Road Safety Fundamentals

Concepts, Strategies, and Practices that Reduce Fatalities and Injuries on the Road

U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

This book provides an introduction to the fundamental concepts of road safety. The book's goal is to equip the reader with a broad base of knowledge about road safety. Thus, the focus is in communicating concepts rather than providing instruction in detailed analysis procedures.

The audience for this book is two-fold. First, this is intended for those whose job addresses some aspect of road safety, particularly in a public agency setting. Second, this book is intended for professors and students in a university setting.

This book seeks to lay the foundation of road safety knowledge regardless of a particular discipline. Professionals with a background in engineering, planning, public health, law enforcement, and other disciplines will benefit from the concepts presented here.

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INTRODUCTION

This book provides an introduction to many of the fundamental concepts of road safety. These concepts cover areas such as the nature of road safety issues, human behavior in the road environment, and identifying and solving road safety problems. The goal of this book is to equip the reader with a broad base of knowledge about road safety. Thus, the focus of the text is in communicating concepts rather than providing instruction in detailed analysis procedures.

The audience for this book is two-fold. First, this is intended for those whose job addresses some aspect of road safety, particularly in a public agency setting. This is especially relevant for individuals who have been tasked with managing road safety but who do not have formal training in road safety management. In order to show practical applications of each road safety concept, this book contains many examples that demonstrate the concepts in real-world settings. Second, this book is intended for professors and students in a university setting who can use individual units or this entire book to add an emphasis on road safety as part of graduate-level work. Each unit provides learning objectives and sample exercises to assist professors as they incorporate content into their courses.

As a final note, this book is intended to lay the foundation of road safety knowledge regardless of a particular discipline. Professionals with a background in engineering, planning, public health, law enforcement, and other disciplines will benefit from the concepts presented here.

ABOUT THIS BOOK

This book is divided into five units according to major topics of road safety knowledge. Each unit is divided into multiple chapters that address the primary concepts of the unit. The beginning of each unit provides a list of learning objectives that indicate what the reader will be able to understand, describe, identify, or otherwise do by the end of the unit.

Each chapter presents call-out boxes, glossary definitions, and references as shown below.

A

Call-out boxes are provided throughout the book to provide examples of concepts presented in the chapter.

Secretary Hoover called a second conference for March 1926. During the interim between the two conferences, a special committee drew up a model "**Uniform Vehicle Code**" covering registration and titling of vehicles, licensing of drivers, and operation of vehicles on the highways. The code incorporated the best features of the numerous and varied State laws then on the statute books. The second conference approved this code and recommended it to the State legislatures as the basis for uniform motor vehicle legislation.

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Federal Government Role in Highway Development

The growing use of motor vehicles during the 1920s was mirrored by the expansion of the Federal Government's role in funding and building roads. In its early form, the Office of Public Roads was organized under the U.S. Department of Agriculture, playing a large role in funding roadways within national parks and forests.

Following the Federal Aid Road Act of 1916, this office would become the Bureau of Public Roads (BPR), charged with working cooperatively with State highway departments on road projects. Work continued on the expansion of highways across the country, and between 1921 and 1939, the distance of paved roads

Uniform Vehicle Code

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8

Source: *America's Highways, 1776-1976: A History of the Federal-Aid Progra* Federal Highway Administration (U.S. Government Printing Office, Washington D.C., 1976).

Balanced Design for Safety

In the 1920s and 1930s, it was good engineering practice to design new highways as much as possible in long straight lines or "tangents." When it became necessary to change direction, the engineer laid out a circular curve, the radius of which he selected to fit the ground with the least construction cost, but which could not be less than a certain minimum fixed by department policy. In practice, engineers made the curves sharper than this minimum when it was cheaper to do so, but with little consistency. Engineers expected motorists driving these roads to adjust their speeds to the varying radii, and on the sharper curves safe design speed might be considerably lower than the posted speed limit.

Increasing concern for road safety led many highway engineers to worry about this inconsistency between posted speed limits and safe design speed on curves. In 1935, highway engineer Joseph Barnett of the BPR proposed that all new rural roads conform to an "assumed design speed," a comfortable top speed for drivers outside of urban areas.

With its adoption by American Association of State Highway Officials in 1938, Barnett's "balanced design" concept became a permanent feature of U.S. roadway design. Today, standards for designing curves, such as design speed, curve radius and superelevation (the tilt of the road through a curve) are provided in A Policy on Geometric Design of Highways and Streets, produced by the American Association for State Highway Transportation Officials.

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B

Glossary definitions are provided along the side of the page. These correspond to words in bold face in the page content.

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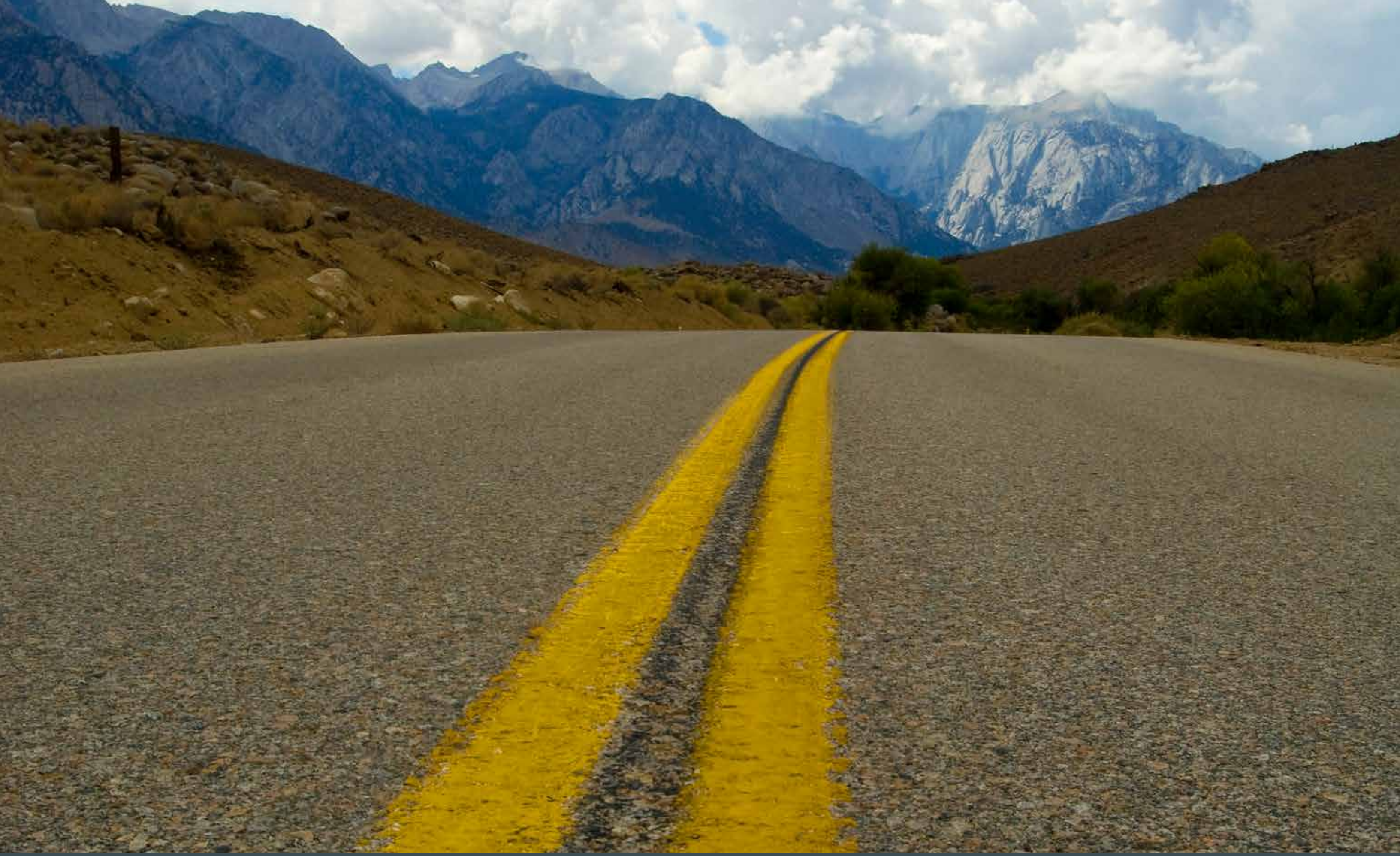
References to source material are provided along the side of the page. These are numbered consecutively through the unit and correspond to numbers in the page content.



UNIT 1 Foundations of Road Safety

LEARNING OBJECTIVES

After reading the chapters and completing exercises in Unit 1, the reader will be able to:

- **DESCRIBE** the importance of road safety and how it relates to public health, economic, environmental and demographic trends
- **RECOGNIZE** roles and responsibilities of various disciplines and approaches to improving road safety
- **DISTINGUISH** between nominal and substantive safety
- **IDENTIFY** key points in the history of road safety in the U.S., including key legislation and agency formation, and understand how these decisions have shaped today's roadways
- **IDENTIFY** different groups of road users and challenges unique to each group

CHAPTER 1

FOUNDATIONS OF ROAD SAFETY

Context of Road Safety

Road safety is an important part of everyday life. Across the nation, people use roads and sidewalks to get to work, school, stores, and home. Public agencies work to ensure that people arrive at their destination without incident.

However, not every trip is without incident. Deaths and injuries resulting from motor vehicle crashes represent a significant public health concern. The World Health Organization (WHO) estimates that motor vehicle crashes kill more than 1 million people around the world each year, and seriously injure as many as 20 to 50 million.[1] These crashes affect all road users, from vehicle drivers and passengers to pedestrians, bicyclists, and transit users.

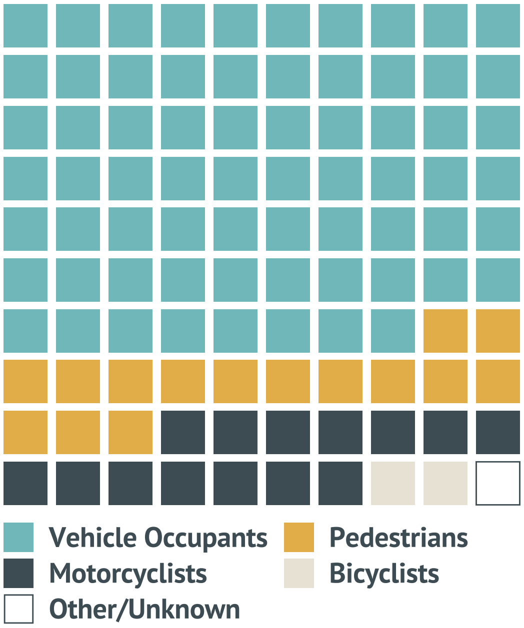


FIGURE 1-2: Traffic Fatalities in the U.S. by Person Type, 2013 (Source: NHTSA FARS)

Though road safety in the U.S. has steadily improved over time, it remains a priority for transportation agencies, legislators, and advocacy organizations. Over the past 10 years in the U.S., an average of approximately 37,000 people were killed each year and an estimated 2.3 million were injured in motor vehicle crashes.[2] While many of these deaths and injuries are sustained by motor vehicle passengers and drivers,

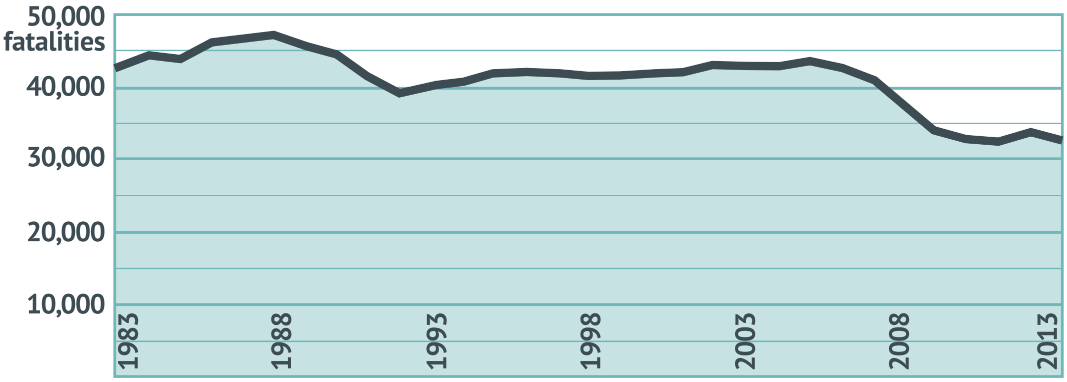


FIGURE 1-1: Traffic Fatalities in the U.S. by Year, 1983-2013 (Source: NHTSA FARS)

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[1] http://www.who.int/features/factfiles/roadsafety/en

[2] National Highway Traffic Safety Administration (NHTSA). Fatality Analysis Reporting System (FARS). http://www.nhtsa.gov/FARS

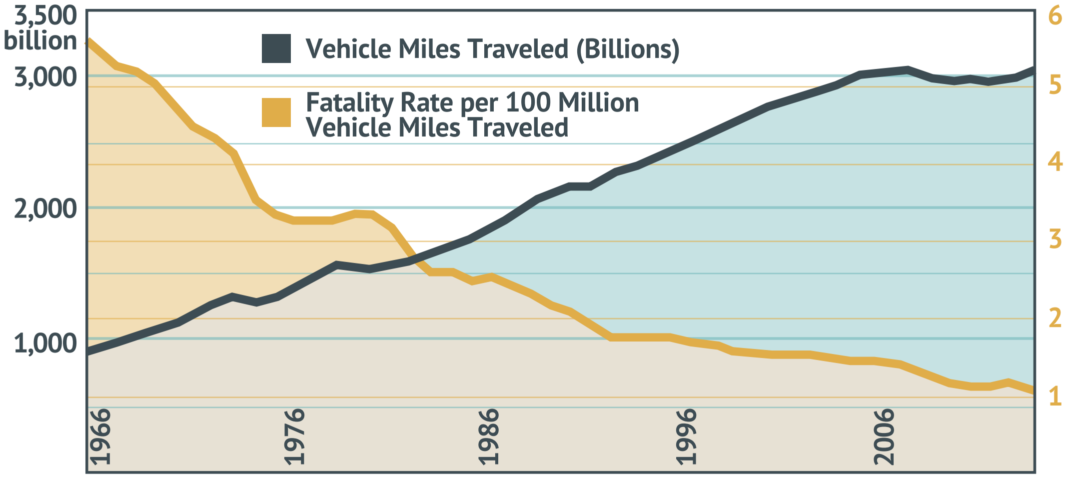

FIGURE 1-3: Fatality Rate and Vehicle Miles Traveled, 1966-2013 (Source: NHTSA FARS)

they also impact motorcyclists, pedestrians, bicyclists, and users of transit vehicles. This challenge requires a comprehensive approach to improving safety, involving numerous stakeholders and decision makers from a variety of perspectives and disciplines.

Defining Safety

In the simplest terms, safety can be defined as the absence of risk or danger. Focusing this term to address transportation, road safety can be characterized by the ability of a person to travel freely without injury or death. A perfectly safe transportation system would not experience crashes between various road users. Though absence of all crashes is an optimal condition, and many transportation agencies have a goal of zero deaths on the road, the reality is that people continue to get injured or killed on streets and highways across the nation. The challenge posed to the road safety field is to minimize the frequency of crashes and the resulting deaths and injuries using all currently available tools, knowledge, and technology. This challenge is made more complex due to the multitude of factors influencing safety, from infrastructure to vehicle design to human behavior.

Road safety professionals typically measure safety by the number and rate of crashes and by the severity of those crashes. **Crash frequency**, or the number of crashes occurring per year or other unit of time, is another commonly used metric. **Crash rates** are numbers of crashes normalized by a particular population or metric of exposure. Commonly cited crash rates include crashes per 100,000 people living in a particular State, city or country. Some crash rates present crash numbers per miles traveled or licensed drivers. **Crash outcomes** can be measured by the types of injuries sustained to the people involved in the crash, typically categorized by fatalities and injury severity. Focusing on crashes that result in severe injuries and fatalities is one strategy that agencies use to prioritize their safety activities.

In addition to the measures described above, safety professionals can use surrogate measures, such as

Crash frequency

The number of crashes occurring per year or other unit of time.

Crash rate

The number of crashes normalized by a particular population or metric of exposure.

Crash outcome

Measured by the types of injuries sustained to the people involved in the crash.

conflicts (near misses), avoidance maneuvers, and the time to collision if no evasive action is taken, to determine the level of safety risk and identify specific problems. Safety problems may exist even in locations that do not have a demonstrated history of crashes, just as someone who smokes is at higher risk for lung cancer even if no cancer has yet been detected. This can be especially true for non-motorized road user safety, such as pedestrians and bicyclists, since crashes involving these road users may be infrequent and appear random at first sight. In such locations where crashes are sparse or distributed across the system, safety professionals can use surrogate measures to fill the gaps and assess the road's level of risk. Observing traffic at an intersection, for example, may reveal a pattern of near misses and other conflicts between vehicles and pedestrians. This pattern may not appear in crash data, but can be a valuable source of information to highlight the potential for safety risk.

Safety perception is also an important consideration for travel choices. There are a number of reasons why someone may or may not choose a particular route to drive, walk or bike. Pedestrians who perceive an intersection to be unsafe may cross in a midblock location, where they are more easily able to find a gap in traffic. Motorists may feel uneasy about making a left turn across multiple lanes of traffic, so they may choose to turn right and travel out of their way to perform a U-turn instead. Safety perception impacts road user decisions but is not easily understood by looking at crash data. Safety professionals can use surveys, driving simulators, and other modern technologies to understand the safety perception of road users.

Evaluating the safety of a particular network, corridor or intersection requires an understanding of both nominal and substantive safety. Originally introduced by Dr. Ezra Hauer,[3] these terms offer a helpful framework for assessing the safety of a particular location. Decades of research and evaluation in the field of road safety have revealed a wealth of knowledge concerning the proper designs and policies that contribute to the safety of a particular location. Roadways constructed according to the best and latest recommended research and design standards are said to be nominally safe. **Nominal safety** is an absolute statement about the safety of a location based only on its adherence to a particular set of design standards and related criteria. A road that was nominally safe when it was first opened to traffic may become nominally unsafe when the roadway design standards change, even though the road's crash performance has not changed.

While nominal safety considers the design of a road, it does not incorporate any information about the frequency, type and severity of crashes occurring on the facility. The historical and long-term objective safety of a location based on crash data is known as **substantive safety**. A particular intersection that has experienced fewer than expected crashes over an extended period will be referred to as a substantively safe location, while a corridor with a higher than expected number of crashes is substantively unsafe.

Nominal safety

An absolute statement about the safety of a location based only on its adherence to a particular set of design standards and related criteria.

Substantive safety

Historical and long-term objective safety of a location based on crash data.

[3] Hauer, E. *Observational Before/After Studies in Road Safety. Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety.* Pergamon Press. 1997.

Unlike nominal safety, substantive safety operates on a continuum and allows for a range of explanations as to why a particular safety problem exists.

Another key distinction is the fact that a location can be nominally safe – adhering to all standards and design criteria – while experiencing high rates of crashes, making it substantively unsafe. Similarly, a substantively safe location (one that has a lower than expected crash rate) may be nominally unsafe if it does not meet the applicable design standards.

Agencies and safety professionals should strive to prioritize the substantive safety of a facility. Simply building a road that meets all the current design standards will not ensure that the road is substantively safe. Using professional judgement to prioritize safety improvements and select appropriate designs within a range of options, based on observations of road user behavior and other available data, will increase the chance that all factors are considered. The end result will be a road that moves a step closer to the ultimate goal of having a transportation system free of injuries and deaths.

Road Safety Decisions and Trade-offs

The goal of improving safety exists alongside other goals of the transportation system, such as mobility, efficient movement of people and goods, environmental concerns, public health, and economic goals. In this way, transportation professionals and policy makers often refer to trade-offs – making a decision to favor one goal at the expense of another. While those in the field of road safety continually look for new designs and technologies to advance all goals, there continue to be many instances where public agencies must weigh competing goals for a location or portion of the road network and decide what trade-offs should be made for the goal of increasing road safety.

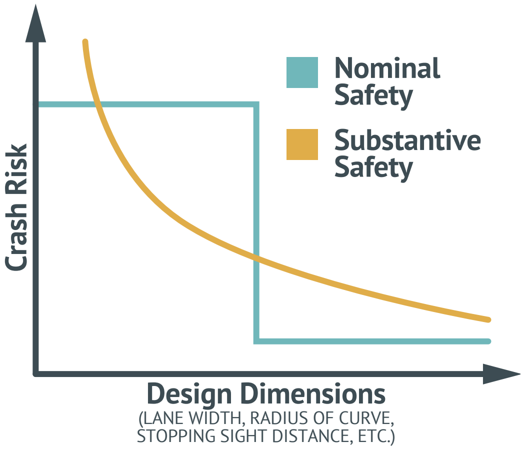

FIGURE 1-4: Comparison of nominal and substantive concepts of safety http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/chapter1/1_comparnominal.cfm (Source: NCHRP Report 480, Transportation Research Board, 2002)

Below are several examples:

- **Roundabouts:** A city may decide to install a roundabout at an intersection to decrease the potential conflicts between various movements at the intersection. Safety is improved, especially related to left-turns, since all turns are now part of the circle. However, a roundabout does require traffic on the main road to slow their speeds and navigate through the roundabout. During heavy traffic, especially if it is unbalanced among the intersection legs, this may cause a decrease in the overall throughput of the intersection. However, this is a trade-off to produce fewer crashes.

- **Bicycle Helmet Requirements:** In order to improve bicyclist safety, some jurisdictions have adopted ordinances that require bicyclists to wear helmets. In practice, this can reduce the risk of head injuries among cyclists, but it may also reduce the number of people who choose to ride a bicycle. Adopting such ordinances would prioritize safety while potentially reducing bicycle ridership.
- **Red Light Cameras:** Red light camera enforcement monitors signalized intersections and records information about those who violate red light laws, typically resulting in citations through the mail. These cameras have been shown to improve safety by decreasing the types of crashes that result in serious injury,[4] but installing the cameras can be met with significant public opposition.
- **Protected Left Turns:** To minimize the risk of severe left-turn crashes at signalized intersections, engineers may choose to provide left turning drivers an exclusive protected left turn phase (green arrow). While this minimizes crash risk by separating the left turning vehicles from other movements, it also requires that extra time be added specifically for left

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[4] Council, et al. Safety Evaluation of Red-Light Cameras. Federal Highway Administration. April 2005. https://www.fhwa.dot.gov/publications/research/safety/05048/05048.pdf

turns, which can increase delay for the rest of the traffic at the intersection.

- **Rumble Strips:** In rural locations, rumble strips can be installed as a measure to alert drivers when they are running off the road. However, these rumble strips are usually installed on the edge of the road or the paved shoulder where bicyclists can safely and comfortably ride separated from traffic. This may result in bicyclists riding in the road where they are more vulnerable to crashes with motor vehicles.
- **Trees and Landscaping:** Street trees, shrubs, and other vegetation can serve a valuable purpose in roadside environments – particularly creating shade for the sidewalk, serving as a buffer between the road and sidewalk area, and even creating "visual friction" that can keep vehicle speeds down. However, trees can also pose a safety risk for vehicles that run off the road and collide with them. Vegetation that is too close to an intersection can restrict sight distance, contributing to crashes. Selected tree and vegetation removal is an excellent example of a trade-off between safety and other beneficial features of trees.
- **Traffic Signal Installation:** A high-speed, high-volume road with multiple traffic lanes may separate housing developments from an elementary school. In order for children living in the housing development to safely travel to and from school, a traffic signal and crosswalk may be installed along the busy road. Motorists will be delayed since they are required to stop for a period of time while the students cross, but the crossing is safer for those students.
- **Access Management:** Left turns in and out of shopping centers, especially along multilane roads, can result in severe injuries to motorists when crashes occur. Eliminating these left turns by building raised median islands and consolidating driveways

can eliminate these risky movements; however, this prevents direct access to the stores by potential customers.

Sometimes improving safety for one group of road users may negatively impact the safety of another group. It can also be the case that improving mobility for a group of road users may negatively affect the safety of that same group. There is no absolutely correct answer to many of these trade-offs, as they are all context-specific. Transportation professionals need to discuss the various trade-offs in the context of a particular community's transportation goals. These types of trade-offs are made every day, and require the cooperation of numerous agencies and stakeholders, all of whom have a role to play in transportation decision-making. Despite the temptation to study road safety as a self-contained system, there are a multitude of factors influencing and being influenced by road safety and travel behavior. In order to make informed decisions about the transportation system, transportation professionals must understand the impacts – both positive and negative – that design, operations, and policy decisions have on the safety of the transportation network as well as the impacts on other areas such as public health, mobility, environmental quality, and economic growth.

EXERCISES

- **LIST** various ways to measure the safety of a road and describe the advantages and disadvantages of each. Consider factors such as the type of information each safety measure provides as well as other issues such as how it can be collected.
- **DESCRIBE** a change that could be made to a road or intersection that would improve one transportation goal (e.g., traffic operations, public health, mobility and access, environmental quality, or economic growth) at the expense of the safety of road users.
- **DESCRIBE** a change that could be made to a road or intersection that would improve road safety at the expense of another transportation goal (e.g., traffic operations, public health, mobility and access, environmental quality, or economic growth).
- **DESCRIBE** a change that could be made to a road or intersection that would improve safety for a road user but not at the expense of other users, or other goals.

Road Safety Through the Years

When examining current efforts to address road safety, it is useful to view them in the context of American transportation history. Recent decades have witnessed numerous advances in the field of road safety. This growing national consciousness about the need for safer roads provides a stark contrast to the first half of the twentieth century when the focus was on highway expansion. The following chapter will provide an overview of the major milestones and achievements that led to the transportation system we have today, as well as the policies and practices that were implemented to address a growing safety problem.

Late Nineteenth Century and the Popularity of Bicycling

An exploration of the history of road safety in the U.S. can begin at many different points – some of our roads were developed as pre-colonial routes and others were trails blazed by Native Americans. In terms of lasting influence on the modern transportation network, however, it is most useful to begin the discussion in the late nineteenth century.

