediate aid to reduce the severity of accidents.
- Occupant Protection: Includes child restraints, seatbelts, and airbag protection
- Traffic Records: Provide for increased accuracy, accessibility, and timeliness of traffic records data.
- Roadway Safety: Support statewide use of traffic signs which comply with the Manual for Uniform Traffic Control Devices (MUTCD) and identify and eliminate construction hazards.

- Motorcycle Safety: Interact with community traffic safety initiatives and create awareness about safety.
- Community/Corridor and College Traffic Safety Programs and Safe Communities: Reduce traffic injuries in local communities.
- Public Information and Education: Develop and implement strategies to increase public awareness of alcohol-related traffic problems.
- School Bus and Commercial Truck Safety: Law enforcement officers monitor school bus routes to enforce the state's no passing law and to ensure the safety of children. Commercial Truck Safety represents danger areas around trucks where accidents are more likely to occur.
- Pedestrian/Bicycle Safety : Implementation of a pedestrian safety program
- Planning and Administration
- Highway Safety Program: Assess the informational needs of the highway safety program.
- Save a Life Program: Safety Program to improve traffic safety in Texas
- Highway Performance Plan: Specific data such as location, driver, vehicle, roadway, and causative factors is collected from the preceding year's accident data records files and are compiled and maintained by the Texas Department of Public Safety. These data include health, injury, safety belt, and child passenger safety seat usage data from local and statewide observational surveys; emergency response data from the Texas Department of Health; and vehicle-miles-traveled information from TxDOT.

UTAH DEPARTMENT OF TRANSPORTATION

- Traffic & Safety Studies: The function of this Section is to maintain and evaluate accident statistics and to perform traffic and safety studies. These studies are to improve the safety performance of the highway system in the state of Utah.
- Ropeways Section: The Utah Passenger Ropeway Safety Committee's job is to ensure the safety of passengers using aerial tramways, surface lifts, and tows.
- Railway Safety Unit: Implement the Federal Railroad Administration (FRA) State Participation Program to inspect track, locomotive, equipment, and railroad crossings throughout Utah; implements Railroad Crossing Safety Program to improve crossing safety; supervises Salt Lake Light Rail System (TRAX) to ensure its compliance with Federal Transportation Administrations (FTA) requirements; and handles additional railroad crossing safety issues.
- Road Side Safety Devices Group: Investigate work zone safety devices, safety barriers (i.e., guardrail, concrete barriers), and establish guidelines for attenuators and end sections.
- Traffic Count Studies: Perform engineering studies to determine appropriate traffic control devices: i.e., traffic signals, stop signs, crosswalk, speed limits, advisory curve speeds, and no-passing zones (striping). Manage/supervise the Traffic Data Collection Group.
- Safety Studies Unit: Prepare Operational Safety Reports (OSR’s) for UDOTS highway projects, respond to various inquiries and complaints from the public regarding highway safety, conduct in-depth safety studies and provide recommendations for traffic and safety design and operation, and manage the federal Hazard Elimination Program (HES).

WISCONSIN DEPARTMENT OF TRANSPORTATION

- Alcohol-impaired driving
- Aggressive driving
- Bicycle safety
- Pedestrian safety program
- Child passenger safety
- Distracted driving
- Drowsy driving
- Drug-impaired driving
- Emergency medical services (EMS)
- Large truck safety
- Motorcycle safety
- Occupant protection
- Older drivers and mobility
- Pedestrian safety
- Pupil transportation safety
- Rail crossing safety
- Safe communities
- Speeding drivers
- Winter drivers
- Young drivers

APPENDIX B FEDERAL HIGHWAY SAFETY PROGRAM GUIDANCE

ALCOHOL-RELATED GUIDELINES

23 U.S.C 158: Minimum Drinking Age

23 U.S.C 158 established 21 as the minimum drinking age. Under 23 CFR 1208, the Secretary of Transportation "shall withhold ten percent of the amount to be apportioned under each of the sections 104 (b)(1), 104 (b)(2), 104 (b)(5) and 104 (b)(6) of Title 23 U.S.C. on the first day of each fiscal year in which the purchase or public possession in such State of any alcoholic beverage by a person who is less than twenty-one years old is lawful."

23 U.S.C 161: Operation of Motor Vehicles By Intoxicated Minors (Zero-Tolerance Laws)

23 U.S.C 161 proposes to treat individuals under the age of 21 operating a motor vehicle with blood alcohol concentrations of 0.02 percent or greater as intoxicated or as driving under the influence of alcohol. The Secretary of Transportation may withhold 10% of the amount of National Highway System dollars, Surface Transportation dollars that would otherwise be apportioned to the State.

23 U.S.C 164: Repeat Intoxicated Driver Laws

23 U.S.C 164 requires that the State's enact laws aimed ay providing increased penalties for repeatedly driving under the influence of alcohol. Individuals convicted of a second offense have their driver's license suspended for at least one year, be subject to the impoundment or immobilization of their vehicles, or have an ignition interlock system installed on their vehicles, and be required to perform 30 days of community service or serve at least 5 days in prison. Third-time offenders must receive, at a minimum, 60 days of community service or 10 days in prison.

State's failing to adopt repeat intoxicated driver laws shall have 3% of their National Highway System, Surface Transportation Program and Interstate Maintenance dollars transferred to the State's National Highway Safety Program, for use either to plan and implement the State's Highway Safety Program, or for use on the State's Hazard Elimination Program.

U.S.C. 154: Open Container Laws

23 U.S.C. 154 requires states to adopt open container laws that prohibit "the possession of any open alcoholic beverage container, or the consumption of any alcoholic beverage, in the passenger area of any motor vehicle (including possession or consumption by the driver of the vehicle) located on a public highway, or the right-of-way of a public highway, in the State." Vehicles designed to carry "many passengers," as well as motor homes, may be exempted from this requirement by the state.

States failing to adopt an open container law will have 3% of the funds originally allocated for the National Highway System, Surface Transportation Program, and Interstate Maintenance Program transferred to the State's Highway Safety program

23 CFR 1270.7 indicates that the funds transferred to the Highway Safety Program may be used for alcohol-impaired driving countermeasures, the enforcement of DWI laws, hazard elimination activities specified under 23 U.S.C 153, which mandates that a state shall conduct engineering surveys to identify hazards on public roads. Within 60 days of the transfer of these funds, the Governor's

Representative for Highway Safety and the State's Secretary of Transportation "shall jointly identify, in writing, to the appropriate NHTSA Administrator and FHWA Division Administrator, how the funds will be programmed among alcohol-impaired driving programs, hazard elimination programs, and planning and administration costs."

ALCOHOL-RELATED INCENTIVE GRANTS

23 U.S.C 163: Operation of Motor Vehicles by Intoxicated Persons

To encourage states to adopt legislation to make it unlawful to operate a motor vehicle with a blood alcohol concentration of 0.08 or higher, 23 U.S.C 163 establishes incentive grants available to states that adopt 0.08 BAC laws. "There are authorized to be appropriated out of the Highway Trust Fund (other than the Mass Transit Account) to carry out this section $55,000,000 for fiscal year 1998, $65,000,000 for fiscal year 1999, $80,000,000 for fiscal year 2000, $90,000,000 for fiscal year 2001, $100,000,000 for fiscal year 2002, and $110,000,000 for fiscal year 2003." Further, 23 CFR 1225 indicates that the 0.08 law should have the full effect of a standard "driving while intoxicated" law for which there is no prescribed BAC level. If, for example, the state has an administrative license suspension or revocation law as a penalty for driving while intoxicated, the State must also use this law as part of its enforcement of the 0.08 BAC law. Because the grant funds awarded under this section are to be used for then enforcement of the 0.08 BAC laws, they appear to function as supplemental income for state and local law enforcement agencies.

23 U.S.C 408: Alcohol Traffic Safety Programs

23 U.S.C 408 allows the Secretary of Transportation to issue grants to States to implement and enforce programs aimed at reducing "traffic safety problems resulting from persons driving while under the influence of alcohol or a controlled substance." States may receive these grants for up to five years, with the Federal share being issued on a sliding scale – 75% the first year, 50% the second year, and 25% for years three through five.

23 U.S.C. 410: Alcohol-Impaired Driving Countermeasures

23 U.S.C. 410 provides additional grant money to States that adopt programs aimed at reduce traffic safety problems resulting from individuals driving under the influence of alcohol. This money is available only to supplement existing programs; States are required to maintain their existing expenditures on DUI enforcement in order to be eligible for additional funding under section 410.

Several different grants are provided under this section. For Basic Grants, States can receive up to an additional 25% over their 1997 allocations under Section 402.

Basic Grant A - States are eligible for this funding provided that they have adopted 5 of the following programs:

- Administrative license revocation for individuals driving under the influence that suspends an offender's license for at least 90 days for a first offence, and at least one year for individuals committing a second offense within a 5-year period.
- An underage-drinking program that seeks to prevent persons under the age of 21 from obtaining alcohol through actions such as color coding their licenses to make them distinguishable form the licenses of people over 21.
- An enforcement program that stops vehicles on "a nondiscriminatory, lawful basis for the purpose of determining whether the operators of such motor

vehicles are driving while under the influence of alcohol," or a high-publicity traffic enforcement program.

- A "3-stage graduated licensing system for young drivers that includes nighttime driving restrictions during the first 2 stages, requires all vehicle occupants to be properly restrained, and makes it unlawful for a person under age 21 to operate a motor vehicle with a blood alcohol concentration of .02 percent or greater."
- Programs aimed to target and penalize people with high blood alcohol level concentrations.
- Young adult drinking programs, such as awareness campaigns, traffic safety partnerships with employers, colleges, and the hospitality industry, assessments of first-time offenders, and incorporation of treatment into judicial sentencing, aimed at persons between 21 and 34 years of age.
- The development of a system for testing the blood alcohol concentrations of drivers involved in fatal accidents that has a testing rate equal to or greater than the national average.

Basic Grant B – States are eligible for funding for meeting each of the following criteria:

- Demonstrating a reduction in the number of fatally injured drivers with of BAC of 0.1 or greater during the previous 3-year period.

In addition to these basic grants, States can additionally apply for supplemental grants if they meet one or more of the following:

- Developing a program to acquire video equipment to be sued for identifying derivers under the influence of alcohol
- Developing a self-sustaining drunk driving prevention program that returns fines collected from driving under the influence offenses to communities "which have programs for the prevention of such operations of motor vehicles.
- Reducing the amount of driving done by individuals with suspended licenses. "Such law, as determined by the Secretary, may require a ''zebra'' stripe that is clearly visible on the license plate of any motor vehicle owned and operated by a driver with a suspended license."
- Developing a program to acquire passive alcohol sensors to detect persons operating motor vehicles under the influence of alcohol, and provide education to police officers on its use.
- Developing a DWI tracking system
- Developing other programs to reduce safety problems associated with drivers operating under the influence of alcohol or controlled substances.

PASSENGER RESTRAINT-RELATED GUIDELINES AND GRANTS

23 U.S.C. 153: Use of Safety Belts and Motorcycle Helmets

23 U.S.C. 153 and 23 CFR 1215 requires that all states make the operation of a motor vehicle "unlawful" when persons in the front seats of the vehicle are unrestrained by a safety belt, and the operation of a motorcycle "unlawful" in any individual on the motorcycle is not wearing a safety helmet. Persons with medical excuses, emergency vehicles, people in the custody of the police, public and livery vehicles, parade vehicles, postal and utility vehicles and persons in vehicles not equipped with safety belts are to be exempted from this requirement. States not in compliance with this shall have 3% of their funds allocated for the Interstate

Highway system, the CMAQ program, and Surface Transportation program to be transferred to the State's Highway Safety Program.

Under 23 U.S.C. 153, the Secretary of Transportation may additionally provide grants to State agencies to encourage them to provide education on safety belts, motorcycle helmets and child restrain systems, enforcement training to law enforcement officials, to monitor State compliance with this code, and the enforcement of this code.

23 U.S.C 157: Safety Incentive Grants for the Use of Seat Belts

23 U.S.C 157 establishes incentive grants, appropriated from the Highway Trust fund, to encourage increases in the statewide rates of seatbelt use. The funding is allocated from 1999 through 2003 in the amounts of $92,000,000, $102,000,000, $112,000,000, $112,000,000 for each sequential fiscal year.

There are two ways in which a State is eligible for an allocation of this funding. First, a state is eligible for these grants if it has a seat belt use rate higher than the national average. Allocations made from surpassing the national average will be based on "Federal medical savings" (23 CFR 1240.10) associated with the increased seatbelt use rate. These Federal medical savings will be determined by NHTSA under the accounting Formula specified in Appendix E of 23 CFR 1240.

The second way a state may become eligible for these grant funds is through the development and implementation of "Innovative Seat Belt Projects." Under 23 U.S.C 157(f), the Secretary of Transportation shall develop guidelines for innovative safety belt plans, and States submitting plans in accordance with these guidelines will be eligible to receive 100% Federal funding for the implementation of the plan.

23 U.S.C. 405: Occupant Protection Incentive Grants

23 U.S.C. 405 allows the Secretary of Transportation to award incentive grants for states engaging in "effective programs to reduce highway deaths and injuries resulting from individuals riding unrestrained or improperly restrained in motor vehicles." Grants may be renewed for up to six years, with states being able to receive 75% of the total cost of operating the program for the first two years, 50% for years 3 and 4, and 25% for years 5 and 6. The amount of the award may amount to 25% of the total Federal apportionment to the State under Section 402, which provide funding to the Governors' Highway Safety Programs.

To be eligible, States must have enacted at least 4 of the following safety-related programs:

- A law requiring the use of a safety belt for all passengers in the vehicle;
- A primary safety belt use law, which specifies that the State will provide the primary enforcement of the State's safety belt use law;
- Minimum fine or penalty points assessed against an individual's driver's license for failing to comply with the safety belt use law of the state and/or for violating the state's child passenger protection laws.
- A Statewide traffic enforcement program focused on occupant protection. The program must "emphasize publicity."
- A child passenger protection education program aimed at educating drivers about the proper use of child restraint systems.
- A child passenger protection law requiring minors in a motor vehicle to be properly secured.

23 U.S.C 406: School Bus Driver Training Grants

23 U.S.C 406 grants the Secretary of Transportation the power to award grants to the States for enacting School Bus Driver Training programs. The programs should target drivers of both public and private school buses, and should be directed towards establishing and enforcing minimum qualifications for school bus drivers, as well as providing initial and refresher training courses. The State program should submit reports to the Secretary of Transportation detailing the results from their program.

23 U.S.C 407: Innovative Project Grants

In addition to the specific grants detailed above, States may be additionally eligible to receive grants for innovative safety projects under 23 U.S.C 407.

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APPENDIX C SAFETY TOOLS

INTRODUCTION

A variety of tools for safety analysis exist that can be used at various levels: some at the regional level, others on a project level, as well as some tools for corridor level safety planning. The use of these tools is essential to allow for the integration of safety into long range transportation-planning. This appendix focuses on the safety tools that are widely available for conducting safety analyses as well a new tool—safety forecasting at the planning level—which has been developed as part of this research.

The aim of this chapter is to provide individuals involved in decision-making and those involved in long-range transportation-planning with enough information to make an appropriate selection of tools for integrating safety into planning in their region or state.

The tools described in this appendix require data with varying levels of detail, ranging from TAZ level information in the *Planning Level Safety Prediction Model* to fairly detailed input in the IHSDM. The tools also vary in terms of purpose: the *Planning Level Safety Prediction Model* is used to perform safety prediction by TAZ area (pro-active), *Intersection Magic* analyzes historical accident data, etc. Finally, the tools vary in their required levels of expertise. All of these important characteristics of available analytical tools are described in this appendix. Analytical tools that are likely to be applicable to a wide audience (i.e., all states) are provided with examples to illustrate an application, whereas tools that are more limited (i.e., serve only a few states) are merely described. The more limited tools are provided mainly to demonstrate the kinds of analytical tool development efforts that are possible through cooperation between states and agencies within the state (DOT, university, etc.). In all cases references are provided so additional information can be found regarding the tools and their successful application.

OVERVIEW

Exhibit 53 lists available analytical safety tools by name, primary purpose, level of detail needed to apply the tool, and required expertise to apply the tool. This initial overview is followed by subsections providing more detailed descriptions of each of the tools.

SUMMARY OF TOOLS

Exhibit 53: Purpose, level of detail, and required expertise for tools available to incorporate safety into long-range transportation-planning

TOOL	PRIMARY PURPOSE	LEVEL OF DETAIL	REQUIRED EXPERTISE
Arizona Local Government Safety Project Analysis Model (LGSP)	Reactive: Generate list of most hazardous locations using user-specified criteria, Provides summary data for other sites for use in Before-After studies, Ranking alternatives by benefit-cost ratios Generation of project details to supplement HES eligibility applications	*High:* Accident data (detail for vehicle, driver, and passengers) Roadway data: grade, number of lanes, lane width, control type, road alignment, etc. Environmental: traffic volume, weather, terrain, etc.	Basic computer skills, familiarity with Microsoft Access desirable.
Before-After Studies as described in "Observational Before-After Studies in Road Safety", Hauer (1997)	Reactive or Proactive tool to assess the safety effectiveness of a given improvement or countermeasure	*Moderate*: Accident data Geometric, traffic, weather, and human attributes	Ranges from fundamental algebra and statistical knowledge, to the more complicated empirical Bayes (EB) approach
Crash Outcome Data Evaluation System (CODES)	Reactive: Generate medical and financial outcome information related to motor vehicle accidents	*High*: Accident Data Emergency Service Data Hospital Inpatient Data Death Certificate Data Vehicle Identification Number Data Trauma Registry Data	Statistical analysis, use of the CODES linkage software
Interactive Highway Safety Design Model (IHSDM)	Pro-active and reactive. Assess the safety of two-lane roadway designs (model for multi-lane roadways in development)	*High*: General data (terrain, volumes, functional classification, speed) Horizontal elements (curves, station equations, intersections) Vertical elements (curves) Cross-sectional data (cross-slopes, pavement type, shoulder detail) Lane dimensions Roadside elements (detailed) Roadway data (accident data, bridge elements, decision sight distance)	Basic understanding of geometric design concepts, ability to input data in Microsoft Windows environment through conversion of detailed geometric designs from other software or comma-separated file format (*.csv)
Intersection Magic	Reactive: Analysis of accident data	*Moderate:* Accident data	Basic computer skills

TOOL	PRIMARY PURPOSE	LEVEL OF DETAIL	REQUIRED EXPERTISE
Level of Service of Safety (LOSS)	Qualitative assessment of safety performance of existing facility planning major corridor improvements	*Moderate*: Accident Data Geometry of existing roadway	Basic understanding of traffic engineering and computer skills
Multimodal Transportation-planning Tool (MTPT) GDOT	Analysis of operational performance of transportation system, includes analysis of transit, bicycle and pedestrian plans.	*High*: Road Characteristics Database Accident Database Statewide modal transportation plans	Basic computer skills
Pedestrian and Bicycle Accident Analysis Tool (PBCAT)	Reactive: Development and analysis of pedestrian and bicycle related accident database, assist in the selection of countermeasures	*Moderate*: Accident data with geometry, time, weather, location, age, gender, subject actions, and other attributes	Basic computer skills
Pedestrian Safety Guide and Countermeasure (PEDSAFE)	Reactive: Analysis of pedestrian related accident data Assist in the selection of countermeasures or treatments: engineering, education, or enforcement	*Moderate*: Accident data	Basic computer skills
Roadside Safety Analysis Program	Pro-active and reactive. Cost effectiveness analysis to assess effectiveness of roadside safety improvements	*Moderate*: Accident Data Geometry of existing roadway	Basic understanding of traffic engineering and Monte Carlo simulation technique.
SafeNET	Pro-active and reactive, Traffic accident prediction for intersections and sections	Differs depending on purpose: Basic: traffic flows averaged over day More detailed: vehicle flow, pedestrian flow, site characteristics, specific geometric features, junction turning flows, and other design features	Basic traffic engineering, accident modeling, 4-step planning models
SafetyAnalyst	Reactive but some pro-active applications: Analysis of accident data: by site, by section or systemwide	*Moderate*: Accident data Geometric, traffic, weather, and human attributes	Statistical analysis & basics of traffic engineering

TOOL	PRIMARY PURPOSE	LEVEL OF DETAIL	REQUIRED EXPERTISE
TRansportation ANalysis and Simulation System (TRANSIMS)	Pro-active: Evaluate transportation alternatives and reliability to determine benefits and adverse effects; predict volumes along the network : are used as input in other tools	*High*: Census data of household surveys Origin/Destination matrices Transportation network data for major intersections, and Other information used to produce pseudo-activities for trip generation	Transportation Network Modeling, Software: TRANSIMS software, Oracle, C++ programming language, or ArcView Avenue programming language
Forecasting Accidents at the Planning Level	Proactive and Reactive. Prediction of accidents by Traffic Analysis Zone (TAZ)	*Moderate to High*: Accident data Census data Bicycle and transit facility locations Functional Classification of road network	Statistical Analysis and the use of GIS software: expertise required for GIS analysis will depend on the nature of existing GIS information and databases.

ARIZONA LOCAL GOVERNMENT SAFETY PROJECT ANALYSIS MODEL (LGSP)

Exhibit 54: Summary of the LGSP tool

LGSP

Vendor name and address: Arizona Department of Transportation, 206 South 17th Avenue, Phoenix, Arizona 85007.

Brief description of transportation safety applications: The Arizona LGSP is a useful tool to facilitate site identification and safety project selection by local jurisdictions and planning organizations. It could feasibly be adapted for use with non-Arizona databases; however, alternative tools might be selected for conducting 'hot spot' identification in non-Arizona states. Based on a database containing information regarding accidents and highways, it can automatically generate a list of the most hazardous locations in terms of user-defined parameters (e.g., alcohol involvement, location reference, distance, weighting method, etc.). It provides not only the total and annualized accident details, but also those details limited to a specific subset. In addition, for the sake of facilitating before-and-after comparisons and estimating regression-to-the-mean potential at a given site, the Arizona LGSP model can create a comparison site list report containing a summary of additional sites in a jurisdiction that have similar characteristics to the site location being analyzed. Finally, the model's project evaluation routine allows multiple projects to be analyzed simultaneously, with minimum run time, providing opportunities to revise site selection and project characteristics throughout the programming process. These project alternatives are ranked by benefit-cost ratios and project details are formatted to supplement HES eligibility applications. With these features, the Arizona LGSP model supports local governments in Arizona to address their highway safety needs on a timelier basis, and ensure that more attention is directed at the most hazardous locations, thereby improving the overall safety of the roadway system.

Types and sources of data needed: To develop appropriate parameters for implementation strategies, a substantial body of data is required to support this model. These data can be divided into the following groups:
Human attributes: number of injuries and fatalities, age, gender, alcohol involvement, driver state, seat belt use, etc.
Vehicle: number of vehicles involved, vehicle type, axles, plate number, etc.
road: grade, number of lanes, lane width, control type, road alignment, etc.
Environmental conditions: traffic volume, weather, terrain, etc.

Expertise required: The Arizona LGSP model was created in MS ACCESS 97. Due to a user-friendly interface and automated processes for site identification and improvement strategies selection, there is no need for special knowledge to run it; however, familiarity with MS ACCESS is a desirable.

Hardware requirements: Windows work station. Because the model consists of a self-contained query and reporting database, and a supplemental database of accident records on CDROM, running the model requires a CDROM drive or network access and approximately 32Mb RAM and 100Mb hard disk space. Due to the computational intensiveness of this model, a higher-speed processor is recommended.

Example application of tool: Exhibit 55 shows that the model can provide the users the list of hazardous sites and evaluations of project alternatives. For example, by clicking the Button 1, the inputs form shown in Exhibit 56 appears. Once the user inputs have been specified, the GET RESULTS button will run the prioritization procedure and return the priority list report containing the 25 most hazardous locations.

Exhibit 55: Arizona LGSP analysis set-up window

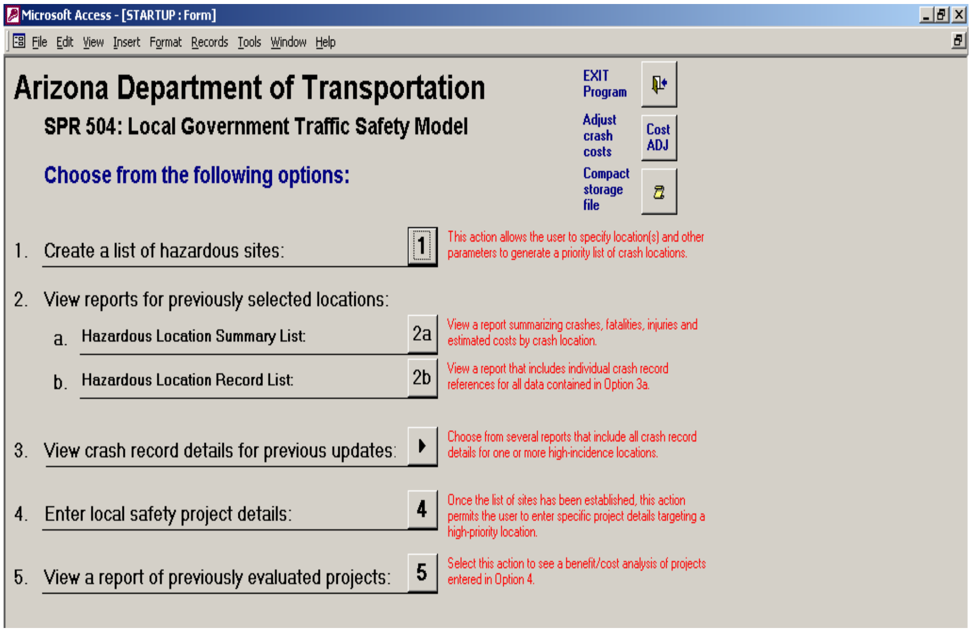
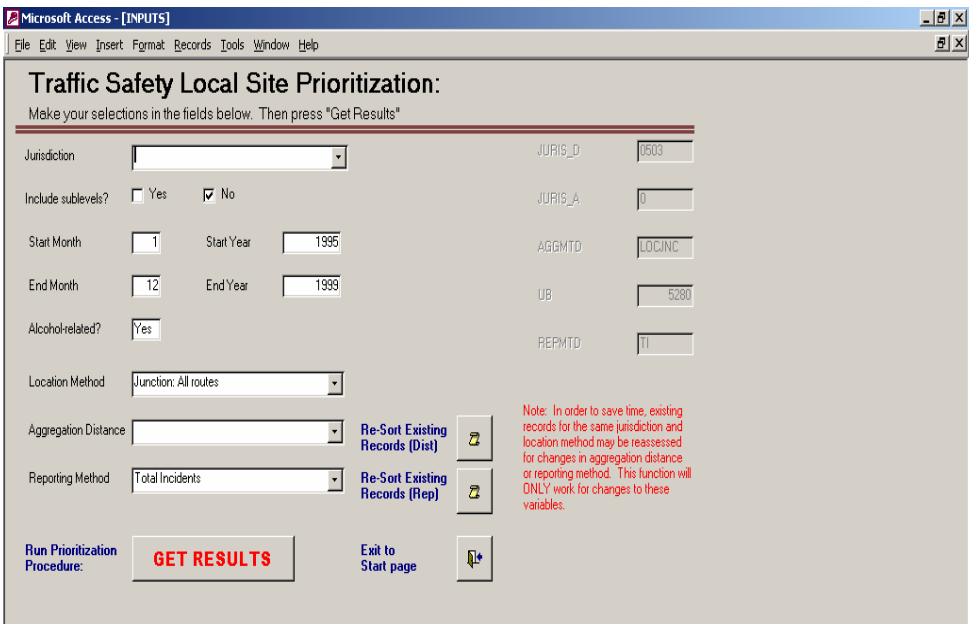


Exhibit 56: Arizona LGSP analysis parameters window



BEFORE-AFTER STUDIES AS DESCRIBED IN "OBSERVATIONAL BEFORE-AFTER STUDIES IN ROAD SAFETY", HAUER (1997)

Exhibit 57: Summary of before-after studies tool as described in Hauer (1997)

BEFORE-AFTER STUDIES

Vendor name and address: Although various transportation agency personnel apply before-after analysis methods to estimate the effectiveness of safety countermeasures, one detailed before-after methodology has emerged as "state of the practice". The currently accepted method is described in Hauer, (1997, Observational Before After Studies in Road Safety, Pergamon).

Brief description of transportation safety applications: This particular tool to assess the effectiveness of safety strategies or countermeasures that have been implemented in a state or region. Example countermeasures might include shoulder widening, signalization, culvert installations, pedestrian crossing improvements or installations, and the addition of bicycle lanes. Hauer develops and describes a detailed methodology which defines target accidents for which the before-after study will be applied. The book also provides guidance on various refinements of a before-after study, including the "Naïve before-after study", the "comparison group" method, the multivariate method, and the most advanced Bayesian before-after method. Each of these refinements are meant to deal with a variety of shortcomings that arise in before-after studies of road safety.

A synthesis on statistical methods in highway safety analysis presented a more elaborate statistical treatise on conventional before-after studies [Griffin and Flowers, 1997]. The report describes six different evaluation designs to determine the impact of selected highway strategies on the accident record. The six evaluation designs covered in the report are: a) simple before and after design, b) multiple before and after design, c) simple before and after design with yoked comparison, d) multiple before and after design with yoked comparison, e) simple before and after design with yoked comparison and check for comparability and f) multiple before and after design with comparisons and check for comparability.

Types and sources of data needed: For this type of analysis, accident data with geometric, traffic, weather, and driver behavior attributes are necessary. The data requirements also depend on the type of treatments and accidents of interest, and can become quite demanding in a thorough and reliable analysis.

Expertise required: The expertise needed for this tool ranges from simple algebra and statistical knowledge to work with before-after comparisons, to the more complicated empirical Bayes (EB) approach. Some background in statistical methods is desirable.

Hardware requirements: Any computer offering spreadsheet capabilities will support the application of this methodology.

Example application of tool: An example of the before and after study tool is illustrated below. The effectiveness of a change is determined by comparing the change in the value of the performance measure (e.g., frequency or rate of accidents) given the change with what would have occurred without the change. This approach is appropriate whether one is evaluating the application of strategies at a particular site, or applied to different accident characteristics (e.g., driver types). The biggest challenge in this effort is estimating what the change would have been if there had not been a treatment. It is especially difficult because all other factors do not remain equal in the after period, including environmental, traffic, and other factors.

Exhibit 58 demonstrates the use of control sites to help address the critical question of what would have happened if no treatment had been made (which is not observed since the site received the treatment). Control sites are locations (or population groups) not receiving a treatment that are considered sufficiently similar in character to the one(s) being treated that any change in performance over the before-and-after time frame can be assumed to be natural maturation of the phenomenon. The period between before and after measurements is shown in Exhibit 58 by the vertical bar. This time period can be fairly short (e.g., the time to install a countermeasure) to a much longer time period (e.g., two years or more after implementation). Performance measurements are taken periodically (e.g., monthly or annually) in the before and after periods for both the control and treated sites.

Exhibit 58: Depiction of before-after study using control sites

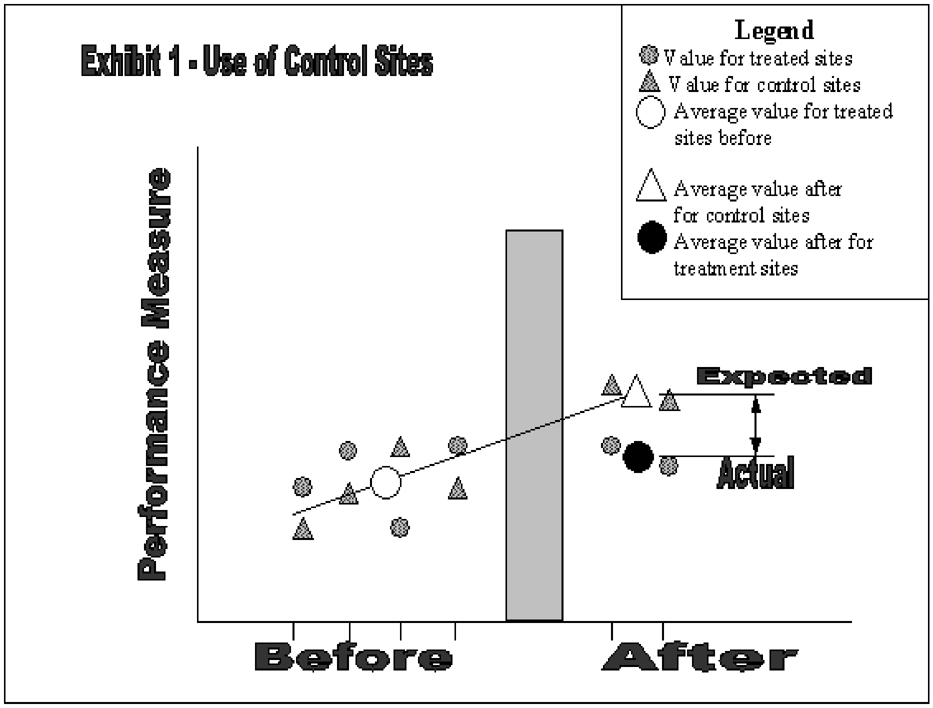


Exhibit 58 suggests that one could estimate the change in performance at the control sites by using averages for the before and after period. The effect of treatment on performance (e.g., fatal crashes, pedestrian crashes, etc.) is estimated as the difference between expected (predicted) and actual crashes. It also shows that individual site values may be used to perform a regression or trend analysis. More recent developments suggest that use of the Empirical Bayes approach may be more appropriate in many instances for estimating the expected value in the after period—due to the often present regression to the mean effect caused by site-selection bias (sites are selected for treatment due to observed high crash counts—part of which may be due to random fluctuations). While this figure merely shows one aspect of the before-after methodology, it demonstrates, in general, the methodology for assessing countermeasures. Further information is provided in Hauer, 1999.

CRASH OUTCOME DATA EVALUATION SYSTEM (CODES)

Exhibit 59: Summary of the CODES tool

CODES

Vendor name and address: U.S. Department of Transportation, National Highway Traffic Safety Administration.

Brief description of transportation safety applications: CODES was designed to generate crash statistics that merge medical and financial outcome information with motor vehicle accidents. The information is used to estimate costs associated with crashes under a variety of circumstances (e.g., rollover crashes, pedestrian crashes, tire blowouts, etc.). The state maintained databases in turn help to conduct analysis toward the prevention of deaths and injuries, the reduction of injury severity and health care costs, and improvement in the basis for decisions related to highway traffic safety investments. CODES is perhaps the most valuable tool available (regarding motor vehicle crashes) to state and federal legislators, since it is the only known software capable of linking accident costs with accidents in a rigorous and defensible way.

Types and sources of data needed: The main aim of CODES is to link various data related to traffic accidents. The data necessary for CODES includes accident data, emergency medical service (EMS) data, hospital inpatient data, death certificates, vehicle identification number data, and trauma registry data.

Expertise required: Knowledge about statistical data analysis and the CODES linkage software. Training in CODES software is absolutely necessary to use this software, and expertise is available already in many states in the U.S..

Hardware requirements: Windows work station running MS Access

Example application of tool: The CODES is a software system that enables probabilistic linkage of accident data from various sources. The data sources usually consist of police-recorded accidents, hospital inpatient data, emergency medical services data, trauma registry data, and death certificate data.

Probabilistic linkage enables the linking (association) of accident records with the highest probability, and is needed because accident records lack a unique identifier throughout the accident process.

An example application is to link all 2001 motor vehicle accident data in the state of Arizona with emergency medical service records, hospital information, trauma registry information, and death certificate data. Then, analysis can be conducted to determine what the costs in the state of Arizona are associated with safety restraint use violations, lack of child-seat usage compliance, or motorcyclists not wearing helmets. Similarly, an analysis can be conducted to estimate the impact of emergency response times on fatality probabilities. Finally, the types of injuries and associated costs of SUV rollover accidents can be examined, as well as other analyses.

CRITICAL ANALYSIS REPORTING ENVIRONMENT (CARE)

Exhibit 60: Summary of the CARE tool

CARE

Vendor name and address: CARE Research and Development Laboratory (CRDL), Department of Computer Science, University of Alabama, Box 870290, Tuscaloosa, AL-35487-0290. This is free software and can be downloaded from internet, and is set up for the analysis of crashes in the state of Alabama.

Brief description of transportation safety applications: CARE is a data analysis software package designed for problem identification and countermeasure development. CARE can be used to retrieve subset of any specific interest from the entire crash dataset in a few seconds, providing the feedback necessary to allow the user to make subsequent queries based on preliminary results. The user can apply CARE to get started immediately without having to do any programming or sophisticated analysis. The information mining capability (IMPACT) of CARE generates information through the comparison of subsets of data (e.g., weather-related vs. non-weather-related cases), and graphically demonstrates possible potential areas for countermeasure implementation. In addition to its capability of identifying high crash locations CARE supplies corrective measures in terms of countermeasure selection. Another attractive feature of CARE is its ability to generate collision diagrams through the popular software "Intersection Magic" that was incorporated into it. The reports produced by CARE can be directly exported to Microsoft Office products such as Word and Excel.

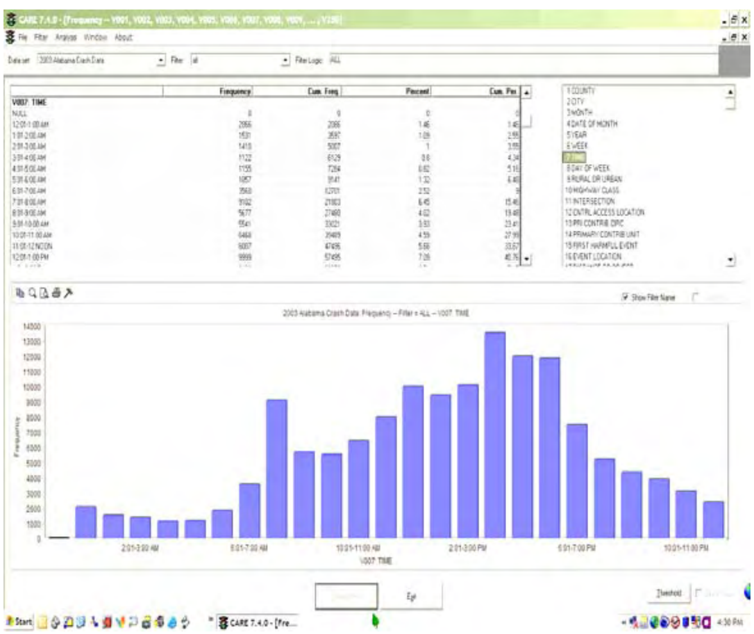
Types and sources of data needed: It is necessary to have the crash data in a specific format to allow CARE to perform the analysis. Users can transform existing datasets to the required format by following the easy steps described in the software manual. If needed CRDL staff can prepare the dataset for a fee.

Expertise required: Although CARE uses advanced analytical and statistical techniques to generate valuable information from the data, users do not have to be familiar with any special knowledge. This user-friendly software can be used efficiently by just following step-by-step menus outlined on screen. Interpretation of the results, however, requires an understanding of the crash database and associated variables.

Hardware requirements: CARE can be used on a desktop or through the internet. The CARE desktop operates in the Microsoft Windows environment (including Windows 95, 98, NT, 2000, ME, XP).

Example application of tool: CARE prepares a variety of canned reports. An example of such a report is shown in Exhibit 61. In this example the user selected a frequency report based on the time of day. For further examples, refer to the software website: http://care.cs.ua.edu.

Exhibit 61: Example output from CARE



INTERACTIVE HIGHWAY SAFETY DESIGN MODEL (IHSDM)

Exhibit 62: Summary of the IHSDM tool

IHSDM

Vendor name and address: Federal Highway Administration / Turner-Fairbank Highway Research Center.

Brief description of transportation safety applications: Currently available for testing and evaluation, the IHSDM can assess the safety implications of two-lane roadway designs. A model to evaluate multi-lane roadways is in the development stages. The 2003 (2-lane version) IHSDM consists of 5 modules: the Accident Prediction Module, Design Consistency Module, Intersection Review Module, Policy Review Module, and Traffic Analysis Module. The multi-lane IHSDM (yet to be released) will also feature a Driver/Vehicle Module, which will consist of a Driver Performance Model linked to a Vehicle Dynamics Model. The IHSDM can review designs in both metric units and U.S. customary units.

Types and sources of data needed: The data required for the IHSDM are numerous:
General data
Terrain type (level, rolling, mountainous, null)
Volumes (daily and hourly)
Functional classification
Speed (design, 85th percentile, and posted)
Horizontal elements
Curves
Station equations (if any)
Intersections
Vertical elements
Curves
Cross-sectional data
Cross-slopes
Pavement type
Shoulder (slope, width, material, category)
Lane dimensions
Roadside elements (slopes, ditch, obstruction offset, bike facilities, driveway density, hazard rating)
Other relevant roadway data:
Accident data (based on accident records)
Bridge elements
Decision sight distance
Design Vehicle

Expertise required: Basic understanding of geometric design concepts and ability to input data into the Windows-based interface, either through detailed geometric elements or by conversion of highway design data to *.csv (comma-separated) format.

Hardware requirements: Windows work station.

Example application of tool: The IHSDM is useful for determining the safety implications of either an existing or planned roadway alignment/configuration. For instance, a two-lane roadway with extensive curvature and other geometric intricacies can be evaluated for a variety of issues, including compliance with federal policy (such as the 1994 or 2001 AASHTO Policy, metric or English units), its expected accident rates or frequencies, how well the roadway design meets with driver expectations, the policy consistency and operational performance of intersections, and various aspects of traffic analysis. The IHSDM can also be used to present graphical representations of an analyzed roadway showing plan, profile, and cross-sectional views.

INTERSECTION MAGIC

Exhibit 63: Summary of the INTERSECTION MAGIC tool

INTERSECTION MAGIC

Vendor name and address:
Pd' Programming, Inc
725 Aegean Drive
Lafayette, CO 80026
Phone Number: Main number: (303) 666-7896
R&D: (303) 666-6035
Fax: (303) 666-7347

Brief description of transportation safety applications: Intersection Magic is efficient software for accident record analysis. From the accident database, it generates automated collision diagrams, pin maps of high accident locations, high accident location lists, frequency reports, and much more. A transportation engineer can easily extract a particular type of accident say, left turning accident, or angle accident at the intersection, and that accident type will be displayed on the screen with the total number of such accidents. Similarly, to locate the accident-prone intersections, pin maps can be generated, along with the name of the intersections and frequency of accidents. Besides these spatial features, the temporal features such as time, month, or year of accidents can also be displayed with the help of presentation graphics. With all these advantages, Intersection Magic is no doubt a useful tool for traffic engineers and planners to identify hazardous locations, which could then be treated to enhance safety.

Types and sources of data needed: For the purpose of analyzing various attributes of accidents, the database can be developed within this software. In addition to this, Microsoft Excel database can also be used.

Expertise required: This is user-friendly software and does not need any special knowledge to use. The software is linked with Arc GIS. This linkage helps in displaying pin maps from high accident location reports, traffic volume maps, corridor line maps from sliding spot reports, comparisons of various kinds of accidents, and so on. However, plotting these special features does not require learning GIS software.

Hardware requirements: Windows work station.

Example application of tool: Refer to the examples provided below.

Intersection Magic (IM) is software that is used to perform accident analysis based on historic accident data at intersections. It generates automated collision diagrams, pin maps of high accident locations, and frequency reports. The software is primarily used as a reactive tool to analyze safety. IM's powerful query system helps an analyst to investigate various spatial and temporal attributes of each accident occurring at an intersection along with a schematic representation of each. This special feature of IM enhances the analysis power, as visual representation of data greatly improves the ability of the individual to evaluate the dataset. While an intersection can be identified as a hot spot, based on high accident statistics, IM can provide a powerful tool to the professional to analyze the intersection to determine the nature of the accidents occurring at the site. In these cases, a quick analysis in IM would give the analyst all possible information associated with the accident; for example, the time of accident occurrence, the maneuver before the accident occurred, the severity of the accident, and much more. Exhibit 63 provides a summary of the IM Tool.

Particular Advantages

In addition to the existing strong analytical capabilities, IM can also be linked to ESRI's Arcview (Geographic Information System software). This enhances the analytical ability of IM as it brings the analysis tools and benefits of the GIS environment to the analysis process.

The web browser facility of IM enables the user to perform analysis via the inter- or intranet and to use all of the analysis capabilities of the software from any computer on the network. Updates are applied automatically, the results of an analysis is automatically saved until the user decides to discard it, and all reports, filters, and charts are stored centrally.

Intersection Magic has a powerful query system to investigate spatial and temporal attributes of each accident along with a schematic diagram.

Examples of Analysis using IM

To demonstrate the various accident analysis features available in IM, a set of analysis examples are provided using accident data from City of Chandler, Arizona. It should be noted that this software description do not intend to substitute for the IM manual; it merely intends to demonstrate by example some of the analysis capabilities of the software. To access a user guide for the software, consult the Intersection Magic User manual or visit www.pdmagic.com.

The identification of accident hot spots in a jurisdiction is a critical element of a hazard elimination program. IM enables the user to identify the hot spots, to evaluate the accident statistics, and to identify possible countermeasure treatments.