In the 1880s and 1890s, bicycles were the dominant vehicle on our nation’s roads. With the introduction of the “safety” bicycle, with two wheels of the same size, and the pneumatic tire in the late 1880s, the bicycling craze became an economic, political, and social force in the U.S. By 1890, the U.S. was manufacturing more than 1 million bicycles each year.

At that time, bicyclist behavior—particularly careless or risk-taking behavior—was a contributing factor to bicycle crashes. However, the biggest contributor to crashes existed outside the cities; the poor condition of the nation’s roads made cycling a laborious and dangerous process. Bicycle groups worked at the Federal, State, and local levels to secure road improvement legislation. The work of these advocacy groups became known as the Good Roads Movement.

Three men with bicycles on bridge near Pierce Mill, Washington, D.C., 1885. *(Source: Brady-Handy Collection, U.S. Library of Congress)*

Consequences of Speeding

As in modern times, in the early days of the automobile, posted speed limits were set far below the speed of which most motor vehicles were capable.

With faster and heavier traffic, it became dangerous to drive in the middle of the road and the States began painting centerlines on the pavements to channel traffic in lanes. At 40 miles per hour, these lanes appeared uncomfortably narrow to most motorists, especially when passing trucks. The lane lines also caused trucks to run closer to the shoulder, causing the slab edges and corners of the road to break. To provide greater safety and reduce edge damage, State highway departments built wider pavements and made new roads straighter.

These improvements along with mechanical advances in vehicles, such as more powerful engines and four-wheel brakes, in turn encouraged even faster speeds.

Thus, after 1918, highway design followed a spiral of cause and effect, resulting in faster and faster speeds and wider and wider pavements. The motivating force behind this spiral was the driving speed preferences of the great mass of vehicle operators. The public authorities were never able to impose or enforce speed limits for very long if the majority of drivers considered the limits unreasonably low. Now, many current engineering practices use the 85th percentile speed – or the speed at which the majority of drivers travel – as the method of setting speed limits.

To build support, advocates tailored their message to farmers with the argument that bad roads, by increasing transportation expenditures, cost more than good roads. While engineers, writers, and politicians joined the movement, bicyclists dominated the Good Roads Movement until cars arrived in the early twentieth century.[5]

By the close of century, automobiles had slowly begun to share the roads with bicyclists and pedestrians, benefitting from many of the road improvement efforts spearheaded by cycling groups. In 1899, a motor vehicle struck and killed a New York City pedestrian. This event marked the first time in the U.S. that a person was killed in a crash involving a motor vehicle.[6]

Rise of Motor Vehicles in the Early Twentieth Century

In 1905, only 78,000 automobiles, most of which were confined to the cities, traveled the U.S. Ten years later, 2.33 million automobiles were traveling the country's roads, and by 1918, this number had increased to 5.55 million. Mass production made this increase possible as it lowered vehicle manufacturing costs, putting vehicles within the reach of the middle class. As more vehicles became available at a lower price, the pattern of daily travel in the U.S. began to shift. Longer vehicle trips replaced shorter trips by foot or bicycle, and development patterns began to follow suit. The motor age had arrived, and with it a new kind of highway would evolve, designed specifically for motor vehicles.

Expansion of automobile use had immediate positive effects on the national economy and quality of life around the country. Yet proliferation of motor vehicles also had a negative side. As millions of new drivers took to the roads, traffic crashes increased rapidly—tripling from 10,723 in 1918 to 31,215 in 1929.[7]

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[5] Source: Richard F. Weingroff, "A Peaceful Campaign of Progress and Reform: The Federal Highway Administration at 100," *Public Roads* 57, no. 2 (Autumn, 1993), http://www.fhwa.dot.gov/publications/publicroads/93fall/p93au1.cfm

[6] Soniak, Matt. When and Where Was the First Car Accident? Mental Floss. 2 December 2012. http://mentalfloss.com/article/31807/when-and-where-was-first-car-accident

[7] Source: *America's Highways, 1776-1976: A History of the Federal-Aid Program.* Federal Highway Administration (U.S. Government Printing Office, Washington D.C., 1976).

Secretary of Commerce Herbert Hoover, center, with President Calvin Coolidge, right, in February 1924. *(Source: Harris & Ewing Collection, U.S. Library of Congress)*

Shifting Attention to Safety

Recognizing the rise in crashes and resulting injuries and fatalities, Secretary of Commerce Herbert Hoover convened the First National Conference on Street and Highway Safety in Washington, D.C., in December 1924. Here, for the first time, representatives of State highway and motor vehicle commissions, law enforcement, insurance companies, automobile associations and a multitude of other stakeholders and interest groups met in one place to discuss how to address the growing number of fatalities and serious injuries.

Prior to the conference, committees were established to perform research into areas such as planning and zoning, traffic control, motor vehicles, statistics, and other areas related to road safety. These committees reported wide differences in traffic regulations from State to State and city to city. For instance, twenty States did not attempt to collect crash statistics, only eight States required reporting crashes that resulted in personal injury, and 38 required railroads and common carriers to report highway crashes. Other committees devoted their attention to issues like traffic control and vehicle speeds, infrastructure and maintenance concerns, and issues impacting vehicles and their drivers.

Conference participants supported a wide range of measures to reduce the rate of crashes and recommended that legislative, administrative, technical, and educational bodies adopt them. Conference participants also recommended that the States take the lead by passing adequate motor vehicle laws and setting up suitable agencies for administering the laws, policing the highways, registering vehicles, and licensing drivers.

To the Federal Government, the conference assigned the role of encouragement, assembly and distribution of information, and the development of recommended practices. Adoption and implementation of these recommended practices would be left to the individual States.

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A code covering registration and titling of vehicles, licensing of drivers, and operation of vehicles on the highways.

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[8] Source: *America's Highways, 1776-1976: A History of the Federal-Aid Program.* Federal Highway Administration (U.S. Government Printing Office, Washington D.C., 1976).

Safety Signs

Before World War I, most States were using signs to warn road users of danger ahead, particularly at railroad crossings; railroad companies themselves were required to post warning signs at all public road crossings. However, there was little agreement between States about the specific design of these warning devices, and the signs were a variety of shapes, sizes, and colors.

In 1929, the American Engineering Council surveyed sign practices in all U.S. cities with a population of more than 50,000 and created a document that was, in effect, a manual of the best practices of the time. Recognizing the need for standard practices for signs in rural and urban areas, the American Association of State Highway Officials and the National Conference on Street and Highway Safety organized a Joint Committee on Uniform Traffic Control Devices in 1931 and introduced a new manual for national use in 1935. The manual of best practices changed over time to become the Manual on Uniform Traffic Control Devices.

increased from 387,000 miles to nearly 1.4 million miles.[9] The BPR recognized that the antiquated highway system was one of the contributing causes of the high crash toll, but did not go so far as to identify primary crash causes or recommend potential solutions.

During this time, an emphasis was placed on expanding the Federal role in the process of highway design and development. This effort culminated in 1944 when Congress approved the development of a National System of Interstate Highways along with that year's Federal Aid Highway Act. Though expansive in scope, calling for a 40,000 mile network, the legislation was not accompanied by any funds to support the development of these highways. Without funding, the legislation did not significantly expand the highway system.

President Harry S. Truman, 1945. *(Source: U.S. Library of Congress)*

Road safety continued to present a national concern. In May 1946, President Harry S. Truman spoke at the Highway Safety Conference to rally public support to improve State motor vehicle laws, driver licensing, and education. After summarizing his unsuccessful efforts as a U.S. senator to enact Federal legislation on motor vehicle registration and driver licensing, the President said Congress was not yet ready to interfere with what many perceived as State prerogatives. However, he noted that the Federal Government would not stand aside if the rates of highway fatalities continued to rise.[10]

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[9] Source: Weingroff, Richard. *A Peaceful Campaign Of Progress And Reform: The Federal Highway Administration at 100*. Public Roads Magazine. Vol. 57 No. 2. July 1993. http://www.fhwa.dot.gov/publications/publicroads/93fall/p93au1.cfm

[10] Source: Richard F. Weingroff and the assistance of Sonquela Seabron, *President Dwight D. Eisenhower and the Federal Role in Highway Safety*, accessed May 23, 2013, http://www.fhwa.dot.gov/infrastructure/safetyin.cfm

President Dwight D. Eisenhower speaks to the White House Conference on Highway Safety, 1954. *(Source: Eisenhower Presidential Library)*

Post War Development and Growth

Economic conditions following World War II led to even higher levels of driving and automobile ownership. Personal savings of almost $44 billion created a market for housing and other types of goods, chief among them new automobiles. Automobile production jumped from a nearly 70,000 in 1945 to 3.9 million in 1948.

Because of this increase in vehicle production, motor vehicle registrations spiked and the number of drivers on the nation's roads and highways reached unprecedented levels. Under wartime rationing of rubber, and specifically tires, States had implemented speed controls to reduce wear and tear and improve tire longevity. With the end of rationing and emergency speed controls at the conclusion of the war, highway travel returned to pre-war levels and began a steady climb of about 6 percent per year, which would continue for nearly three decades.

While the increasing popularity of low density housing development (i.e., the suburbs) and the availability of motor vehicles created perfect conditions for more driving, the nation's roads and highways were unprepared for the increase in traffic. Under wartime restrictions, States were unable to adequately maintain their highways. With widespread operation of overloaded trucks and reduced maintenance, the State highway systems were in worse structural shape post-war than before the war.

Development of the Interstate Highway System

Though the National System of Interstate Highways had been established by legislation in 1944, little progress was made over the next decade. Without funding, established routes were slow to develop. That changed in 1956, when President Dwight D. Eisenhower signed the Federal-Aid Highway Act of 1956. This legislation linked the development of the interstate highway system to the interest of national defense and assigned funding that would rapidly expand the highway network.[11] The act established a dedicated funding stream and a plan for highway development that launched the nation into an unprecedented era of expansion in which new interstate corridors linked cities and towns to one another.

[11] http://www.fhwa.dot.gov/publications/publicroads/06jan/01.cfm

Despite the enthusiasm of political and business leaders, the growth of this system was not without its critics. These critics primarily denounced the destruction of homes and separation of communities that sometimes resulted from new highways bisecting established neighborhoods. Though this opposition halted projects in some locations, it did not stop the expansion of the interstate highway system.

Highway Safety Act of 1966

In 1964, the U.S. faced a sharp rise in the number of traffic fatalities. An increased number of vehicles on the roadways combined with a public culture that did not prioritize roadway safety consciousness led to 47,700 deaths on the nation's highways, an increase of 10 percent over the number of fatalities that occurred in 1963. These deaths prompted the nation to take a hard look at road safety efforts and resulted in Congressional hearings in March 1965 to raise public awareness of the growing national crisis.[12]

To respond to these trends, the nation needed a change of direction in the design and operation of its roads and vehicles. This change began with reviewing safety standards in these areas and conducting research to identify effective measures to improve safety. The 1960s was a pivotal decade for road safety due to the passage of laws that provided funding and new policies. On September 9, 1966, President Lyndon B. Johnson signed the National Traffic and Motor Vehicle Safety Act of 1966 and the Highway Safety Act of 1966. The signing ceremony in the Rose Garden of the White House marked a transformation in the role of the Federal Government in road safety. This role had been growing during the Eisenhower administration, but became a larger area of emphasis as fatalities on the nation's highways climbed toward 50,000. Those in the federal government observed that the steps taken during the previous two decades to reverse the climbing number of fatalities had failed, and they believed that road safety should no longer be left solely to the responsibility of the States, the automobile industry, and the individual drivers.[13]

This legislation established the U.S. Department of Transportation (USDOT) and transformed the Bureau of Public Roads into the Federal Highway Administration (FHWA). New bureaus were added to address safety in areas of growing concern, such as the Bureau of Motor Carrier Safety and National Highway Safety Bureau (these would later become the Federal Motor Carrier Safety Administration and the National Highway Traffic Safety Administration, respectively). The USDOT proceeded to develop programs and initiatives and pave the way for activities still in place today.[14]

Advances in vehicle design and policy were also an area of emphasis during the 1960s. In 1968, federal legislation required vehicles to provide seat belts. [15] Federal law also required States to begin implementing motorcycle helmet laws in order to qualify for particular sources of funding.[16] These requirements led to more widespread implementation of safety policies through the late

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[12] [13] Source: Richard F. Weingroff and the assistance of Sonquela Seabron, *President Dwight D. Eisenhower and the Federal Role in Highway Safety*, accessed May 23, 2013, http://www.fhwa.dot.gov/infrastructure/safetyin.cfm

[14] http://www.fhwa.dot.gov/infrastructure/50interstate.cfm

[15] Title 49 of the United States Code, Chapter 301, Motor Vehicle Safety, https://www.gpo.gov/fdsys/pkg/USCODE-2009-title49/html/USCODE-2009-title49-subtitleVI.htm

[16] Federal Motor Vehicle Safety Standard (FMVSS) No. 218, https://www.federalregister.gov/documents/2015/05/21/2015-11756/federal-motor-vehicle-safety-standards-motorcycle-helmets

President Lyndon B. Johnson signs the National Traffic and Motor Vehicle Safety Act of 1966 and the Highway Safety Act of 1966. *(Source: LBJ Presidential Library)*

1960s and 1970s. Section 402 of the Highway Safety Act established a revenue stream for funding to directly support State programs aimed at improving road safety. Known as the State and Community Highway Safety Grant Program, the funds originally supported a variety of program areas, including many many behavioral safety programs that are still in existence today. [17]

Energy Crises and Safety Legislation in the 1970s and 1980s

The 1970s and 1980s were characterized by energy crises in 1973 and 1979 that had immediate and lasting impacts on travel trends. Vehicle Miles Traveled (VMT) decreased following each of these events, as Americans drove less due to rising fuel costs. Strategic legislative action by Congress, such as the National Maximum Speed Law of 1974 which prohibited speeds higher than 55 miles per hour also helped by decreasing fuel costs. The law would later be repealed in 1995, allowing States to set their own maximum speed limits.

Between 1970 and 2007, there were two periods of time when VMT decreased from the previous year. These years include 1974 and 1979, each of which saw a roughly 18 billion mile decrease in VMT from the previous year.[18] As driving decreased, so did traffic fatalities. From 1973 to 1974, for example, traffic fatalities went down 16 percent – the largest single year decline since 1941–1942.[19] Driving levels began to increase again once fuel costs normalized, so the reductions were not sustained beyond the period of economic stagnation.

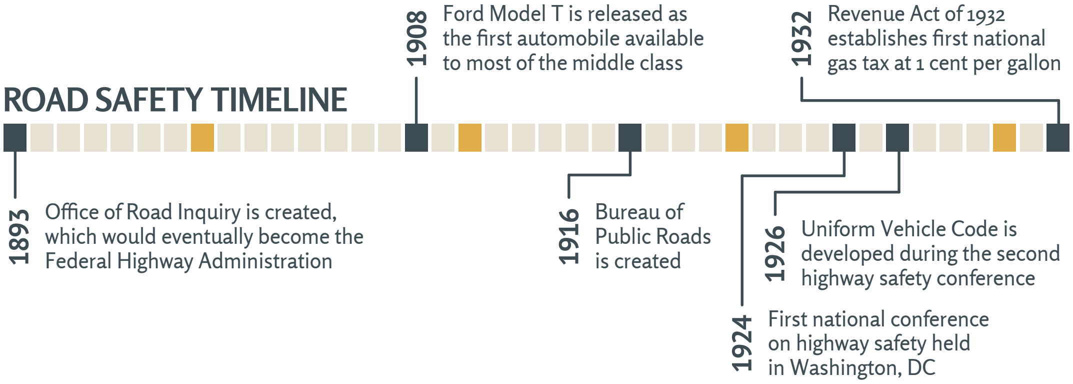
The Highway Safety Act of 1973 established a specific methodology for improving roadway safety from an engineering perspective. It required the States to first survey all hazardous locations and examine

[17] Governors Highway Safety Association. Section 402 State and Community Highway Safety Grant Program. http://www.ghsa.org/about/federal-grant-programs/402

[18] http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm

[19] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811346

ROAD SAFETY TIMELINE



1893 Office of Road Inquiry is created, which would eventually become the Federal Highway Administration

1908 Ford Model T is released as the first automobile available to most of the middle class

1916 Bureau of Public Roads is created

1924 First national conference on highway safety held in Washington, DC

1926 Uniform Vehicle Code is developed during the second highway safety conference

1932 Revenue Act of 1932 establishes first national gas tax at 1 cent per gallon

the causes of crashes at these sites. A benefit/cost analysis was then performed to prioritize needed improvements. This process set the stage for the current safety management processes and would be refined and improved over the years.

The Highway Safety Act of 1973 also clarified the relationship between the Federal Government and the States. The Federal Government was to direct policy and program components, while the States were responsible for implementing those policies and programs.[20]

During the 1970s, Congress also established the Motor Carrier Safety Assistance Program (MCSAP). This program provides financial assistance to States to reduce the number and severity of crashes and hazardous materials incidents involving commercial motor vehicles (CMV) through inspection and enforcement programs focused on trucks, carriers, and driver regulations. [21]

Vehicle safety continued to be a priority in the 1970s and 1980s, as more States began to implement laws requiring the use of seat belts and motorcycle helmets. New York became the first State to adopt a mandatory seat belt law in 1984, and other States soon followed suit.[22]

The Federal Motor Vehicle Safety Standard 213 brought attention to child passenger safety. This standard was the first to outline specific requirements for restraint systems designed for children.

Multimodal Shift in the 1990s

The 1990s saw a shift from transportation policies that focused on motor vehicle safety and efficiency to an acknowledgement of alternate modes of transportation, such as bicycling, walking and use of public transit. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) added a multimodal perspective to the Federal-aid highway program.

While ISTEA was not specifically focused on transportation safety, it created some programs to promote safer travel. For example, ISTEA enhanced road safety with new programs that encouraged the use of safety belts and motorcycle helmets.[23] The legislation also required the installation of airbags for drivers and front passengers in all cars and trucks.[24]

In 1998, the Transportation Equity Act for the 21st Century (TEA-21) provided more focus for roadway safety planning by establishing safety and security as planning

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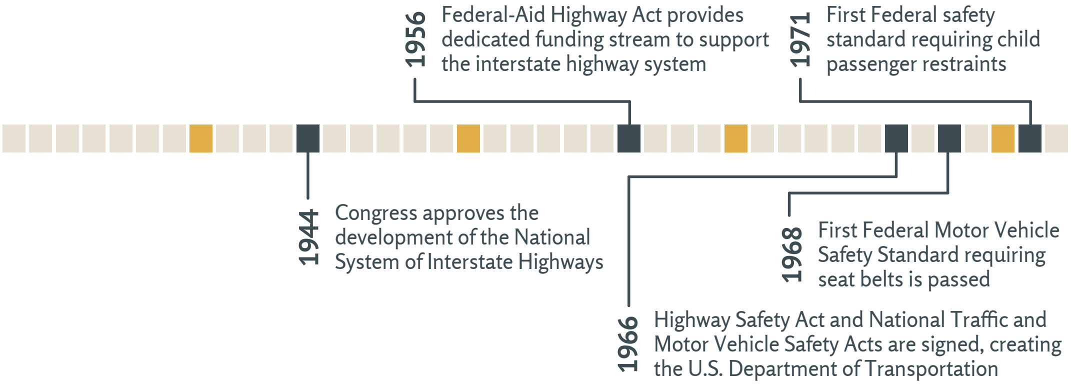
[20] Source: "HSIP History," accessed October 22, 2013, http://safety.fhwa.dot.gov/hsip/gen_info/hsip_history.cfm and "Subchapter J—Highway Safety: Part 924—Highway Safety Improvement Program," accessed October 21, 2013, http://www.gpo.gov/fdsys/pkg/CFR-2003-title23-vol1/pdf/CFR-2003-title23-vol1-chapI-subchapJ.pdf.

[21] Source: "What is the Motor Carrier Safety Assistance Program (MCSAP)?" accessed May 23, 2013, https://www.federalregister.gov/documents/2000/03/21/00-6819/motor-carrier-safety-assistance-program

[22] http://www.iihs.org/iihs/topics/laws/safetybeltuse

[23] Source: "Intermodal Surface Transportation Efficiency Act of 1991 Information," last updated May 16, 2013, accessed July 05, 2013, http://www.fhwa.dot.gov/planning/public_involvement/archive/legislation/istea.cfm.

[24] See next page.



Officers use specialized devices to measure drivers' blood alcohol content.

priorities. Prior to TEA-21, a State or Metropolitan Planning Organization (MPO) may have incorporated safety in its goals or long-range transportation plan, but specific strategies to increase safety were seldom included in statewide and metropolitan planning processes or documents.

TEA-21 established the Highway Safety Infrastructure program (not to be confused with the Highway Safety Improvement Program, which would be developed several years later), which funded safety improvement projects to eliminate safety problems.

The TEA-21 legislation also encouraged States to adopt and implement effective programs to improve the quality (e.g. timeliness, accuracy, completeness, uniformity and accessibility) of State data needed to identify safety priorities for national, State and local road safety programs.[25]

Not to be lost among the TEA-21 legislation, another pivotal moment in transportation legislation came in 2000 when an important provision related to alcohol was included in the USDOT appropriation act. The appropriation carried a requirement that all States must enact laws to limit the legal **blood alcohol content** (BAC) of drivers to 0.08 percent.[26] This limit was in line with similar limits imposed on drivers in other countries, though some European countries limit the legal BAC to 0.05 percent.

While 19 States and Washington, D.C., had already enacted this law, the Federal mandate provided a further incentive for other States to do so: States that did not pass the law by 2004 would forego a portion of their transportation funding. Though specific laws vary, each State now recognizes the legal limit of 0.08 percent blood alcohol content.[27]

Blood alcohol content

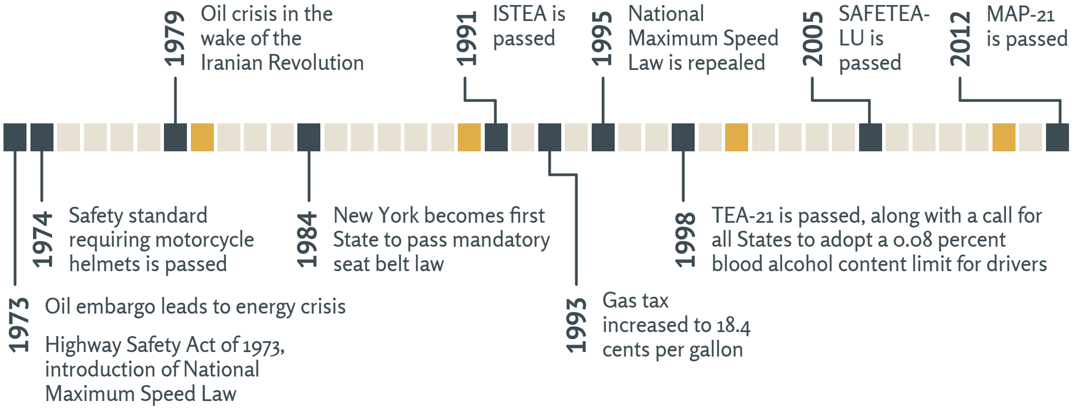
The percentage of alcohol in a person's blood, used to measure driver intoxication.

[24] http://www.history.com/this-day-in-history/federal-legislation-makes-airbags-mandatory

[25] Source: "TEA-21 – Transportation Equity Act for the 21st Century Fact Sheets," last modified April 5, 2011, accessed June 2, 2013, http://www.fhwa.dot.gov/tea21/factsheets/index.htm

[26] Rodriguez-Iglesias, C.; Wiliszowski, CIH.; Lacey, J.H. Legislative History of .08 Per Se Laws, National Highway Traffic Safety Administration, Report No. DOT HS 809 286, June 2001

[27] http://www.ghsa.org/html/stateinfo/laws/impaired_laws.html



Legislation in the 21st Century

Twenty-first century legislation continued to move Federal transportation funding and policy in the direction of focusing on multimodal, data-driven approaches to improving the transportation system. One specific area of focus was a move toward safety planning. Transportation safety planning shifts the focus of traditional planning efforts to a more comprehensive process that integrates safety into transportation decision-making. Safety planning encompasses corridors and entire transportation networks at the local, regional, and State levels, as well as specific sites.[28]

In 2005, Congress passed the Safe, Accountable, Flexible, and Efficient Transportation Equity Act—A Legacy for Users (SAFETEA-LU). SAFETEA-LU raised the stature of Federal road safety programs by establishing the Highway Safety Improvement Program (HSIP) as a core Federal-aid program tied to strategic safety planning and performance. HSIP is one of six core Federal-aid programs under which funds are apportioned directly to the States. One of the major elements of the HSIP was the requirement for each State to develop and implement a Strategic Highway Safety Plan (SHSP).[29] The plans sought to establish data-driven approaches that were coordinated with a broad range of stakeholders and utilized a diverse set of disciplines (e.g., engineering, enforcement, education and emergency response). These data-driven plans had to include clear methods for measuring progress toward safety goals.

The Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law in 2012. The 2012 legislation transformed the policy and programmatic framework for investments in the country's transportation infrastructure, enhancing the programs and policies established in 1991.

MAP-21 doubled funding for road safety improvement projects, strengthened the linkage among modal safety programs and created a positive agenda to make significant progress in reducing highway fatalities and serious injuries. It provided increased focus on the importance of high quality data, transportation infrastructure and the safety of local streets.