Identify locations

In this example, a list of intersections is generated with at least one accident. This is done by selecting: Select Reports / Listings / High Accident Locations and by following the steps to extract the information from the database:

- First the number of intersections in the dialogue box are specified, say in this case 100 intersections with at least an accident are selected.
- In the same dialogue box, the user has the option to specify a date range, sorting criteria of accidents such by counts/rates and so on.
- There are also options as to display the volume, rate, counts and other records for the intersection.

This procedure generates a list of intersections with accident counts that can be compared to each other, used to identify 'high risk' locations (most likely along with additional numerical analysis), or to trigger field audits. Two screen captures from the analysis showing list and diagram are shown in Exhibit 64 and Exhibit 65 respectively.

An analyst could also target specific types of accidents, such as accidents that occurred during night time or rear end crashes. This is accomplished by clicking on the Diagram/Settings tab and then selecting the desired accident labels. Accident labels can be made visible or not; however, a couple of aspects should be kept in mind:

- If labels are visible, the diagram as shown in Exhibit 65 will include specific information.
- If the number of accidents becomes large, the diagram becomes congested and the labels result in a cumbersome diagram rather than improving the analysis capability. In this case, the various attributes of accidents are represented by different colors. For example, bad weather accidents such as during rain in red, accidents during dawn/dusk in blue, and so on. This is done by selecting the

option Diagram/Accidents/Toggle highlighter and then choosing specific colors to represent typical accident types.

Exhibit 64: Screen grab for top 100 Intersections with at least one accident

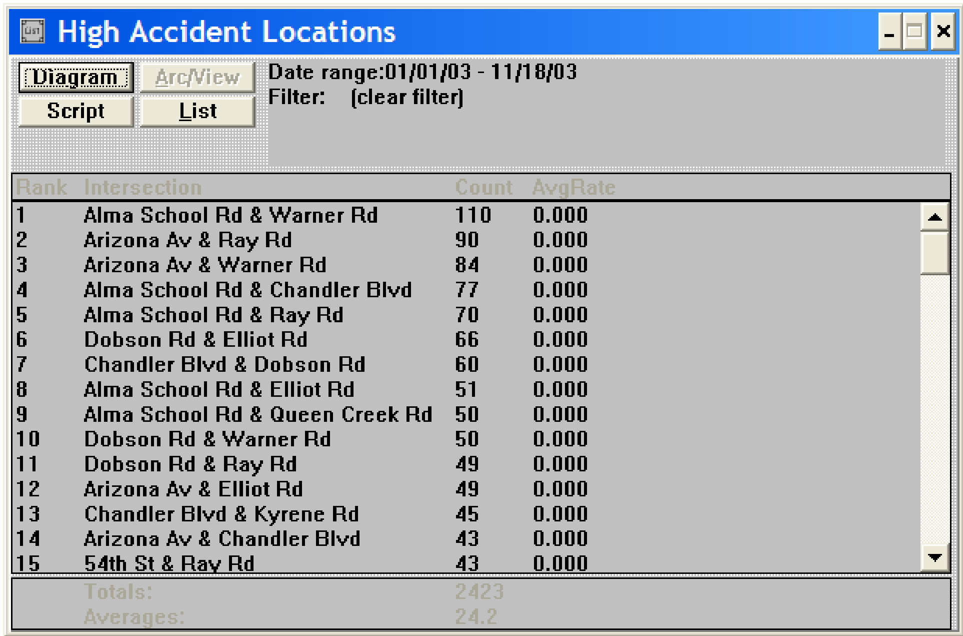
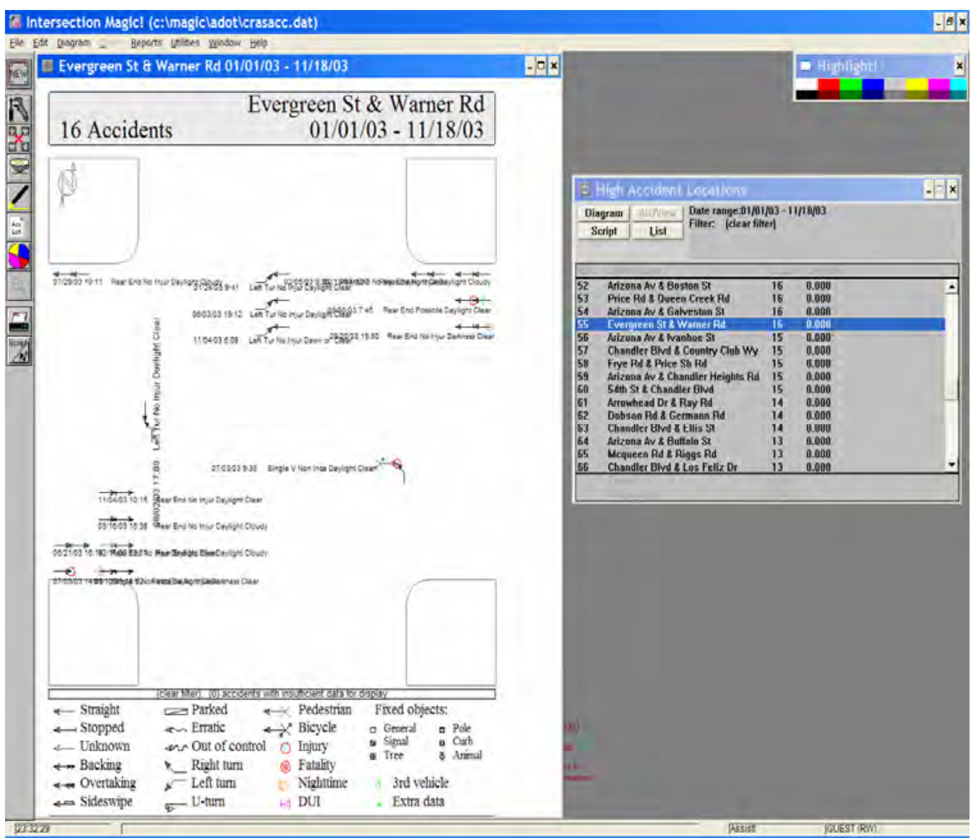

High Accident Locations

Diagram | Arc/View | Script | List

Date range:01/01/03 - 11/18/03
Filter: (clear filter)

Rank	Intersection	Count	AvgRate
1	Alma School Rd & Warner Rd	110	0.000
2	Arizona Av & Ray Rd	90	0.000
3	Arizona Av & Warner Rd	84	0.000
4	Alma School Rd & Chandler Blvd	77	0.000
5	Alma School Rd & Ray Rd	70	0.000
6	Dobson Rd & Elliot Rd	66	0.000
7	Chandler Blvd & Dobson Rd	60	0.000
8	Alma School Rd & Elliot Rd	51	0.000
9	Alma School Rd & Queen Creek Rd	50	0.000
10	Dobson Rd & Warner Rd	50	0.000
11	Dobson Rd & Ray Rd	49	0.000
12	Arizona Av & Elliot Rd	49	0.000
13	Chandler Blvd & Kyrene Rd	45	0.000
14	Arizona Av & Chandler Blvd	43	0.000
15	54th St & Ray Rd	43	0.000
	Totals:	2423	
	Averages:	24.2	

Exhibit 65: Screen grab for Alma School & Warner Road intersection accident diagram



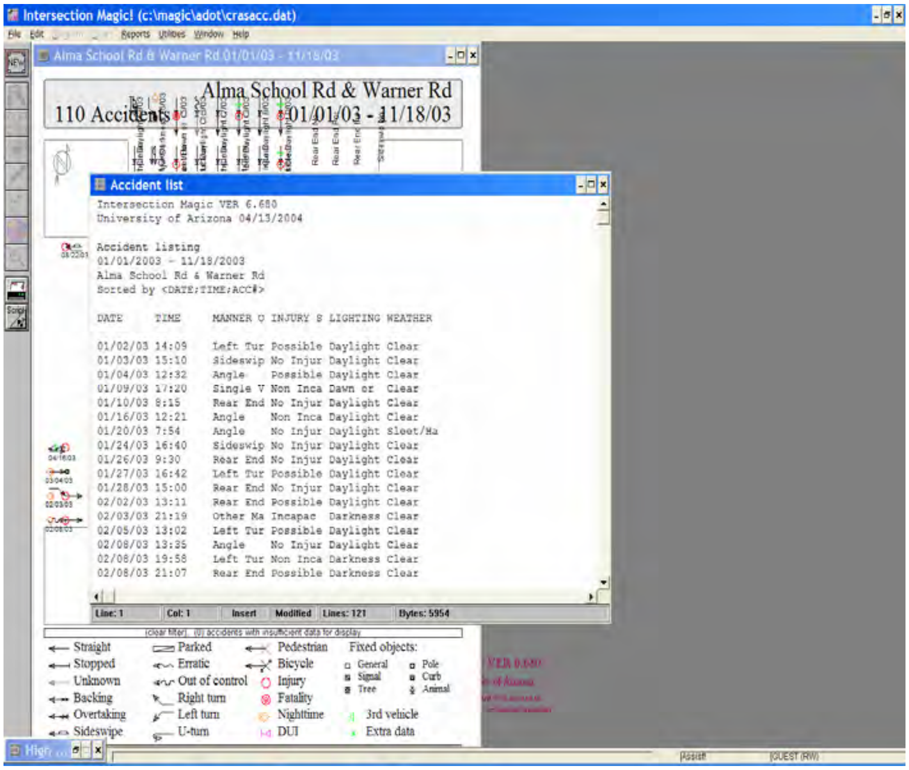


Exhibit 66: Screen grab for Evergreen St & Warner Road intersection accident diagram with labels

Filters help the analyst to extract specific attributes of interest. For example, after getting the intersection list from the previous step, a filter is used to identify intersections that have an associated accident rate above a certain value, or accidents resulting in incapacitating injuries or fatalities. To create a filter, to the user selects "record filter" and then "edit filter" to write the filter expression. Once the filter expression is given, the conditions to qualify the accidents to be included in the list/diagram is complete. For example:

- Suppose the analyst wants to know about the top 100 intersections with at least 1 incapacitating/fatal accident. Hence, a filter is created that extracts only those intersections in the database as shown in Exhibit 67. The list yields 92 intersections; so there are 92 intersections in the city of Chandler where at least one severe/fatal accident occurred during the first 11 months of 2003. The list also shows the count of such accidents in descending order, helping to characterize the safety problem at different intersections.

IM's filter tool helps analyst extracting specific attribute of accident from the database.

Identification of Problems

Next, the intersections on the top 100 list are examined to identify possible underlying problems associated with each. To accomplish this, the analyst completes the following:

- A schematic diagram is created of the accidents at each intersection to visualize the accidents occurring each of the sites.
- During an analysis of the diagram, the analyst can click on each accident position (precisely the junction of the two arrows indicated as accident) to get access to all available details of the accident record about the circumstances in which the accident occurred.

Exhibit 67: Screen grab for top 92 Intersections with at least one severe accident

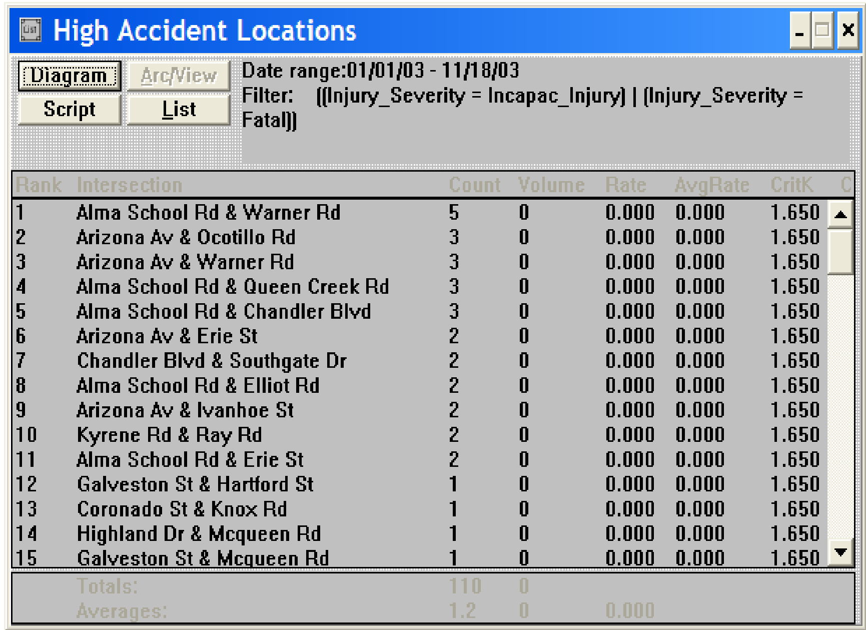

High Accident Locations

Diagram | Arc/View | Script | List

Date range:01/01/03 - 11/18/03
Filter: ((Injury_Severity = Incapac_Injury) | (Injury_Severity = Fatal))

Rank	Intersection	Count	Volume	Rate	AvgRate	CritK
1	Alma School Rd & Warner Rd	5	0	0.000	0.000	1.650
2	Arizona Av & Ocotillo Rd	3	0	0.000	0.000	1.650
3	Arizona Av & Warner Rd	3	0	0.000	0.000	1.650
4	Alma School Rd & Queen Creek Rd	3	0	0.000	0.000	1.650
5	Alma School Rd & Chandler Blvd	3	0	0.000	0.000	1.650
6	Arizona Av & Erie St	2	0	0.000	0.000	1.650
7	Chandler Blvd & Southgate Dr	2	0	0.000	0.000	1.650
8	Alma School Rd & Elliot Rd	2	0	0.000	0.000	1.650
9	Arizona Av & Ivanhoe St	2	0	0.000	0.000	1.650
10	Kyrene Rd & Ray Rd	2	0	0.000	0.000	1.650
11	Alma School Rd & Erie St	2	0	0.000	0.000	1.650
12	Galveston St & Hartford St	1	0	0.000	0.000	1.650
13	Coronado St & Knox Rd	1	0	0.000	0.000	1.650
14	Highland Dr & Mcqueen Rd	1	0	0.000	0.000	1.650
15	Galveston St & Mcqueen Rd	1	0	0.000	0.000	1.650
	Totals:	110	0			
	Averages:	1.2	0	0.000		

Filters can also be saved for future analyses. All generated diagrams can also be saved for future reference. Another useful command is Sliding Spot Listing. It provides the user with a means of locating high accident locations on roads with hundred block or milepost data. Specifically, for each specified road, this function examines the entire length and sorts the high accident locations into the list of all roads specified for processing.

LEVEL OF SERVICE OF SAFETY (LOSS)

Exhibit 68: Summary of the LOSS tool

LOSS

Vendor name and address: National Cooperative Highway Research Project 17-18(4)

Brief description of transportation safety applications: The concept of Level of Service of Safety was first introduced by Kononov and Allery (2003). As an effort to develop Highway Safety Manual (HSM) under the NCHRP project 17-18(4), they have developed a detailed procedure to identify the existing level of service of safety for highways. According to the authors, the concept of level of service uses qualitative measures that characterize the safety of a roadway segment in reference to its expected performance. They also explain that the level of safety predicted by the Safety Performance Function (SPF) will represent the normal or expected number of accidents at a specific level of AADT, and the degree of deviation from this norm or expected value can be stratified to represent specific levels of safety. In the case of roadway safety, both frequency and severity are important. Hence it is necessary to calibrate two kinds of SPFs, one for the total number of accidents, and another for injury and fatal accidents only. When the magnitude of the safety problem is assessed using the LOSS methodology, it is done so from frequency and severity standpoints. Four Levels of Service of Safety (LOSS) were proposed by Kononov and Allery (2003), these are:

LOSS-I - Indicates low potential for accident reduction
LOSS-II- Indicates better than expected safety performance
LOSS-III - Indicates less than expected safety performance
LOSS-IV – Indicates high potential for accident reduction

The LOSS concept is widely used by the Colorado Department of Transportation for system-level planning, as well as project scoping. Kononov and Allery assert that this approach will bring about badly needed consensus in the transportation engineering profession on the subject of the magnitude of safety problems for different classes of roads. In addition, the classification will also make it possible to take the following critical steps in effective and responsible resource allocation directed at improving road safety:

Qualitatively describing the degree of safety or un-safety of a roadway segment
Effectively communicating the magnitude of the safety problem to other professionals or elected officials
Bringing the perception of roadway safety in line with reality of safety performance reflecting a specific facility
Providing a frame of reference for decision making on non-safety motivated projects (resurfacing or reconstruction, for instance)
Providing a frame of reference from a safety perspective for planning major corridor improvements.

Types and sources of data needed: Information about the accident history and the geometry of the existing roadway, as well as exposure (traffic volumes or flows) information to support the development of SPFs.

Expertise required: No special expertise is needed, although basic understanding of statistics is desirable.

Hardware requirements: Windows workstation with spreadsheet and/or database capabilities.

Example application of tool: To identify the existing LOSS, a highway is divided into a number of segments. Accident counts per segment are then obtained from which accidents per mile per year are identified. After this process, the existing LOSS is easily identified using the SPF graphs and the existing Annual Average Daily Traffic (AADT). A similar procedure can be used for forecasting future accidents if the traffic engineer has predicted traffic volumes. Kononov and Allery (2004) have shown an example in their recent paper to illustrate the appropriate use of LOSS as a proactive tool to predict safety. A more detailed discussion of LOSS is described in the following section.

LOSS is very similar to that of Level of Service in Highway Capacity Manual. However, LOSS concept is intended to reflect the performance in terms of expected accident frequency and severity at a specific level of AADT, as opposed to the measure of delay, conventional in the Level of Service Analysis.

Exhibit 68 briefly introduces the concept of Level of Service of Safety (LOSS) that was developed as a part of Highway Safety Manual (HSM) under National Cooperative Highway Research Program (NCHRP) Project 17-18 (4). Although the concept of the LOSS is new, it is similar to the Level of Service concept used in the Highway Capacity Manual (HCM). The LOSS reflects the performance of a site, project, or facility in terms of expected accident frequency and severity at a specific level of AADT. The LOSS concept was developed by Jake Kononov and Bryan K. Allery. In their most recent papers (2003, 2004), the concept of Safety Performance Function (SPF) is discussed in great detail as well as the development of LOSS using SPFs. Brief descriptions of these terms is provided here; however for additional details, readers are encouraged to refer the previously mentioned papers. Information about HSM is also available at www.hsm.fhwa.com.

Safety Performance Function (SPF)

The SPF is simply a function that relates expected crash frequencies to exposure. Different facilities and traffic control situations deserve their own SPFs; for examples SPFs are appropriate for signalized intersections, stop controlled intersection, 2-lane highway segments, 4-lane highway segments, etc. Typically these relationships are fitted using Negative Binomial or Poisson regression models. In many cases these relationships are not straight lines (linear functions), and as a result provide evidence against the use of accident rates for assessing the safety performance of sites. Details about dataset preparation and model fitting for the development of the Safety Performance Functions (SPF) are described by Kononov and Allery (2003), whereas discussion about the non-linearity of SPFs is provided in Hauer (1997).

Level of Service of Safety (LOSS)

LOSS is developed using the concept of the SPF. The LOSS concept uses qualitative measures that characterize safety of a roadway segment in reference to its expected performance. If the level of safety predicted by the SPF represents normal or expected number of accidents at a specific level of AADT, then the degree of deviation from this expected count can be stratified to represent specific levels of safety. Kononov and Allery calibrated two kinds of SPFs, one for the total number of accidents and another for injury and fatal accidents. There are four level of service for safety as follows:

LOSS-I - Indicates low potential for accident reduction

LOSS-II- Indicates better than expected safety performance

LOSS-III - Indicates less than expected safety performance

LOSS-IV – Indicates high potential for accident reduction

To illustrate how LOSS is applied in practice, a case study conducted by Kononov and Allery (2004) in the Denver Metro Area is presented. In this case study, the authors examined a segment of a major 6 lane urban freeway in the Denver Metropolitan Area, shown in Exhibit 69.

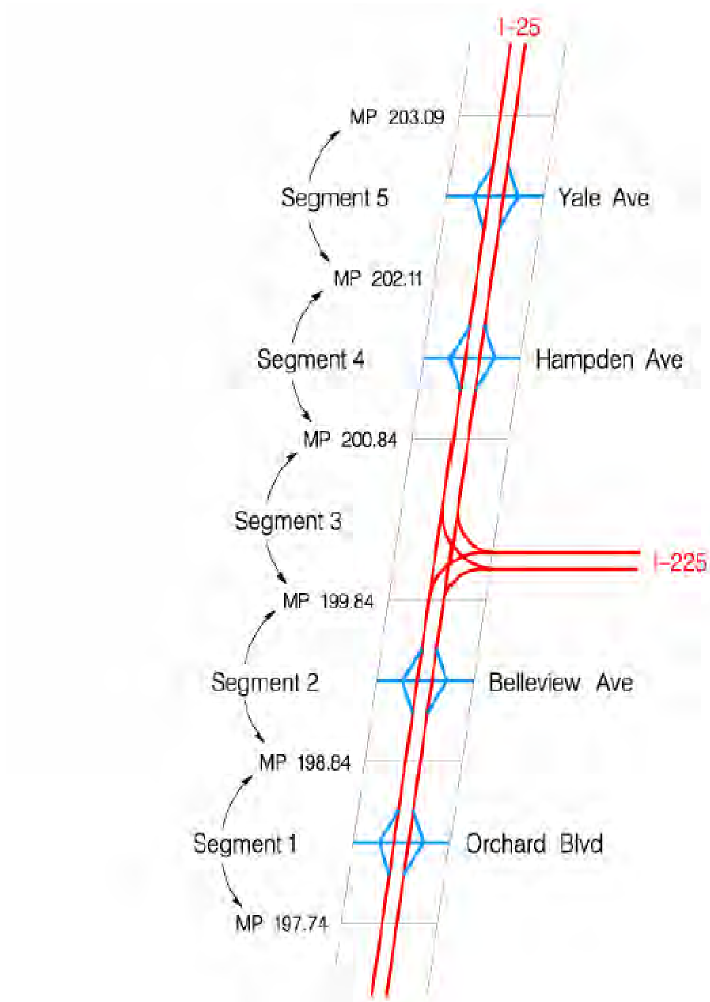


Exhibit 69: Project area map, Denver Colorado metropolitan area corridor study

The analysis begins with a LOSS analysis that reflects average safety performance of the section for three years (2000-2002), followed by a diagnostic investigation of accident causality. A running average of the 3 years was used to smooth out peaks related to annual fluctuations in accident frequency. The results of the LOSS total frequency analysis of the urban 6-lane freeway in the study area are shown in Exhibit 70, while the results of the LOSS injury and fatal only analysis are presented in Exhibit 71.