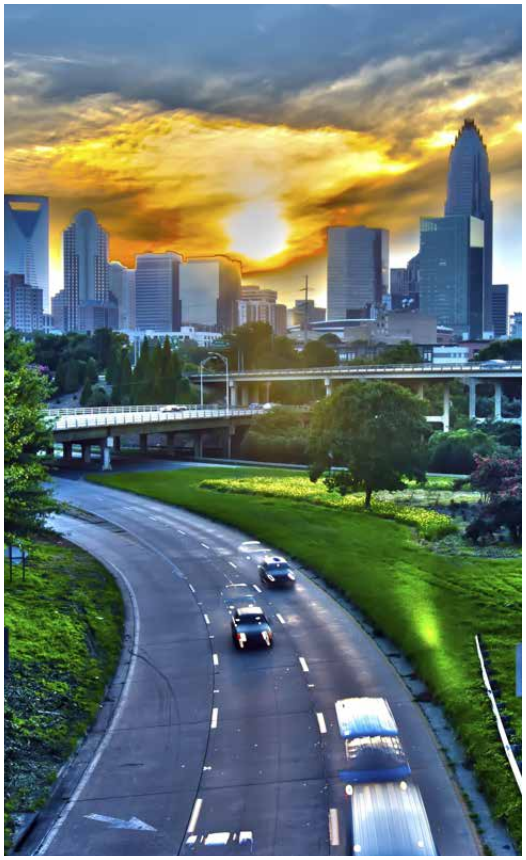
[28] Source: "Transportation Safety Planning (TSP)," accessed August 13, 2013, http://safety.fhwa.dot.gov/hsip/tsp/ and "Transportation Safety Planning Fact Sheet," accessed August 13, 2013, http://safety.fhwa.dot.gov/hsip/tsp/fact_sheet.cfm.

[29] Title 23 United States Code § 148

Conclusion

Exploring the history of travel trends and safety in the U.S. helps illustrate how past decisions have led to the transportation system seen today. Safety has not always been a deciding factor in how roads are built. However, today, safety is a top priority of the USDOT.[30] Most State and local transportation agencies share USDOT's goal; some have even set goals to reduce total traffic fatalities to zero. These "vision zero" and "toward zero deaths" goals are guiding transportation projects by requiring safety to be incorporated into every step of project planning, design, construction and operation.

Future safety issues will certainly arise as technological advancements lead to changes in the vehicle fleet. Autonomous and potentially driverless vehicles are being developed and tested across the world. Though safety improvements are touted as a benefit of these advanced vehicles, safety will continue to be a priority as they begin to share the roads with older vehicles, bicyclists, and pedestrians. As can be learned from the history of road safety in the U.S., complex problems must be met with safety advancements, legislative action, and collaboration.



EXERCISES

- **RESEARCH** a federal transportation law addressed in this chapter and write a summary about the law, emphasizing the safety aspects.
- **FIND** a recent news article that involves road safety (more than just a local news article on a recent crash) and write a summary describing the effort undertaken by the public agency, how it was received by the public, and whether it was shown to be effective in increasing road safety.
- **USE** https://www.govtrack.us to find a transportation bill currently proposed or under review by Congress. Describe how the legislation would be expected to affect road safety.
- **RESEARCH** the legal driving Blood Alcohol Content (BAC) by state in the U.S. and create a table showing the comparison. Select one state where the legal BAC is lower than the federal requirement, locate a paper or news article describing how that BAC level was decided, and write a summary.

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[30] U.S. Department of Transportation. Strategic Plans. November 2015. https://www.transportation.gov/mission/budget/dot-budget-and-performance-documents#StrategicPlans

Multidisciplinary Approaches

Road safety is a complex issue, and any efforts to improve safety must address not only the roadway but also road user behavior, vehicle design, interaction between road users, and the effect of the roadway on all road users. Road safety partners include anyone who influences road user safety, including those in infrastructure safety, behavioral roadway safety, transportation planning, public health, public safety and many other disciplines. Each of these disciplines is able to provide a unique perspective and each has specific methods for addressing road safety. It is becoming increasingly common for these various disciplines to work in collaboration with one another to address road safety through comprehensive programs. Instead of focusing on traditional "silos" of activity, agencies hope that this interaction and collaboration among various disciplines will lead to continued safety improvements.

The E's

A popular multidisciplinary approach to road safety is sometimes referred to as the "four E's": Engineering, Education, Enforcement, and Emergency response. These E's broadly represent the various disciplines that bring together stakeholders who care about making the road safe for all users. Sometimes a fifth "E" for evaluation is added to this list to represent the important role of evaluating what works and what doesn't. This emphasizes the fact that good data is crucial to the improvement of road safety.

This chapter will discuss road safety efforts from the disciplines of roadway design and engineering, public education, and enforcement campaigns. Working in collaboration with one another, as described above, these groups can share the burden of road safety responsibilities and create comprehensive programs to address the various factors that may contribute to crashes.

Roadway Design and Engineering

Several types of transportation professionals are responsible for roadway safety engineering. Broadly speaking, the roadway safety engineering community includes transportation planners and engineers.

Transportation planning plays a critical role in determining the shape of the transportation system and provides an early opportunity for professionals to address safety needs. Before a road project is designed or built, it is influenced by any number of comprehensive and strategic transportation plans that are coordinated to ensure that the system being developed is one that matches the vision of the local community. Planners work with stakeholders such as the general public, business owners, policy makers, and advocates to establish plans for how the transportation system can best serve every group's needs.

In the past, the traditional planning process focused on economic development, environmental quality, and mobility as the three primary concerns. Most States consider infrastructure safety improvements as part of preservation or improvements projects or within operational changes undertaken by traffic offices. States are now able to use the Highway Safety Improvement Program (HSIP) to fund safety projects in at high priority locations. This program allows development of targeted solutions and approaches that address the contributing factors to collisions, thereby seeking to achieve a higher return on safety investments.

Roadway engineers work on the design, construction and system preservation of the roadways. In particular, engineers are charged with designing roads that minimize the chance that crashes will occur while balancing the needs for efficiency and mobility. Engineers also work to design roads and intersection in such a way that minimizes crash severity and injury risk when crashes do occur. Engineers affect the safety of the built environment by incorporating safety in to the planning process at the beginning of a project; selecting design alternatives that prioritize safety considerations; using design elements that maximize the safety of each part of the road or intersection; ensuring quality and safe construction, operation, and maintenance of the roads; and addressing safety problems at existing locations.

Infrastructure improvements such as paved shoulders, rumble strips, and improved nighttime visibility may prevent drivers from veering off the roadway, and still other opportunities exist for improving the roadside and road user behavior. For example, when a driver veers off the roadway, it is important to provide a roadside environment that reduces the potential for crashes and injury. Roadside slopes and objects such as drainage structures, trees, and utility poles are examples of roadside elements that engineers can target for improvements to road safety performance. One engineering method to increase roadside safety is to create a clear zone—an unobstructed, traversable roadside area that allows a driver to stop safely or regain control of the vehicle that has left the roadway.

[31] Countermeasures that Work: A Highway safety Countermeasures Guide for State Highway Safety Offices, 7th edition, 2013 DOT HS 811 727

Countermeasures That Work

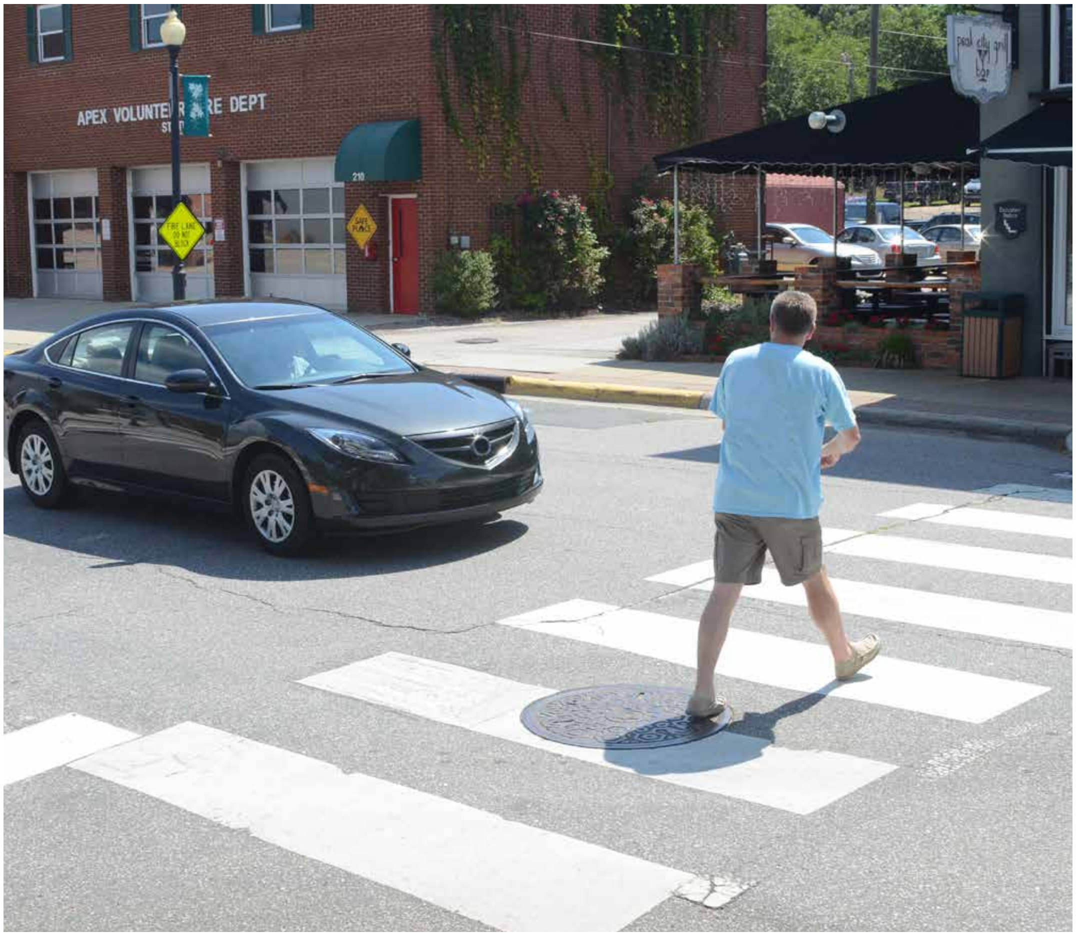
Countermeasures That Work[31] is a comprehensive guidance document providing details of different programs and interventions that are effective in improving safety. The guide is published regularly by NHTSA.

Engineering solutions must incorporate the different needs and preferences of a variety of user groups. As mentioned previously, this often means that tough decisions and trade-offs must be made to arrive at infrastructure solutions that balance the needs of different users. This trade-off can be illustrated with an example of a signalized intersection. Improving intersection safety for pedestrians may involve adding pedestrian crossing time to the signal or separating turn movements to eliminate high risk conflicts. Protected left-turn phases can also improve safety for vehicles, as shown previously. But these new or longer signal phases either add time to the cycle length or keep the same length while reducing time for the through movements. Regardless, the result is more delay to both pedestrians and motorists. In such situations, it is necessary to consider all of these needs and select the appropriate signal timing that meets the needs of all users. Adhering to design standards – creating nominally safe conditions – is only one aspect of the complex roadway design and engineering field. Addressing substantive safety through design strategies requires an understanding of multiple perspectives, trade-offs and user needs.

Public Education and Enforcement Campaigns

Public education and communications campaigns are commonly used to improve road user attitudes and awareness. The structure and delivery methods of these campaigns can take many forms. However, they generally involve materials (media advertisements, informational brochures, posters, presentations, etc.) to inform people of a desired behavior and the benefits of such behavior (or conversely, the risks of an unwanted behavior).

While standalone informational or educational campaigns can improve awareness or perceptions about road safety issues, they are unlikely to change road user behavior. Rather, campaigns that educate the public about increased law enforcement efforts aimed at a particular behavior have been shown to be effective. Generally referred to as "high-visibility enforcement" these campaigns increase the perceived enforcement of a particular law. When people believe there is a high probability of being caught, they are more likely to follow the law. The Click it or Ticket campaign is one of the most widely known examples of high-visibility enforcement. In this case, simply enforcing the seatbelt law was not sufficient. The key to this program's success was the media coverage and other informational campaigns telling the public that law enforcement officers are looking for people who are not wearing a seatbelt. In other words, for those people who do not typically wear a seatbelt, the law itself was not sufficient motivation to change. The motivation came from a



perceived threat of being caught and ticketed.

When safety professionals analyze possible educational campaigns, they must consider the factors that affect people's behavior and the probability that the campaign will change such behavior. Simply communicating safety messages and enforcing laws may not lead to a change in behavior if a road is designed in a way that allows (or unintentionally encourages) unsafe behaviors. For example, to address a speeding problem on a wide multilane arterial where the posted speed is 35 miles per hour, enforcement and education may not be the only solution. Narrowing the roadway and creating more "visual friction" along the roadside may be needed to alter the desired design speed of the road. Supplemental education and enforcement campaigns can then help reinforce the proper behavior. This emphasizes the need for cooperation and coordination between disciplines to accomplish

Targeted Enforcement

To reinforce pedestrian safety laws, police departments can initiate targeted enforcement operations at crosswalks. Under this approach, a law enforcement officer in plain clothes will attempt to cross the street at an uncontrolled crosswalk. Drivers who do not yield to the officer will be pulled over and either cited or warned by patrol vehicles waiting beyond the crosswalk. More info: http://www.nhtsa.gov/staticfiles/nti/pdf/812059-PedestrianSafetyEnforceOperaHowToGuide.pdf meaningful improvements to road safety.

While there is evidence to suggest some success for well-designed and executed safety education campaigns when they are targeted at children,[32] the same results have not been shown for teens and adults when an educational campaign stands alone. Though well-intentioned, these approaches generally assume that people are not performing the desired behavior simply because they lack the appropriate information. However, this idea fails to take into account the fact that, in general, most human behavior is not the result of conscious, rational deliberation. People are largely influenced by emotions, values, social context, and culture, among many other factors. Thus, simply being presented with information or facts alone is unlikely to lead to any lasting behavior change. In the context of transportation safety, most people do not engage in risky or undesirable behaviors due to a lack of knowledge about the desired behavior. Instead, people act based on a variety of contributing factors.

For example, consider the behavior of a pedestrian on a multi-lane undivided arterial. The goal of the pedestrian is to get to a bus stop located directly across the street from his current location. The pedestrian almost certainly knows that the desired behavior is to walk a quarter mile to the signalized intersection, wait and cross with the crossing signal, and then to backtrack a quarter mile to the bus station. However, instead the pedestrian chooses to cross in the middle of the block. The fact is that there are many factors that influence the pedestrian's decision to cross mid-block (time, ability, weather, etc.), but likely the most important factor is that doing so just makes sense. People are wired to choose the option that makes the most intuitive sense. Efforts to change this behavior only through signs, posters or other educational campaigns will likely have only minimal effect.

Similar examples can be found throughout the transportation safety field. Most people already know they should wear their seatbelt, obey posted speed limit signs, and limit distractions while driving. Yet some people refuse to wear a seatbelt,

Bicycle Safer Journey

Bicycle Safer Journey is an educational program intended to provide bicycle safety skills and education to children. The program uses interactive video lessons to teach children safe bicycling skills and provides resources for parents and teachers. The program can be accessed online at http://www.pedbikeinfo.org/bicyclesaferjourney.

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[32] Zegeer, C. V., Blomberg, R. D., Henderson, D., Masten, S. V., Marchetti, L., Levy, M. M., Fan, Y., Sandt, L. S., Brown, A., Stutts, J., & Thomas, L. J. (2008b). Evaluation of Miami–Dade pedestrian safety demonstration project. Transportation Research Record 2073, 1-10.

Click It or Ticket

Click It or Ticket is a successful seat belt enforcement campaign that has helped to increase the national seat belt usage rate. The program uses public education to communicate the law and risks of not using seat belts in a variety of settings. The campaigns provide waves of education and enforcement along with high visibility media coverage to publicize and sustain the campaign. NHTSA manages this campaign annually with assistance from the State Highway Safety offices, law enforcement agencies, and national- and local-paid advertising.

some people speed, and some people text while driving. Knowledge alone is not enough.

Successful education and enforcement campaigns recognize the reality of people's behaviors and apply this knowledge to the safety efforts. For example, social norms and cultural influences can provide some explanation for why certain behaviors are common – even those behaviors known to be unsafe. Marketing interventions based on social norms have been applied to the areas of distracted driving and driving under the influence of alcohol. Such methods provide a way to examine safety problems and

Media Campaign Effectiveness

Well planned and executed media campaigns centered on reducing alcohol-impaired driving can be effective in reducing the occurrence of alcohol related crashes. A study in 2004 pointed to a 13 percent decrease in alcohol related crashes following these types of campaigns.[33]

[33] Elder, R.W., et al. Effectiveness of mass media campaigns for reducing drinking and driving and alcohol-involved crashes: a systematic review. July 2004. http://www.sciencedirect.com/science/article/pii/S0749379704000467

what might be done to address them through education and enforcement.

Comprehensive Safety Programs

While each discipline has its own strengths, significant improvements in roadway safety are more likely when a program encompasses many disciplines rather than just one. Interdisciplinary team efforts can take on safety problems using multiple approaches and are therefore greater in scope than individual disciplines working in isolation. The need for this "multiple approach" solution requires collaboration among many parties. This type of collaboration is most clearly seen when agencies seek to create a comprehensive safety plan. Creating a comprehensive safety plan for a city, county, or state must be a data driven process. In doing so, agencies first begin by analyzing their safety data to identify emphasis areas where concentrated efforts are likely to yield the largest reduction in fatalities and serious injuries.

A State's **Strategic Highway Safety Plan** (SHSP) is an example of a comprehensive safety plan, and one of the best examples of a multi-disciplinary, data driven planning effort. A State SHSP provides a framework for developing a coordinated and comprehensive approach to addressing road safety across a State. In the development of a State's SHSP, safety stakeholders from across the State and across disciplines will consider all the data available (i.e., crash, injury surveillance, roadway and traffic, vehicle, enforcement, and driver data) that will help an agency understand where more safety emphasis is needed.[34] Beyond crash records, an agency may choose to rely on alternate data sources like roadway characteristics and its own knowledge of crash risk to pursue systemic safety strategies. A systemic approach proactively identifies locations that may have a high risk of crashes but where the risk has not yet resulted in actual crashes.[35]

Strategic Highway Safety Plan

Provides a framework for developing a coordinated and comprehensive approach to addressing road safety across a State.

[34] https://safety.fhwa.dot.gov/shsp/guidebook/

[35] http://safety.fhwa.dot.gov/systemic

Demographic data showing where population growth has occurred, or where it is expected, can also influence an agency's safety plans. One of the most critical components of the SHSP is an evaluation of past efforts, so that the agency can know what strategies are working and so that progress toward goals can be measured and tracked over time.

Road safety planning, like the field of safety itself, is multidisciplinary in nature and relies upon the expertise and involvement of numerous perspectives. Once developed, these safety plans influence activities ranging from roadway design and engineering to law enforcement and safety education.

Each of the agencies and organizations involved in transportation safety brings a unique and valuable perspective to bear on the roadway safety problem. Their competing philosophies, worldviews and problem solving approaches, however, can make collaboration difficult. Creating a foundation for effective collaboration and establishing a process to support collaborative efforts are two ways to overcome these barriers. One way to create a foundation for collaboration is to ensure that each agency understands the impact that its actions have on road safety and that each makes safety its top priority. The example of a State Strategic Highway Safety Plan shows this type of collaboration. The SHSP process brings together all potential areas of safety emphasis, including intersections, non-motorized users, rural crashes, and others, and uses a data driven approach to identify priorities and areas of need. This foundation can be further strengthened by identifying which agencies or organizations are responsible for implementing each of the strategies identified in the SHSP.

In the U.S., no single player manages all programs and disciplines that impact road safety. Therefore, collaboration among all players is fundamental to consistently reduce serious injuries and fatalities.

EXERCISES

- **FIND** the website for your State or local road safety program. Identify initiatives that your State or local agency is implementing in the areas of planning, engineering, education, and enforcement.
- **CONSIDER** a hypothetical situation where it is your job to convene a team of professionals to visit a high crash intersection and explore possible solutions to the safety problem. Create a list of the people who should be included on that team and briefly describe each person's role. Be sure to consider the many different types of programs and strategies that can be used to improve road safety.
- **SELECT** an area of concern, either a specific type of road user or an unsafe behavior, and discuss how road safety in this topic area could be addressed or improved through multiple disciplines. Possible topics include:
  - Older drivers
  - Underage drinking
  - Fatigued or drowsy driving
  - Pedestrians

Road Users

Drivers of motor vehicles are far from the only users of the road, despite accounting for the majority of trips taken in the U.S. The public right-of-way on most roads is usually shared by a number of different users, traveling by a variety of modes for any number of different reasons. Transportation professionals must understand the mobility and safety needs of different user groups and how they interact with one another to gain a better understanding of safety problems and their potential solutions.

Road user groups include:

- Passenger vehicle drivers and occupants
- Drivers of trucks and other large vehicles
- Motorcyclists
- Pedestrians
- Bicyclists

Passenger Vehicle Drivers and Occupants

Passenger vehicles are typically defined as sedans, pickup trucks, minivans, and sport utility vehicles and represent the primary mode of transportation for the majority of Americans. Since these vehicles account for the vast majority of registered vehicles and vehicle miles traveled, it is not surprising that much of the transportation infrastructure prioritizes the needs of these drivers.

However, despite the priority given to drivers of passenger vehicle, there remain many unresolved safety issues for these drivers. At the core of most of these issues are the driver's actions while navigating the road network. Engineers may work to make a road nominally safe by ensuring it follows the latest recommendations and design standards. However, drivers do not always interact with the road system as road designers expect them to. Thus, a nominally safe road may be much less safe in a substantive sense. While the common reaction has been to assume that some fault or "driver error" led to the crash, this approach fails to take into account a common behavioral principle known as behavioral adaptation. Simply put, behavioral adaptation refers to the unconscious process by which people react to their environment -- people cannot be considered to be a constant in the system.

Consider a town that wants to resurface and widen a two-lane collector roadway through an older neighborhood with mature street trees. The existing road has 9.5 foot wide lanes, a 30 mi/h (48 ki/h) speed limit, and street trees between the roadway and sidewalk. Design guidance may suggest a typical lane width of 12 feet and a wider roadside clear zone. It is easy to assume that the safest choice would be to design a road with the widest lanes possible and removal

The intended speed of this road is 35 miles per hour, but the wide design of the road and the number of lanes leads drivers to drive much faster.

of the roadside hazards. However, after this resurfacing and widening project was completed, both traffic speeds and crash severity along this roadway may increase considerably. On the surface, this may seem counterintuitive.

In essence, most people drive at a speed that *feels* safe to them. To reach this "safe speed," people unconsciously assess the roadway and its characteristics. Navigating a narrow, curvy road with significant roadside hazards is more challenging than navigating a straight, wide road with large clear zones, so people unconsciously drive slower and more cautiously on the narrow road. When the driving task is made easier by widening the lanes and removing roadside hazards, people will not maintain their original behavior. In fact, the assumption should be that people will adapt to this change and unconsciously change their behavior accordingly, in this case by increasing their speed.

Behavioral adaptation is not specific to passenger vehicles. When designing the transportation infrastructure, engineers must consider how human behavior plays affects all roadway users. Roadway designers must design roads not for the way in which they would like users to behave, but for the way in which users actually behave. Behavior of drivers and other road users will be covered in a greater detail in Unit 2.

Drivers of Trucks and Other Large Vehicles

Much of the transportation network across the country serves an important commercial need. Truck drivers, in particular, play a significant role in the national economy and are responsible for moving goods between and within cities and States. Large trucks account for only 4 percent of registered vehicles in the U.S., but they make up 9 percent of total vehicle miles traveled and accounted for 12 percent of total traffic fatalities in 2013.[36] These large trucks share space on the roads with passenger vehicles, and have their own safety needs. Nationally in 2013, there were just under 4,000 people killed in crashes involving large trucks, and 71 percent of them were occupants of the other vehicle involved in the crash. However, large truck safety has improved over time. Between 2004 and 2013, the miles covered by large trucks increased by roughly 25 percent, while fatalities involving large trucks decreased by about 20 percent (from 4,902 to 3,906).[37]

Commercial trucks are not the only large vehicles on the roads. Transit vehicles occupy space on our roadways as well, though they typically serve pedestrians and bicyclists. Transit vehicles that share space with passenger vehicles also have unique needs and challenges. Many of the safety issues associated with transit vehicles are similar to those of large trucks. Bus operators have to consider how stopping in traffic impacts the flow and operation of the transportation system, and must also consider the safety of their passengers boarding and disembarking the vehicle.

Road designs that accommodate large vehicles can sometimes be directly at odds with designs that favor pedestrians and bicyclists. For example, a pedestrian is more comfortable crossing an intersection if the turns are very tight, where the distance between corners in minimized to shorten the walking distance and decrease the time in the roadway. Large trucks and buses, however, require a larger turning radius (when compared to passenger vehicles) in order to turn safely. When designing intersections for large trucks, designers are tempted to increase the amount of space in an intersection and widen the corners. This change will make the turn easier, but it will also be more uncomfortable (and possibly less safe) for pedestrians. As described previously, these trade-offs need to be assessed and discussed when planning road projects.

Motorcyclists

In recent years, motorcycling has become increasingly popular throughout the U.S. Since 2000 the number of registered motorcycles in the U.S. has nearly doubled. [38] [39] The result was a 71% increase in the number of motorcyclist fatalities (from 2,897 in 2000 to 4,957 in 2012). Motorcyclists represented 15 percent of all traffic fatalities in 2012, compared to just 7 percent of fatalities in 2000. [40] Motorcyclists are significantly overrepresented in traffic fatalities since they account for only 3 percent of registered vehicles and 0.7 percent of total vehicle miles traveled in 2012.[41]

[36] [37] http://www-nrd.nhtsa.dot.gov/Pubs/812150.pdf

[38] http://www.fhwa.dot.gov/policyinformation/statistics/2013/pdf/mv1.pdf

[39] https://www.fhwa.dot.gov/ohim/hsoo/pdf/mv1.pdf

[40] http://www-fars.nhtsa.dot.gov/Main/index.aspx

[41] http://www-nrd.nhtsa.dot.gov/Pubs/812035.pdf

In general, many of the roadway modifications done to improve safety for passenger vehicles can pose a challenge for motorcyclists. Rumble strips can be difficult to traverse, especially at low speeds. Guard rails, in particular cable barriers, can present a serious hazard to a motorcyclist impacting one at a high speed. Within the driving environment, motorcyclists are small compared to larger vehicles and can be difficult to see, especially early or late in the day when lighting levels are lower.

Pedestrians

Walking is the most basic form of transportation. At some point during a typical day, nearly every person is a pedestrian. People walk to get to a bus station, to go from home to school, or to get from a parked vehicle to the front door of a business. Some walking trips are taken out of necessity – not all households own a vehicle, [42] and children and individuals with disabilities may not have the option to drive. Many more walking trips are taken by choice, especially for exercise or health. A 2012 survey found that 39 percent of trips taken by foot are done for exercise or personal health purposes. [43] Walking is also more common in densely populated urban areas, due to the close proximity of destinations and other services like transit stations.

Regardless of the reasons for walking, this mode accounts for nearly 11 percent of all trips taken in the U.S., according to the 2009 National Household Travel Survey (NHTS). [44] The NHTS shows that about a third of all trips taken in the U.S. are shorter than one mile, and 35 percent of these trips are taken by foot. In the 2005 Traveler Opinion and Perception Survey (TOP), conducted by FHWA, data showed that about 107.4 million Americans (51 percent of the traveling public) use walking as a regular mode of travel. [45]

Pedestrians (along with bicyclists) are among the most vulnerable road users, and this is reflected in crash data. The 4,743 pedestrians killed in 2012 represented 14.1 percent of total traffic fatalities in the U.S. that year. Between 2008 and 2012, motor vehicle fatalities decreased 13 percent, while pedestrian fatalities increased 8 percent. Within the population of pedestrians, there are certain groups which are especially vulnerable. These include young children, older adults, and individuals with disabilities.

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[42] https://info.ornl.gov/sites/publications/Files/Pub50854.pdf

[43] http://www.pedbikeinfo.org/data/factsheet_general.cfm

[44] http://www.pedbikeinfo.org/cms/downloads/15-year_report.pdf

[45] http://www.fhwa.dot.gov/reports/traveleropinions/1.htm

Before (left) and after (right) pictures of Stone Way North. *(Source: Seattle DOT)*

Road Diet

In 2008, Seattle Department of Transportation implemented a road diet on a 1.2-mile (1.9-kilometer) section of Stone Way North from N 34th Street to N 50th Street. In addition to serving motor vehicles, this segment of Stone Way North helps connect a bicycle path with a park. Within five blocks are eight schools, two libraries, and five parks.

The modified segment was originally a four-lane roadway carrying 13,000 vehicles per day. For this corridor, the city's 2007 bicycle master plan recommended climbing lanes and shared lane markings (previously known as "sharrows"). The cross section reduced the number of travel lanes to add bicycle lanes and parking on both sides. The resulting corridor saw a decrease in the 85th percentile speed, while the overall capacity remained relatively unchanged despite the reduction in the number of lanes. The number of bicyclists on the corridor increased by 35 percent, but crashes involving bicyclists did not increase. Pedestrian crashes declined by 80 percent following the project.

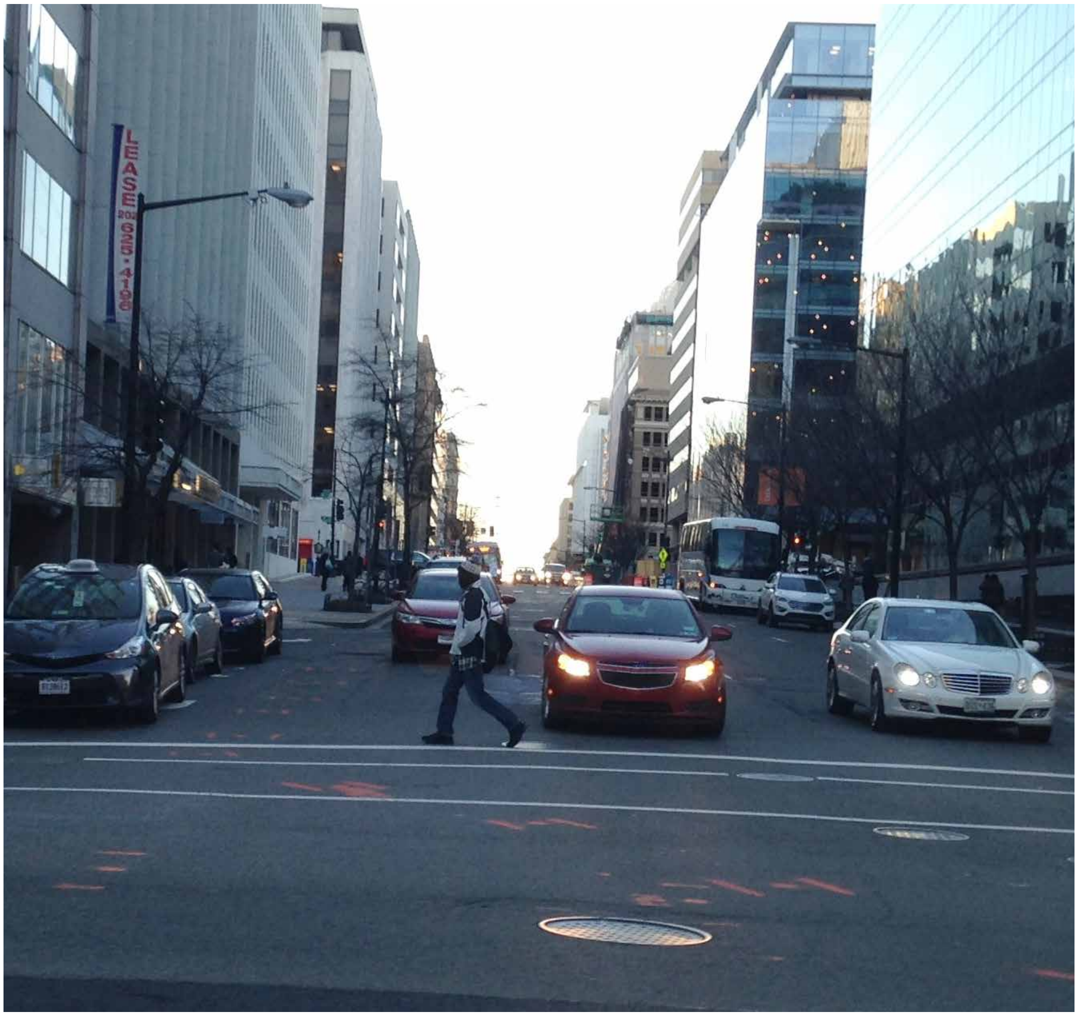
Summarized from a 2011 Public Roads article: http://www.fhwa.dot.gov/publications/publicroads/11septoct/05.cfm

Young children are a vulnerable road user group, and may be more likely than adults to rely on walking as a primary transportation mode – especially before they are old enough to drive. One area of concern is creating a safe environment for young children when they walk to school. Safety professionals need to ensure that sidewalks and street crossings have the appropriate measures to assist children in traveling safely, and educate children about safe walking.

Another vulnerable portion of the pedestrian population includes those who are blind or visually impaired. These pedestrians have increased challenges in navigating the road safely, particularly at street crossings. Challenges faced by a blind or visually impaired pedestrian include finding the appropriate crossing point at an intersection corner or midblock location, determining the appropriate time to cross, and crossing quickly and accurately. Both crossing and traversing a sloped sidewalk can be equally difficult for an individual in a wheelchair, where even slight cracks or bumps in the sidewalk can present major obstacles. The difficulties of these challenges increase at locations with unusual geometry, irregularly timed signals, or non-stop vehicle flow such as roundabouts and channelized turn lanes.

Older adults face many challenges as well. There are a number of age-related changes that affect the functional ability of older adults to safely walk and cross the street. These changes include diminished physical capability, sensory perception, cognitive skills and lag in reflexive responses. Eyesight deterioration can diminish an older person's ability to see and read guide signs, slow their reaction time and decrease their ability to gauge a vehicle's approaching speed or proximity. [46]

Drivers and pedestrians share responsibility for many pedestrian fatalities, as both parties attempt to navigate through the same space at the same time. Though we know that certain factors are likely to result in more severe pedestrian crashes, such as speed [47], no single cause stands out as the major contributor to pedestrian crashes. For this reason, no single countermeasure alone would likely make a substantial impact on the number of pedestrian crashes. A successful countermeasure program should use a mix of engineering, environmental, educational and enforcement measures to improve pedestrian safety. [48]



[46] Source: "Identifying Countermeasure Strategies to Increase Safety to Older Pedestrians," National Highway Traffic Safety Administration, 1.

[47] https://www.aaafoundation.org/sites/default/files/2011PedestrianRiskVsSpeed.pdf

[48] Source: "Identifying Countermeasure Strategies to Increase Safety to Older Pedestrians," National Highway Traffic Safety Administration, 36

Bicyclists

Bicyclists were some of the first users of U.S. roads, and the group that made the earliest push to improve road conditions. In recent years, bicycling has seen a rise in popularity for both recreation and transportation. Data from the 2009 NHTS showed that while only 1 percent of all trips are taken by bicycle, the number of bicycle trips doubled between 1990 and 2009.[49]

While bicyclists account for only 1 percent of all trips, the 726 bicyclist fatalities in 2012 represented 2 percent of all traffic fatalities that year.[50] While the number of bicyclists killed has risen only slightly since 2008, the decline in motor vehicle deaths means that bicyclists account for an increasing share of total traffic fatalities.

Bicyclists face unique challenges as road users. More often than not, bicyclists share space with motor vehicles and are considered legal users of the road in most locations. Many potential bicycle riders are not comfortable sharing the road with heavy vehicular traffic and may be deterred from riding their bicycles. Intersections can also pose a challenge to bicycle riders when they include high volumes of turning traffic and a large number of lanes. These barriers to bicycling, busy street segments and intersections, often discourage potential riders even when the rest of a bicycle network is comfortable. Many bicyclists are willing to go out of their way to use a route that has lower vehicle volumes and speeds, or bicycle facilities that are separated from traffic. Safe bicycle facilities can also improve connections to shopping, transit, jobs, schools, and essential services.

Conclusion

Successful road safety programs will consider the needs of all users when planning and developing transportation projects. Each user group plays an important role in the transportation system, and each has unique safety needs that safety professionals must consider. Road user decisions are influenced by a variety of factors, and the combinations of factors that result in particular travel behavior cannot easily be categorized or understood in simple terms.

EXERCISES

- **PROVIDE** an example of a road project where the changes resulted in improvements for one user group, but negatively impacted another group. This example could be hypothetical or based on a real world experience.
- **VISIT** the Fatality Analysis Reporting System (FARS) Encyclopedia home page (http://www-fars.nhtsa.dot.gov/Main/index.aspx). Use the data available for the most recent year to document fatality numbers for the different road user groups discussed in this chapter (e.g. motorists, pedestrians, bicyclists). What other information on road user safety can you find with the tools available in FARS, and what data is not included?

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[49] http://www.pedbikeinfo.org/cms/downloads/15-year_report.pdf

[50] http://www-nrd.nhtsa.dot.gov/Pubs/812018.pdf

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UNIT 2

Human Behavior and Road Safety

LEARNING OBJECTIVES

After reading the chapters and completing exercises in Unit 1, the reader will be able to:

- **EXPLAIN** the systems that drive human behavior and give examples of each
- **EXPLAIN** why it is important to consider the nature of human behavior when designing and implementing systems or programs

Understanding Human Behavior

Introduction

Guinea worm disease is a parasitic infection that occurs in remote parts of Africa. Symptoms of Guinea worm disease can be debilitating and lead to secondary infections, both of which can affect an infected person's ability to perform everyday tasks including working, harvesting food and caring for children. The disease is caused by drinking water contaminated with Guinea worm larvae. When a worm is mature, it creates a painful blister on the infected person's skin. If the person immerses the affected body part in water, it can temporarily relieve the pain from the blister. However, this also allows the worm to release eggs into the water, continuing the infection cycle by spreading the disease to others[1].

There were 3.5 million cases of Guinea worm disease throughout the world in 1986. By 2015, there were only 22 cases. In 30 years the disease has been nearly eradicated — the only human disease to be eradicated besides smallpox[2,3]. How were such large advances made in only 30 years, and what does this have to do with road safety?

Unlike smallpox, there are no known medicines or vaccines that prevent Guinea worm disease. Eradication, therefore, required a different approach: changing human behavior.

The Human Factor

A report from the National Cooperative Highway Research Program (NCHRP) defines "human factors" as follows:

Human factors is an applied, scientific discipline that tries to enhance the relationship between devices and systems, and the people who are meant to use them. As a discipline, human factors approaches system design with the "user" as its focal point. Human factors practitioners bring expert

[1] Cairncross, S., Muller, R., and Zagaria, N. (2002). Dracunculiasis (Guinea Worm Disease) and the Eradication Initiative. Clinical Microbiology Reviews, 223-246.

[2] World Health Organization and the Carter Center, Eradication of Guinea Worm Disease: Case Statement, 2016. Available at: https://www.cartercenter.org/resources/pdfs/health/guinea_worm/2016-gw-case-statement.pdf

[3] WHO, Dracunculiasis Fact Sheet. May 2016. Available at: http://www.who.int/mediacentre/factsheets/fs359/en/

knowledge concerning the capabilities and limitations of human beings that are important for the design of devices and systems of many kinds.[4]

In road safety, the term human factors is typically used to describe how people respond to the roadway environment. However, people are not simply users of the transportation system. Humans also design, engineer, build and maintain the roadway environment, the vehicles using it and the laws governing behavior of roadway users and vehicle manufacturers. In that sense, the entire transportation system is a product of human factors. The term human factors conveys an oversimplified notion of the role of human behavior in transportation safety. The human part of the equation is more complex than simply a list of discrete factors.

Key Principles of Human Behavior

To understand human behavior, it is important to bear in mind four key principles.

- Human behavior is guided by two different systems (deliberative and intuitive).
- Humans are not exclusively logical, rational beings.
- Human behavior is heavily influenced by the environment.
- Humans make mistakes.

Let's discuss these concepts as they relate to road safety.

Human behavior is guided by two different systems

Human behavior is largely guided by two different systems – a deliberate, rational system (deliberative) and an implicit, unconscious system (intuitive)[5].

The deliberative system is a conscious system wherein a person considers information using rational thought, logic and reasoning in deciding on an action.

For example:

When driving home after work, a driver decides to change routes to avoid an area that is usually congested at this time of day.

In this example, the driver considered the available information (time of day and previous experience with that location) and made a conscious decision to take another route.

The intuitive system is an implicit, unconscious process by which a person makes nearly instantaneous decisions and takes a resulting action.

For example:

As a driver approaches a signalized intersection, the light turns yellow. Without conscious thought, the driver either proceeds through the intersection or comes to a stop.

In this example, the driver receives information from the environment (the yellow light), combines it with an understanding of the specific circumstance based on the driver's previous experiences, and takes an action almost immediately. It is important to realize the intuitive system acts nearly instantaneously without the driver's awareness of the process.

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[4] John L. Campbell, Monica G. Lichty; et al. (2012). National Cooperative Highway Research Program Report 600: Human Factors Guidelines for Road Systems (Second Edition). Washington, D.C.: Transportation Research Board.

[5] Kahneman, D. (2011) Thinking, Fast and Slow. Farrar, Straus and Giroux

We often incorrectly assume that human behavior is largely controlled by the deliberative system when, in fact, most behaviors are a result of the intuitive system. In other words, most human behavior is not the result of conscious, rational deliberation. For most actions, we don't have enough time or available information to do a logical analysis before acting. The intuitive system allows us to act without this time-consuming conscious decision-making process.

To think of this another way, consider the deliberative system as similar to the decision making process of a computer. Computers function exclusively using a deliberative system. They take in information, process it using explicit algorithms and deliver a result. However, humans do not function this way. They generally make decisions that appear to reflect instinctual processes rather than systematic rational considerations.

Humans are not exclusively logical, rational beings

Although people take in and interpret information, they do so in the context of a number of factors, such as prior experience, emotions, cultural norms, moral beliefs, social pressures, convenience, habits and financial considerations, among many others. Rational calculations based on objective evidence are often not even possible, and when they are, they must compete with these other influences. This is why people often make decisions that are not necessarily the most appropriate choice for their health and well-being.

We know that cooking dinner at home may be healthier, but sometimes it is easier and more convenient to have a pizza delivered instead. We know we should exercise more and get the recommended amount of sleep each night, but work, family and other obligations

Flossing and human behavior

At some point in your life, you have probably been told that regular flossing is good for your dental health. Through the years, you've likely had conversations about flossing with your dentist or dental hygienist who encouraged you to floss more. Perhaps they showed you the proper way to floss and sent you home with your own floss in an effort to encourage you to start. For a few days or weeks after the appointment, you may have deliberately flossed more regularly. But if you're like most people, you soon reverted to old habits, and the floss sat unused in a cabinet. Why do we do this?

Typically, programs aimed at influencing human behavior take an educational or informational approach on the assumption that people act a certain way because they lack knowledge about the potential consequences, benefits or alternatives. Surely, if people simply were aware of the benefits of flossing or the consequences of not flossing, they would change their behavior and become regular flossers. This approach appeals to the belief that human behavior is rational.

Although commonly used, this approach fails to take into account the complexities of human behavior. Other factors influence our behaviors – flossing is inconvenient, takes time and can be uncomfortable. The negative consequences of not flossing (e.g., gum disease) are not immediately visible. Although people repeatedly hear messages explaining why flossing is important, rates of flossing among the general population remain low.

can make this difficult. We know we should get a flu shot, but a fear of needles may keep us away.

Humans are largely intuitive beings which means their actions are rarely the result of a systematic, rational decision making process. For years, many people did not brush their teeth daily, even though the benefits of brushing were widely known. It was not until mint flavoring was added to toothpaste that daily brushing became the norm. That is, information about the benefits of brushing did little to change behavior; what convinced people to brush was a desire for the clean feeling they associated with the mint.[6] Because the factors that affect human behavior are complex and interrelated, behavior is not easily changed. When attempting to change the behavior of others, we tend to assume that people are entirely logical and rational beings. However, experience repeatedly shows this is not the case.

This situation is not unique to dental hygiene. We regularly do things that we generally realize are not in our best interest. We don't eat the recommended amounts of fruits and vegetables. We don't get enough sleep. We don't exercise as much as we should. Think about examples from your own life.

Optical Speed Bars

Optical Speed Bars (OSBs) have shown promise in reducing vehicle speeds in advance of hazardous locations[7]. OSBs are a series of white rectangular markings, placed just inside both edges of the travel lane and spaced progressively closer, to create the illusion of increasing speed when traveling at a constant rate as well as the impression of a narrower lane[8]. A compelling characteristic of optical speed bars is that they operate on intuitive, rather than conscious, decisions made by drivers/riders. By creating a sense of increasing speed as riders approach a dangerous curve, they should induce riders to slow down – as an instinctive reaction rather than a conscious decision.

Human behavior is heavily influenced by the environment

Often the environment has a much stronger influence on a person's behavior than internal conditions (e.g., attitudes and personality) commonly assumed to be influential. The environment includes the physical environment, as well as social and organizational contexts, such as policies and social norms.

Given that most behavior is intuitive, people generally do not know the true reasons for their actions, nor can they validly articulate what might influence their actions. People can usually provide explanations for their behavior after the fact, but research shows people are often not aware of the strong influence of environmental factors on their behavior. An example in Unit 1 of this book describes a town that aims to resurface and widen a

[6] Duhigg, Charles. The Power of Habit: Why We Do What We Do in Life and Business

[7] Gates TJ, Qin X, Noyce DA. Effectiveness of Experimental Transverse-Bar Pavement Marking as Speed-Reduction Treatment on Freeway Curves. In Transportation Research Record: Journal of the Transportation Research Board, No. 2056, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 95–103.

[8] Federal Highway Administration. Engineering Countermeasures for Reducing Speeds: A Desktop Reference of Potential Effectiveness. http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/ch7.cfm.

Environment affects behavior

Research has shown that people are more likely to help another person (in a non-emergency situation) if they see someone else helping first. Social psychologist Robert Cialdini demonstrated this by counting donations given to a street musician with and without a colleague first modeling the behavior by donating money. He found that many more people gave the musician money when the behavior was modeled than in the control condition with no behavior modeling (eight donations in the modeled condition versus one donation in the control condition). Further, when people in the modeled condition were asked why they donated, no one realized that they had been influenced by the behavior of another person. Instead, they attributed their donations to something else, such as enjoyment of the song or how they felt about the person playing the music[9,10,11].

two-lane collector roadway through a neighborhood with mature trees. However, after completing the project, both speeds and crash severity increased. Behavioral adaptation refers to the unconscious process by which people react to their environment. While driving, people unconsciously assess the roadway and its characteristics and modify their behaviors accordingly.

This may seem counterintuitive, but as discussed, human behavior is an intuitive process that is heavily influenced by the environment. A wider road with limited roadside hazards feels safer and people unconsciously adapt their behavior accordingly. You should assume people would not maintain their original behavior when the driving environment is changed.

Roadway designers must design roads not for the way in which they would like users to behave, but for the way in which users actually will behave. In general, people don't just do what they are told to do — by a sign, a law or another person. Instead, they integrate information from many parts of their environment along with their own historical experience as they determine (usually non-consciously) what they should do in a given situation[12].

Humans make mistakes

Both our deliberative and intuitive systems can lead us to make mistakes. Actions reached by a deliberative process can be mistaken if we fail to consider all relevant information or if we process it incorrectly. Similarly, our intuitive system can lead to errors in situations with which we have little or no experience. Experience helps to refine the intuitive processes, so the likelihood of mistakes declines with exposure to situations. However, mistakes are inevitable and the transportation infrastructure needs to be designed with the recognition that road users will make mistakes and that they will often make them in predictable ways.

Have you ever looked down at your speedometer and realized that you were driving substantially over the speed limit? You probably didn't make a conscious (deliberative) decision to exceed the speed limit. Instead, you reached that speed by taking cues about the proper speed from your environment (intuitive). Characteristics of the road, such as wide lanes, multiple travel lanes,

[9] Cialdini. R.B. (20005). Basic Social Influence Is Underestimated. Psychological Inquiry, 16: 158-161

[10] Cialdini, R.B., Demaine, L.J., Sagarin, B.J., Barrett, D.W., Rhoads, K., & Winter, P.L. (2006). Managing social norms for persuasive impact. Social Influence, 1: 3-15

[11] Cialdini, R.B. (2007). Descriptive social norms as underappreciated sources of social control. Psychometrika, 72: 263-268

[12] Etzioni, Amitai. Human Beings Are Not Very Easy To Change After All, Saturday Review, June, 1972.

FIGURE 2-1: Example of unconscious clues leading to higher speed

presence of a median and long gentle curves, convey the message that the road can accommodate high speeds. Additionally, the speed of other vehicles is a particularly salient indicator of the right speed.

Recall this example from Unit 1 (Figure 1–1). Although the posted speed limit is 35 mph, many people drive much faster than that. This is not because they all have a blatant disregard for safety. Instead, they are unconsciously taking cues from their environment, which is telling them it is safe to travel at a higher speed. Add to this the fact that modern vehicles have been engineered for occupant comfort, so many of the auditory and haptic cues (e.g., wind noise, bumps, road noise, etc.) that previously gave drivers feedback about their speed have been eliminated. On a road with very few other vehicles, the only clear clue to one's speed is the speedometer.

Roads constructed according to the recommended design standards may be considered safe, but in reality, they may only be nominally safe. The fact that some road designs encourage higher speeds can make it substantively unsafe. The transportation system is designed, built, maintained, governed and used by humans. It is often cited that human error contributes to more than 90% of traffic crashes, most often referring to a road user error. However, it is important to remember that errors by road users are not the only human errors that can occur.

For example:

On a rural two–lane road, an SUV

driver over-compensates when a tire slips off the roadway causing the vehicle to roll over and strike a tree on the opposite side of the road.

Where was the human error in this example? Was it in the driver who didn't stay on the road and overcompensated with steering? Was the road maintained improperly or inadequately? Could the crash have been prevented if edgeline rumble strips had been installed, or if the road had a paved shoulder instead of a soft gravel shoulder? Should the tree next to the roadway have been removed? Could SUVs be designed so they are less susceptible to roll over? The answer is that a combination of several of these caused the crash, not simply the driver's error. Just as in airplane crashes, it is quite rare that any single factor in a motor vehicle crash was the sole reason for the crash or for its severity.

Meeting nominal safety does not guarantee that a crash will never occur, nor does it guarantee that users will behave in the intended way. Those in charge of the road should use professional judgement to prioritize safety improvements and select appropriate designs within a range of options based on consideration of road user behavior. Unit 3 discusses how many kinds of data, such as crash data and behavioral observation, can be used to evaluate the substantive safety of the road.

EXERCISES

- **MAKE** a list of your own driving behaviors. What behaviors involve the deliberative system? What behaviors are intuitive?
- **WORK** with your state department of transportation to identify a crash cluster in your area. It's highly unlikely that many drivers have independently made the same mistake at the same location. What characteristics of the roadway — as designed or built — may have contributed to this cluster of crashes? What modifications might be made that would not be offset by behavioral adaptation?

Changing Human Behavior

Let's return to the Guinea worm disease example. You may be wondering why something so seemingly unrelated to improving safety in a modern transportation system was used to introduce this unit. The fact that Guinea worm disease is nearly extinct in only 30 years is a tremendous achievement. The fact that it was done through behavior change alone, without the use of vaccines or medication, is unprecedented.

Road safety professionals would be wise to consider the successful approach to eradicate Guinea worm disease. Although the desired behaviors may be different, the general strategies for influencing human behavior are the same. Even though changing human behavior is exceedingly difficult, it is possible to achieve behavior change. However, this requires that we take into account the nature of human behavior instead of assuming that simply providing information is sufficient.