The models shown in Exhibit 70 and Exhibit 71 reflect 14 years of accident data. The models represented by dark blue and dark red curves in the figures represent expected crashes predicted by the Negative Binomial regression models estimated using the observed crash data. Noteworthy observations are as follows:

- Segments #1, 3, 4 and 5 performed more or less as expected for an aging urban freeway. Observed frequency and severity are in the LOSS-II and LOSS-III range.
- Segment #2, however, showed highly undesirable safety performance in the high range of the LOSS-IV for both frequency and severity, which suggested a high potential for accident reduction.

At this stage of the diagnostic investigation, the researchers concluded that the site experienced significantly more accidents than expected for some unknown reason. Based on this observation, they followed up by examining the accident type distribution observed on the study segment over a period of three (3) years. This examination led to the distribution presented in Exhibit 72. The distribution shows a high percentage of rear-end collisions followed by sideswipes in the same direction on the segment under study.

Exhibit 70: LOSS-injury and fatal accident frequency in the study area

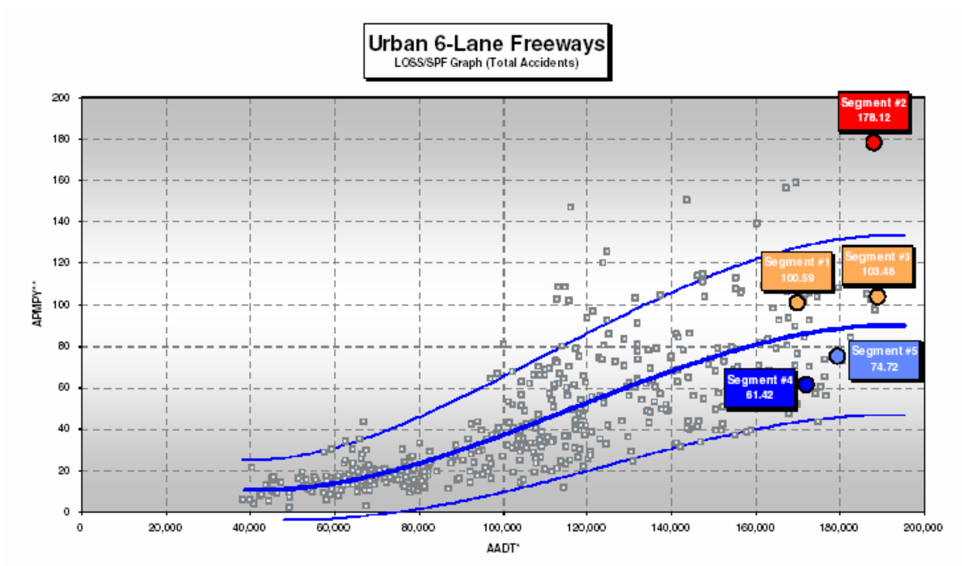


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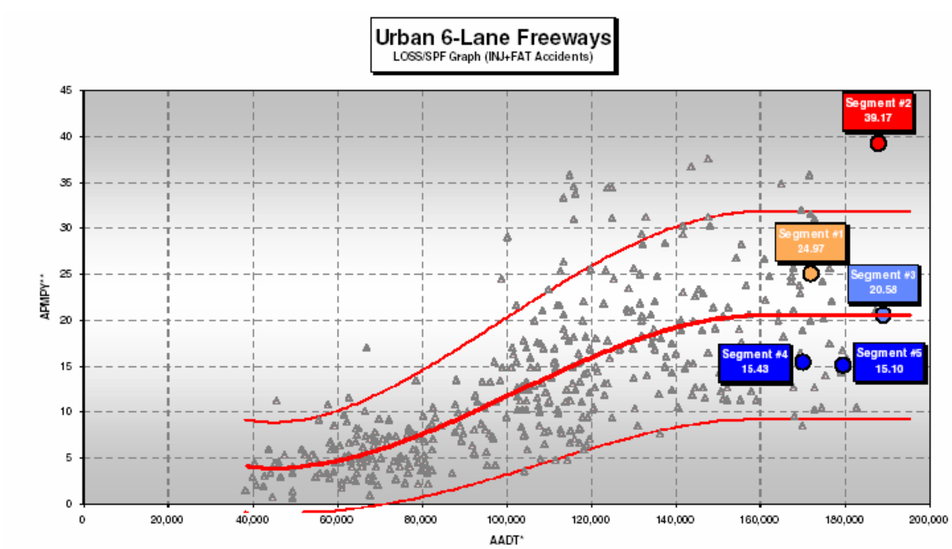
Exhibit 71: LOSS-total accident frequency in the study area



Rear-end collisions represented 73% of the accident types. This was higher than the expected 44.5% level, which is typical for 6-lane urban freeways. Same direction sideswipe accidents represented 18% of the accidents, which is also higher than the expected 12.6% for similar types of segments.

Based on these findings, the authors concluded that elements in the roadway environment possibly triggered a deviation from the random process of accident occurrence in the direction of reduced safety. More specifically, it triggered rear-end and sideswipe collisions.

Subsequent plan reviews and site visits by the researchers revealed the existence of a highly constrained weave type C section within segment #2 in the southbound direction (Exhibit 73 and Exhibit 74). Specifically, vehicles entering the freeway on the left side were attempting to exit on the right side while crossing three highly congested through lanes of traffic and one auxiliary lane over a very short distance. Operational Level of service (LOS) analysis procedures outlined in the Highway Capacity Manual (TRB) showed a LOS-F in the weaving section in the southbound direction. In this case, a traffic operational problem related to the highly constrained weave type C translated into a significant safety problem manifested by the high frequency and severity of rear-end and sideswipe collisions. They concluded that the high number of rear-end and sideswipe accidents is the reason behind the highly elevated accident frequency and severity on this segment. They recommended the removal of the type C weave by reconfiguring the interchange and constructing a flyover ramp or a tunnel to facilitate the conflicting vehicular movements.

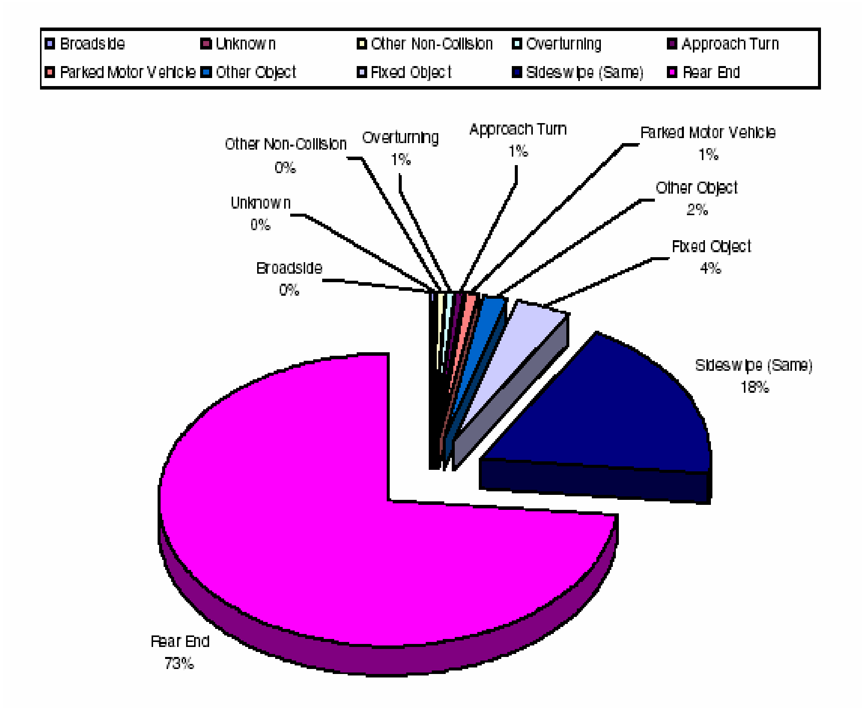


Exhibit 72: Breakdown by accident type in the study area

Exhibit 73: Wave type C-LOSS analysis for total accidents
Researchers identified a highly constrained weave type C section within segment #2 in the southbound direction which contributed to the higher number of rear-end and sideswipe collisions

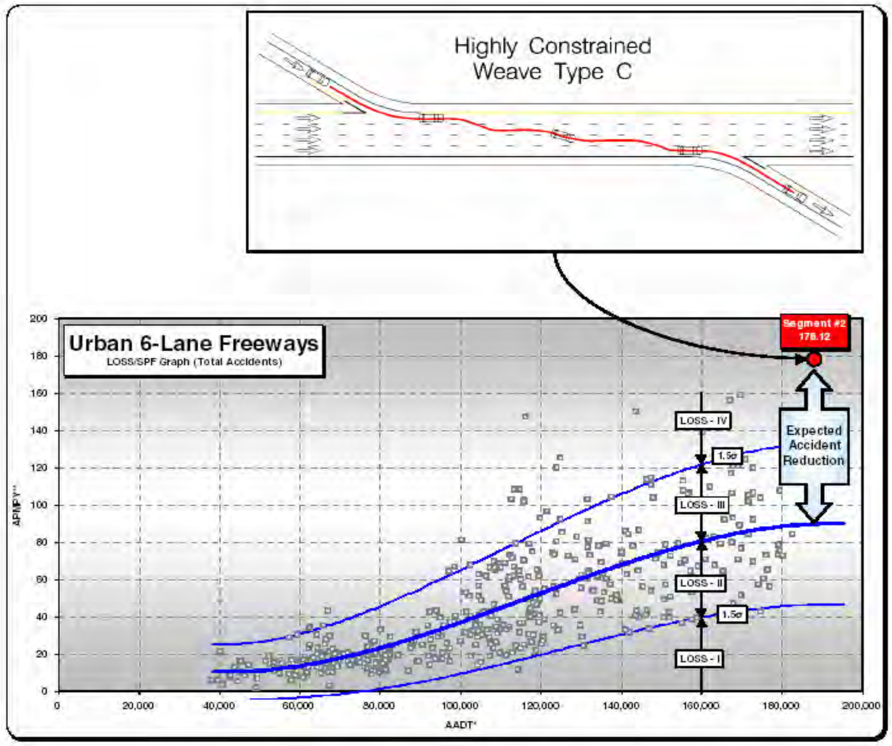
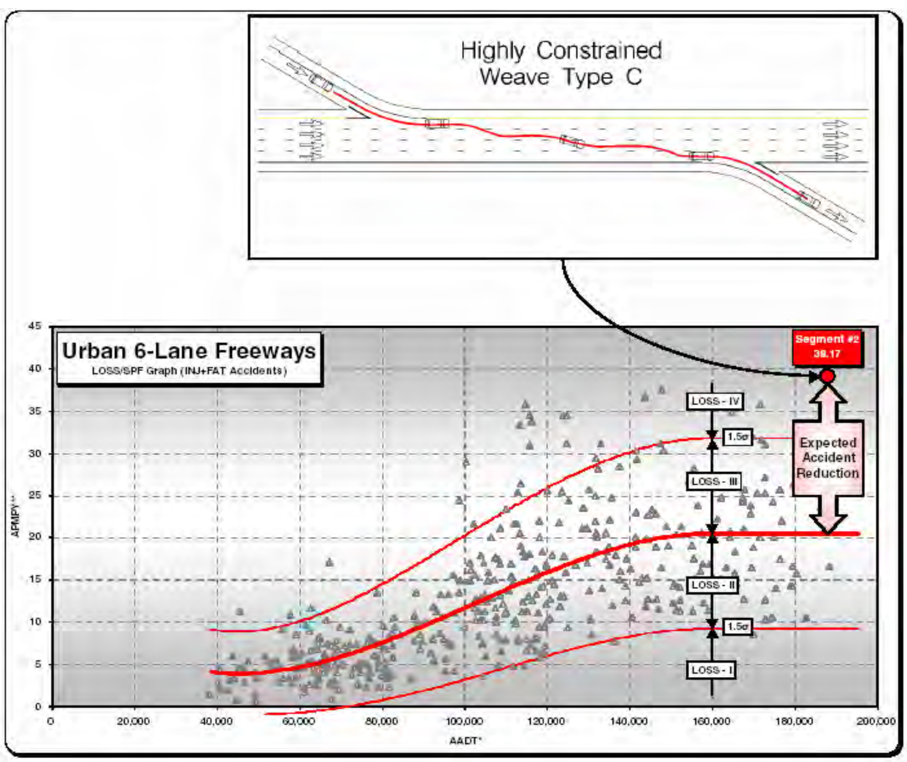


Exhibit 74: Wave type C-LOSS analysis for injury and fatal accidents



The researchers concluded that removing the weave type C section from segment #2 will improve safety performance to an average 6-lane freeway segment in an urban environment (the comparison group mean). To determine the expected accident frequency and severity they used the SPF graphs and estimated that at the current AADT level of 188,000, approximately 90 accidents per mile are expected, of which approximately 20.5 collisions will result in injuries or fatalities. The improvement, they estimated, would result in a reduction of approximately 88 accidents, including 19.5 injuries, during the first year following construction. It is important to note that within segment #2, each injury accident results in injuries to 1.3 people on average. This suggests that removal of the type C weave section could potentially prevent injuries to 25 people in the first year following construction. Exhibit 73 and Exhibit 74 graphically illustrate the anticipated accident reduction resulting from the elimination of the constrained weave in the southbound direction.

In addition to the safety improvements, a corridor expansion from 6 to 8 lanes was also planned and the researchers estimated that the improvement would prevent 34 accidents, 11.5 of which result in injury.

This example illustrates how safety can be explicitly addressed while planning long-range major transportation improvements in urban corridors. The analysis is achieved with fairly simple tools, and with some basic knowledge in the estimation of statistical models (Negative Binomial or Poisson Regression), some spreadsheet functions, and as always sound engineering judgment.

MULTIMODAL TRANSPORTATION-PLANNING TOOL (MTPT) GDOT

Exhibit 75: Summary of the MTPT tool

MTPT (GDOT)

Vendor name and address:
Georgia Department of Transportation: Office of Planning, 2 Capitol Square, Atlanta, GA 30334

Brief description of transportation safety applications: This tool is a first-step analysis of the operating performance of the Georgia's rural transportation system. The tool consists of modules corresponding to different transportation modes, including,

Highway – The highway module incorporates several roadway analysis elements. Essentially, the module determines level of service for existing and future conditions, evaluates delay associated with interrupted flow conditions (in the form of signalized intersections), identifies high risk accident locations, and prioritizes possible improvement strategies for the individual road. Improvement recommendations may range from "No action required" to "Requires Immediate Action". Below are overviews of the individual modules incorporated in the highway analysis. The accident analysis component of this module permits the program user to identify regions within the study area where the number of accidents exceeded statewide averages for that specific roadway functional classification.

Rural Transit – The rural transit analysis module performs several tasks. First, it eliminates urbanized and FTA Section 5311 public transit service provider regions from analysis due to the focus of the module on rural conditions. Next, the module evaluates the socioeconomic characteristics of a region to determine transit needs, prioritizes the identified needs, and then estimates implementation costs.

Commuter and Passenger Rail – The Georgia State Commuter Rail Plan is available to the MTPT as a two-phase plan. The current program analysis includes a list of proposed station locations and the recommended implementation phase from the Commuter Rail Plan. Phase 1 indicates service proposed for initial plan implementation. Phase 2 represents rail service proposed for later implementation.

Aviation – The MTPT aviation analysis is based upon two GDOT data sources. The five-year aviation capital improvements plan (CIP) provides anticipated improvement projects based upon local input. A separate database record is maintained for each airport, and the airports are categorized according to "associated city". FAA-funded airports are also available to the program. This resource permits the MTPT to include recommendations for the appropriate airport (current status, availability, etc.) when a city or county analysis is undertaken.

Bicycle and Pedestrian – Two separate analyses are performed for the statewide bicycle plan. First, if the program user selects bicycle analysis then the program queries the bicycle lane database and identifies corridors that are common to the proposed bike plan. Next, the program evaluates the specific road characteristics (lane width, surface type, shoulder width, etc.) to determine what improvements are required before the bicycle lane can be accommodated. An upgrade designation ranging from Minor 1 (essentially only an overlay required) up to Major 2 (full roadway reconstruction and widening necessary) is assigned to the road and an estimated improvement cost is applied. The second bicycle analysis feature is implemented during highway analysis. At that time, when a road level of service has been analyzed, an "action priority code" is assigned to the road that indicates if the road is currently suitable. One step in assigning this code is evaluation of the corridor for suitable conditions to accommodate future bicycle facilities based on physical road characteristics.

Intercity Bus – The Georgia intercity bus plan provides information on where current services are potentially vulnerable to abandonment, and where new services should be considered. The MTPT includes a database query that identifies potential new routes and all routes vulnerable to abandonment.

Types and sources of data needed: The data are derived from several sources at the Georgia Department of Transportation. The Road Characteristics Database and the Accident Database are the two most important data sources for the highway and pedestrian/bicycle analyses. Other information is provided from current statewide modal transportation plans.

Expertise required: The package comes with a simple tutorial on how to use the system. No special expertise is needed to use the package.

Hardware requirements: The package is currently available in Windows 98, Windows 2000, NT Service Pack 5, and Windows XP.

Example application of tool: One of the more innovative applications of this tool is found in the Environmental Justice module, which relates motor vehicle/ pedestrian accidents to socio-economic characteristics of the surrounding area. Pedestrian/bicycle accident rates (from the state's accident database) are linked to the Road Characteristics database through GIS and where high accident rates are found to occur on high-volume, high-speed roads, the corridors are flagged for further attention.

PEDESTRIAN AND BICYCLE ACCIDENT ANALYSIS TOOL (PBCAT)

Exhibit 76: Summary of the PBCAT tool

PBCAT

Vendor name and address: Federal Highway Administration (FHWA). See http://www.fhwa.dot.gov/ or http://www.hsrc.unc.edu/ for additional information.

Brief description of transportation safety applications: The PBCAT is utilized to develop and analyze databases containing details associated with accidents between motor vehicles and pedestrians or bicyclists. The tool includes “accident type”, which describes the actions of the parties involved immediately prior to the accident. The software was developed based on NHTSA’s development of “typing” methodology in the 1970’s to better describe the sequence of events and precipitating actions that led up to the accidents. Once the supporting database is developed, the tool can be utilized to select countermeasures to address identified problems.

Types and sources of data needed: Accident type data with geometric, time, weather, location, age, sex, subject actions, and other attributes.

Expertise required: Basic computer knowledge. The software contains user-friendly, online instructions and help features, along with a user's manual.

Hardware requirements: Windows work station.

Example application of tool: The accident-typing methodology included in the PBCAT allows the user to determine the accident type through a series of on-screen questions about the accident, accident location, and the maneuvers of the parties involved. The PBCAT enables practitioners to generate information for promoting bicycle and pedestrian safety and designing safer facilities where bicyclists, pedestrians, and motor vehicles interact. The software is designed with recommended countermeasures linked to specific bicycle and pedestrian accident types and has related resource and reference information. Countermeasures may include physical roadway improvements such as raised pedestrian crossings or other measures, or may include targeted enforcement.

Users also have the ability to customize the database in terms of units of measurement, variables, and location referencing, as well as import/export data from/to other databases, as shown in Exhibit 77 and Exhibit 78. Users can produce a series of tables and graphs defining the various accident types and other factors associated with the accidents such as age, gender, light conditions, etc.

Exhibit 77: PBCAT style and navigation window

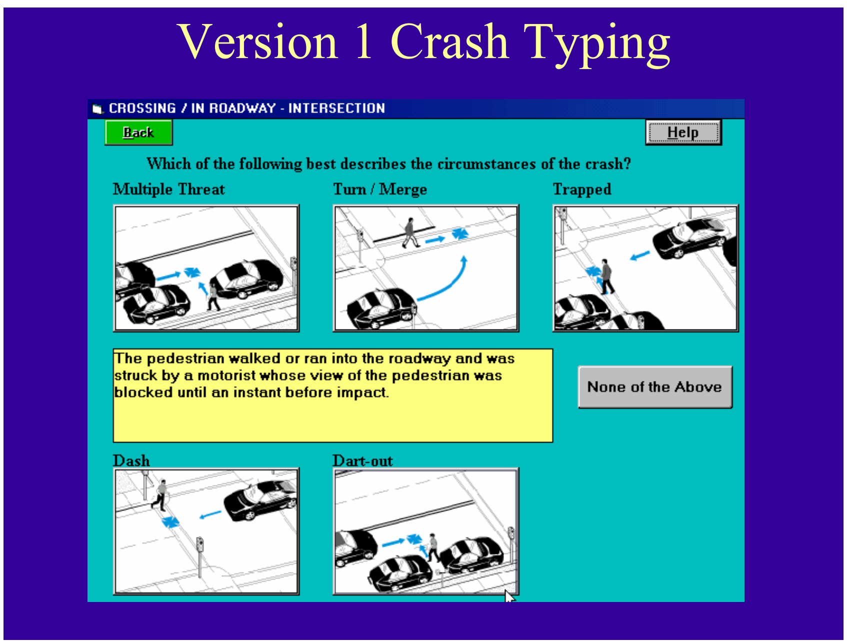


Exhibit 78: PBCAT style and navigation window

PEDESTRIAN SAFETY GUIDE AND COUNTERMEASURE (PEDSAFE)

Exhibit 79: Summary of the PEDSAFE tool

PEDSAFE

Vendor name and address: University of North Carolina, sponsored by Federal Highway Administration (FHWA). See http://www.fhwa.dot.gov/ or http://www.hsrc.unc.edu/ for additional information.

Brief description of transportation safety applications: The PEDSAFE prototype is currently under beta testing and will incorporate the content of the FHWA Pedestrian Facilities User Guide into a system that allows the user to select appropriate countermeasures or treatments to address specific safety problems for pedestrians. PEDSAFE also includes a large number of case studies to illustrate treatments implemented in several communities throughout the United States and Europe. PEDSAFE was designed to enable practitioners to select engineering, education, or enforcement treatments to help mitigate a known accident problem and/or to help achieve a specific performance objective.

Types and sources of data needed: Accident type data with geometric, time, weather, location, age, sex, subject actions, and other attributes.

Expertise required: Basic computer knowledge. The software contains user-friendly, online instructions and help features, along with a user's manual.

Hardware requirements: Windows work station.

Example application of tool: PEDSAFE uses known characteristics of the environment and permits the user to either view all countermeasures associated with a given objective or accident type or to view only those that are applicable to a defined set (as input by the user) of geometric and operating conditions. While the majority of the specific treatments are engineering countermeasures, many of the case studies include supplemental enforcement activities (e.g., neighbor speed watch programs) and/or educational approaches (e.g., in conjunction with school route improvements).
The objectives of the product are as follows:

- Provide user with information on which countermeasures are available for prevention of specific categories of pedestrian accidents or to achieve certain performance objectives.
- Outline considerations to be addressed in the selection of a countermeasure.
- Provide a decision process to eliminate countermeasures from the list of possibilities.
- Provide case studies, statistics, and other resources for the short list of countermeasures.

Upon completion of beta testing and continued revision, the PEDSAFE Guide and Countermeasure Selection System will be incorporated into the Pedestrian and Bicycle Accident Analysis Tool (PBCAT).

ROADSIDE SAFETY ANALYSIS PROGRAM (RSAP)

Exhibit 80: Summary of the RSAP tool

RSAP

Vendor name and address: American Association of State Highway and Transportation Officials, 444 North Capitol Street N.W., Suite 249, Washington, D.C., 20001.

Brief description of transportation safety applications: Provides a software tool to perform economic analysis of roadside safety feature or treatment alternatives.

Types and sources of data needed: Traffic related information (including traffic volumes, expected traffic growth); highway characteristics (such as type, horizontal and vertical alignment); roadside safety feature impact characteristics; expected crash costs for various injury severity levels; and the costs associated with installation, maintenance and repair of roadside safety feature or system.

Expertise required: Knowledge of roadside safety features considered, associated costs, and interpretation of benefit/cost analysis. The user-friendly interface requires a basic computer knowledge.

Hardware requirements: Minimum requirements: a Pentium III PC or equivalent platform, 128MB RAM, 8.5MB hard disk space for program files and an additional 1MB for temporary data files, mouse for navigation within the software, Microsoft Windows operating system (98, NT, ME, 2000, or XP)

RSAP was developed under NCHRP Project 22-9 and was incorporated in the *AASHTO Roadside Design Guide* (2002). An Engineer's Manual (2003) and User's Manual are available from the Transportation Research Board. The purpose of this section is to briefly describe the methodology used by RSAP using Appendix A of the AASHTO Roadside Design Guide as reference.

RSAP is used for the evaluation of alternatives of roadside safety-related projects. It supports the principle that investments in the roadside, whether it be the selection of roadside features or a particular roadside design, be made based on maximizing the benefits of public funding. The software defines benefits as the savings in societal cost from a reduction in the frequency and/or severity of roadside-related crashes. Costs refer to the direct costs related to the installation, maintenance and repair of the particular device or system.

The incremental benefit cost ratio is calculated during the analysis and refers to the increased benefit and cost related to the improvement option selected over another alternative or existing condition.

The software uses an Encroachment Model with the following basic form:

$$E(C) = VP(E)P(C \mid E)P(I \mid C)C(I)$$

Where

$E(C)$ = Estimated accident cost

V = Traffic volume

$P(E)$ = Probability of encroachment (encroachment rate)

$P(C \mid E)$ = Probability of accident given encroachment

$P(I \mid C)$ = Probability of injury given accident

$C(I)$ = Cost of injury.

In the encroachment probability-based-cost-effectiveness analysis procedure, four different modules are used: the Encroachment Module, the Crash Prediction

Module, the Severity Prediction Module, and the Benefit/Cost Module. The procedure calculates the estimated accident cost by calculating:

a) the encroachment frequency with the Encroachment Model,

b) the likelihood that the encroachment will result in an accident with the Crash Prediction Model,

c) the estimated severity in the event that an accident occur with the Severity Prediction Module, and

d) the annualized crash cost (AC) with the first part of the Benefit/Cost Module.

The annual direct cost (DC) related to the roadside safety feature is calculated in the Benefit/Cost Module by adding the following:

a) the annualized initial installation cost: annualized over the lifetime of the project by using the discount rate,

b) the annual general maintenance cost, and

c) the estimated annual accident maintenance repair cost: estimated by using the likely damage in the event of an impact.

In the last part of the Benefit/Cost Ratio Module all alternatives are compared in a pair wise manner by using the following equation:

$B/C\ Ratio_{2\text{-}1} = (AC_1 - AC_2) / (DC_1 - DC_2)$, where

$B/C\ Ratio_{2\text{-}1}$ = incremental benefit/cost ratio of Alt. 2 compared to Alt. 1.

AC_1, AC_2 = annualized crash or societal cost of Alternatives 1 and 2.

DC_1, DC_2 = annualized direct cost of Alternatives 1 and 2.

REFERENCES

American Association of State Highway and Transportation Officials. *Roadside Design Guide*, Washington, D.C., 2002.

King, K.M, and Sicking, D.L. *Roadside Safety Analysis Program (RSAP) – Engineer's Manual*, National Cooperative Highway Research Program Report 492, Washington D.C., 2003.

King, K.M, and Sicking, D.L. *Roadside Safety Analysis Program (RSAP) – User's Manual*, National Cooperative Highway Research Program Project 22-9: Improved Procedures for Cost-Effectiveness Analysis of Roadside Safety Features, Transportation Research Board, Washington D.C., 2002.

SAFENET

Exhibit 81: Summary of the SAFENET tool

SAFENET

Vendor name and address: UK Department for Transport e-mail: softwarebureau@trl.co.uk

Brief description of transportation safety applications: SafeNET is an interactive software package developed under UK Department for Transport for safety management. SafeNET includes various traffic accident prediction models for different types of intersections as well as roadway segments. This system is used as a stand-alone product to assess safety and predict total as well as specific types (e.g., pedestrian accidents, rear end or head on accidents) of accidents in a transportation network. Additionally, SafeNET is used with a traffic assignment model "CONTRAM", from which SafeNET can extract traffic flow data on the transportation network. This specific feature enables SafeNET to produce more information by accounting for safety and congestion issues simultaneously. The graphical display allows the engineer to visualize the effect on accident frequency of any change in junction design, form of control, and traffic assignment. The various types of road networks that can be modeled by SafeNET include:
Roundabouts
Mini-roundabouts
Signalized intersections
Urban and rural priority T-intersections
Urban crossroads and staged intersections
Urban collector roads
Urban roads including minor intersections
Traffic calming measures

Types and sources of data needed: In SafeNET, models are possible at various "levels" with different input requirements. The most basic levels require simple traffic inflows averaged over the average day (ADT or AADT). More detailed analysis requires information on vehicle flows, pedestrian flows, site characteristics, specific geometric features, junction turning flows, and other design features.

Expertise required: Basics of traffic engineering and knowledge about accident modeling as well as 4-step planning methods.

Hardware requirements: Windows work station.

Example application of tool: A description of the software as provided on the website of UK Department for Transport under "Traffic Advisory Leaflet, 08/99: Urban Safety Management: Using SafeNET" is provided below.

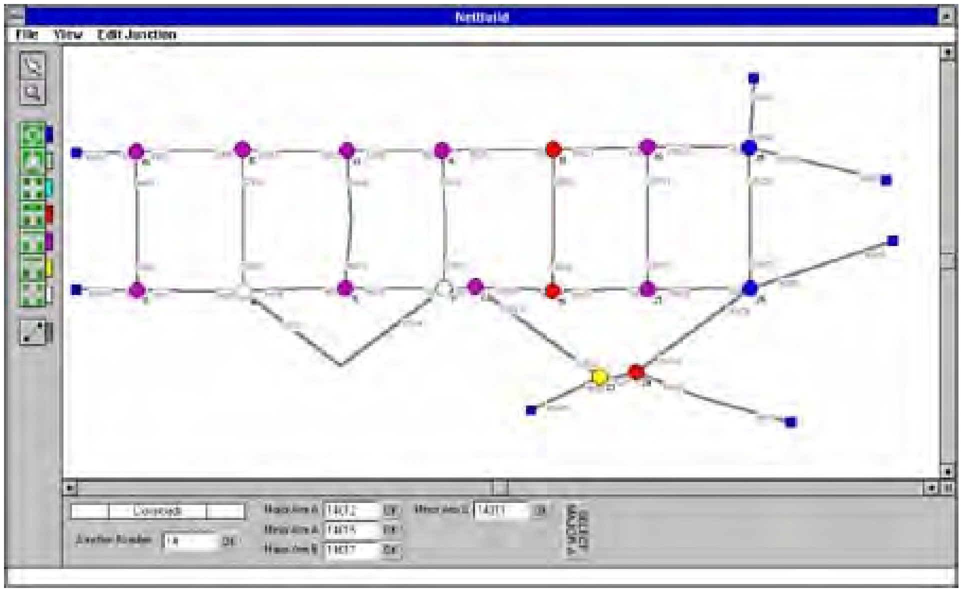
A road network in a typical SafeNET window is shown in Exhibit 82. This network consists of two east-west routes into a town center and a number of connecting north-south roads. The above east-west route has been designated as A road and it is a wide single carriageway, whereas the bottom east-west route, designated as B road, is connected with a school, a number of shops, and some residential locations. All of the north-south routes connected with the above and bottom east-west roads are largely residential areas.

The main problem in the area is the B road, as it carries local traffic as well as flow of traffic to and from the town center which would be more suited to the A road. A considerable portion of drivers also use one or other of the residential north-south roads. As a result, the speeds and flows through parts of the network are inappropriate for the character of the roads concerned. The main treatments being considered are:

- to close some of the junctions between the north-south and the east-west routes to reduce the opportunities for 'rat running', and to traffic calm those north-south roads which would remain fully open;
- to install traffic calming on the B road near the shops and the school;

- to convert a number of junctions from major/minor priority junctions to mini-roundabouts."

Exhibit 82: Road network in SafeNET



As described on the manufacturer's website, one of the key aims of this scheme was to achieve a re-allocation of traffic to more suitable routes. Hence, it was necessary to use a traffic assignment model to input the traffic flow along the various links of the network. As mentioned previously, SafeNET can extract the total daily flows from the CONTRAM assignment program model outputs. Consequently, CONTRAM is used as an assignment model and is modified to represent the proposed network with the relevant closures and changes in intersection control.

The impact on safety of the plan can then be assessed using SafeNET. In practice, it is wise to compare and contrast the results of several 'build' alternatives. Frequently it will become apparent that some modifications to the plan are necessary to achieve the desired safety (and other) objectives. For example, features may be needed to reduce congestion, cause a further re-distribution of traffic, or to achieve greater safety. A modification for one purpose might have unintended, possibly undesirable, effects on other aspects of performance. The link between the traffic assignment and impact on safety makes it easy to account for interactions between traffic volumes, safety, and mobility. In particular, the process allows rapid adjustment of the flows, which yield key inputs to the accident prediction models.

According to the website, in this case, the initial proposal proved to be flawed due to a significant number of vehicles using an alternative route to avoid traffic calming installed outside the shops. The extent of this fresh "rat running" was apparent from the CONTRAM run and the accident predictions from SafeNET showed the expected effect on safety. When additional measures were included in the proposed plan and modeled by CONTRAM, the revised flows were immediately available to SafeNET, which can then be used to predict the safety effects of the network changes.

SAFETYANALYST

Exhibit 83: Summary of the SAFETYANALYST tool

SAFETYANALYST

Vendor name and address: Federal Highway Administration, www.fhwa.dot.gov

Brief description of transportation safety applications: SafetyAnalyst addresses site-specific safety improvements that involve physical modifications to the highway system. SafetyAnalyst is not intended for direct application to non-site-specific highway safety programs that can improve safety for all highway travel, such as vehicle design improvements, graduated licensing, occupant restraints, or alcohol/drug use programs. However, SafetyAnalyst has the capability not only to identify accident patterns at specific locations and determine whether those accident types are overrepresented, but also to determine the frequency and percentage of particular accident types system-wide or for specified portions of the system (e.g., particular highway segments or intersection types). This capability can be used to investigate the need for system-wide engineering improvements (e.g., shoulder rumble strips on freeways) and for enforcement and public education efforts that may be effective in situations where engineering countermeasures may not.

Types and sources of data needed: Accident data with geometric, traffic, weather, and driver demographics.

Expertise required: Knowledge about statistical analysis and basics of traffic engineering is sufficient to handle this tool.

Hardware requirements: Windows work station

Example application of tool: SafetyAnalyst consists of six software programs to analyze the safety performance of specific sites, to suggest appropriate countermeasures, quantify their expected benefits, and to evaluate their effectiveness.

Planning for SafetyAnalyst development began in April 2001. The software to implement the SafetyAnalyst tools will be developed in a two-stage process. Interim tools with some, but not necessarily all, of the planned capabilities are planned for release in 2004. The interim tools will be revised based on user experience and expanded to include all planned capabilities. The final software tools are planned for release in 2006. SafetyAnalyst is envisioned as a set of software tools used by state and local highway agencies for highway safety management. The website for safety analyst www.safetyanalyst.org provides considerable information about how to use the suite of software as when they are appropriate.

According to the website, "SafetyAnalyst will be used by highway agencies to improve their programming of site-specific highway safety improvements. SafetyAnalyst will incorporate state-of-the-art safety management approaches into computerized analytical tools for guiding the decision-making process to identify safety improvement needs and develop a system wide program of site-specific improvement projects." In addition, SafetyAnalyst can be used for cost-effectiveness analysis of safety improvements to ensure that highway agencies get the greatest possible safety benefit from each dollar spent in the name of safety.

SafetyAnalyst consists of six software programs to analyze the safety performance of specific sites, to suggest appropriate countermeasures, quantify their expected benefits and to evaluate their effectiveness. These six tools are

- Network Screening Tool
- Diagnosis Tool
- Countermeasure selection Tool
- Economic Appraisal Tool
- Priority Ranking Tool

- Evaluation Tool

Network Screening Tool: The main aim of this tool is to identify sites that need safety improvements. This requires advanced data management as well as appropriate statistical methodology. As a result of extensive research on highway safety and statistical analysis over last 20 years, SafetyAnalyst software will implement these new approaches in its network screening. For example, the Empirical Bayes (EB) approach is included in the tool. EB combines observed and expected accident frequencies to provide estimates of the safety performance of specific sites that are not biased by regression to the mean, which is a drawback of traditional methods. The EB approach also incorporates nonlinear regression relationships between traffic volume and expected accident frequency. The sites identified by the network screening methodology are referred to as "sites with promise", as they are sites that have promise as locations where improvements can result in substantial accident reductions.

Another new measure that has been proposed for network screening application is the potential for safety improvement (PSI) index. PSI is a measure of the excess accident frequency, above the expected frequency, that might be reduced if a safety improvement were implemented. An example of the application of PSI and how it is beneficial in safety improvement is demonstrated on the SafetyAnalyst website and is also presented here. Exhibit 84 shows a group of signalized intersections that have been ranked according to their accident frequencies during a five-year period. The last column in the table shows the ranking based upon the PSI. Based on accident frequency ranking alone, one might improve the highest-volume location first. Alternatively, using the PSI to rank sites, the highest-ranking intersection is a lower-volume intersection, ranked sixth in accident frequency, showing a greater potential for accident reduction.

Exhibit 84: Comparison of rankings by accident frequency and PSI for signalized intersections in a particular city

Intersection	Total Accident Frequency (1995-99)	Average Annual Daily Traffic (veh/day)	Accident Frequency Ranking	Potential for Safety Improvement (PSI) Ranking
A	131	63502	1	2
B	104	35284	2	3
C	77	57988	3	11
D	75	46979	4	6
E	66	51933	5	10
F	51	48427	6	1
G	51	20423	7	15
H	46	34759	8	5
I	42	53396	9	61
J	38	25223	10	17

In Exhibit 85, intersections in a city have been ranked according to accident rate. The last column in the table shows the ranking based upon the PSI. If the five highest-ranking intersections based on accident rate were selected for improvements, the three highest-ranking intersections based on the PSI would not receive attention. The figures also indicate that scarce financial resources are allocated to sites ranked 33rd and 35th in PSI, while over 30 intersections with greater potential for safety improvements will not receive attention (application of countermeasures).

Exhibit 85: Comparison of rankings by accident rate and PSI for signalized intersections in a particular city

Intersection	Total Accident Frequency (1995-99)	Average Annual Daily Traffic (veh/day)	Accident Frequency Ranking	Potential for Safety Improvement (PSI) Ranking
N	18	5063	1	33
M	22	7009	2	9
L	27	8152	3	8
R	14	4402	4	35
K	33	10458	5	4
B	104	35284	6	3
O	18	4242	7	14
A	131	63502	8	2
P	16	7815	9	19
J	38	25223	10	17

Diagnosis Tool: This tool is used to diagnose the nature of safety problems at specific sites. Although highway agencies use various different software packages to generate collision diagrams (see for example Intersection Magic), these tools are independent and do work seamlessly with Safety Analyst. The diagnosis tool in SafetyAnalyst generates collision diagrams that identify collision types that are overrepresented at specific locations. The software will also examine common factors that might exist among similar crash outcomes. As a result, the software serves as an expert system to guide the user through field investigations of particular sites. As described on the SafetyAnalyst website, the software generates site-specific lists of questions to be asked during a field visit to the site based on the generated collision diagram, available data about the accident experience, geometric design features, as well as traffic control at the site. The field investigation will then serve to aid in the identification of appropriate countermeasures for improving safety at the site.

Countermeasure Selection Tool: This tool assists users selecting countermeasures to reduce accident frequency and severity at specific sites. It aids investigators to identify appropriate countermeasures for a particular site from lists of potential countermeasures incorporated in the software. The logic that identifies appropriate countermeasures considers the accident patterns and related site conditions investigated in the diagnostic process. The user can select one or more of the suggested countermeasures for further consideration or can add other countermeasures that they consider appropriate. When two or more countermeasures are selected by the user, a final choice among them is made using the economic appraisal and priority-ranking tools.

Economic Appraisal Tool: SafetyAnalyst permits users to conduct economic appraisals of the costs and safety benefits of countermeasures selected for a specific site. The economic appraisal results are used to compare alternative countermeasures for a particular site and to develop improvement priorities across sites. SafetyAnalyst includes an optimization program that is capable of selecting a set of safety improvements that maximizes the system wide safety benefits of a program of improvements with a specific improvement budget. Safety effectiveness measures are estimated from data on the observed, expected, and predicted accident frequency and severity at the site, the accident patterns identified in the preceding tools, and accident modification factors (AMFs) for specific countermeasures. The AMFs representing the safety effectiveness of particular countermeasures are based on the best available safety research. The analyses will include appropriate consideration of the service life of the countermeasure and the time value of money. This tool is capable of performing economic analyses consistent with the requirements of the Federal Highway Safety Improvement Program (HSIP) so that analysis results are readily acceptable to FHWA for implementation with federal funds.

The Priority Ranking Tool: This tool provides a priority ranking of sites and proposed improvement projects based on the benefit and cost estimates determined by the economic appraisal tool. The priority-ranking tool compares the benefits and costs of projects across sites and ranks the projects on the basis of cost effectiveness, benefit-cost ratio, or net present value. This comparison will allow users to fund projects in priority order, with the highest-ranked projects being funded first. The priority-ranking tool also determines an optimal set of projects to maximize safety benefits.

Evaluation Tool: Most highway agencies do not routinely conduct evaluations of implemented countermeasures, and few evaluations that are conducted are well designed. SafetyAnalyst provides a tool to enable the design and application of well-designed before/after evaluations. These evaluations are highly desirable to increase knowledge of project effectiveness and supplement or improve the safety effectiveness measures for improvements available for use in SafetyAnalyst. This tool is capable of performing before-after evaluations using the Empirical Bayes (EB) approach. As mentioned previously, the EB approach is a statistical technique that compensates for regression to the mean, and allows for the proper accounting of changes in safety that may be due to changes in other factors, such as traffic volumes. This tool will also provide, where appropriate, users with the ability to perform before-after evaluations using statistical techniques other than the EB approach.

TRANSPORTATION ANALYSIS AND SIMULATION SYSTEM (TRANSIMS)

Exhibit 86: Summary of the TRANSIMS tool

TRANSIMS

Vendor name and address: TRANSIMS technology is being developed under U.S. DOT and EPA funding at the Los Alamos National Laboratory (LANL). IBM Business Consulting has created a commercial version of TRANSIMS named TRANSIMS-DOT. See http://transims.tsasa.lanl.gov/ for more details.

Brief description of transportation safety applications: TRANSIMS is an integrated system of travel forecasting models designed to give transportation planners accurate, complete information on traffic impacts, congestion, and pollution. The design of TRANSIMS is based on requirements in the Intermodal Surface Transportation Efficiency Act (ISTEA), the Transportation Equity Act for the 21st Century (TEA-21), and Clean Air Act Amendments. The software consists of mutually supportive simulations, models, and databases that employ advanced computational and analytical techniques to create an integrated regional transportation system analysis environment. By applying advanced technologies and methods, it simulates the dynamic details that contribute to the complexity inherent in today's and tomorrow's transportation issues. The integrated results from the detailed simulations will support transportation planners, engineers, decision makers, and others who must address environmental pollution, energy consumption, traffic congestion, land use planning, traffic safety, intelligent vehicle efficiencies, and the transportation infrastructure effect on the quality of life, productivity, and economy. Although safety is not currently integrated into the tool, it is possible and/or likely that safety considerations may be added in future revisions to the software.

Types and sources of data needed: TRANSIMS uses census data of household surveys such as production/attraction (PA) tables, origin/destination (OD) matrices, the transportation network data for major intersections, and other information to produce pseudo-activities for trip generation.

Expertise required: TRANSIMS contains an easy-to-use Graphical User Interface for the transportation modeling function, a GIS-based network editor, a 3D data visualization and animation software, and a reporting system. Hence knowledge of Oracle database, C++ programming language, or the ArcView Avenue programming language is preferred to handle this tool, although not essential. The essential expertise, of course, is needed in the field of transportation network modeling. It is also likely that full-time maintenance and operation of models is needed due to the sophistication and complexity of the simulation characteristics, inputs, and outputs. It is also anticipated that running TRANSIMS will require significantly greater resources—both human and computer—than traditional 4-step travel demand models.

Hardware requirements: Programs in the TRANSIMS-DOT software are distributed applications with components running on different hardware/software platforms. In order to install and run all of the components of the TRANSIMS-DOT, it is necessary to have the following three types of computer systems:

a) UNIX or LINUX servers for hosting the core LANL TRANSIMS software, and Oracle database and server-side components of the TRANSIMS-DOT Modeling Interface. To execute large-size problems, it is necessary to install a multi-server Linux computing cluster or an equivalent multi-processor UNIX-based framework.

b) Windows workstation(s) for running the Network Editor, the client-side GUI Modeling Interface, and Crystal Reports.

c) Optional Linux workstation(s) for running the Visualizer. Alternatively, it is possible to equip the Linux server with a high-end graphics card to use it as the Visualizer platform.

Example application of tool: TRANSIMS models create a virtual metropolitan region with a complete representation of the region's individuals, their activities, and the transportation infrastructure. Trips are planned to satisfy the individuals' activity patterns. TRANSIMS then simulates the movement of individuals across the transportation network, including their use of vehicles such as cars or buses, on a second-by-second basis. This virtual world of travelers mimics the traveling and driving behavior of real people in the region. The interactions of individual vehicles produce realistic traffic dynamics from which analysts using TRANSIMS can estimate vehicle emissions and judge the overall performance of the transportation system.