Understanding factors that influence human behavior

To change human behavior, it is important to identify and understand not only the target behavior but also any other factors that influence the behavior. Attempting to change a behavior without a full understanding of the many contributing factors will almost certainly fail.

FIGURE 2-2: Guinea worm disease hotspots in Africa

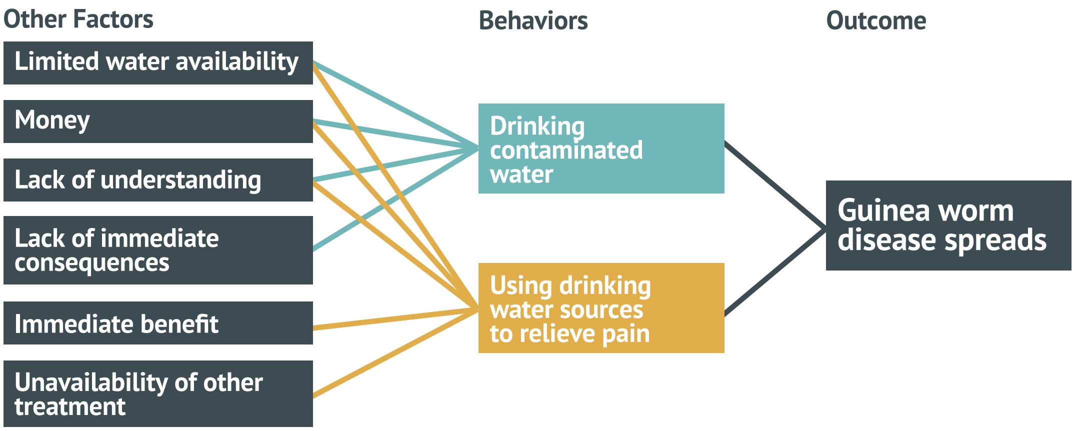


FIGURE 2-3: Guinea worm disease factors, behaviors and outcomes

Doctors knew that Guinea worm disease spreads by people drinking contaminated water, and contamination of the water supply occurred when an infected person used the water supply to temporarily relieve the symptoms of infection. Hence, the eradication campaign focused on two main behaviors:

- Drinking contaminated water
- Using drinking water sources to temporarily relieve the pain caused by the infection

Simply identifying these behaviors was not sufficient. In order to be successful, public health officials considered many other factors influencing these behaviors.

Why were people drinking contaminated water?

- **Availability** – Uncontaminated drinking water may not have been available in the community.
- **Money** – People and communities lacked financial resources to obtain clean drinking water.
- **Understanding** – People did not know that the water was contaminated and/or how the disease was transmitted.
- **Lack of immediate consequences** – Guinea worm disease symptoms did not appear until one year post-infection.

Why were people using drinking water to relieve the pain caused by the infection?

- **Immediate benefit** – Water submersion resulted in immediate pain relief.
- **Limited availability of water** – Because water is scarce, most water sources were used for drinking.
- **Unavailability of alternative treatments** – The lack of medical infrastructure meant limited access to treatment options.
- **Money** – People lacked financial resources to obtain medical treatment even when available.
- **Understanding** – People lacked knowledge about how the disease is transmitted.

A thorough understanding of the factors that influence behavior is necessary to develop a plan for behavior change.

To develop a plan, we cannot merely look for the cause of the outcome, instead we need to look for the weak links in the causal chain and intervene at these links. In the case of Guinea worm disease, the limited availability of water and lack of understanding about the disease and its transmission were factors influencing both behaviors. Thus, these factors were targeted in the intervention.

Public health officials informed the people about the dangers of drinking contaminated water and how the water was becoming contaminated. However, they knew that simply providing this information would not be sufficient.

In order to make the right behavior the easy choice, officials combined education with environmental change – they educated people on guinea worm disease and made clean water more accessible. Water sources known to be contaminated were treated to prevent transmission, and new clean water sources were created. When water sources could not be treated, villagers were given cloth filters to decontaminate their water before drinking. When people had access to clean water, they were less likely to drink contaminated water, thus significantly reducing the chance of infection[13]. This change to the environment (i.e., making clean water available) proved to be key in eliminating the disease.

While this is an oversimplified description of the complex and multifaceted approach that occurred over 30 years, it highlights what can be accomplished when principles of behavior change are at the core of a comprehensive approach.

Approaches to Changing Behavior

We are constantly exposed to attempts to influence our behavior. Consider the following things that you may encounter in everyday life:

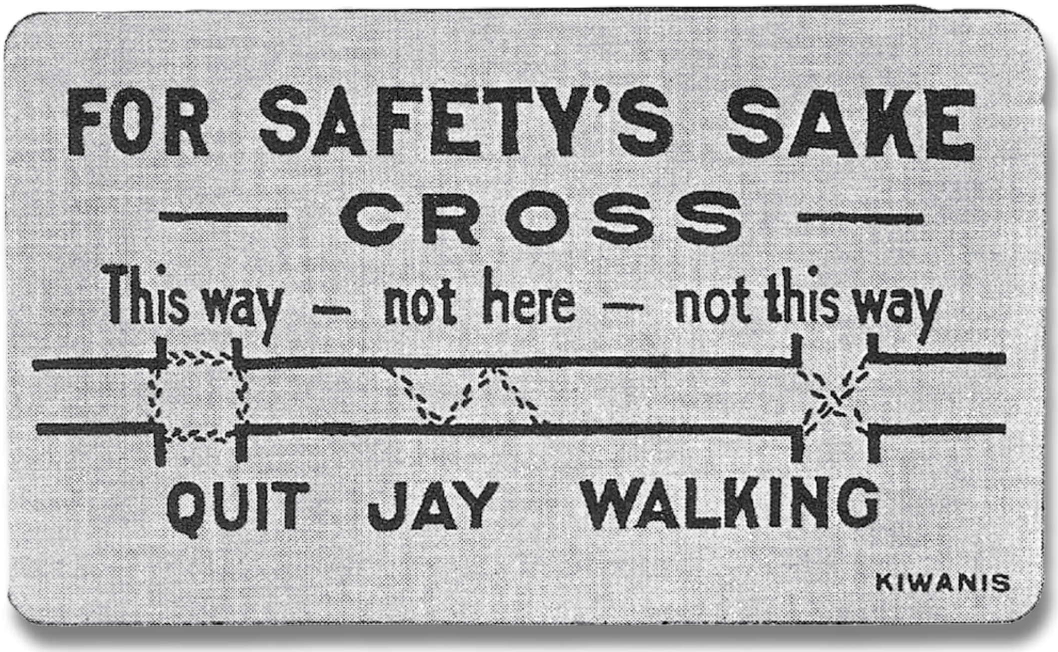
- A brochure in your doctor's office about the benefits of getting a flu shot
- A requirement that restaurants include nutritional information in their menu
- Stores that charge for plastic shopping bags
- Public service announcements (PSAs) about bullying
- Cities that provide large recycling bins and small garbage bins
- A law requiring that everyone wear seatbelts

Most of these attempts either provide information (e.g., a brochure with information about flu shots or a PSA detailing the negative impact of bullying), or they change the environment in such a way to encourage a different behavior (e.g., stores that charge for plastic shopping bags or cities that provide large recycling bins and small garbage bins). Understanding the nature of the problem is important in determining which approach has the best chance of success.

Education, safety messages and raising awareness

Education and awareness-raising campaigns are often the first and only tools tried when attempting to influence behavior. In general,

[13] Cairncross, S., Muller, R., and Zagaria, N. (2002). Dracunculiasis (Guinea Worm Disease) and the Eradication Initiative. Clinical Microbiology Reviews, 223-246.



This tip card from the early 1900s was likely ineffective in changing the crossing habits of people since it relied solely on providing information.

the goal of such campaigns is to communicate information with the assumption that once the audience is aware of the information, they will then act in the desired manner. In other words, educational campaigns appeal to the deliberative system and assume that human behavior is usually a product of rational thought. Because of this, information alone almost never works. However, information can be helpful as part of a more comprehensive program.

Far too often information-based approaches are used in isolation, without careful consideration of whether the problem can be effectively addressed through raising awareness alone. Is the information new to the audience? Is it likely that knowing this information will produce the desired outcome? To draw from a previous example: does simply knowing that you should floss convince you to floss regularly?

Consider the effect of an educational campaign on Guinea worm disease. Would an educational or awareness raising campaign be enough to produce lasting and consistent behavior change? On the one hand, there was a lack of knowledge about the disease among those affected, especially about how the disease was transmitted. However, this education cannot influence the additional — and likely more important — factors contributing to the problem. For example, education will not improve the availability of clean drinking water or access to alternative medical resources, nor will it provide the financial resources necessary to increase access to either. Thus, an education campaign, on its own, would not

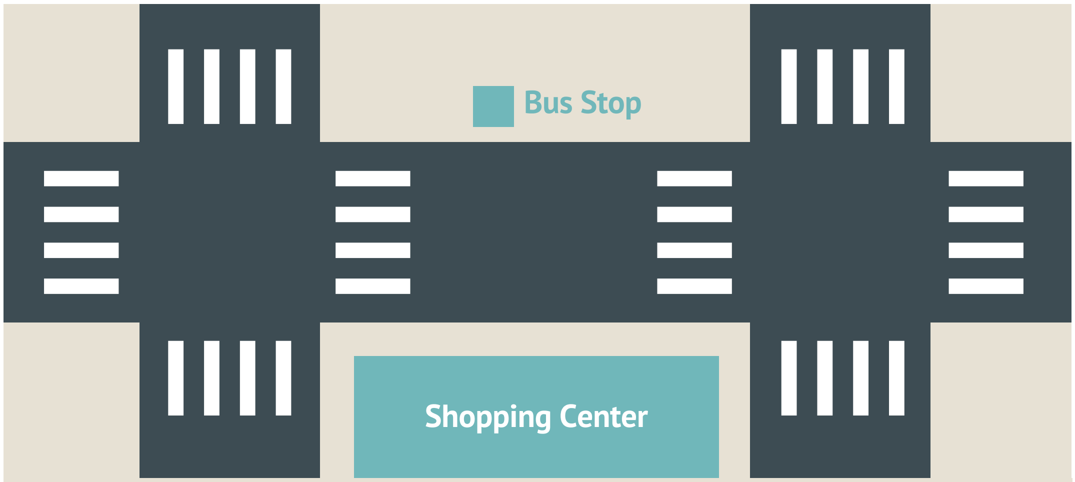


FIGURE 2-4: Example of shopping center and bus stop

have been a successful tactic. Instead, health officials needed a more comprehensive approach.

The same considerations can be applied to road safety problems. Consider the following example:

Your city manager notices an increase in pedestrian crashes following the placement of a new bus stop on Elm Street, a busy multi-lane road without a median. The bus stop is located in the middle of the block across from a large shopping center (Figure 2-4). The nearby intersections on either side are signalized and have street lights, crosswalks and pedestrian signals. The intersection and crosswalks meet all applicable design standards and are therefore nominally safe. Although city engineers intended that people would cross the street at the intersections, observations show that many people are crossing mid-block from the shopping center to the bus stop, resulting in frequent conflicts with vehicles. The city wants to improve safety in this area and has decided to undertake a media campaign encouraging people to cross only at crosswalks.

What behavior is being targeted?

Crossing Elm Street midblock.

What are the other factors influencing this behavior?

- **Convenience** – Crossing mid-block provides a more direct route to the bus stop. People coming from the shopping center are likely carrying shopping bags, which could be difficult to carry long distances.
- **Previous experience** – It is likely that people have successfully crossed similar streets (or even the same street) in this manner many other times, so their limited previous experience suggests this is a safe option. (we say limited experience because people not likely to be aware of the location's crash history).
- **Time pressure** – Buses run on a schedule, and people may want to cross as quickly as possible to be sure they catch the next bus.

Is an educational or awareness raising campaign targeting this behavior likely to be effective? No. In all likelihood, people who are crossing the street in this spot know there are crosswalks at the nearby intersections. They are crossing the street here because it is easier and more convenient, and their previous experiences tell them they will be successful. Additional information is unlikely to alter these factors; therefore an informational or awareness-raising campaign alone will not be effective. However, that does not mean that all hope is lost. Improving the safety of pedestrians crossing Elm Street is still possible with the right approach.

Changing the environment

A preferred alternative to education is changing the environment. We know that people act based on information gleaned from the world around them, and that most of our behavior is unconscious and driven by the intuitive system. By changing the environment, people can be moved towards the behavior of interest. In other words – if you can't change the person, change the world so that the person will follow.

We know that people are crossing Elm Street mid-block because it is quicker, easier and more convenient than using the crosswalks at the nearby intersections. Information or awareness campaigns are unlikely to influence this behavior because the behavior is not due to a lack of awareness or information. Instead, we need to change the environment so that the pedestrians are no longer crossing somewhere other than a marked crosswalk.

Possible changes to the environment include building a wall or putting up a fence to deter people from crossing at the mid-block, or building a pedestrian bridge to keep people out of the flow of traffic. These solutions might be cost prohibitive, and research shows that most pedestrians will still cross a street at ground level even when a pedestrian bridge is available.[14,15]

FIGURE 2-5: Pedestrian hybrid beacon (Source: pedbikeimages.org/Mike Cynecki)

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[14] Moore, R.L., Older, S.J., Pedestrians and Motors are Compatible in Today's World. Traffic Engineering, Institute of Transportation Engineers, Washington, DC, September, 1965.

[15] Rasanen, M, T. Lajunen, F. Alticafarbay, and C. Aydin, Pedestrian Self Reports of Factors Influencing the Use of Pedestrian Bridges, Accident Analysis and Prevention, 39, pp. 969-973, 2007.

Another approach would be to move the bus stop closer to the existing crosswalks, assuming people will choose to cross at the crosswalk since it is now more convenient. Finally, another alternative would be to install a marked crosswalk with a pedestrian hybrid beacon close to the area where people are crossing (Figure 2-5). This solution recognizes the factors influencing people's behavior and provides an alternative that would improve safety and be acceptable to pedestrians.

We know that people respond in predictable ways to their environments — far more than to internal conditions like attitudes and personality. Environment can include both the physical (built) environment and things like policies, laws and social norms. Let's revisit the speeding example from earlier in the unit (Figure 2-1). Although the posted speed limit is 35 mph, in reality many people drive much faster than that. What might we do to get drivers to slow down on this road? One option is to post additional speed limit signs or run local PSAs about the dangers of speeding. However, consider whether informational signs would result in lower speeds. Are drivers speeding because they are not aware of the speed limit? Are drivers unaware of the potential dangers of high speeds? The answer to both of these questions is "not likely."

One example of environmental change to reduce driver speed is the use of traffic calming measures. Features such as speed humps and mini roundabouts are examples of physical alterations to the driving environment that influence how road users respond. In the previous speeding example, the overall design of the road has already been established, but the lanes could be narrowed or even reduced to one in each direction to communicate, "This is a road where you should drive slower." Traffic calming addresses the intuitive system in that it results in drivers slowing down

Seat belt usage in the United States

Seat belt use in the United States has a remarkably similar, though opposite trajectory to that of Guinea worm disease. Though seatbelts were required in U.S. vehicles starting in the late 1960s, use of this equipment was low. Observational surveys from the early to mid-1980s found use of 5-14 percent.[16] By 2015, however, observed seatbelt use had climbed to 88.5 percent.[17]

As with Guinea worm disease, no single effort was responsible for increasing seat belt use in the United States. Instead, efforts that focused on changing the environment (e.g., enactment of seat belt and child passenger safety laws) were coupled with high visibility enforcement (e.g., Click-it-or-Ticket). Education played a role in these efforts, but not in raising awareness for the dangers of not wearing seat belts. Rather, education was needed to inform people that belt use is required and, especially, to create the perception among the driving public that police were actively enforcing seat belt laws.

[16] Tison, J. & Williams, A.F. (2012). Analyzing the First Years of the Click It or Ticket Mobilizations (DOT HS 811 232). Washington, D.C.: National Highway Traffic Safety Administration.

[17] Pickrell, T. M., & Li, R. (2016, February). Seat Belt Use in 2015—OverallResults (Traffic Safety Facts Research Note. Report No. DOT HS 812 243). Washington, DC: National Highway Traffic Safety Administration.

without being aware of doing so.[18]

Consider behavior in addressing travel safety

Making strides in road safety is possible. However, as with the near eradication of Guinea worm disease, significant achievements will not happen overnight. When implementing a program or intervention aimed at changing behavior, it is important to remember that any road safety issue is likely the result of a combination of factors. Consequently, it is unlikely that any one program or intervention will completely solve the problem. However, combining behavioral science principles with engineering design can help to produce significant advances. See Unit 4 for a discussion of how to identify and address road safety problems.

Conclusion

In short, human behavior is extraordinarily complex. Consequently, it is difficult to influence. Simple, common sense approaches like merely raising awareness or otherwise providing information about an issue virtually never succeed.

Humans are not exclusively logical, rational beings.

We often assume human behavior is controlled by a logical deliberative process when, in fact, most behaviors are a result of an intuitive process. Many factors influence behavior including education, emotions, cultural norms, religious beliefs, social pressures, convenience, habits and finances. Understanding human behavior and the many factors that influence behavior is crucial to solving safety problems.

People generally don't simply do what they are told to do.

Information and awareness-raising campaigns are often the first tools used in efforts to influence behavior. However, these approaches are too often adopted without careful consideration of whether the behavior is likely to be changed merely with information (which the public often already has).

The environment heavily influences human behaviors. We are constantly processing information and adjusting our behaviors accordingly. Most of this behavior is unconscious and driven by the intuitive system.

Changing behavior requires an understanding of all influencing factors.

Before attempting to influence behavior, it is essential to identify and understand the important factors influencing a behavior. Targeting a behavior without a full understanding of these factors will almost certainly be unsuccessful.

Because so much of what we do is intuitive and heavily influenced by our environment, we sometimes respond to the transportation infrastructure in ways not anticipated by the engineers who designed it. By changing the environment, people can be nudged towards the behavior of interest.[19] In other words, if you can't change the person (and you usually can't!), change the world so that the person will follow.

[18] Lewis-Evans, B. & Charlton, S.G. (2006), Explicit and implicit processes in behavioural adaptation to road width. Accident Analysis & Prevention, 38, 610-617.

[19] Thaler, R.H., and Sunstein, C.R. Nudge: Improving Decisions About Health, Wealth, and Happiness.

Bus stop with crossing pedestrians in Portland, Ore. (Source: pedbikeimages.org/Laura Sandt)

The transportation system is designed, built, maintained, governed and used by humans.

Using the term human factors to refer exclusively to the user perspective (i.e., drivers, pedestrians, etc.) can easily convey an oversimplified notion of the role of humans in the transportation system. From design to use, humans play a role in every step of the transportation system. In that sense, the entire transportation system is a product of human factors. For that reason, safety professionals must consider both the role of the environment (e.g., transportation infrastructure) and the user when trying to understand behavior and develop solutions to safety problems.

In sum, significant advances in road safety are possible, but changes will not happen overnight. Human behavior is not easy to change. With thoughtful, comprehensive approaches that take into account an understanding of human behavior and the environment in which people live, we can develop programs, policies and countermeasures that have a better chance of significantly improving road safety.

EXERCISES

- **CREATE** a causal diagram to model the behavior(s) and environmental factor(s) that contribute to the following.
    - The flu
    - Unhelmeted motorcyclist fatalities
- Using the causal diagrams from exercise 1, **IDENTIFY** the weak links in the causal chain and describe an intervention aimed at changing the target behavior(s).

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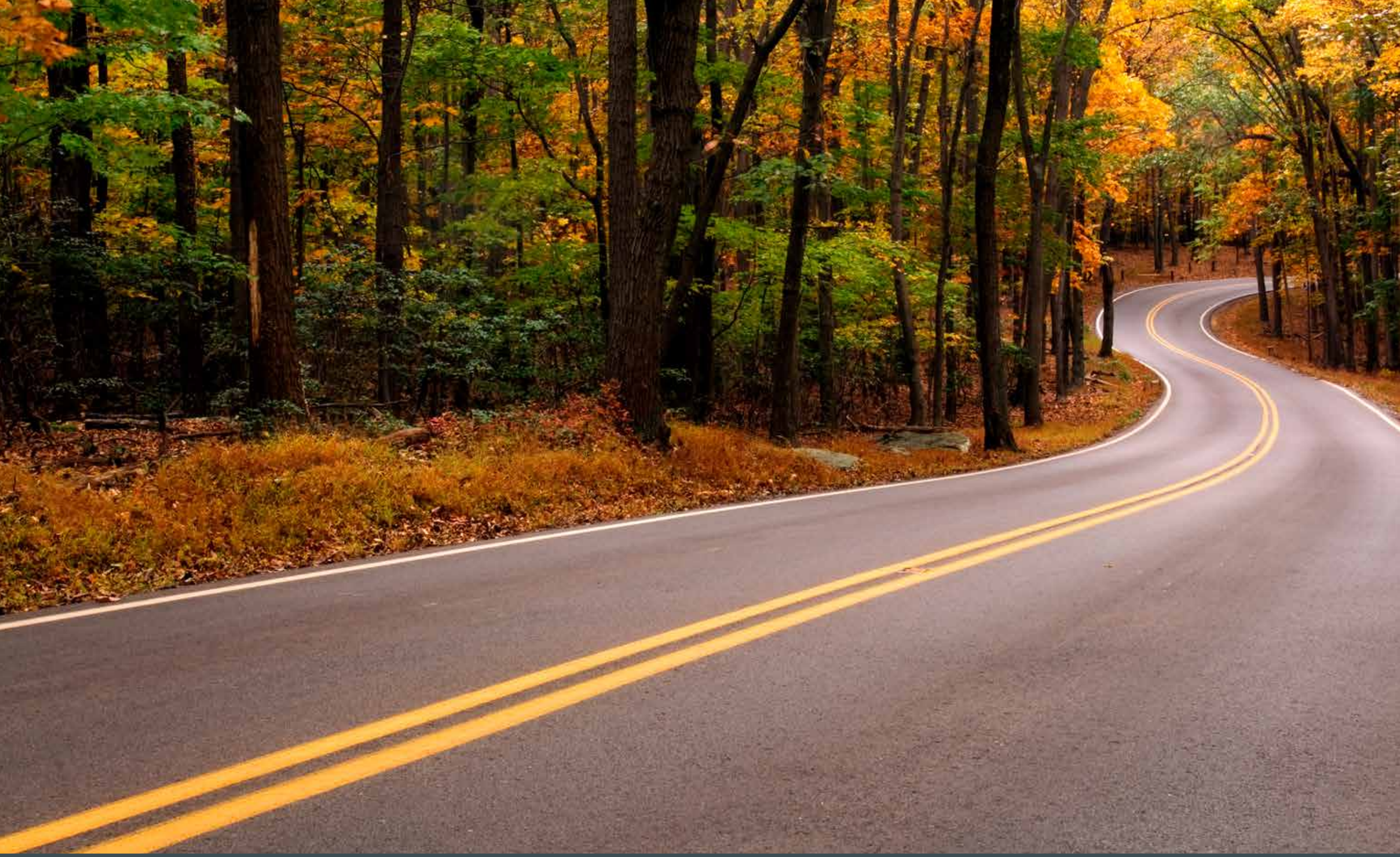


UNIT 3

Measuring Safety

LEARNING OBJECTIVES

After reading the chapters and completing exercises in Unit 3, the reader will be able to:

- **DESCRIBE** why measuring safety is important
- **IDENTIFY** the different types of available data
- **UNDERSTAND** the challenges and accuracy of data
- **SELECT** data for different road safety objectives

Importance of Safety Data

Good quality safety data are the core of any successful effort to improve road safety. Local, State, and Federal agencies use crash data as well as roadway, vehicle, driver history, emergency response, hospital, and enforcement data to improve road safety. All of these data sources can be used, in isolation or jointly, to produce projects, programs, and guide policies that reduce injuries and save lives. These types of data are collectively categorized as safety data in this book.

Safety professionals in many disciplines – highway design, transportation planning, operations, road maintenance, law enforcement, education, emergency response services, policy makers, infrastructure program management, road safety management, and public health – use safety data to identify problem areas, select countermeasures, and monitor countermeasure impact.

Road safety management and project development has become increasingly data-driven and evidence-based. This approach to road safety emphasizes safety performance (i.e., number of crashes), rather than solely adhering to engineering standards, personal experience, beliefs, and intuition. For example, in the past, road improvements were considered "safe" if the improvements met the standards contained in the Manual on Uniform Traffic Control Devices (MUTCD) and A Policy on Geometric Design of Highway and Streets, also known as the Green Book[1,2]. However, most of these standards are engineering based (i.e., nominal safety as discussed in Unit 1), and were not necessarily based on an evaluation of actual road safety performance. Presently, transportation professionals use safety data (such as crash data, road characteristics, and traffic volume) to evaluate road safety performance and inform their decisions. This substantive approach challenges professionals to quantify the expected consequences and outcomes of safety strategies in real measurements, such as the expected number of crashes, injuries, and fatalities.

The selection of road safety measures and treatments can benefit from an understanding of the intricacies and limitations of safety data. This unit presents many kinds of safety data, explores the current process used to collect data, and discusses the impact that these processes have on data quality (i.e., accuracy and reliability). The unit also discusses ways to improve data quality and analysis.

Relating Nominal and Substantive Safety to Data

The concepts of nominal and substantive safety were first introduced in Unit 1 of this textbook. Nominal safety refers to whether

[1] Manual on Uniform Traffic Control Devices (MUTCD), Federal Highway Administration, 2009.

[2] A Policy on Geometric Design of Highways and Streets, American Associations of State Highway Transportation Officials, 6th edition, 2011.

or not a design (or design element) meets minimum design criteria based on national or State standards and guidance documents, such as the AASHTO Green Book or the MUTCD. Substantive safety refers to the actual safety performance, such as expected number of collisions by type and severity on a road.