Previous transportation-planning (usual four step methods) surveyed people about elements of their trips such as origins, destinations, routes, timing, and forms of transportation used, or modes. TRANSIMS starts with data about people's activities and the trips they take to carry out those activities, and then builds a model of household and activity demand. The model forecasts how changes in transportation policy or infrastructure might affect those activities and trips. TRANSIMS tries to capture every important interaction between travel subsystems, such as an individual's activity plans and congestion on the transportation system. For instance, when a trip takes too long, people find other routes, change from car to bus or vice versa, leave at different times, or decide not to do a given activity at a given location.

Also, because TRANSIMS tracks individual travelers—locations, routes, modes taken, and how well their travel plans are executed—it can be used to evaluate transportation alternatives and reliability to determine who might benefit and who might be adversely affected by transportation changes. In addition, it can make better volume predictions along the network, which in turn is useful for safety analysis.

PLANSAFE: PLANNING LEVEL SAFETY PREDICTION MODEL

Introduction to PLANSAFE

The researchers involved with NCHRP 8-44 developed a planning level safety prediction model, dubbed PLANSAFE, which is intended to serve as a useful tool for regional level safety planning. The model is intended to support and supplement some of the planning level activities described in this guidance. The reader should be aware that the majority of tools described in this appendix are corridor or project level analysis tools, and are not suitable for forecasting crashes at a planning scale. Planning level safety decisions, unlike corridor and project level analyses, do not involve considerations about design details of facilities. The PLANSAFE model, in keeping, is inappropriate for supporting decisions regarding design details of facilities. As an example, the congestion impacts of signal timing schemes are not considered in travel demand models nor are the safety impacts of signal timing schemes estimated when using PLANSAFE. The PLANSAFE model uses typical planning level information: socio-economic, demographic, and transportation-related data to predict the safety of TAZs or larger sub-areas of a jurisdiction. The intent, of course, is to enable straightforward analyses using travel demand model output and planning level data to support the PLANSAFE models and ultimately to guide decision making at the planning.

The PLANSAFE model is extremely useful for a variety of planning level activities, which are described in detail later in this section. For example, setting safety performance targets requires an estimate of what safety will be in some future time period *in the absence of 'additional' safety countermeasures*. The PLANSAFE model supports this type of forecast, where the smallest analysis unit is a traffic analysis zone (TAZ), and the largest unit of analysis is an entire region (say a non-attainment area or metropolitan planning region). These and other types of analyses are described in this section.

There are few, if any, planning level safety prediction models available for use and relatively little research on them has been conducted as of the date of this report. The need for these models has arisen from the ISTEA legislation, which requires the explicit consideration of safety at the planning level, but has left the profession lacking a complete set of tools.

Planning level safety prediction models are fundamentally different in nature to corridor or site specific crash prediction models because;

1) The input data are aggregate and not site or project specific;

2) The focus is prediction and not explanation of safety; and

3) The model should not be used to choose between investment alternatives but instead to inform the user of safety impacts of alternative investments and to establish future performance targets. Exhibit 87 summarizes the PLANSAFE model characteristics and attributes.

Exhibit 87: Summary of the PLANNING LEVEL SAFETY PREDICTION MODEL tool

PLANNING LEVEL SAFETY PREDICTION MODEL

Vendor name and address: Simon Washington and Ida van Schalkwyk, Arizona State University. Tempe, Arizona, 85287. simon.washington@asu.edu

Brief description of transportation safety applications: The Planning Level Safety Prediction Model is a planning-level model used to predict motor vehicle accidents per traffic analysis zone (TAZ) area or larger sub-areas of a jurisdiction. Thus, the smallest unit of analysis is the TAZ, whereas the largest unit of analysis is collections of TAZs such as neighborhoods, those TAZs affected by a major transportation project, etc. Crashes of various types are modelled as functions of various predictors such as the distribution and mileage of the functional classifications of highways, vehicle miles traveled, socio-economic and demographic factors, and population characteristics.

For development of the models under NCHRP 8-44, data from Pima and Maricopa Counties in Arizona and the state of Michigan were used. These regions represent a fairly diverse range of geography and driving populations in order to derive models that may approximate aggregate relationships across the U.S..

Types and sources of data needed: TAZ level data regarding population, travel, schools, infrastructure (e.g., residential units, commercial units, etc.), and crashes.

Expertise required: Knowledge of GIS, some statistical modelling, or statistical model interpretation skills.

Hardware requirements: Desktop PC with database and GIS software.

Example application of tool: The tool can be used to forecast the projected increase (over baseline totals) in fatal, injury, pedestrian, and total crashes expected in 10 years given population growth, the provision of new schools, and other changes under the 'no-build' scenario and various 'build' scenarios (refer to the section titled When to use the PLANSAFE (and when not to).

This remainder of this appendix provides details of the operation, assumptions, and output of the PLANSAFE model, whose core models are estimated using data from the states of Arizona and Michigan. Appendix D, in contrast, is targeted to agencies with the resources and desire to develop models that are based on local, regional, or statewide data. The remainder of this section is divided into five subsections:

- Why TAZ level safety prediction models are logically feasible and defensible;
- When to use the PLANSAFE (and when not to);
- What data are needed to apply the PLANSAFE models;
- The PLANSAFE set of forecasting models;
- How to apply PLANSAFE models; and
- Examples of PLANSAFE applications.

Why TAZ level safety prediction models are logically feasible and defensible

The safety profession is replete with models that predict crashes at the microscopic level—say for intersections or for road segments. Many of the analysis tools described in this appendix include microscopic safety crash models. A reasonable question to ask is "Are macroscopic, or TAZ level statistical models defensible and logically feasible?" The following arguments, based on accepted principles and logic from the road safety and statistics communities, support the use of aggregate level safety prediction models.

1. Crashes are largely random events. Much research has shown that crashes are largely caused by human errors, with estimates ranging between 60% and 90% of crashes being caused by human errors. Thus, many crashes are more a function of human-related factors rather than roadway-related factors. As simple examples, crashes that result from of a driver tuning a radio, answering a cell phone, following another vehicle too closely, speeding, and running a red light are events that occur somewhat randomly on a network. It is easy to understand, then, that modelling crashes at the segment or intersection level is challenging, because there is a large random component to crashes that is not explained by local road characteristics. At a more aggregate level, in contrast, crashes are related to aggregate predictors, such as population demographics, 'high risk' driving populations, the general classes of road facilities, etc., and assigning crashes to specific links or segments is not necessary. Thus, by aggregating the transportation system at the TAZ level, some of the difficulties caused by 'lumpiness' of random events that we see across intersections or across road segments are reduced.
2. Aggregate safety differences are substantiated by research. Much research supports 'aggregate' or average safety differences across groups. Older drivers suffer from reduced reaction and perception times, as well as reduced vision and flexibility. Younger drivers suffer from inexperience and aggressiveness. Minorities have been shown to wear safety restraints less than whites, and restraint use in rural areas is less than in urban areas. Interstates are associated with relatively low crash rates, while rural roads with high speeds are associated with more serious injury crashes. Crashes in urban areas are attended by emergency medical services more quickly than crashes in rural areas. Intersections are locations of complex traffic movements and thus are associated with greater numbers of crashes than road segments. Increasing traffic congestion tends to reduce crash severity. School zones are associated with bicycle and pedestrian crashes. These well supported aggregate relationships, and others not listed here, are the relationships captured in aggregate level prediction models. The aggregate relationships described above form the basis for the statistical modelling at the TAZ level. It is the reliance on these 'average' relationships, and characteristics measured at the TAZ level, on which model predictions are based.
3. Models for predicting have fewer restrictions than models for explaining. Intersection and road-segment level accident prediction models are usually held to a high standard, as they are often used both to predict the expected performance of such facilities but also to explain relationships between variables. Often, and sometimes wrongly, these microscopic models are used to infer the effects of countermeasures, such as the safety effect of the presence of a left-turn lane on angle crashes. When a model is used simply for prediction, however, and not inference, there is greater flexibility in model estimation and variable selection choices. The PLANSAFE model is intended only for prediction, and not explanation. Thus, for example, if a population variable is used to predict fatal crashes per TAZ, its estimated coefficient is used solely in the prediction equation but is not interpreted to have specific explanatory marginal effects.

These three arguments, or justifications, form the basis for the development of aggregate level accident prediction models. A consequence of these arguments, however, is that the models cannot be used for explanation of crash causation or for the assessment of roadway-specific countermeasures. The aggregate relationships modeled are suitable for predicting a hypothetical or future outcome should the set of predictors be changed. This restriction is not too dissimilar from the restriction placed on travel demand models, whose primary purpose is to predict demand for roadway space of motor vehicles in hypothetical or future scenarios.

When to use the PLANSAFE (and when not to)

As described in the previous section, the PLANSAFE model has limitations and assumptions. Most importantly, PLANSAFE is fundamentally different from many other safety prediction models that have been presented and discussed previously in this appendix (e.g., IHSDM, SafetyAnalyst, etc.). Exhibit 88 lists appropriate and inappropriate uses of PLANSAFE models. The appropriate uses fall squarely in the domain of planning, prediction, or forecasting, while the inappropriate uses fall in the domain of traffic and safety engineering.

An important assumption of the PLANSAFE model is that 'new' safety countermeasures are not applied in future scenarios. In other words, the 'average' set of design standards with respect to safety are assumed to exist in the future, while innovative, newly adopted, or progressive safety countermeasure investments are analyzed independently by some other model or research study. As a result, an investment in innovative safety countermeasures in the future will yield improvements in safety over and above those predicted by PLANSAFE models.

Appropriate and inappropriate uses of PLANSAFE are provided in Exhibit 88.

Exhibit 88: Appropriate and inappropriate uses of PLANSAFE models

Appropriate Applications of PLANSAFE	
Setting safety targets or performance measures	Safety targets serve as milestones for accomplishment. For example, a region may want to achieve a measurable decrease in pedestrian involved crashes in a future time period, say 5 years hence. The PLANSAFE model is suitable for establishing the expected number of crashes in some future period *in the absence of targeted safety countermeasures*. PLANSAFE is useful because crashes in the future are expected to change as a result of population growth, new road mileage, new schools, changing of the driving population, etc. Using simply the baseline (e.g., the current year's) crash frequencies (e.g., fatal crashes, injury crashes, etc.) to set performance targets is strictly incorrect, since the impacts of growth alone will have an impact on the expected safety of a region or sub region.
Understand the safety impacts of large scale projects (corridor level or higher)	Large-scale projects that may affect VMT, future growth, and other planning related factors will affect safety. The PLANSAFE model is appropriate for forecasting the future expected safety performance of these projects *in the absence of targeted safety countermeasures.* Given that a future project will influence the forecasting variables in the PLANSAFE model, the PLANSAFE model will produce a prediction of the effect of the project on safety (i.e., crashes of various types).
Compare and contrast growth scenarios	Growth scenarios are often compared looking 5, 10, and 20 years into the future. PLANSAFE is suitable for predicting the safety performance of the region under different growth scenarios (e.g., infill development, sprawl, interstate vs. highway, population and demographic shifts, new schools, etc.) *in the absence of new or innovative and targeted safety countermeasures.* These types of analyses are informative to determine how much safety

	investment is needed to meet safety performance targets. For example, three different growth scenarios will produce three different estimates of future safety (in say the affected TAZs). These different growth scenarios would imply then, three different levels of safety investment required to meet regional safety performance targets. Additional analysis, through other means (say IHSDM or SafetyAnalyst software), would then be used to meet the safety objectives under the different growth scenarios.
Inappropriate Applications of PLANSAFE	
Select land-use/transportation investment strategies based on model results	Different growth scenarios will yield different estimates of future safety; however, the PLANSAFE models are predictive models and cannot account for the safety-related complexities present in real life growth scenarios. A future scenario with relatively 'worse' predicted safety does not mean it is a bad project, it may simply mean that more serious attention to safety investments may need to be made if that particular growth scenario is adopted. There are many factors other than safety to consider in land use/transportation investment, such as maintenance costs, air quality impacts, congestion, and environmental impacts (e.g., water, wetlands, endangered species, and archaeology).
Evaluate or select safety countermeasures	PLANSAFE models do not contain variables that are proxies for countermeasures. PLANSAFE models *predict* but do not *explain* crashes. Thus, PLANSAFE models are not suitable for evaluating roadway- or intersection-specific countermeasures.

What data are needed to apply the PLANSAFE Models?

Application of the PLANSAFE model requires forecasting data from the region where the model is applied. For example, a model that uses a particular population characteristic, percentage of a particular functional road class, and density of households would require estimates of these variables in both the 'base' and 'future' scenarios. To allow local calibration (to enable the model to reflect local conditions), the particular accident variable that is predicted also needs to be known in the base year.

The required input (forecasting) variables needed for the base year and future year/proposed project for the set of affected TAZs are shown in Exhibit 89. The table shows the abbreviated name of the variable, the units of measure, and the source of the data. In many cases, variables were extracted from U.S. census block group data. All variables are calculated by TAZ. For example, the *Total Accident Frequency Model* requires as predictors the population density of the TAZ (persons per acre), the total population aged 16 to 64 in the TAZ, and the total mileage of all federal road functional classifications in the TAZ.

Exhibit 90 shows the predictor variables required for eight safety-related outcome variables; total crashes, property damage only crashes, fatal crashes, incapacitating and fatal injury crashes, nighttime crashes, pedestrian crashes, injury crashes, and bicycle-involved crashes. Thus, at this time the PLANSAFE model includes the ability to predict eight safety-related outcome variables as a function of various predictor variables.

Exhibit 89: Variables and descriptions for the PLANSAFE models

VARIABLE	DESCRIPTION (all units are calculated per TAZ)
Total Accident Frequency Model	
POP_PAC	Population density (population estimates from U.S. Census SF1) in persons per acre
POP16_64	Total population of ages 16 to 64 (from U.S. Census SF1)
TOT_MILE	Total mileage of all functional classes of roads
Property Damage Only Accident Frequency Model	
PH_URB	Number of urban housing units (U.S. Census SF1) as portion of all housing units
POP_PAC	Population density (population estimates from U.S. Census SF1) in persons per acre
VMT	Vehicle miles traveled (it is estimated using road section lengths and section traffic counts)
Fatal Accident Frequency Model	
INT_PMI	Number of intersections per mile (using total mileage in the TAZ)
PNF_0111	Total mileage of urban and rural interstates as a portion of the total mileage (federal functional classifications 01 and 11)
PNF_0512	Total mileage of other freeways and expressways (i.e., not interstate and also not principal arterials) as a portion of the total mileage
POP00_15	Total population of ages 0 to 15 (from U.S. Census SF1)
PPOPMIN	Total number of minorities (from U.S. Census SF1) as a portion of the total population.
Incapacitating and Fatal Accident Frequency Model	
INT_PMI	Number of intersections per mile (using total mileage in the TAZ)
PNF_0111	Total mileage of urban and rural interstates as a portion of the total mileage (federal functional classes 01 and 11)
PNF_0512	Total mileage of other freeways and expressways (i.e., not interstate and also not principal arterials) as a portion of the total mileage
POP00_15	Total population of ages 0 to 15 (from U.S. Census SF1)
Nighttime Accident Frequency Model	
MI_PACRE	Total mileage of the TAZ per acre of the TAZ
PNF_0111	Total mileage of urban and rural interstates as a portion of the total mileage in the TAZ (federal functional classes 1 and 11)
PNF_0214	Total mileage of urban and rural principal arterials as a portion of the total mileage in the TAZ (federal functional classes 2 and 14)
PNF_0512	Total mileage of other freeways and expressways (i.e., not interstate and also not principal arterials) as a portion of the total mileage
PPOPMIN	Total number of minorities (from U.S. Census SF1) as a portion of the total population.
WORKERS	Total number of workers 16 years and older (from U.S. Census SF3)
Accidents Involving Pedestrians Frequency Model	
HH_INC	Median household income in 1999 (P053001 from U.S. Census SF3)
POP_PAC	Population density (population estimates from U.S. Census SF1) in persons per acre
POPTOT	Total population (P001001 from U.S. Census SF1)
PWTPRV	Proportion of workers 16 years and older that use a car, truck, or a van as a means of transportation to work (from U.S. Census SF3)
Injury Accident Frequency Model	
HU_PACRE	Number of housing units per acre: (H001001 from U.S. Census SF1)/Acres
PPOPURB	Urban population (P002002 from U.S. Census SF1) as a portion of the total population.
VMT	Vehicle miles traveled (it is estimated using road section lengths and section traffic counts)
Accidents Involving Bicycles Frequency Model	
HU	Number of housing units (from U.S. Census SF1)
TOT_MILE	Total mileage of all functional classes of roads
VMT	Vehicle miles traveled (it is estimated using road section lengths and section traffic counts)
WORK_PAC	Total number of workers 16 years and over (from U.S. Census SF3) per acre

The PLANSAFE set of Forecasting Models

This section describes the statistical modelling results of the PLANSAFE models that are available for forecasting crashes by TAZ, and describes two of the models in greater detail. The application of these PLANSAFE models is described in the next section. The statistical modelling results presented here are based upon data from:

- Pima Assocation of Governments (includes City of Tucson), Arizona.
- Maricopa Association of Governments (Phoenix metropolitan area), Arizona.
- The state of Michigan.

Exhibit 90 shows the variables, the estimated coefficients, and the associated *t*-statistics with the PLANSAFE set of eight models.

Exhibit 90: PLANSAFE Models with variable coefficients and t-statistics

VARIABLE	COEFFICIENTS	t-STATISTIC
Total Accident Frequency Model*		
POP_PAC	0.474×10^{-1}	9.067
POP16_64	0.196×10^{-3}	36.373
TOT_MILE	0.151×10^{-2}	3.482
Property Damage Only Accident Frequency Model*		
PH_URB	0.515	13.626
POP_PAC	0.566×10^{-1}	11.894
VMT	0.392×10^{-5}	37.554
Fatal Accident Frequency Model*		
INT_PMI	-0.924×10^{-1}	-18.535
PNF_0111	1.762	8.958
PNF_0512	1.389	4.755
POP00_15	0.263×10^{-3}	26.340
PPOPMIN	0.319	5.577
Incapacitating and Fatal Accident Frequency Model*		
INT_PMI	-0.659×10^{-1}	-9.864
PNF_0111	3.328	11.892
PNF_0512	3.674	8.723
POP00_15	0.512×10^{-3}	36.793
Nighttime Accident Frequency Model*		
MI_PACRE	-19.167	-12.126
PNF_0111	3.524	14.661
PNF_0214	1.414	5.393
PNF_0512	3.588	10.038
PPOPMIN	0.861	11.261
WORKERS	0.238×10^{-3}	37.741
Pedestrians Accident Frequency Model*		
HH_INC	-0.706×10^{-5}	-7.040
POP_PAC	0.129	27.101
POPTOT	0.884×10^{-4}	24.520
PWTPRV	-0.902	-3.808
Injury Accident Frequency Model*		
HU_PACRE	0.153	11.669
PPOPURB	0.768	18.401
VMT	0.443×10^{-5}	39.250
Accidents Involving Bicycles Frequency Model**		
HU	0.252×10^{-3}	10.394
TOT_MILE	0.162×10^{-2}	2.012
VMT	0.292×10^{-5}	9.730
WORK_PAC	1.539	15.600

NOTE:

* indicates models developed using data from the State of Michigan,

** indicates that model was developed using data from Maricopa County (AZ).

The standard form of the models is a log linear regression model. The expressions for the PLANSAFE models are provided in Exhibit 91. To transform any of the models into original scale units, both sides of the equation are exponentiated, then 1 is subtracted from both sides. For example, the prediction equation for the Total Accident Frequency Model is:

Acc_Freq = exp(5.020 + 0.0474(*POP_PAC*) + 0.00196(*POP16_64*) + 0.00151(*TOT_MILE)*) – 1

The log linear regression was chosen over the negative binomial form because:

1) It is known a priori that TAZs are of different size and therefore the underlying process is not a Poisson process with gamma heterogeneity of means;

2) Goodness of fit statistics are more intuitive and comparable using ordinary least squares estimated coefficients; and

3) Predictions and of non-integer values are acceptable for aggregated data.

Exhibit 91: PLANSAFE model forms

MODEL FORMS

Total Accident Frequency Model

$$Log(Accident\_Frequency+1)$$
$$= 5.020 + 0.474 \times 10^{-1}(POP\_PAC) + 0.196 \times 10^{-3}(POP16\_64) + 0.151 \times 10^{-2}(TOT\_MILE)$$

Property Damage Only Accident Frequency Model

$$Log(PDO\_accident\_frequency+1)$$
$$= 4.762 + 0.515(PH\_URB) + 0.566\times10^{-1}(POP\_PAC) + 0.392\times10^{-5}(VMT)$$

Fatal Accident Frequency Model

$$Log(Fatal\_accident\_frequency+1)$$
$$= 0.652 - 0.924\times10^{-1}(INT\_PMI) + 1.762(PNF\_0111) + 1.389(PNF\_0512) + 0.263\times10^{-3}(POP00\_15) + 0.319(PPOPMIN)$$

Incapacitating and Fatal Accident Frequency Model

$$Log(Incpacitating\_and\_Fatal\_accident\_frequency+1)$$
$$= 2.257 - 0.659\times10^{-1}(INT\_PMI) + 3.328(PNF\_0111) + 3.674(PNF\_0512) + 0.512\times10^{-3}(POP00\_15)$$

Nighttime Accident Frequency Model

$$Log(Nighttime\_accident\_frequency+1)$$
$$= 4.092 - 19.167(MI\_PACRE) + 3.524(PNF\_0111) + 1.414(PNF\_0214) + 3.588(PNF\_0512) + 0.861(PPOPMIN) + 0.238\times10^{-3}(WORKERS)$$

Pedestrians Accident Frequency Model

$$Log(frequency\_of\_accidents\_involving\_pedestrians+1)$$
$$= 1.443 - 0.706\times10^{-5}(HH\_INC) + 0.129(POP\_PAC) + 0.884\times10^{-4}(POPTOT) - 0.902(PWTPRV)$$

Injury Accident Frequency Model

$$Log(frequency\_of\_injury\_accidents+1)$$
$$= 3.108 + 0.153(HU\_PACRE) + 0.768(PPOPURB) + 0.443\times10^{-5}(VMT)$$

Accidents Involving Bicycles Frequency Model

$$Log(frequency\_of\_Accidents\_involving\_bicyclists+1)$$
$$= 0.655\times10^{-1} + 0.252\times10^{-3}(HU) + 0.162\times10^{-2}(TOT\_MILE) + 0.292\times10^{-5}(VMT) + 1.539(WORK\_PAC)$$

It is worthwhile to discuss and assess a couple of the PLANSAFE models to illustrate how relationships are captured by the model and how predictions of these models are made.

Discussion 1: Frequency of Incapacitating and Fatal Accidents

This discussion focuses on the PLANSAFE model that predicts the frequency of incapacitating and fatal injury accidents within TAZs. The model prediction equation is given by:

$$
\begin{aligned}
&Log(Incpacitating\_and\_Fatal\_accident\_frequency + 1) \\
&\quad = 2.257 - 0.659 \times 10^{-1}(INT\_PMI) + 3.328(PNF\_0111) + 3.674(PNF\_0512) \\
&\quad + 0.512 \times 10^{-3}(POP00\_15)
\end{aligned}
$$

The model predictor variables include intersections per mile of road, mileage of rural and urban interstates as a proportion of the total mileage, mileage of other freeways and expressways as a proportion of total mileage, and proportion of the population aged 0 to 15. Because the logarithm is a monotonically increasing function, a positive coefficient in the logarithm implies a positive effect of the predictor variable on crashes.

As the number of intersections per mile increases, the predicted count of incapacitating and fatal accidents decreases, suggesting that greater urbanization is associated with greater congestion, lower travel speeds, and less serious crashes on average. The interstate and primary arterial mileage represents the exposure of vehicular traffic on relatively higher speed roads, and as the proportion of these facilities increase so do the predicted counts of incapacitating and fatal crashes. As the number of individuals between ages 0 and 15 increases, so does the predicted number of incapacitating and fatal accidents. Exhibit 92 shows the relationship between the predicted count of incapacitating and fatal accidents and the persons aged 0 to 15, with other variables held constant. Exhibit 93 shows the relationship between the predicted count of incapacitating and fatal accidents and the number of intersections per mile, with other variables held constant. The population variable is one of four exposure based variables, with two road mileage variables and one intersection exposure variable. Young children typically represent 'active' households with respect to VMT, and also represent an increased exposure to pedestrian and bicycle involved serious injury crashes. It is likely that this population based variable captures both the aggregate population effect as well as the 'activity' factor associated with families with young children.

Discussion 2: Frequency of Accidents Involving Pedestrians

The pedestrian crash prediction model is given as:

$$
\begin{aligned}
&Log(frequency\_of\_accidents\_involving\_pedestrians + 1) \\
&= 1.443 - 0.706 \times 10^{-5}(HH\_INC) + 0.129(POP\_PAC) + 0.884 \times 10^{-4}(POPTOT) \\
&\qquad - 0.902(PWTPRV)
\end{aligned}
$$

Four predictor variables are included in the model predicting the frequency of pedestrian involved accidents. The first is median household income; as median household income increases, predicted pedestrian involved accidents decrease. The effect of income captures many facets of pedestrian crashes: lower income neighborhoods are less likely to have sidewalks, are more likely to have unattended children walking in the streets, and are more likely to

Exhibit 92: Predicted number of incapacitating and fatal injury crashes by population count ages 0 to 15 by TAZ:- PLANSAFE incapacitating and fatal model

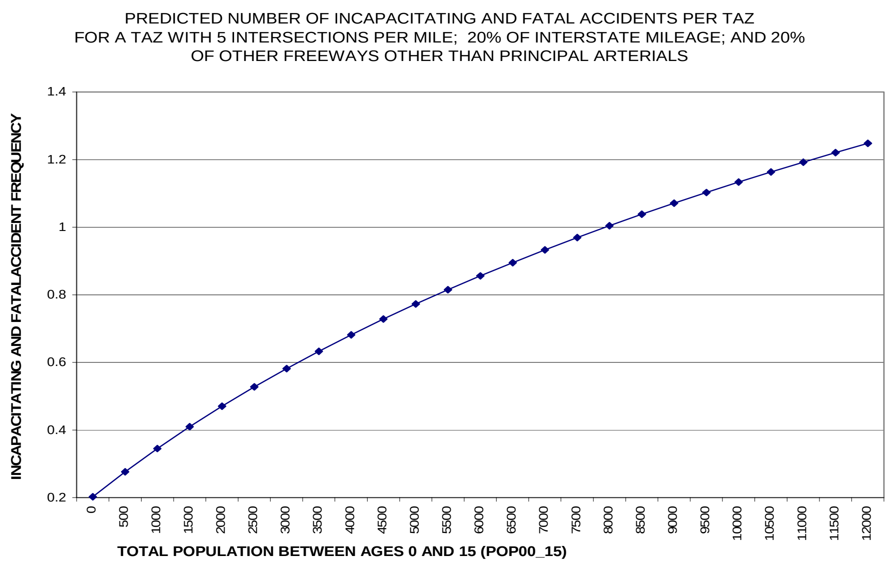
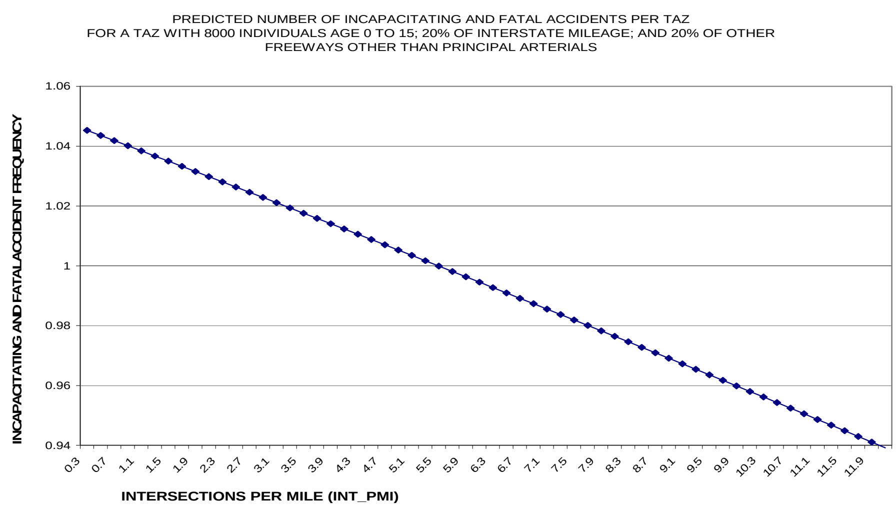


Exhibit 93: Predicted number of incapacitating and fatal injury crashes by intersection count per mile by TAZ:- PLANSAFE incapacitating and fatal model



have workers commuting by walking among other possible aspects on average.

The second predictor variable, density of the population in a TAZ, is another exposure variable as higher population densities typically indicate more urban environments where a greater amount of walking takes place and also where the available walking destinations increase, and therefore lead to an increased likelihood of walking as a transportation mode. Thus, the variable captures pedestrian exposure. The number of individuals living in a TAZ is another measure of exposure, and as such increases the likelihood of accidents involving pedestrians. The fourth variable, the portion of workers age 16 and older that use private transportation to travel to work, is also an exposure-related variable. A worker is less likely to be injured in a pedestrian accident when traveling by vehicle then by walking, bicycling, or when taking public transit. Exhibit 94 and Exhibit 95 illustrate the predicted relationships between pedestrian-related accidents and population density and workers aged 16 and older, with other predictor variables held constant.

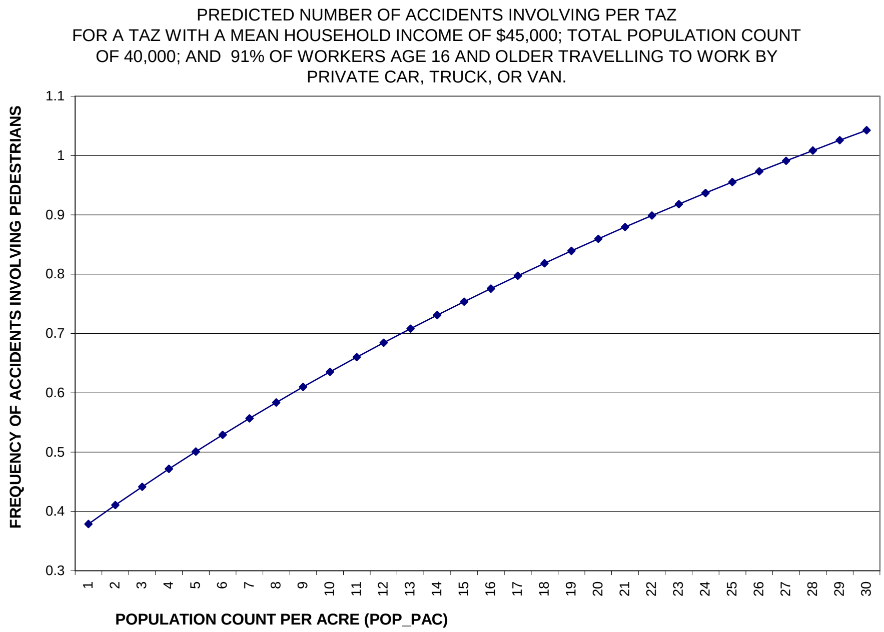


Exhibit 94: Predicted number of crashes involving pedestrians by TAZ by population count per acre by TAZ:- PLANSAFE pedestrian model

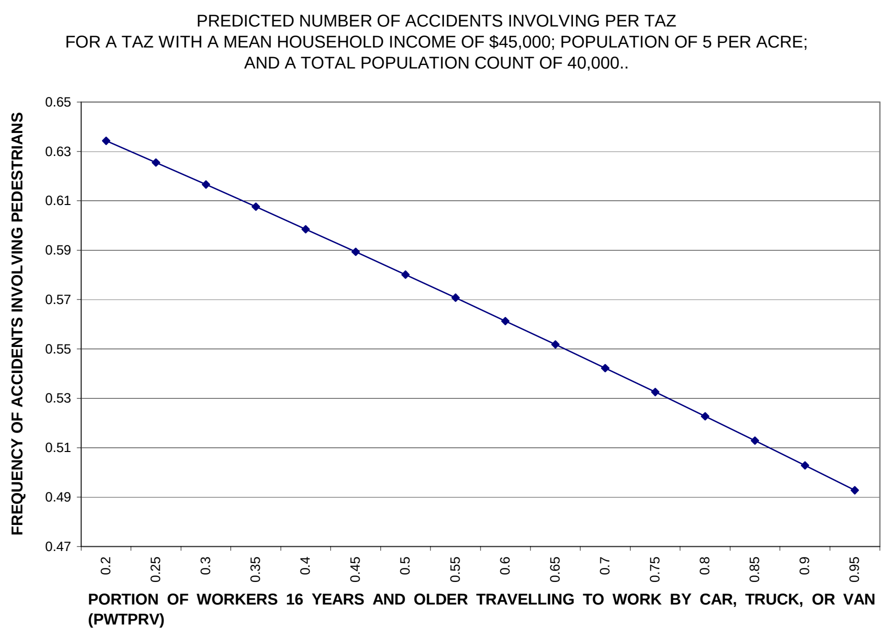


Exhibit 95: Predicted number of Crashes involving pedestrians by TAZ by portion of workers age 16 and older traveling to work by car, truck, or van, by TAZ:- PLANSAFE pedestrian model

This section describes the PLANSAFE accident prediction models with various summary statistics. Two of the PLANSAFE models are illustrated and fair detail, describing the nature of the modeled relationships. It is re-emphasized that although valid explanations are provided for the predictor variables in the models, the models are not used for explaining but instead for predicting crash outcomes by TAZ. Thus, one would not interpret a change in one of the predictor variables as a marginal change in accidents to reflect the outcome of a countermeasure application. For example, one would not want to increase the number of workers taking an auto, truck, or van to work (in a TAZ) in order to reduce pedestrian crashes—this is an incorrect use of this model, and there exist far more effective methods and tools for assessing a pedestrian crash 'problem' once a problem is identified. Instead, one should simply use the model to forecast whether a pedestrian crash problem may exist in some future time or given a hypothetical growth scenario, and then plan to remediate pedestrian crashes with specific countermeasures as required by the local conditions and further study.

How to Apply PLANSAFE Models

The PLANSAFE Models are used to forecast safety in future periods or for various project/build scenarios at the TAZ level, as described previously. The same variables (data) used to estimate the models are also needed in order to make forecasts. Application of the PLANSAFE models proceeds by applying the following six analysis steps.

1. ***Collect variables needed to run models***: All model variables need to be collected for TAZs in the affected analysis area for the base and forecast years or scenarios. The analysis area could be a set of TAZs affected by a large-scale project or the entire metropolitan region. The relevant crash data for the base year or scenario are also needed. All information should be manipulated in a GIS environment to allow for assignment of data to the TAZs or group of TAZs (the data collection and generation process is described in Appendix D). The most recent census block group data will constitute a major portion of the explanatory variables.

2. ***Generate the expected crash counts in a spreadsheet program (such as Microsoft Excel) or database management software program (such as Microsoft Access):*** The simple equation derived from the logarithmic linear regression model estimation results presented in the previous section is used to calculate the expected crash counts (e.g., pedestrian, total, fatal, etc.) by TAZ for the selected crash outcome. The model inputs are current crash counts by TAZ and independent variables for the baseline as well as forecasted independent variables for the future year scenarios.

3. ***Compute baseline correction factors, BCF***: The baseline correction factors (BCFs) are obtained using the expected crash counts generated in step 2 to predict crashes in the baseline scenario. The BCF is an essential component of the analysis, as it corrects for differences between model calibrated safety and safety in the local region or state and is used to assess the goodness of fit of the model. In effect, the BCF is used to adjust for differences in expected accident frequencies observed in the states of Arizona and Michigan used to estimate the PLANSAFE models and the forecast state or region where the model is being applied.

The asymptotically unbiased BCF, used to correct future predictions from the PLANSAFE models, is obtained using

$$BCF_{unbiased} = \frac{\dfrac{\sum_{i=1 to N} O_i}{N}}{\dfrac{\sum_{i=1 to N} P_i}{N}} = \frac{\sum_{i=1 to N} O_i}{\sum_{i=1 to N} P_i}.$$

It should be noted that this asymptotically unbiased estimate of the BCF is not the average of the BCFs across TAZs, but instead the ratio of the average of observed crash frequencies divided by the average predicted frequencies.

To assess model fit, BCFs need to be calculated for individual TAZs. The BCF for TAZ *i* is calculated as,

$BCF_i = O_i/P_i$,

where

O_i is the locally observed crash frequency for TAZ *i*, and

P_i is the predicted crash frequency using the PLANSAFE model for TAZ *i*.

The next step is to compute the average BCF across TAZs, using

$$BCF_{average} = \sum_{i=1toN} \frac{O_i}{P_i}.$$

The standard deviation and coefficient of variation of individual BCFs are then calculated to enable goodness of fit assessment and comparison across PLANSAFE models. These two summary statistics are obtained using

$$SD_{BCF} = \left(\frac{\sum_{i=1toN} \left(\frac{O_i}{P_i} - BCF_{average} \right)^2}{N} \right)^{1/2} ;\ CV_{BCF} = \frac{SD_{BCF}}{BCF_{average}}.$$

The standard deviation is the simple population standard deviation of the TAZ level BCFs, and the coefficient of variation is the standard deviation divided by the mean.

4. ***Predict future crashes***: The baseline (comparison scenario) data for the TAZs of interest are used to calculate the BCFs described in step 3. The model is then used with forecasted independent variables to predict future crashes. The model predictions for all TAZs are then multiplied by the unbiased BCF computed previously to obtain the 'best' estimate of crashes in the future/scenario forecast. These estimates reflect the forecast of the PLANSAFE models adjusted for local/regional conditions.

5. ***Compare BCF coefficient of variations***: To assess goodness of fit of the PLANSAFE model or to compare goodness of fit of several models, the TAZ level BCFs are used. The coefficient of variation (CV)—the standard deviation of BCF divided by the average BCF (not the unbiased BCF) gives a measure of the unexplained crash variation from the PLANSAFE model. A CV near zero suggests that the model fits the observed data perfectly, a CV equal to 1 suggests that there the standard deviation is as large as the mean, and CV values much greater than 1 would suggest that there is significant unexplained variation in the local data. CV values equal to or greater than 1 may indicate a problem of lack of model fit, and preferably values considerably less than 1 are preferred.

6. ***Incorporate modelling results into planning process:*** The modelling results are now used to inform decision making in the transportation process. The modelling results provide a prediction of expected safety in a TAZ, a collection of TAZs, or an entire region because of growth in various forms. Growth can affect population, road mileage, and intersection density. The modelling results provide the planner information about the expected future safety, assuming that similar roadway design standards and no new safety initiatives are implemented. Using the forecasts, the

planner can then estimate how much safety investment is needed to attain regional or project level safety targets.

Example: Application of PLANSAFE: Incapacitating and Fatal Injury Crashes

Using the 6-step procedure described previously and the PLANSAFE incapacitating and fatal injury models, an application of the models is illustrated.

Step 1: An analyst has decided to apply the PLANSAFE *Incapacitating and Fatal Injury Crash Frequency Model* to make predictions across 10 TAZs within a jurisdiction. A major corridor improvement is being considered, which will bring about new residential and commercial development to the 10 TAZs, as well as traffic volumes and associated activity. A host of new intersections will be added because of the project, as well as new road mileage. Of course, interest focuses on what changes to safety are anticipated as result of this project—assuming similar road designs and no innovative safety countermeasures. The baseline data are shown in Exhibit 96 for the 10 TAZs under consideration. The count of incapacitating and fatal crashes in the base year is known, whereas incapacitating and fatal crashes will be predicted for the future 'project build out' year. Increases in road mileage and intersections are forecasted for each TAZ as a result of the major project, as shown in Exhibit 96.

Exhibit 96: Base Year data for PLANSAFE example application

TAZ NUMBER	INT_PMI	PNF_0111	PNF_0512	POP00_15
Base Year Data for Existing Conditions				
1	1	0.12	0.15	2500
2	4	0.09	0.12	6500
3	5	0.12	0.16	2780
4	2	0.17	0.2	8000
5	4	0.03	0.04	5400
6	6	0.023	0.035	2000
7	2	0.095	0.1	3526
8	1	0.045	0.06	4578
9	2	0.014	0.025	3278
10	7	0.021	0.3	6900
Data for Future Conditions at Implementation of Planned Project				
1	3	0.15	0.15	6500
2	5	0.09	0.15	10000
3	6	0.15	0.16	6400
4	2	0.17	0.25	12000
5	5	0.03	0.04	5400
6	7	0.028	0.044	2600
7	4	0.095	0.1	3526
8	3	0.045	0.075	4578
9	4	0.018	0.025	9500
10	7	0.021	0.3	6900

Step 2: MS Excel is used to set up a spreadsheet equation for predicting crashes in the baseline and future years. The appropriate prediction equation for the PLANSAFE Incapacitating and Fatal Injury Model is given as

$$Incpacitating\_and\_Fatal\_accident\_frequency$$
$$= \exp(2.257 - 0.659 \times 10^{-1}\left(INT\_PMI\right) + 3.328\left(PNF\_0111\right) + 3.674\left(PNF\_0512\right)$$
$$+ 0.512 \times 10^{-3}\left(POP00\_15\right)\ ) - 1 .$$

Each of the independent variables is used to forecast the base and future year scenarios. Of course, the impact of the future scenario on the value of the independent variables needs to be forecast. In this particular model the number of new intersections, road mileage of various types, and new population aged 0 to 15 are needed to forecast crashes.

Step 3: The (asymptotically unbiased) BCF is calculated to be 1.594 for the base year conditions and is shown in Exhibit 97. The table also shows the BCF calculations across the 10 TAZs impacted by the major project. The spreadsheet is used to calculate predicted crashes, and the BCF is calculated for each TAZ prediction. Then, the average and standard deviation of the BCF is calculated for the PLANSAFE Incapacitating and Fatal Injury Model to assess model fit. If multiple models are being considered (say a fatal and incapacitating fatal and injury model), then the coefficient of variations of the BCFs should be compared to see if one prediction model is significantly outperforming another—the significantly smaller coefficient suggesting better fit of the PLANSAFE model to the local data. In this example, BCF CV is about .18 or 18%, which means that the standard deviation is about 18% of the mean value. The unbiased average BCF reflects the average bias between the PLANSAFE Incapacitating and Fatal Injury Model and the region where the model is applied. In this example, the PLANSAFE model is under-predicting incapacitating and fatal injury crashes, on average, by a factor of about 1.6. This under-prediction is the result of multiple potential factors that are not included in the prediction models, including differences in weather (e.g., wet, ice, snow, and fog conditions), driver population differences, and other factors between the application and calibration data. The BCF, therefore, is used to adjust pedestrian crash predictions in future years, which would otherwise be biased low in this particular example.

Exhibit 97: BCF calculations for PLANSAFE example application

Base Year Data for Status Quo

TAZ	Observed Crashes	Predicted Crashes	BCF
1	4	3.4207	1.169
2	8	5.0598	1.581
3	5	3.3369	1.498
4	10	6.5194	1.534
5	7	4.0033	1.749
6	3	2.0798	1.442
7	8	5.9589	1.343
8	8	3.8539	2.076
9	6	2.9276	2.049
10	9	5.4950	1.638
Totals	68	42.6552	
		unbiased BCF	1.594
		average BCF	1.607
		std.dev. BCF	0.287
		CV BCF	0.179

Step 4: The PLANSAFE Incapacitating and Fatal Injury Model is applied again to forecast future pedestrian crashes under the project scenario. To make these forecasts, future values of explanatory variables, road mileage and intersections, are forecasted using knowledge of the project and its impact on these variables. Although in this example these variables are provided, considerable discussion and additional modelling may be required to forecast the predictor variables. The forecasted incapacitating and fatal crash frequencies (derived from the PLANSAFE model) are

multiplied by the unbiased BCF to obtain the forecasted estimate of incapacitating and fatal crashes in the future project scenario. Exhibit 98 shows the results of this step. New road mileage, intersections, and additional residential development will lead to predicted increases in crashes in the absence of new, innovative, or progressive safety interventions. In other words, if the project is built using roadway design standards commonly used in the base year, an increase in incapacitating and fatal injury crashes from 68 observed crashes to 87 crashes is expected.

Exhibit 98: Predicted future incapacitating and fatal crashes for PLANSAFE example application

TAZ	Predicted Project Scenario Crash Frequency	BCF	Adjusted Project Scenario Crash Frequency
1	5.70	1.594	9.09
2	7.39	1.594	11.79
3	5.36	1.594	8.54
4	9.02	1.594	14.37
5	4.34	1.594	6.91
6	3.28	1.594	5.24
7	3.83	1.594	6.11
8	3.84	1.594	6.13
9	6.25	1.594	9.96
10	5.76	1.594	9.18
		Total	87.31

The increase in expected crashes that results from the project is not an argument in of itself for or against the project, and in fact is merely an *informative* statement regarding safety and not a *value* statement about safety. That incapacitating and fatal crashes are predicted to increase from 68 to 87.31 merely represents an increase in injury severity risk expected by increases in the number of intersections, residential development, road mileage, and local population increases.