The contrast of these concepts is directly linked to this discussion of safety data. To determine if a road is nominally safe we do not need safety data; we only need to know if all design standards were followed. However, we need high quality safety data and data analysis to determine if a road is substantively safe. Typically, the analysis includes estimating the expected number of crashes and comparing it against the road's actual safety performance. More information on safety analysis is presented in Unit 4, Solving Safety Problems.

Use of Safety Data in Road Safety Management

Data are integral to safety decision making, both in prioritizing investments and in identifying analyzing the most effective techniques and interventions. The more comprehensive and accurate the data, the better the resulting decisions. Understanding contributing factors to crashes and how best to implement potential countermeasures is complex, and it may involve a variety of agencies and historical data challenges. Because of this complexity, both accurate data and high quality data analysis is necessary for road safety management. A great database is only as useful as the analysis and application of that data. Table 3–1 explores the relationship between data quality and data analysis quality and shows why agencies should strive to improve both of these areas.

	HIGH QUALITY ANALYSIS	LOW QUALITY ANALYSIS
HIGH QUALITY DATA	**BEST CASE** The agency is likely to reach the best safety decisions. Analysts are aware of data capabilities and limitations. This is the most expensive to achieve, due to the need for good data and training on how to conduct analyses.	**MISSED OPPORTUNITY** The agency needs to invest in high quality analysis. Otherwise, the agency has wasted money in databases that are not being utilized to their potential. Good data with poor analysis will lead to poor decisions.
LOW QUALITY DATA	**PROMISING** A robust analysis that recognizes the limitations of the data can still produce useful results. The agency should focus on improving data quality.	**WORST CASE** Poor data and poor analysis will lead to bad decisions. The agency may be better off relying on judgment.

TABLE 3-1: Data and Analysis Quality Comparison

Crash data analysis using quantifiable metrics and scientifically defensible methods can help decision makers improve road safety by reducing more injuries and saving more lives at a lower cost. Accurate crash data help determine crash and severity trends, such as increases or decreases in certain types of crashes. Data also help safety professionals pinpoint high crash locations and identify high-risk users, such as younger drivers, older drivers, impaired drivers, and motorcyclists. Examining the characteristics of crashes allows road safety professionals to identify contributing crash factors related to roadway environment, design, or behavioral adaptations. This type of analysis will lead to a more effective selection of countermeasures that will reduce future crash occurrences or crash severity. Planners and engineers can use crash data to show quantitative information to decision makers on how specific planning guidance, design proposals, or engineering countermeasures can save lives.

Safety professionals could seek to improve safety by relying merely on their gut judgment. The results of such an approach, however, would be quite unreliable. As shown in Table 3-1, safety professionals can improve their decision making process by using high quality data together with robust analysis processes. This unit will focus on the data itself. The use of the data in safety management is presented and discussed in Unit 4.

Good quality safety data and analysis are the keys to identifying real safety issues on roads and evaluating the best methods for improving safety. The following chapters provide an overview of different types of safety data and of ways in which agencies can improve the quality of their data.

Types of Safety Data

As highway safety analysis methods continue to evolve, it is equally important to focus on quality data to conduct these safety analyses. Transportation agencies can and should incorporate road characteristics, traffic volume, and enforcement and citation data, and other information into their safety analysis processes. This will enable them to better identify safety problems and prescribe solutions that improve safety and make more efficient use of safety funds.

Single sources of safety data also do not give a complete picture of the safety risks on our roads. For example, using crash data by itself leaves safety practitioners with purely reactive approaches—identifying locations where crashes have already happened. By combining crash data with other types of data, more details begin to emerge. For example, by combining crash data and detailed road inventory information, safety practitioners can develop a more in-depth understanding of the road attributes that contribute to crash risk. This will allow them to adopt a proactive approach, seeking out those factors associated with a high risk of crashes and addressing sites that share those "**elements**" before a crash occurs.

Roadway elements

Physical features of the road such as travel lanes, shoulder width, pavement condition, and roadside characteristics

Chicago's Use of Injury Data to Benchmark Safety Goals and Progress

Chicago DOT completed a comprehensive pedestrian crash analysis in 2011 to inform the citywide Chicago Pedestrian Plan. This analysis evaluated various crash types, contributing environmental factors, and different age groups using the Illinois Department of Transportation crash data files. The findings present crash density citywide, by ward, and around schools. The data also highlighted key crash conditions and served as a benchmark for measuring the City of Chicago's road safety goals.

Reference: City of Chicago 2011 Pedestrian Crash Analysis, Summary Report, Chicago Department of Transportation, Accessed September 2016 at https://www.cityofchicago.org/city/en/depts/cdot/supp_info/2011_pedestrian_crashanalysis.html

Crash, roadway, and traffic data should be integrated or combined using common or "linking" reference systems, such as mileposts or geospatial position. These data should also have the ability to be linked to the State's other road safety databases, including citation data or injury surveillance systems. Additionally, commercial motor vehicle data could also be linked based upon common data elements involved in crashes and inspections.

Not all types of safety data are available or used by all practitioners. Safety data exist in distinct databases that are maintained by different agencies and often are accessible only to those agencies. One role for safety professionals is to bring together safety databases and analyze them using logical and statistically robust processes.

Safety data can be categorized into two groups based on criteria of core data needs for safety evaluations, data availability, accuracy, and usefulness to safety practitioners and researchers. Some safety data are used often and are critical to safety analysis for many agencies. Other safety data are used less often but can be supplemental to specific safety analyses. This chapter provides general information on safety data in these two groups:

Critical data

- Crashes
- Traffic volume
- Road characteristics

Supplemental data

- Conflicts and avoidance maneuvers
- Injury surveillance and emergency medical systems
- Driver history
- Vehicle registrations
- Citations and enforcement
- Naturalistic
- Driving simulator
- Public opinion
- Behavioral observation

Crash Data

Description

Crash data is the most widely used type of safety data, and it is essential in road safety analysis. Crashes are currently viewed as the most objective and reliable measurements of road safety. However, there are challenges with crash data, such as human error in reporting, unreported crashes, and the length of time it often takes for crashes to be entered into a database. Crash data is also the primary measure of effectiveness for safety efforts, since the goal is to decrease crash occurrences and lower the severity of crashes that do occur. Crash records typically provide details on events leading to the crash, vehicles, and people involved in crashes, as well as the consequences of crashes, such as fatalities, injuries, property damage, and citations.

Data collection process

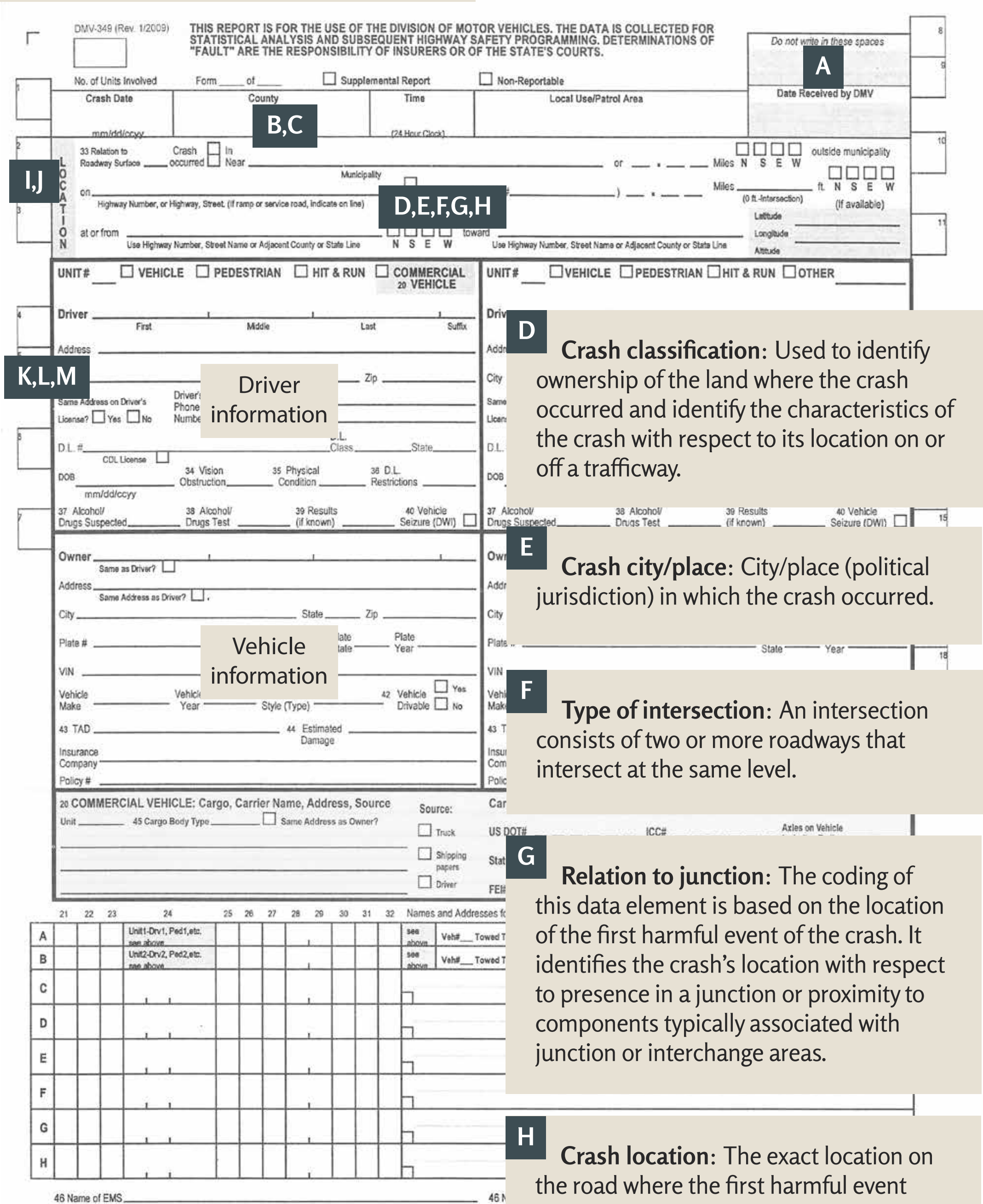
Crash data collection begins when a State highway patrol trooper or local police officer arrives at the crash scene. The officer completes a crash report, documenting the specifics of the crash. While the specifics and level of detail of the crash data vary from State to State, in general, the most basic crash data consist of where and when the crash occurred, what type of crash it was, and who was involved. The specific data collected on crashes is determined by State agencies, local government agencies, and often a coalition of law enforcement agencies. The exact data fields and coding differ from State to State. The level of detail in a crash report may also differ by the severity of a crash. For instance, in some States property damage only crashes (PDO) are self-reported and, thus, often have less information than injury crashes, which are reported by law enforcement officers.

States also differ in the threshold of what is required for a crash to be reported. Reporting of crashes can vary by threshold requirements, such as “only injury crashes” or “PDO crashes over an estimated $2,000 in damage.” These thresholds are

A **Case identifier**: The unique identifier within a given year that identifies a specific crash within a State.

B **Crash date and time**: The date (year, month, and day) and time (00:00-23:59) when the crash occurred.

C **Crash county**: The county or equivalent entity where the crash physically occurred.



DMV-349 (Rev. 1/2009)

THIS REPORT IS FOR THE USE OF THE DIVISION OF MOTOR VEHICLES. THE DATA IS COLLECTED FOR STATISTICAL ANALYSIS AND SUBSEQUENT HIGHWAY SAFETY PROGRAMMING. DETERMINATIONS OF "FAULT" ARE THE RESPONSIBILITY OF INSURERS OR OF THE STATE'S COURTS.

Do not write in these spaces

No. of Units Involved Form ___ of ___ ☐ Supplemental Report ☐ Non-Reportable

Crash Date mm/dd/ccyy | County | Time (24 Hour Clock) | Local Use/Patrol Area | Date Received by DMV

33 Relation to Roadway Surface | Crash occurred ☐ In ☐ Near | Municipality | or __ . __ Miles N S E W outside municipality

on ___ Highway Number, or Highway, Street (if ramp or service road, indicate on line) | Miles (0 ft.-Intersection) ft. N S E W (if available)

at or from ___ Use Highway Number, Street Name or Adjacent County or State Line | N S E W toward | Use Highway Number, Street Name or Adjacent County or State Line | Latitude | Longitude | Altitude

UNIT # ☐ VEHICLE ☐ PEDESTRIAN ☐ HIT & RUN ☐ COMMERCIAL 20 VEHICLE

UNIT # ☐ VEHICLE ☐ PEDESTRIAN ☐ HIT & RUN ☐ OTHER

Driver First Middle Last Suffix

Address

City State Zip

Same Address on Driver's License? ☐ Yes ☐ No | Driver's Phone Number

D.L. # | D.L. Class | State | CDL License ☐

DOB mm/dd/ccyy | 34 Vision Obstruction | 35 Physical Condition | 36 D.L. Restrictions

37 Alcohol/ Drugs Suspected | 38 Alcohol/ Drugs Test | 39 Results (if known) | 40 Vehicle Seizure (DWI) ☐

Owner Same as Driver? ☐

Address Same Address as Driver? ☐

City State Zip

Plate # | Plate State | Plate Year

VIN

Vehicle Make | Vehicle Year | Style (Type) | 42 Vehicle Drivable ☐ Yes ☐ No

43 TAD | 44 Estimated Damage

Insurance Company

Policy #

20 COMMERCIAL VEHICLE: Cargo, Carrier Name, Address, Source

Unit ___ 45 Cargo Body Type ___ ☐ Same Address as Owner? | Source: ☐ Truck ☐ Shipping papers ☐ Driver | US DOT# | ICC# | Axles on Vehicle

21	22	23	24	25	26	27	28	29	30	31	32	Names and Addresses
A			Unit1-Drv1, Ped1,etc. see above									see above Veh# __ Towed
B			Unit2-Drv2, Ped2,etc. see above									see above Veh# __ Towed
C												
D												
E												
F												
G												
H												

46 Name of EMS

47 Injured Taken by EMS to ___ (Treatment Facility and City or Town)

D **Crash classification**: Used to identify ownership of the land where the crash occurred and identify the characteristics of the crash with respect to its location on or off a trafficway.

E **Crash city/place**: City/place (political jurisdiction) in which the crash occurred.

F **Type of intersection**: An intersection consists of two or more roadways that intersect at the same level.

G **Relation to junction**: The coding of this data element is based on the location of the first harmful event of the crash. It identifies the crash's location with respect to presence in a junction or proximity to components typically associated with junction or interchange areas.

H **Crash location**: The exact location on the road where the first harmful event of the crash occurred. It is best if this information includes a geolocation based on a Geographic Information System (GIS) or Linear Referencing System (LRS) location coordinates.

I **Roadway surface conditions**: The roadway surface condition at the time and place of a crash.

J **Contributing circumstances, road**: Apparent condition of the road that may have contributed to the crash.

K **Weather conditions**: The prevailing atmospheric conditions that existed at the time of the crash.

L **Contributing circumstances, environment**: Apparent environmental conditions which may have contributed to the crash.

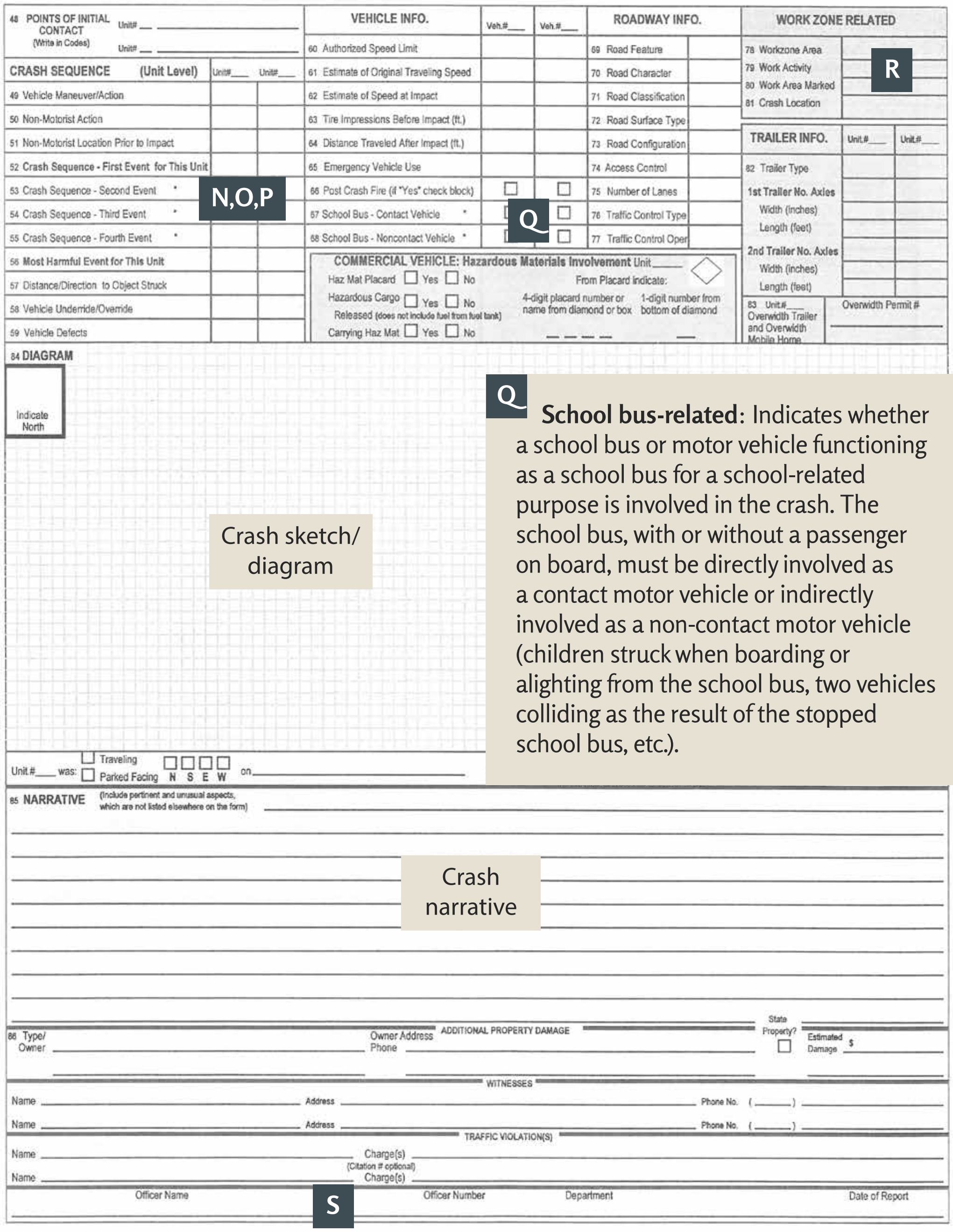
M **Light conditions**: The type/level of light that existed at the time of the motor vehicle crash.

N **Manner of crash/collision impact:** The identification of the manner in which two motor vehicles in transport initially came together without regard to the direction of force. This data element refers only to crashes where the first harmful event involves a collision between two motor vehicles in transport.

O **First harmful event:** The first injury or damage-producing event that characterizes the crash type.

P **Location of first harmful event relative to the trafficway:** The location of the first harmful event as it relates to its position within or outside the trafficway.

R **Work zone-related:** A crash that occurs in or related to a construction, maintenance, or utility work zone, whether or not workers were actually present at the time of the crash. Work zone-related crashes may also include those involving motor vehicles slowed or stopped because of the work zone, even if the first harmful event occurred before the first warning sign.



48 POINTS OF INITIAL CONTACT (Write in Codes) Unit# __ ______
Unit# __ ______

CRASH SEQUENCE (Unit Level)	Unit#___	Unit#___
49 Vehicle Maneuver/Action		
50 Non-Motorist Action		
51 Non-Motorist Location Prior to Impact		
52 Crash Sequence - First Event for This Unit		
53 Crash Sequence - Second Event *		
54 Crash Sequence - Third Event *		
55 Crash Sequence - Fourth Event *		
56 Most Harmful Event for This Unit		
57 Distance/Direction to Object Struck		
58 Vehicle Underride/Override		
59 Vehicle Defects		

VEHICLE INFO.	Veh.#___	Veh.#___
60 Authorized Speed Limit		
61 Estimate of Original Traveling Speed		
62 Estimate of Speed at Impact		
63 Tire Impressions Before Impact (ft.)		
64 Distance Traveled After Impact (ft.)		
65 Emergency Vehicle Use		
66 Post Crash Fire (if "Yes" check block)	☐	☐
67 School Bus - Contact Vehicle *	☐	☐
68 School Bus - Noncontact Vehicle *	☐	☐

ROADWAY INFO.	
69 Road Feature	
70 Road Character	
71 Road Classification	
72 Road Surface Type	
73 Road Configuration	
74 Access Control	
75 Number of Lanes	
76 Traffic Control Type	
77 Traffic Control Oper	

WORK ZONE RELATED	
78 Workzone Area	
79 Work Activity	
80 Work Area Marked	
81 Crash Location	

TRAILER INFO.	Unit#___	Unit#___
82 Trailer Type		
1st Trailer No. Axles		
Width (inches)		
Length (feet)		
2nd Trailer No. Axles		
Width (inches)		
Length (feet)		

83 Unit#___ Overwidth Trailer and Overwidth Mobile Home — Overwidth Permit # ______

COMMERCIAL VEHICLE: Hazardous Materials Involvement Unit______
Haz Mat Placard ☐ Yes ☐ No
Hazardous Cargo ☐ Yes ☐ No
Released (does not include fuel from fuel tank)
Carrying Haz Mat ☐ Yes ☐ No
From Placard indicate:
4-digit placard number or name from diamond or box — — — —
1-digit number from bottom of diamond —

84 DIAGRAM
Indicate North

Unit #___ was: ☐ Traveling ☐ Parked Facing ☐ ☐ ☐ ☐ N S E W on______

85 NARRATIVE (Include pertinent and unusual aspects, which are not listed elsewhere on the form) ______

ADDITIONAL PROPERTY DAMAGE
86 Type/Owner ______ Owner Address Phone ______ State Property? ☐ Estimated Damage $______

WITNESSES
Name ______ Address ______ Phone No. (____) ______
Name ______ Address ______ Phone No. (____) ______

TRAFFIC VIOLATION(S)
Name ______ Charge(s) ______
(Citation # optional)
Name ______ Charge(s) ______

Officer Name ______ Officer Number ______ Department ______ Date of Report ______

Q **School bus-related:** Indicates whether a school bus or motor vehicle functioning as a school bus for a school-related purpose is involved in the crash. The school bus, with or without a passenger on board, must be directly involved as a contact motor vehicle or indirectly involved as a non-contact motor vehicle (children struck when boarding or alighting from the school bus, two vehicles colliding as the result of the stopped school bus, etc.).

S **Source of information:** Affiliation of the person completing the crash report.

FIGURE 3-1 (above, left): Data elements on a crash report form. (Source: North Carolina DOT) unrelated to the number of crashes that are actually occurring on a road, but the reported numbers could look quite different. Changes to the crash reporting thresholds can happen abruptly and may significantly affect the crash data. Consider how the safety of a road, based on reported crashes, would appear in the years before and after a crash reporting threshold change from $1,000 to $4,000. You would expect to see fewer reported crashes after the change, since crashes with damage below $4,000 would no longer be reported, even though there may be no real change in the number of crashes occurring.

After the crash investigation is completed by the officer for the investigating agency, it usually undergoes an internal quality review. Passing the internal review, the crash report is sent to the State crash database. In some cases, the data is transmitted electronically, while in other cases the State agency receives a paper copy of the crash report.

The agency that maintains crash data for the State may be the State department of transportation (DOT), the department of motor vehicles (DMV), or a State law enforcement agency. This agency will in turn make the data available to various other agencies. Federal, State, and local governments, as well as metropolitan planning organizations, advocacy groups, auto and insurance industries, and private consultants request crash data to conduct various transportation planning activities and analysis. The agency maintaining the data may provide raw or filtered datasets to local agencies and to national databases, such as the National Highway Traffic Safety Administration's (NHTSA's) Fatality Analysis Reporting Systems (FARS).

The time between the crash occurrence and the availability of the crash data from the State crash database varies and typically depends on the type of crash reporting system and the State and local government capabilities. This time period between crash occurrence and the report's availability for analysis defines the timeliness of the crash data. While some agencies can provide complete data with a very short turnaround (i.e., less than a month), others take significantly longer (i.e., up to two years) due to backlogs and personnel shortages. Agencies who have the majority of their crashes reported electronically from law enforcement typically have shorter turnarounds on the crash data.

Common data elements

Common data elements for crash data include information on date, location, injury severity, types of vehicles, and characteristics of persons involved. Crash narratives and diagrams are typically found in the original crash reports, though generally not in the crash database. Narratives and diagrams are most useful when the safety professional desires to know the exact location of the crash, such as the particular approach of an intersection.

NHTSA developed the Model Minimum Uniform Crash Criteria (MMUCC) in 1998 as a model set of data elements that should be collected to enable safety professionals to conduct data-driven analyses. States are encouraged to adopt MMUCC standards, though they are not required to match these recommendations. MMUCC, currently in its fourth edition, recommends the crash data elements listed below. Chapter 9 presents further information on MMUCC on page 3-30.

Data sources and custodians

Crash details may be available from different sources or systems. State agencies and institutions typically maintain the State crash database. These include State departments of transportation, departments of motor vehicles, departments of public safety, or in some cases, State universities under contract to a specific department. Local agencies, such as cities or metropolitan planning organizations, may also maintain their own crash databases within local record management systems. These local systems are most frequently housed by the local police, public works, or transportation departments.

Transportation safety applications

Crash data serve as the primary observable measure of safety (or lack thereof) on the road. Transportation professionals can use crash data to analyze a single crash, a specific site, an entire corridor, or a large area, such as in regional or Statewide planning. Crash data can be used to provide guidance to transportation decision makers and to guide the formation of safety legislation.