<u>Steps 5 and 6</u>. Since only one PLANSAFE model is being considered in this example, a comparison of CVs across models is not appropriate in this case (in addition the CV is considerably less than 1). The results of this analysis might be coupled with the analysis of other projects to compare and contrast the expected change in safety. For example, one might apply the same procedure using a total crash model and the fatal injury model. If the CVs are comparable across models then all models might be used; however, if one of the CVs is considerable lower than the other models it might be preferred for prediction than the models with relatively high CVs.

The information provided through this analysis suggests that the project will bring about a sizeable increase in incapacitating and fatal crashes because of the project and new population growth. If a regional safety goal was to reduce fatal and incapacitating injury crashes by 20%, then one would obtain a target for this project using [87.31*0.80] = 69.84 crashes. The next step would be to examine design policies and safety investments, using software such as the IHSDM (for example) to seek reductions in crashes. To meet the regional safety goal the project would need to demonstrate through additional safety investments and strategies an expected reduction of [87 – 70] = 17 fatal and incapacitating injury crashes.

A point of note here is that a statewide or regional safety objective of a 20% reduction in incapacitating and fatal crashes does not correspond with a reduction of the current level of incapacitating and fatal crashes, because growth in population and other factors will necessarily lead to increases in crashes in most cases. Thus, the PLANSAFE Incapacitating and Fatal Crash Model in this example provides planners with a tool for setting targets for meeting safety objectives and performance milestones.

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APPENDIX D DEVELOPING A PLANNING LEVEL FORECASTING MODEL (PLANSAFE)

Appendix C described the application of a PLANSAFE model for forecasting crashes at the planning level. The focus in Appendix C was on forecasting crashes (total, fatal, pedestrian, etc.) in future periods or for build scenarios for use in planning applications. Primary uses include the setting of safety performance targets and for feedback on development and/or growth scenarios.

This Appendix, in contrast, provides the details necessary to *develop* (as opposed to *apply*) a planning level forecasting model. This appendix is intended to serve as a resource for an agency that has both the desire and ability to develop their own set of regression models for forecasting safety at the planning level. The motivation for such an undertaking would be the desire to increase the confidence in the relationships captured in the models using local or regional data instead of data from other regions (Pima County, Maricopa County, and Michigan State).

This section is organized as follows. First, the limitations of planning level safety forecasting models are described. The data requirements for such a model are then discussed, followed by software requirements and required expertise. Development of the datasets is followed by a discussion of the development of the statistical models. Detailed development of the planning level safety predictions models is then provided. Finally the methodology for GIS processing required to develop the datasets are discussed.

LIMITATIONS OF PLANNING LEVEL SAFETY FORECASTING MODEL

A safety model at the planning level is fundamentally different than corridor and site level safety models with which most safety professionals are familiar. The differences need illumination so that model misuses are avoided. Following are the limitations of these models.

- the model can only be used at a TAZ area level: it can not be used for corridor or project-level-related assessments and analysis,
- the model is not suitable for bolstering arguments for or against particular safety, land use, or transportation investments. In other words these models are predictive in nature and intend to inform the analyst as to *when* certain outcomes will occur; however, it they are not explanative models that describe *why* certain outcomes occur.
- a geo-coded road network and linked accident and other transportation data (refer to the section discussing data requirements) are required to develop the model,
- the creation of the data sets necessary to develop the model requires the transformation of census block group data to TAZ area which requires GIS expertise,
- the modelling requires the careful identification of independent variables and the selection of these variables requires considerable statistical modelling expertise, and
- special expertise is required to prepare the dataset and to develop the model (refer to Exhibit 87).

The model uses the linear regression model with logarithmic transformation of the dependent variable. This distribution is sensitive to any correlation between variables in the model and the selection of independent variables is therefore essential for the successful development of this model. The professional can use a correlation matrix to assist with in the selection of independent variables during the model development process.

DATA REQUIREMENTS OF PLANNING LEVEL SAFETY FORECASTING MODEL

Both the development and use of the prediction model requires data by traffic analysis zone (TAZ). TAZs are the smallest analysis unit. Larger units can be analyzed by aggregating TAZs. For example, a change to a commute corridor that impacts numerous TAZs can be modeled by considering the impacts of the project on all affected TAZs.

The models require data sets referring to geographical areas such as census block groups and transportation facility datasets in geospatial information systems. Geographical information systems (GIS) are used extensively to develop the data sets in support of these models. GIS layers in the development of the prediction model include:

- The TAZ areas that makes up the area for the prediction model, as defined by the transportation agencies of the area,
- Tracts and/or block groups as defined by the U.S. Census (the use of block groups is recommended) with the associated demographics, socio-economics and other data,
- The entire road network of the area: i.e., including facilities managed by the state, counties, regional agencies, and local agencies,
- The federal functional classification of the entire road network of the area,
- The vehicle miles traveled on the road network on the area (can be calculated by generating known section lengths and multiplying it with known section traffic volumes),
- Bike facilities and routes,
- Transit facilities,
- Unique accident record identification numbers for accidents for a minimum of one year and ideally three years, and
- Locations of institutions such as schools and police stations.

The details for the development of these datasets are described later in this section.

SOFTWARE REQUIREMENTS

The analyst develops the model by using GIS software and statistical analysis software, such as LIMDEP, SPLU.S., GENSTAT, SPSS, SAS, aML, etc. The researchers at the University of Arizona used ArcGIS, and LIMDEP for the development of models described in this section and in Appendix C.

REQUIRED EXPERTISE

The estimation of planning level safety forecasting models requires the following expertise.

Development of datasets. GIS software-related expertise is required for the preparation of data needed in the development of the model. The individual will have to perform various types of GIS processing to assign data to the TAZ areas and have a fair knowledge of vector and raster modeling and spatial analysis in the GIS environment.

Development of the models. The development of the statistical models, using the dataset created for the model, requires experience in statistical modelling and transportation safety. Knowledge about basic hypothesis testing, regression and the ability to evaluate a model using goodness-of-fit are basic requirements. As the development requires the use of statistical software such as LIMDEP or STATA, the individual also has to be able to use the software and interpret the results provided by the software. The individual should also be knowledgeable in the field of transportation safety as the evaluation of the variables in the generated models requires an understanding of the relationships between the variables and accident-related variables.

DETAILED DEVELOPMENT OF A SAFETY PREDICTION MODEL AT THE TAZ LEVEL

Exhibit 99 depicts the process that the analyst follows to develop the planning level safety prediction model. The process consists of three basic steps:

- data collection,
- development of a dataset containing variables used in modelling, and
- development/estimation of the statistical models used for forecasting.

All of these activities support development of the planning level safety prediction model. Before one begins this process, it is important to recognize that the ultimate model drives all the activities preceding it. So, a review of the safety model and what factors are thought to affect safety at the aggregate level is worthwhile at this point.

Safety, as defined by total crashes, severe crashes, injury crashes, pedestrian crashes, and bicycle crashes are influenced by numerous factors. These factors must be viewed in the framework of aggregated data and crashes cannot be examined in isolation. Exhibit 89 lists potential variables that may capture the underlying effects listed in the first column. For example, weather is known to affect crashes, with wet, ice, and snow affecting crashes considerably. At the TAZ level, the proportion of wet pavement days may help to capture the variability in crashes observed within a TAZ. Similarly, high risk driving populations are involved in crashes more frequently than average drivers. Identifying the proportion of high risk drivers residing within a TAZ may help to capture some of this effect—predominately those crashes that occur close to home (which is a significant proportion). The list of variables listed in the table is meant to provide a basis from which TAZ data collection is conducted. The list is not exhaustive, but captures most of the major factors involved with crashes at the TAZ level.

Exhibit 99: Process followed to develop PLANSAFE by TAZ for planning level safety prediction

DATA COLLECTION

Prepare a dataset by TAZ area using GIS technologies such as dynamic segmentation and spatial joining.

a) Collect road network related data: usually includes local, county and state road network & use dynamic segmentation to assign mileage and other attributes to the particular TAZ
b) Collect census related data by block group and assign with GIS technologies to the TAZ polygons. Prepare a dataset with potential socio-economic and demographic variables by TAZ.
c) Collect crash data for at least one year and develop a dataset with potential crash related variables by TAZ zone.

IDENTIFY INDEPENDENT VARIABLES FOR USE IN THE MODEL

Develop a set of independent variables using road network characteristics, socio-economic and demographics, and crash history

a) Prepare a correlation matrix for the dataset using software such as Limdep or Stata
b) Identify variables that do not correlate with other variables
c) Prepare dataset with independent variables that can potentially be used for the model

DEVELOP THE MODEL

Develop an initial model using a set of independent variables generated in previous step using Lindep or Stata and linear regression with the transformation of the dependent variable.

Test the model by:
a) Determining the significance of each of the variables in the model
b) Determine whether the relationship provided by the model can be logically explained

Repeat process and estimate a number of candidate models using variations of variables and by adding, maintaining or dropping variables based on tests required in previous step

Select the model with the best goodness-of-fit

Exhibit 100: Major contributing factors in crashes at the TAZ level and potential variables

Major Contributing Factor	Potential Aggregate (TAZ level) Variables that may capture effect of Major Factor (assumes time scale is year)
Weather	Proportion of wet pavement days per year Proportion of icy pavement days per year Proportion of snow days per year Proportion of fog/reduced visibility days per year Proportion of sunny days per year
High risk driving populations	Population/number of licensed drivers Proportion of population between 16 and 24 Proportion of population over 60 Number of DUI arrests Employed/unemployed workers
High risk non motorized populations	Number of crosswalks Number of schools (elementary, middle, high, college) Percentage/mileage of sidewalks (of street mileage) Percentage/mileage of bicycle facilities
Speed, design standards of facilities, and access control	Total street mileage Proportion of local road mileage Proportion of collector road mileage Proportion of arterial road mileage Proportion of rural highway mileage (urban/rural) Proportion of interstate (urban and rural)
Conflicts	Number/proportion of signalized intersections Number/proportion of stop-controlled intersections Intersection density Total area

DATA COLLECTION AND PREPARATION

During the data collection and preparation process, the analyst develops datasets that tabulate the particular variable(s) per TAZ area. The major factors and their associated variables (or similar ones) listed in Exhibit 100 serve as motivation for obtaining certain information in the data collection phase.

The data collection effort for the TAZ based (planning level) safety prediction model requires cooperation among the different transportation agencies in the region. Data are collected at the different levels of agencies and sharing of data between these agencies can present difficulties, it is therefore recommended that the support of the state DOT, county and metropolitan/regional level be sought at the start of the data collection process.

Typically, data will be gathered from the State DOT, the included counties, and, in some cases, metropolitan/regional/local agencies. In some areas, there may also be other agencies to consider and data sources will vary from area to area.

Typical data per TAZ area considered for inclusion into the model are:

- road network mileage by federal functional classification,
- accident data: a variety of variables can be generated varying from degree of injuries sustained in the accidents, number of injuries and fatalities, or accident types,
- census data: population, age distribution within a TAZ (e.g., number of individuals age 17 and younger), employment, housing units: vacant and occupied, persons with disabilities, etc., and
- traffic volume data: vehicle miles traveled.

This section describes the data preparation process, the development of a dataset for modeling, and the creation of a crash prediction model.

Data Preparation

As listed in Exhibit 100 the model development process uses information related to the census, the road network, and historical accident data. The development of the model requires a data matrix by TAZ area number.

During the data preparation process GIS technology is utilized to develop the datasets. Specific issues that arise with respect to GIS are described in the next subsection of this appendix. The ArcGIS environment is used but similar processing can be performed in other GIS environments as the description is intended to provide the sequence for processing operations in command line or graphical user interface environments; or for scripted batch processing. Refer to the section titled *Using GIs in the Development of the Planning Level Safety Forecasting Model* for a discussion of the GIS processing procedures.

This section describes the four different data categories that can be considered for a PLANSAFE model.

Road Network Data

During the development of the model, the following road network information per TAZ, among others, the analyst can consider the following as potential variables:

- total mileage per functional class of all the roads, i.e., all state, county, regional, and local streets,
- total number of intersections,
- positions of bus stop and transit facilities,
- mileage of bike facilities,
- portions of signalized and stop controlled intersections, and
- population and vehicle-miles-traveled.

Vehicle miles traveled by TAZ area is recognized as an important element of the development of accident prediction models and the researchers recommended that the data collection efforts for the Highway Performance Monitoring System (FHWA) can be used for this purpose unless the agency has VMT data available for all the road sections. It is also possible, however, that population serves as a sufficient exposure metric, as it is probably more accurate than VMT in its measurement. Having both may be the best approach for model testing and refinement.

VMT may be approximated by multiplying average annual daily traffic (AADT) for a particular road section by the length of the road section. This requires that the analyst ensures that road segments that make up the road network be provided with a unique segment identifier that can be linked to a unique road segment identifier within the HPMS data set. In some cases it may be necessary to obtain the HPMS data on a county level and also on a state level to ensure that such unique route identifiers exist.

Careful attention needs to be paid during the assignment of mileage to the different TAZ areas to ensure that arcs representing the road network do not get lost due to complex GIS-related calculations. It would therefore be valuable to calculate the total mileage per functional class for the entire area and then for the different TAZ areas and compare the total mileage per class with the sum of the mileage per class per TAZ values to ensure that all the sections are included in the dataset.

Census Data

The U.S. Census data for SF1 and SF3 is used to identify potential variables related to socio-economic, demographic, and employment data.

Based on the case studies presented as part of this section, it is recommended that the census data be transformed from a block-group level to the TAZ level. Census data is not reported by a sub-area where the data can be personally identifiable, i.e., variables with low frequencies in an area may be presented as zero values in the data from the census. This causes false zeros in block data. The tract areas, on the other hand, is large compared to the TAZ area and is therefore expected to generalize the data too much when it is transformed to the TAZ area.

Census data can either be downloaded from the U.S. Census website through the American Fact Finder web page at http://factfinder.census.gov/ or by creating datasets by using the U.S. Census 2000 Data Engine CD's that are available per state per SF1 and SF3. NCHRP 8-48 is currently reviewing the use of the new American Community Survey data for transportation-planning and can potentially be a source of data for the development of the prediction model.

In some cases transit and other transportation studies generate data that can be used in the development of the model. These data are generally available per census tract and in these cases can be transformed into TAZ level data.

The next section presents step-by-step instructions to transform census block-group data or data per tract or other sub area to TAZ areas in ArcGIS (refer to the section titled Using GIS in the Development of the Planning Level Prediction Model). In the GIS environment, the block group data are assumed uniform and the assignment to the TAZ is done using proportion per area of overlap.

Institutions

The number of relevant institutions per TAZ, such as police stations, schools, colleges, and universities are considered as potential variables for the model. The final section of this appendix provides step-by-step instructions to calculate the frequencies of each of these institutions per TAZ area.

Accident History

Accident data is geo coded in a number of different ways and the GIS environment is used to generate the outcome variables that are considered during the model development process.

The analyst uses a shape file containing the point events, i.e., accidents, by unique accident report number, together with a shape file containing the TAZ boundaries, to generate of a data set that contains the unique accident report number and the TAZ area it is located in (refer to the step-by-step instructions to calculate the frequencies of each of these institutions per TAZ. The data set can then be used to generate a table of frequencies of accidents per TAZ by summarizing the data points per TAZ.

Accident-related variables to be investigated as possible accident outcome predictions: accident severity, injuries sustained in the accident, pedestrian involved crashes, fatal crashes, and other accident-related variables.

Development of a dataset containing modelling variables

The next step in the process of developing a planning level safety prediction model is the development of a data set containing independent variables. It is recommended that a correlation matrix be prepared to assist the statistical specialist in this effort. The correlation matrix is helpful for identifying which variables are capturing essentially the same or similar underlying phenomenon. The use of variables described in previous sections will motivate the development of this variable list. This step requires the use of database management software such as MS Excel, Access, or other database management system. Finally, prior to modelling, all variables should be examined individually to determine whether the variables make sense. Reasonable checks for reasonableness include computing means, medians, modes, maximums, and minimum values of all variables in the database. Often times coding and transcription errors can be detected during this process so as to avoid negative influences on the modelling results.

Development of Crash Prediction Model

The researchers of NCHRP 8-44 developed a safety prediction model by using the following approach and assumptions:

- ***Accident count distribution.*** Accident counts are assumed to be well approximated by the negative binomial distribution when observed per unit area or per unit time (e.g., crashes at intersections for one year each). A linear regression model with logarithmic transformation of the count data will produce a satisfactory model when data are aggregated at the TAZ level (i.e., lots of intersections, road segments, etc.) and TAZs are of varying sizes. Mean crash frequencies are thought to vary across TAZs due to unobserved characteristics of the TAZs.
- ***Simultaneity of accident occurrences.*** Simultaneous model estimation techniques may be used to model the simultaneity of the accident occurrences (see Washington, Karlaftis, and Mannering, 2004, "Statistical and Econometric Methods for Transportation Data Analysis", Chapman Hall, for details on simultaneous model estimation techniques). This need arises due to the likely correlation of error terms across crash prediction models. If modeled separately (and not simultaneously) the coefficients will be inefficient.
- ***Variables maintained due to statistical significance and agreement with expectation.*** Variables are maintained in the models by determining the significance level (95% is accepted as a minimum) and by assessing whether the relationships between the particular variable and accident outcome, including direction of the effect, agrees with theoretical expectations of accident outcomes.
- ***Error terms correlated across models.*** The error terms in the models are thought to consist of omitted variables and measurement errors. Omitted variables are assumed to affect all accident injury outcomes (e.g., fatal, serious, slight, total injuries) and the original error term in the model is not correlated to the observable variables.
- ***Contemporaneous correlation.*** During model estimation additional information from contemporaneous correlation is used. The simultaneous equations are solved by using system estimation methods such as the three-stage least squares.
- ***Simultaneous negative binomial equations.*** An iterative estimation process is followed using a likelihood maximization algorithm until convergence is achieved and parameters are estimated
- ***Measurement of Goodness of Fit.*** The goodness of fit for the simultaneous model system is assessed using the R^2 statistic, and individual t-statistics for variables.

Modelling trial and error is used to derive meaningful and useful models. Knowledge of transportation safety is used to derive a model that is consistent and in agreement with current knowledge of motor vehicle crashes and safety.

U.S.ING GIS IN THE DEVELOPMENT OF THE PLANNING LEVEL SAFETY FORECASTING MODEL

The Planning Level Safety Prediction Model requires the analyst to perform various calculations within the GIS environment. The purpose of this section is to describe a general methodology for the processing of data within the GIS environment.

- Creating census data sets per TAZ, i.e., distribution of demographic data in block groups to TAZ areas by assuming uniformity of values in block groups,
- Creating accident data sets per TAZ, i.e., assignment of total road mileage to each TAZ
- Creating road mileage and VMT summary sets for the road network by TAZ, i.e., association of accident events (points) with the TAZ.

The ArcGIS environment is used but similar processing can be performed in other GIS environments as the description is intended to provide the sequence for processing operations in command line or graphical user interface environments; or for scripted batch processing.

Conceptual Framework

This section places the described methodologies within a conceptual framework for conceptualizing the data processing.

The association of the attributes of TAZ by their spatial relationship with the attributes of other spatial themes, such as traffic accidents and census block groups is a fundamental function of GIS. Overlay functions handle the association of the attributes of one feature class with those in another feature class. Once the attributes are feature classes are associated the values of an attribute of one feature class can be summarized by the values of another. For example, the summarization of demographic data by TAZ to produce proportional population counts for each TAZ. Since the transportation data (daily trip counts, etc.) are associated with the zones of the TAZ, it is the proportional demographic data, for example, that will be associated with the TAZ numbers. The proportional population counts can then, be summarized by TAZ number for further statistical processing. One of the important assumptions of this method is the uniform distribution of persons and person characteristics within a census block group.

Methods

This section discusses the methodologies that could be used to perform the GIS processing needed in the process of creating census, road mileage, and accident data per TAZ.

Distribution of demographic data in block groups to TAZ areas

Census data sets can be obtained from the U.S. Census or the agency responsible for the area. To enable the analyst to summarize census data per TAZ, the following are needed:

- A shape file with the geographic boundaries of the census block groups for the corresponding census data collection year – this file should match the datum, projection coordinate system and units of any other shape files. The boundaries are then associated with a database file, either in Microsoft Access or in dbf format, that contains the census data.

- A shape file with the geographic boundaries of the TAZs for the area.

Exhibit 101 describes the data that are required to perform the GIS processing.

Exhibit 101: Data required to distribute demographic data in block groups to TAZ areas

Type	Name	Description
Feature class polygon	block_groups	U.S. Census Block Groups
Feature class polygon	TAZ	Traffic Analysis Zones

The GIS processing steps are as follows:

1. Obtain required digital data sets with metadata
2. Verify spatial and attribute domains
3. Normalize spatial data sets to common projection and datum
4. Vertically integrate data sets
5. Calculate density for census block groups
6. Overlay TAZ and census block feature classes
7. Calculate population for unioned polygon feature class
8. Summarize counts by TAZ for output unioned feature class polygon

Assignment of total road mileage to each TAZ

Some of the variables considered during the development of a planning level safety prediction model and subsequently required during the application of the model, includes the length of roads within a particular TAZ with a particular functional classification or characteristic. To generate such a data set, the analyst needs the following:

- A shape file containing the TAZ boundaries
- A shape file containing the road network and associated characteristic values for the road sections that makes up the road network.

Exhibit 102 describes the data that are required to perform the GIS processing.

Exhibit 102: Data required to assign road mileage to TAZ areas

Type	Name	Description
Feature class polygon	TAZ	Traffic Analysis Zones
Feature Class line	Street_network	Line theme of road network

The GIS processing steps are as follows:

1. Obtain required digital data sets with metadata
2. Verify spatial and attribute domains
3. Normalize spatial data sets to common projection and datum
4. Vertically integrate data sets
5. Overlay street network and TAZ boundaries
6. Summarize counts by output intersected feature class line
7. Associate summary street length values with TAZ polygons

Association of accident events (points) with the TAZ

In the planning level safety prediction model, the analyst uses the frequency of accidents or severity of accidents or any other related events per TAZ. The analyst therefore has to develop a data set that summarizes the particular data points within each TAZ.

Exhibit 103 describes the data that are required to perform the GIS processing.

Exhibit 103: Data required to assign accidents to TAZ areas

Type	Name	Description
Feature class polygon	TAZ	Traffic Analysis Zones
Accident Location Data	Accidents	Database Table

The GIS processing steps are as follows:

1. Obtain required digital data sets with metadata.
2. Verify spatial and attribute domains.
3. Classify and scrub accident data for subprocessing procedures.
    - Build route systems
    - Calibrate route systems
    - Create event theme for linear reference accidents

    OR

    - Verify reference theme for address matching
    - Create address locator service
    - Geocode addresses
4. Derive point feature class for georeferenced accident locations.
5. Overlay point feature class accidents on TAZ polygons.
6. Summarize accidents by TAZ number.

References

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
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	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
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development 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