Coordination or integration with other data sets

In transportation departments, other data elements frequently used along with crash data include road characteristics and traffic volume data. For example, by combining road characteristics with crash data, safety professionals are able to identify road elements that may lead to higher frequency or injury severity of crashes, and therefore develop a systemic approach to reduce that crash risk at many of the locations that have those risk elements. Using traffic volume, agencies can calculate crash rates (e.g., crashes per road vehicle) to better identify locations requiring safety improvements.

Caution on the use of crash rates

Crash rate calculation (crashes per amount of traffic) is a simplistic measure that may be useful when comparing sites with similar characteristics and traffic volumes. However, the relationship between crashes and volume is not linear and can therefore lead to wrong conclusions if that assumption is made when considering volume increases on a road or comparing roads of different types. Unit 4 discusses how an analyst can use safety performance functions to avoid this error.

Data challenges and gaps

Some of the most common issues found in crash reporting include incomplete data (for example a driver's blood alcohol content is often missing), delays in entering the data into databases, inaccurate crash locations, and wrongly assigned fault and wrong choice of crash type. Some of these issues can be fixed by training police officers and those who enter the data into the database, as well as by using technology checks in data collection. Agencies should periodically conduct independent quality checks on the accuracy and reliability of their data.

Challenges with the Use of Crash Data to Systemically Identify High Risk Locations

The Oregon DOT identified pedestrian and bicycle crashes as one of its primary focus areas for infrastructure funding. While pedestrians and bicyclists account for more than 15% of all traffic fatalities statewide, the locations of serious injuries and fatalities appear to be random. Therefore, in 2013, ODOT set out to develop a program that focuses the limited available funding for infrastructure countermeasures on locations with the greatest crash potential. In order to identify these higher-risk locations, ODOT is working to discover behavioral patterns and road conditions that lead to pedestrian and bicycle crashes. While a promising approach, this analysis is constrained by the limited availability of road information (e.g., bicyclist and pedestrian volumes, the presence of crosswalks, turn lanes, driveway activity, and sight distances). While the lack of these data does not preclude such an analysis, it does reduce the certainty of the findings. An additional benefit from this effort is that it has helped ODOT identify current data deficiencies which ODOT is currently working to fix.

Reference: Pedestrian and Bicycle Safety Implementation Plan, Oregon Department of Transportation, February 2014. Accessed September2016athttps://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/13452_report_final_partsA+B.pdf

Traffic Volume Data

Description

Traffic volume data indicates how many road users travel on a road or through an intersection. The most prevalent type of volume data is a count of daily use by motorized vehicle traffic. This type of traffic volume data can be measured in many ways depending on the intended use. Volume measurements include:

- Annual average daily traffic (AADT)
- Average daily traffic (ADT)
- Total entering vehicles (TEV) for intersections
- Turning movement counts
- Vehicle miles traveled (VMT)
- Pedestrian counts
- Bicyclist counts
- Percentage of traffic for specific vehicle types (e.g., heavy trucks or motorcycles)

AADT is the average number of vehicles passing through a segment from both directions of the mainline route for all days of a specified year. As AADT requires continuous year–round counting, these data are often unavailable for many road segments. In these cases, ADT is used to estimate AADT by using shorter duration counts of that road and then adjusting those volumes by daily and seasonal factors. Other data used for crash analysis include turning movement counts and TEV at intersections and VMT on a road segment, which is a measure of segment length and traffic volume. VMT are useful for highway planning and management, and a common measure of road use. Along with other data, VMT is often used to estimate congestion, air quality, and expected gas tax revenues, and can serve as a proxy for the level of a region’s economic activity. Volume data is also occasionally collected for bicyclists and pedestrians at road segments and crossing locations.

Data collection process

Volume data can be collected automatically or manually. Vehicle volume data is typically collected using automated counters, such as magnetic induction loops, pneumatic tube counters, microwave, radar, or video detection. These automated counters can also be configured to classify vehicles and produce counts by vehicle type (e.g., trucks, single passenger vehicles, etc.). For shorter durations or occasional counts, transportation agencies use manual traffic counts performed by observers, either in the field or through video cameras. Manual counting is also used often for bicyclist or pedestrian counts, although there are a number of additional technologies, such as infrared beams, that can be used to collect non-motorized volume data. These manual counts can range in length from one-hour counts to full-day counts, depending on the agency's needs and practices. Fitness tracking apps may also provide additional information to jurisdictions regarding where bicyclist and pedestrian activity is occurring. Some care is needed when using these data due to the self-selection bias present from users having to opt-in to the tracking and only using for specific types of activities (e.g., fitness cycling rather than commuting).

What's the difference between ADT and AADT?

Short term traffic counts are typically collected at a location for a 12-, 18-, or 24-hour period. Average Daily Traffic (ADT) is the count of traffic calculated to reflect the 24-hour (daily) volume of the date it was collected. The Annual Average Daily Traffic (AADT) is calculated for an entire year from the ADT by adjusting that simple average traffic volume to take into account the different travel patterns that occur during short duration count periods. For example, a summer traffic count taken in a beach vacation town would need to be adjusted downward to reflect the average traffic volume for the year, since traffic would be much higher in the summertime.

Each State has its own traffic data collection needs, priorities, budget, and geographic and organizational constraints. These differences cause agencies to select different equipment for data collection, use different data collection plans, and emphasize different data reporting outputs. The FHWA Traffic Monitoring Guide (TMG) highlights best practices and provides guidance to highway agencies in traffic volume data collection, analysis, and reporting[3]. The TMG presents recommendations to improve and advance current programs with a view towards the future of traffic monitoring. Traffic data is used to assess current and past performance and to predict future performance. Some States are utilizing traffic data from intelligent transportation systems (ITS) to support coordination of planning and operations functions at the Federal and State levels.

Common data elements

Volume data must include the counted volume, location, date, and duration of the count. Depending on the method used, the volume data may also contain information on vehicle classification, speed, or weight; lane position; weather; and directional factors. From these data, transportation professionals can calculate the average number of

[3] Traffic Monitoring Guide, Federal Highway Administration, Office of Highway Policy Information, September 2013.

vehicles that traveled each segment of road and daily vehicle miles traveled for specific groups of facilities, vehicle types, and vehicle speeds.

Data sources and custodians

State highway agencies collect and maintain traffic volume data for State-controlled roads. These data are shared with the U.S. Department of Transportation in order to monitor road usage and safety trends. Local jurisdictions also collect and maintain traffic volume data; the scope, consistency, and quality of these data varies by jurisdiction.

Transportation safety applications

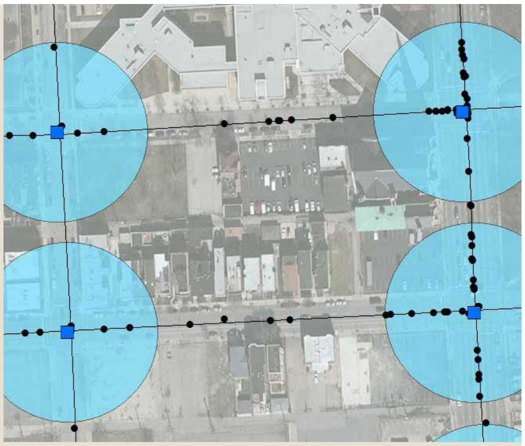
Agencies use volume data to support activities in design, maintenance, operations, safety, environmental analysis, finance, engineering, economics, and performance management. For instance, total traffic volume estimates or forecasts on a section of road are used to generate State and nationwide estimates of total distance traveled. Annual traffic volumes are also essential in network screening, diagnosis, and the selection of countermeasures (see further presentation of these processes in Unit 4). When selecting appropriate crash modification factors (CMFs) to estimate the benefit of potential countermeasures, a safety practitioner must use traffic volumes to confirm that the CMFs are suitable for the site in consideration.

Coordination or integration with other data sets

Other data elements frequently used with traffic volume data in safety applications include road characteristic inventories and crash data. For example, an agency that uses traffic volume and crashes together can identify sites with highest potential for safety improvements and target specific crash types. This allows them to better identify and prioritize locations for safety improvements.

Spatial Data and Road Safety

Many of the types of data presented in this chapter can be stored in a spatial format and displayed in a GIS. GIS is a particularly powerful tool designed to store, manipulate, analyze, and visualize data that is linked to a location. This makes it valuable to highway safety practitioners who can use a common referencing system for much of their highway data and link it together in GIS. For example, a single GIS database can contain road attributes, such as number of lanes, pavement condition, and lighting; crash information; and traffic volumes. This information can then be used to analyze crash hotspots and trends, such as multi-vehicle crashes in the vicinity of signalized intersections.



This GIS map displays signalized intersections as squares and crashes as dots and allows the analyst to easily identify crashes occurring within 150 feet of a signalized intersection (denoted by circular areas around each intersection).

Data challenges and gaps

One of the biggest challenges in collecting accurate volume data is implementing a quality assurance process to ensure that counts are accurately recorded. Traffic volume for most roads is also based on sampling, which leads to estimates of volume on much of the road. As technology continues to develop and become more prevalent on our roads and in our vehicles, the accuracy will improve considerably. Additionally, pedestrian and bicyclist counts are more susceptible to higher variability due to their lower volumes; thus, longer count durations and additional locations are required for accurate data applications.

Road Characteristics Data

Description

Road characteristics data is also referred to as road inventory data. The most basic road characteristics data typically includes road name or route number, road classification, location coordinates, number of lanes, lane width, shoulder width, and median type. Intersection characteristics typically include road names, area type, location coordinates, traffic control, and lane configurations. The collection of these data elements supports an enhanced safety analysis and investment decision making when combined with other datasets, such as crash information.

Data collection process

Road characteristics data can be collected through several methods including photo or video logs, field surveys, aerial surveys, integrated GIS and global positioning systems (GPS) mapping, and vehicle-mounted Light Detection and Ranging (LIDAR) technology. Some States find it more cost effective to purchase these data from third party providers.

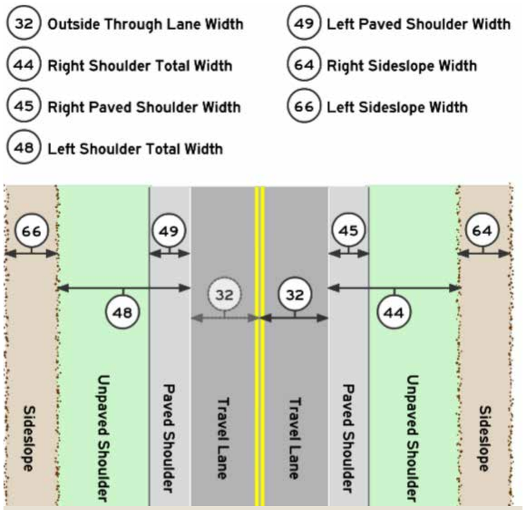


FIGURE 3-2: This image from the FHWA Model Inventory of Roadway Elements (v. 1.0) illustrates roadway elements.

Common data elements

Transportation agencies typically collect those road characteristics that they need or can be collected based on the available funds. Road characteristics are collected for many different purposes, such as road maintenance and improvement projects. Given that States have different priorities and funding structures, the elements of road characteristics data is not the same from State to State or among local agencies.

To provide guidance on road characteristics that are the most needed for safety analysis, the FHWA developed the Model Inventory of Roadway Elements (MIRE). MIRE provides a recommended (but not required) list of road characteristics elements specifically for safety analysis. The elements are divided into the categories shown in Table 3-2. Chapter 9 presents further information on MIRE on page 3-32.

Data sources and custodians

Road characteristics data are collected at both the local and Statewide levels. At the local level, having data on details, such as traffic control devices, sidewalks, or the number of travel lanes, can be beneficial for safety evaluations and safety project prioritization. These data are maintained by the city or by a higher level agency such as a MPO.

State road characteristics data include physical road attributes, traffic control devices, rail grade crossings, and structures, such as bridges and tunnels. Each State highway agency, some local transportation and public works departments, and regional planning agencies collect and maintain road characteristics data. In addition, most States also have supplemental inventory data for bridges as part of the National Bridge Inventory and railroad grade crossings as part of the Federal Railroad Administration's Railroad Grade Crossing Inventory. These databases usually can be linked to the Statewide road inventory.

Transportation safety applications

Road safety professionals can use road characteristics data to access data about the physical characteristics of crash sites or other priority sites. Road characteristics data is essential for network screening, development or calibration of crash prediction models, and related applications. These data are also valuable on the large scale level to estimate where crashes are expected to occur on the system.

Coordination with other data sets

Road characteristics data can be linked with crash and volume data to improve safety analysis and problem identification. Combining datasets in this way allows safety professionals to identify areas with a high

CATEGORY	EXAMPLES OF MIRE DATA ELEMENTS
Roadway Segment	Roadway classification Paved surface characteristics Number and type of travel lanes Shoulder, median, and roadside descriptors Pedestrian and bicyclist facilities Traffic volumes
Roadway Alignment	Curve and grade information
Roadway Junction	Traffic control devices Intersection features Interchange and ramp descriptors

TABLE 3-2: Categories of MIRE Elements

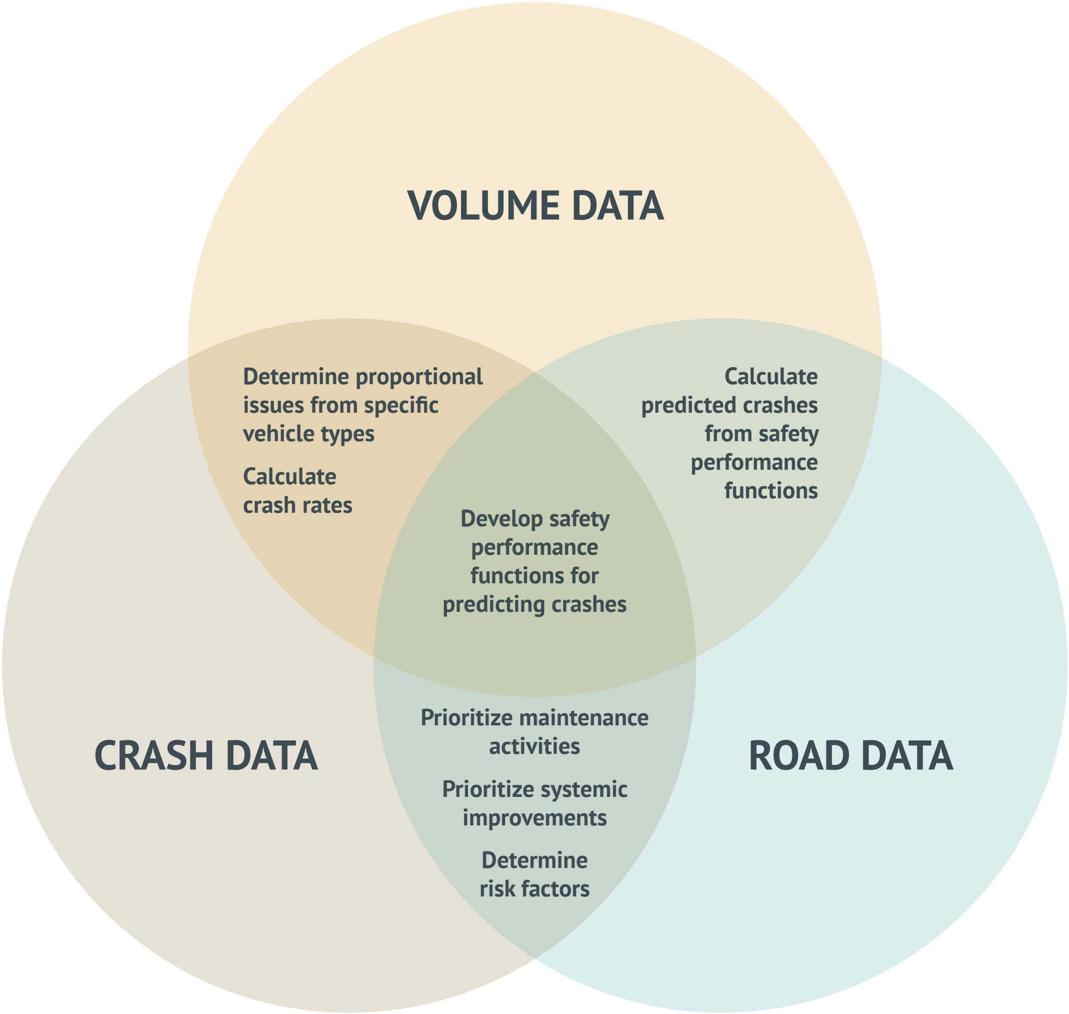
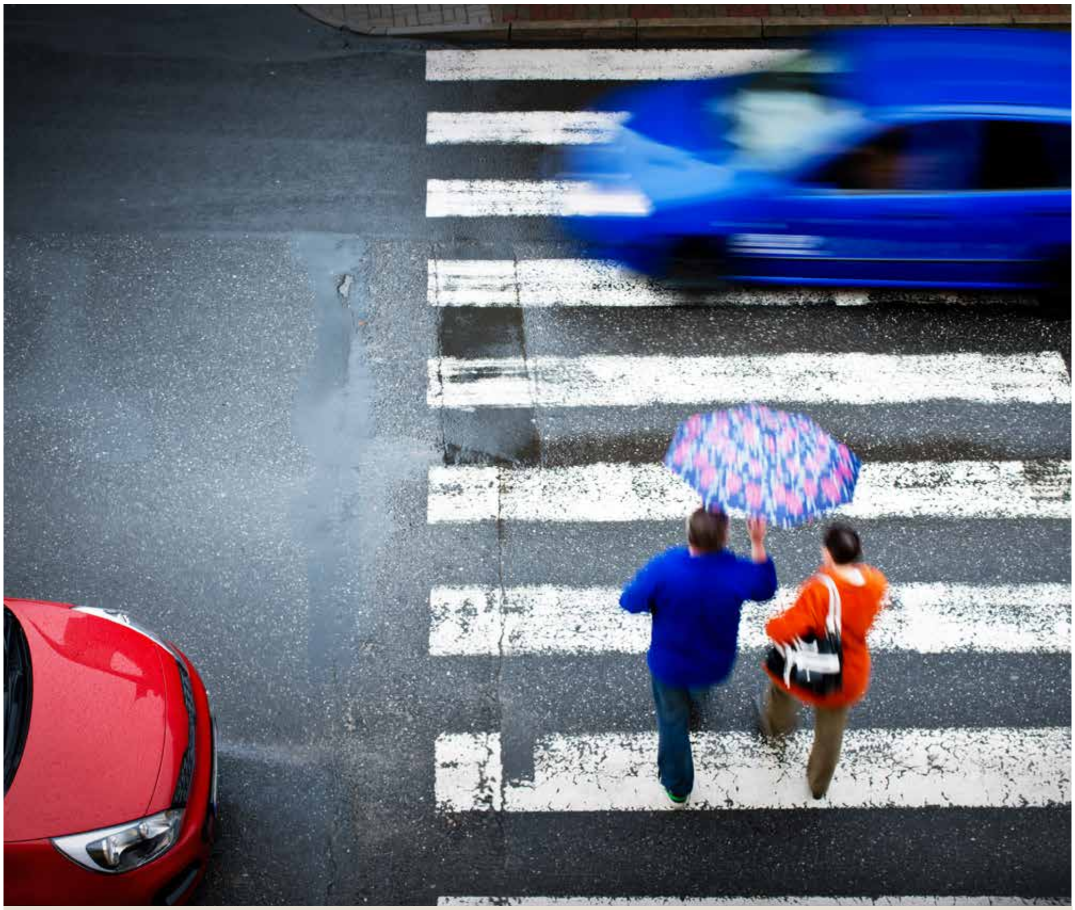


FIGURE 3-3: Using Safety Data Together

potential for safety improvements (by means of a network screening process) and identify appropriate countermeasures. However, the road characteristics data must share a common reference system with the crash and volume data in order to link them together. The most common methods of linking road data with crash or volume data use a linear referencing system, such as routes and mileposts, or a spatial referencing system, where all files share the same coordinate system.

Data challenges and gaps

Collecting accurate road characteristics data can be a time-consuming and expensive process. Data collection that is done only for part of a road network results in gaps in inventories of road features such as the location of guardrails, shoulder widths, and rumble strips. Transportation agencies are continually looking for newer technologies to streamline the collection of this detailed data. Also, it is more common for road characteristics data to be fuller and more detailed for State system roads compared to local roads, since local agencies typically have less funding, fewer staff, and less general prioritization for collecting road characteristics data.



Observing interactions between road users, like these drivers and crossing pedestrians, can be a good way to gain supplemental data about safety effects.

Supplemental Safety Data

In addition to the critical transportation safety datasets (crashes, road characteristics, and traffic volume), there are many other datasets that can be used and combined to conduct additional types of evaluations on the effectiveness of programs, human behaviors and safe decision making, and public opinions.

Conflicts, Avoidance Maneuvers, and Other Interactions

Observing conflicts between road users, avoidance maneuvers, such as swerving or hard braking, and other interactions, such as failures to yield can provide valuable information on road safety. These other measures of safety are referred to as surrogate measures. They occur more frequently than actual crashes and therefore enable agencies to identify safety risks more quickly and in a proactive manner (i.e., before the crash occurs). However, by their nature of being surrogates, there is potential for inaccuracy in determining which types of conflicts are good indicators of crashes.

Surrogate safety data is collected by in-field observers or through recordings that capture the behaviors and interactions of road users. These recordings can be made through stationary cameras or dashboard-mounted video cameras.

Increasingly, researchers are using programs to automatically identify potential events. This eliminates the need to scan visually through the entire video.

Observing interactions between road users can provide valuable information on the safety effect of certain road elements, such as signals or signs, and help identify the probability of crashes under different conditions. If a reliable relationship between the observations and crashes is known, such studies may also provide insights into the potential for safety issues between road users, such as between vehicle drivers and pedestrians.

However, one of the biggest challenges for using observations of road user interactions is that they are surrogate measures of safety. To date, we lack good research that would quantitatively equate surrogate measures of safety to crash data. If such relationships were known, safety professionals could conduct evaluations with a large number of surrogate measures in a relatively short period of time. This contrasts with the need to wait for years for sufficient crash data to support a good analysis.

Evaluation of Children Involved in Off-Roadway Crashes Using Trauma Center Records

Many off-roadway crashes are not reported by law enforcement and are thus missed when conducting safety evaluations using police crash reports. One group that is particularly affected by this lack of data is young children injured by passenger vehicles in driveways and parking lots. This lack of information provides safety professionals with little knowledge about crash risk factors and actual incident rates that could be used to allocate resources and promote safety interventions and good design and behaviors. A 2010 study (Rice et al.) in California used records from eight trauma centers to identify the frequency and characteristics of these crashes. This study highlighted the inconsistencies with external cause-of-injury codes used by emergency departments, but suggests that there is value to surveillance of off-roadway pedestrian injuries at trauma centers as a way of identifying incidents that are not captured by other data sources.

Reference: Rice TM, Trent RB, Bernacki K, Rice JK, Lovette B, Hoover E, Fennell J, Aistrich, AZ, Wiltsek D, Corman E, Anderson CL, Sherck J. (2012). Trauma center-based surveillance of nontraffic pedestrian injury among California children. Western Journal of Emergency Medicine; 13.2.

Injury Surveillance and Emergency Medical Systems Data

Injury surveillance systems (ISS) typically provide data on emergency medical systems (EMS), hospital emergency departments, hospital admissions/discharges, trauma registry, and long-term rehabilitation. This information is used to track injury causes, severity, costs, and outcomes. Although an injury associated with a traffic crash is only one type of injury in these medical systems, traffic crash injuries can be a useful source of data in bridging the gap between traditional traffic safety and public health issues. Hospital records are also often the only source of information on bicycle and pedestrian crashes that are not recorded by the police, such as those that occur in non-roadway locations like parking lots and driveways.

Hospitals often use the external cause of injury classifications to code causes of patient injuries, including those from traffic crashes. These data can provide a description of injury severity, type of crash (e.g., motor vehicle passenger, bicyclist), and, in some cases, the location of incident. However, the data is often incomplete or non-specific. In order to provide a more comprehensive understanding of motor vehicle crash outcomes, NHTSA developed the Crash Outcome Data Evaluation System (CODES), which links crash, vehicle, and behavior characteristics to their specific medical and financial outcomes. Hospital injury data most often includes date, injury severity, cause, and demographic information. Personal identifying information is not included.

Hospital data can be used by a variety of governmental and non-governmental agencies to investigate the causes of injuries. Based on this analysis, the agencies can develop a safety campaign to reduce injuries to particular demographics. It can also be used to identify the full magnitude of crashes for a specific user group or demographic that is not recorded or reported by law enforcement. For example, hospital data can help safety professionals better understand the number of bicyclist crashes, since many bicycle-related crashes are not reported to law enforcement.

Hospital data are often difficult to use for those who administer roads, primarily the State DOT. The data is time consuming to acquire and may not contain complete data. Additionally, since there are no personal identifiers relating hospital injury data to specific crash records, the linkage is difficult and is seldom done. For these reasons, State DOTs rarely use these data; it is most often employed by public health researchers. However, there continues to be efforts at both Federal and State levels to develop better ways to integrate injury surveillance and emergency medical systems data with crash data.

Hospital data can be used to investigate causes of injuries, and is often the only source of information on some bicycle and pedestrian crashes.

Driver History Data

Departments of Motor Vehicles (DMVs) maintain driver history data on all licensed drivers in the State. DMVs typically create a driver record when a person enters the State licensing system to obtain a driver's license or when an unlicensed driver commits a violation or is involved in a crash. State driver history databases interact with the National Driver Register (NDR) and the Commercial Driver License Information Systems (CDLIS) to prevent drivers with a history of at-fault crashes or inordinate number of citations from obtaining multiple or subsequent licenses.

The driver history data contain information such as:

- Basic identifiers (e.g., name, address, driver license number)
- Demographics (e.g., age, birth date, gender)
- Information relevant to license and driver improvement actions (e.g., license issue, expiration and renewal dates, license class, violation dates, suspension periods)

One challenge with using these data is that they are almost never shared outside a DMV. State or local DOTs do not have access to these data while developing their HSIPs (or conducting location specific safety studies). Sharing driver history data nationally is limited and could be improved by creating inter-agency data sharing partnerships that address privacy concerns and allow State DOTs to work with the data.

Vehicle Registration Data

Vehicle registration data includes information about registered vehicles in a State and is also typically maintained by the DMV. Vehicle registration systems may also contain information regarding commercial vehicles and carriers registered in a particular State and licensed to travel in other States. These data can provide information on the vehicle population within a State or county to be used in large scale safety analysis. These data can also help identify owners in the event of a crash or traffic violation.

Typical vehicle registration data may include owner information, license plate number, vehicle make, model, and year of manufacture, body type, vehicle identification number, and miles traveled. Common data for commercial vehicles may include U.S. Department of Transportation (DOT) number, carrier information, and inspection or out-of-service information.

Citations and Enforcement

Citation data refers to data on individual drivers that records any illegal actions that were cited by a law enforcement officer. It includes traffic violations, such as reckless driving, driving under the influence, and not carrying adequate car insurance; traffic crashes; driver's license suspensions, revocations, and cancellations; and failures to appear in court. The data can also include the traffic infractions that have been adjudicated by the courts.

These data are helpful in identifying and tracking those individuals with a higher potential for unsafe driving behaviors. In an attempt to control crash occurrences, States may monitor high-risk drivers by reviewing their driver history records, paying particular attention to driver citations. Ideally, States track a citation from the time it is issued by a law enforcement officer through its disposition in a court of law. Citation information tracked and linked to driver history files enable States to screen drivers with a history of frequent citations for actions known to increase crash risk. States have found citation tracking systems useful in detecting repeat traffic offenders prior to conviction. It can also be used to track the behavior of particular law enforcement agencies and the courts with respect to dismissals and plea bargains. Many law enforcement agencies use citations as a method of tracking and measuring the effectiveness of enforcement efforts.

Some constraints exist with the use of citation and enforcement data to help prevent crashes. Some States have difficulty in maintaining accurate citation information because local jurisdictions may collect different data elements from varying citation forms. Obtaining and managing judicial information is also a challenge because of the various levels of court administration and jurisdiction. Unfortunately, in some States judges do not have access to the offender's driver history at the time of sentencing, so many offenders escape the stricter penalties sanctioned for repeat offenses. In addition, the traffic safety community often lacks access to adjudication information due to privacy concerns.

Naturalistic Driving Data

Naturalistic driving data are driver behavior data collected during actual driving trips through technology placed in the vehicle. This technology typically includes video camera views of the driver, speed and vehicle motion sensors, and location tracking equipment. Data such as video might be collected on a continuous basis, or only after certain events like hard braking. Using data collected by this equipment, researchers are able to gather information on the underlying causes of crashes by observing drivers in a natural driving situation. Frequently collected data include road environment information, such as weather; driver information, such as eye movements; and information on vehicle movement including location on the road, acceleration, deceleration, and speed.

Strategic Highway Research Program 2

The largest naturalistic study in the United States to date is the second Strategic Highway Research Program (SHRP2), which included over 3,400 drivers participating in the study. SHRP2 data includes over 5,400,000 individual trips and over 36,000 crash, near crash, and baseline driving events. FHWA provides more information on SHRP2 at https://www.fhwa.dot.gov/goshrp2.

These data are used to evaluate how drivers interact with and react to the road, other road users, and other environmental features. Driver observation is used to understand fundamental issues of driver behavior and to develop improved safety countermeasures. The data are primarily used in research studies on a variety of topics. The data from the SHRP2 program have been used to study safety

Driving simulators like this one are often used to evaluate driver behavior under specific conditions and in a cost-effective way.

issues including prevention of road departures, driver reaction to posted speed limits, and driver response to curves in the road, in addition to many non-safety-related topics.

A challenge with collecting a large amount of naturalistic data is the high cost of recruiting participants, instrumenting vehicles, and reducing and analyzing the data. The process of coding (observing) the behaviors of the driver while driving is time-consuming and is typically conducted on a frame-by-frame basis, leading to expensive data collection and lengthy study periods. The data are highly private (i.e., contains videos of driver faces), and therefore are typically difficult to access or distribute. Despite these challenges, naturalistic driving data provides a unique and extremely insightful look at fundamental issues of road safety.

Driving Simulator Data

Due to the high cost of naturalistic driving studies and the rarity of traffic crashes, driving simulators are often used to efficiently and safely evaluate driver behavior under different conditions. Researchers are able to study many different conditions and complex environments without exposing drivers to danger through replicating a wide range of road, traffic, and environmental conditions, as well as driver behaviors such as distractions, impairment, and fatigue. New types of road designs can be guided by the use of simulators, particularly complex features, such as urban highway interchanges.

Simulators can also be used for driver education to teach people about the effects of driver distractions or to prepare young drivers for different conditions before they encounter them on the road. Truck simulators are used to replicate the driving environment for different types of commercial trucks and used to safely train new drivers.

Public Opinion Data

Feedback from the general public can be a useful source of information for safety professionals. Safety professionals can use information on road safety issues and concerns from the public to identify specific locations or types of conditions where people have real or perceived traffic safety concerns.

There are many different ways to collect this information, such as a phone-based survey, web-based tools (pins on maps or online forms), meetings, or intercept surveys. Common data collected are the type of concern, location, and type of mode (i.e., walking, bicycling, transit user, or driving).

These data are typically collected at the local level, frequently as part of a transportation planning process or as a collaborative effort with law enforcement. Bringing residents and police officers to join the road safety audit teams or diagnosis teams during their field visits is also a beneficial way to learn about the experiences of the road users in the study area.

These data may provide valuable insights about what the travelling public perceives as dangerous; however, it may be a biased sample based on those who self-select to provide the information to the researching agencies. Findings will be subjective as each person perceives a condition based on their individual experiences only. Different persons perceive different issues and recommend different "best" solutions for the same condition. Conclusions based on survey findings should be used with care.

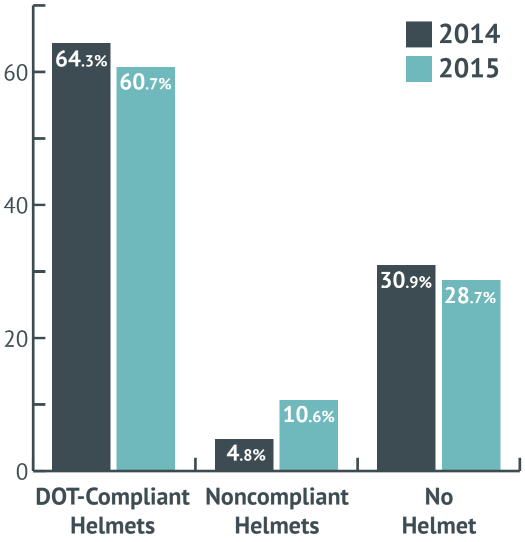


FIGURE 3-4: Observations of motorcyclists showed how many were wearing DOT-compliant helmets (Source: National Occupant Protection Use Survey)

Behavioral Observation

Observational surveys of road user behaviors are an effective method of data collection on information that may otherwise be inaccurately recorded due to self-reporting bias or are difficult to capture through other means. Several examples of data typically recorded using direct observation are the use of mobile devices (texting or calling), right turn on red, safety belt use, motorcycle or bicycle helmet use, and traffic control violations, such as rolling through stop signs.

These data are collected through observing road users on the road. Large scale surveys collecting a high number of observations will provide the most accurate sample of the road user population in the study area. Additionally, robust observation data will cover differing road types and land use characteristics and contain observations at different times of day, week, and season. An example of a large-scale data collection effort is the National Occupant Protection Use Survey conducted annually by NHTSA. In 2013, over 52,000 occupants were observed in nearly 40,000 vehicles. The data, summaries, and evaluations from this program may be viewed on the NHTSA website[4].

Data Users

While many agencies use safety data, most of them have different goals. For example, a city traffic engineer may have a specific scope for identifying and treating specific high priority sites, whereas a safety analysist with a State may be focused on safety at the system level. Moreover, safety researchers and graduate students may be focused on a whole range of safety evaluations that are not intended to be action plans to improve safety at a specific site or system. Each type of data user may have different levels of access to these various types of safety data.

The following tables provide common uses and data needs for these different types of data users.

	DATA TYPE	USEFULNESS	ACCESSIBILITY	OFTEN PAIRED
ACADEMICS AND RESEARCHERS	**Crash**	Essential	High	Road characteristics, Traffic volumes
	Road characteristics	Essential	High	Crash, Traffic volumes
	Traffic volumes	Essential	High	Crash, Road characteristics
	Naturalistic driving	Supplemental	Moderate	
	Conflicts/avoidance maneuvers	Supplemental	Low	Road characteristics, Traffic volumes
	Citations	Supplemental	Low	Crash, Traffic volumes, Road characteristics
	Driving simulator	Supplemental	Low	Road characteristics
	Behavior observation	Supplemental	Low	Crash, Road characteristics
	Injury surveillance	Supplemental	Very low	
	Driver history	Supplemental	Very low	
	Vehicle registration	Supplemental	Very low	
	Public opinion	Supplemental	Very low	

TABLE 3-3 (above/next page): Data Use by Safety Professionals, Academics and Researchers

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[4] https://crashstats.nhtsa.dot.gov

SAFETY PROFESSIONALS FOR **SYSTEM LEVEL ANALYSIS**

DATA TYPE	USEFULNESS	ACCESSIBILITY	OFTEN PAIRED
Crash	Essential	High	Road characteristics, Traffic volumes
Road characteristics	Essential	High	Crash, Traffic volumes
Traffic volumes	Essential	High	Crash, Road characteristics
Public opinion	Supplemental	High	Crash, Road characteristics
Conflicts/avoidance maneuvers	Non-essential	Low	Road characteristics, Traffic volumes
Citations	Non-essential	Low	
Behavior observation	Non-essential	Low	
Injury surveillance	Non-essential	Very low	
Driver history	Non-essential	Very low	
Vehicle registration	Non-essential	Very low	
Naturalistic driving	Non-essential	Very low	
Driving simulator	Non-essential	Very low	

SAFETY PROFESSIONALS FOR **SPECIFIC SITES**

DATA TYPE	USEFULNESS	ACCESSIBILITY	OFTEN PAIRED
Crash	Essential	High	Road characteristics, Traffic volumes
Road characteristics	Essential	High	Crash, Traffic volumes
Traffic volumes	Essential	High	Crash, Road characteristics
Public opinion	Supplemental	High	Crash, Road characteristics
Conflicts/avoidance maneuvers	Supplemental	Low	Road characteristics, Traffic volumes
Citations	Supplemental	Low	Crash, Traffic volumes, Road characteristics
Behavior observation	Supplemental	Low	Crash, Road characteristics
Injury surveillance	Non-essential	Very low	
Driver history	Non-essential	Very low	
Vehicle registration	Non-essential	Very low	
Naturalistic driving	Non-essential	Very low	
Driving simulator	Non-essential	Very low	

Other Types of Road Safety Data

Additional types of data can also be useful to road safety professionals. These types of data may include:

Insurance data

(e.g., carrier, policy number, expiration date, claims cost)

These data can provide insights into associations between insurance status and safety.

Demographic data

(e.g., population by gender, age, rural/urban, residence, and ethnicity)

These data can be used for normalizing crash data to a state's general population.

Safety program evaluation data

(e.g., surveys, assessments, inspections)

These data can provide feedback on the effectiveness of a new safety program.

Maintenance data

(e.g., guardrail replacement)

These data may indicate where unreported crashes are occurring.

EXERCISES

- **IDENTIFY** possible relationships between the safety data presented in this chapter and census data (e.g., traffic safety vs. population density).
- **CONSIDER** if, in the future, vehicles store pre-crash data in a "black box" type of event recording device. What types of data would you like it to store and how would you use this data (i.e., what types of analysis would you recommend conducting)?
- **EXPLORE** what type of safety analysis could be made possible using communication between vehicles (V2V) and also between vehicles and infrastructure (V2I - i.e., roads, intersections, etc.).
- **DETERMINE** how safety professionals can incorporate operational data, such as those from dynamic tolling lanes and speed sensors, into a safety analysis program.

Improving Safety Data Quality

Quality Measures Of Data

The previous chapters in this unit have made the case that data are critical when seeking to improve road safety. However, simply having data is not enough. Good decisions require good data. When collecting, recording, maintaining, and analyzing safety data, road safety professionals must focus on the quality of data. Data-driven analysis tools are continually advancing and can help set priorities and select appropriate safety strategies, but the need for quality data to drive these tools is clear. Professionals commonly recognize that data quality can be measured on six criteria – timeliness, accuracy, completeness, uniformity, integration, and accessibility. Each of these criteria are presented in this chapter.

Timeliness

Timeliness is a measure of how quickly an event is available within a data system. State and local agencies can use technologies to automate crash data collection and quickly process police crash reports for analytic use. However, some agencies still rely on traditional methods, such as paper form data collection and manual data entry; these data collection methods can result in significant time lags. Many States, however, are moving closer to real-time data collection methods by using electronic reporting to improve the timeliness of data collection and submission.

Accuracy

Accuracy is a measure of how reliable the data are and whether they correctly represent reality. For example, exact crash location is an important detail for accuracy. A crash occurring at the intersection of First Street and Main Street should be recorded as occurring at that intersection. Accurate data are crucial during the analysis phase to generate road safety statistics and to pinpoint safety problems. Errors may occur at any stage of the data collection process. Common data accuracy errors include:

- Typographic errors (for data entered manually)
- Inaccurate and vague descriptions of the crash location
- Incorrect descriptions or entry of road names, road surface, level of accident severity, vehicle types, etc.
- Subjectivity on details that rely on the opinion of the reporting officer (e.g., property damage thresholds, excessive speed for conditions)

Technology can and is currently being used to improve accuracy and reduce errors. Automatic internal data quality checks are important for this purpose. These types of checks would determine if two data fields contain possibly conflicting data, and if so, bring it to the attention of the data analyst. An example of

Many police officers now use in-car computers to complete and submit electronic crash reports, increasing the timeliness of data availability. (Source: Town of Hanover, NH)

conflicting data fields would be a crash type recorded as "rear end" but the crash report says that one car was hit on the "side".

Completeness

Completeness is a measure of missing information. It may range from missing data on the individual crash forms to missing information due to unreported crashes.

Unreported crashes, particularly non-injury crashes, present a drawback to crash data analysis. Without knowing about these crashes, we cannot recognize the full magnitude of certain types of crashes (e.g., pedestrian involved crashes). Non-injury crashes, or property damage only (PDO) crashes, involve damage less than a specified threshold (e.g., $1,000); these thresholds vary from State to State. The parties involved in PDO crashes are typically not required to report the crash and often agree to work out the financial damages personally or through their automobile insurance policies. In some States, even when PDOs are reported, they are not always added into the crash database.

In addition to the limitations from absent data due to unreported crashes, fluctuations in the thresholds (i.e., dollar amounts) can make it difficult to compare data from previous years. Unreported PDO crashes are one of many measures of "completeness" that road safety professionals must consider when collecting and analyzing data. A lack of complete data hinders the ability to measure the effectiveness of safety countermeasures (e.g., safety belts, helmets, and red light cameras) or change in crash severity.

Uniformity

Uniformity is a measure of how consistent information is coded in the data system or how well it meets accepted data standards. Numerous law enforcement agencies within each State, some of which are not the primary users of the crash data, are responsible for crash data collection. The challenge for States is ensuring there is consistency among the various agencies when collecting and reporting crash data. One example of inconsistent or non-uniform data can be the location of a crash. If one agency, for example the State highway patrol, uses GPS to document a crash at one of several entrances (driveways) to a shopping center, but the city police use a linear reference system (e.g., distance from an intersection), there is a potential for inconsistent crash location data.

The Model Minimum Uniform Crash Criteria (MMUCC) is used by States to ensure uniform crash data. MMUCC is an optional guideline that presents a model minimum set of uniform variables or data elements for describing a motor vehicle crash. This uniformity assists transportation safety professionals and governments in making decisions that lead to safety improvements. Similarly, MIRE provides a recommended list of elements to use when reporting road and traffic characteristics, thereby increasing uniformity of road network data. More information on MMUCC and MIRE is presented at the end of this chapter.

Integration

Data integration is a measure of whether different databases can be linked together to merge the information in each database into a combined database. Each State maintains its own crash database. However, crash data alone do not typically provide sufficient details on issues like environmental risk factors, driver experience, or medical consequences. Linking crash data to other databases, such as road characteristics, driver licensing, vehicle registration, and hospital outcome data assists analysts and planners in evaluating the relationship of the circumstances of the crash and other factors (e.g., human, road, medical treatment) at the time of the crash. In addition, integrated databases promote collaboration among agencies, which

Crash Data Improvement Program

The Federal government established the Crash Data Improvement Program (CDIP) to provide states with a means to measure the quality of the information within their crash database. It is intended to provide the states with metrics that can be used to establish measures of where their crash data stand in terms of its timeliness, the accuracy and completeness of the data, the consistency of all reporting agencies reporting the information in the same way, the ability to integrate crash data with other safety databases, and how the state makes the crash data accessible to users. Additionally, CDIP was established to help familiarize the collectors, processors, maintainers, and users with the concepts of data quality and how quality data help to improve safety decisions. CDIP also included a guide that presents information on each data quality characteristic and how to measure them.

Reference: Crash Data Improvement Program, National Highway Traffic Safety Administration, https://safety.fhwa.dot.gov/cdip/summary.cfm can lead to improvements in the data and the data collection process.

Some data are more challenging to integrate with other data sets. For example, hospital data are difficult to integrate with crash data due to the lack of a common identification system (as well as medical privacy laws). This is different from crash, road characteristics, and volume data, which can share a common referencing system on the road and thus be integrated and linked more easily for analysis.

Spatially-located data in a GIS system can be integrated simply based on spatial position. This geographic integration can assist agencies in bringing together data that were gathered by various departments or agencies that may use different data storage standards and reference systems.

Accessibility

Accessibility is a measure of how easy it is to retrieve and manipulate safety data in a system, in particular by those entities that are not the data system owners. Complete, accurate, and timely data easily made available to localities, MPOs, and other safety partners can greatly enhance transportation planning and safety investments. Agencies or departments who house safety data, especially crash data, should consider how accessible the data are to external parties and how the process of obtaining data could be streamlined.

Data Improvement Strategies

Local, State, and Federal agencies, as well as non-governmental organizations, require accurate data to be available for analysis and problem solving. Thus, programs to improve data should be in the work programs of all agencies invested in road safety. Data could be improved by changes in policy, technology, assessments, and training.

Policy

With so many agencies and organizations involved in the data collection process, published policy is a necessity. A standard set of procedures can provide a clear expectation of each agency's roles and responsibilities in data collection. Federal guidance and State legislation or administrative policy and regulations generally form a basis for policy. An example of Federal guidance comes from the provision in the MAP-21 transportation legislation that requires States to collect a comprehensive set of roadway and traffic fundamental data elements (FDEs) on all public roads[5].

Technology

Technology plays an important role in data collection improvement. Federal legislation provides funds that allow States to improve their data collection systems with the latest technology for quality data collection and integration. Technology is not static and is always changing. Some technology examples that help facilitate data collection include electronic crash reporting systems, GPS location devices, barcode or magnetic strip technologies, wireless communications, error checking, and conflicting fields.

Assessments

Assessments are official evaluations that government agencies conduct

[5] Moving Ahead for Progress in the 21st Century Act, Section 1112, §148(f)(2)

to determine the effectiveness of a traffic safety process or program. A team of outside experts conducts a comprehensive assessment of the highway safety program using an organized, objective approach and well-defined procedures that:

- Provide an overview of the program's current status in comparison to pre-established standards
- Note the program's strengths and weaknesses
- Provide recommendations for improvement

Both FHWA and NHTSA provide these types of assessments, such as the Roadway Data Improvement Program (RDIP), which can improve the quality of an agency's data through expert technical assistance and fresh perspectives. When State agencies request an RDIP assessment, an FHWA team reviews and assesses a State's roadway data system for the content of the data collected; for the ability to use, manage and share the data; and to offer recommendations for improving the road data. The RDIP also examines the State's ability to coordinate and exchange road data with local agencies, such as those in cities, counties, and MPOs[6].

Training

Education and training of transportation professionals play a vital role in improving data and data collection. For example, law enforcement officers create the crash data that is used by safety professionals to conduct studies and evaluate road safety. Thus, law enforcement need to understand how crash data are used in policy development and investment decisions, infrastructure improvements, and safety planning. Through proper education and training programs, law enforcement can have a broader perspective of their contribution to reducing crashes through improved data reporting. Other examples include training transportation professionals on the latest data collection tools and technology, advising court officials and adjudicators on important changes to safety legislation and penalties, and training personnel on how to handle crash reports with inaccurate or missing information.

Federal Guidance

The following two sections present examples of Federal guidance that leads State agencies into improving the quality of their safety data.

Model Minimum Uniform Crash Criteria

Statewide motor vehicle traffic crash data systems provide the basic information necessary for effective road safety efforts at any level of government—local, State, or Federal. Unfortunately, the use of State crash data is often hindered by the lack of uniformity between and within States. Data definitions, the number and type of data elements, and the threshold for collecting data varies from jurisdiction to jurisdiction. The Model Minimum Uniform Crash Criteria (MMUCC) was developed to help bring greater uniformity to crash data collection and provide national guidance to data collectors. MMUCC represents a voluntary and collaborative effort to generate uniform, accurate, reliable, and credible crash data to

[6] Federal Highway Administration Roadway Safety Data Program, http://safety.fhwa.dot.gov/rsdp/technical.aspx

support data-driven highway safety decisions at a State and a national level. MMUCC serves as a foundation for State crash data systems.

Since MMUCC is a minimum set of recommended crash data, States and localities may choose to collect additional motor vehicle crash-related data elements if they feel the data are necessary to enhance decision-making. Implementation of MMUCC is a collaborative effort involving the Governors Highway Safety Association, FHWA, NHTSA, and the Federal Motor Carrier Safety Administration (FMCSA).

The MMUCC Guideline is updated every four or five years to address emerging highway safety issues, simplify the list of recommended data elements, and clarify definitions of each data element.

MMUCC Data Elements

MMUCC consists of data elements recommended to be collected by investigators at the crash scene. From the crash scene information, additional data elements can be derived to assist law enforcement. Additional data elements are available through linkage to driver history, hospital and other health/injury data, and road inventory data. Each group of data elements has a unique identifier that describes the type of data element and whether it is derived or linked data.

MMUCC data elements are divided into four major groups that describe various aspects of a crash: crash, vehicle, person, and roadway. Each data element includes a definition, a set of specific attributes, and a rationale for the specific attribute.

For the entire list of MMUCC data elements, refer to the latest edition of the MMUCC Guideline located at **www.mmucc.us**.

MMUCC Example Element

The following is the MMUCC format for "Person Data Element Derived from Collected Data."

PD1. Age

Definition: The age in years of the person involved in the crash

Source: This data element is derived from Date of Birth (P2) and Crash Date and Time (C3).

Attribute:

- Age in years

Rationale: Age is necessary to determine the effectiveness of safety countermeasures appropriate for various age groups.

The MMUCC data elements represent a core set of data elements. The fourth edition (2012) of the MMUCC Guideline contains 110 data elements and recommends that States collect all 110 data elements. To reduce the data collection burden, MMUCC recommends that law enforcement at the scene should collect 77 of the 110 data elements. From crash scene information, 10 data elements can be derived, while the remaining 23 data elements should be obtained after linkage to other State data files. States unable to link to other State data to obtain the MMUCC linked data elements should collect, at a minimum, those linked data elements feasible for collecting on the crash report. At the same time, States should work to develop data linkage capabilities so they eventually are able to obtain, via linkage, all of the information to be generated by the MMUCC linked data elements.

ROADWAY SEGMENT

Segment location/linkage elements
Segment classification
Segment cross section
Segment roadside descriptors
Other segment descriptors
Segment traffic flow data
Segment traffic operations/control data
Other supplemental segment descriptors

ROADWAY ALIGNMENT

Horizontal curve data
Vertical curve data

ROADWAY JUNCTION

At-grade intersection/junctions
Interchange and ramp descriptors

FIGURE 3-5: MIRE Data Elements Category Descriptors (Source: MIRE version 1.0)

Model Inventory of Roadway Elements

Critical safety data include not only crash data, but also road inventory data, traffic data, and other information. State DOTs need accurate and detailed data on road characteristics as they develop and implement strategic highway safety plan (SHSPs) and look toward making more data driven safety investments.

With the need for and availability of so many types of data, the question becomes "How can transportation agencies be sure that they are collecting the necessary roadway data to make effective road safety decisions?" MIRE is a vitally important resource that defines the data needed to help transportation agencies build a road characteristics database that will lead to good safety analysis. MIRE defines 202 individual characteristics of the road system that should be collected. These characteristics are referred to as data elements. The elements fall into three broad categories:

- Roadway segment descriptors
- Roadway alignment descriptors
- Roadway junction descriptors

Most State and local transportation agencies do not have all the data needed to use analysis tools such as SafetyAnalyst, the Interactive Highway Safety Design Model, and other tools and procedures identified in the Highway Safety Manual. MIRE provides a structure for road inventory data that allows State and local transportation agencies to use these analysis tools with their own data rather than relying on default values that may not reflect local conditions.

As the need for road inventory information has increased, new and more efficient technologies to collect road characteristics have emerged. However, the collected data need a framework for common information sharing. Just as MMUCC provides guidance for consistent crash data elements, MIRE provides a structure for roadway inventory data elements using consistent definitions and attributes. It defines each element, provides a list of attributes for coding, and assigns a priority status rating of "critical" or "value added" based on the element's importance for use in analytic tools, such as

SafetyAnalyst.

The latest version of MIRE can be viewed and downloaded from the FHWA Office of Safety site, **http://safety.fhwa.dot.gov/tools/data_tools/mirereport/.**

Figure 3-5 displays a breakdown of the major data element categories and subcategories contained in MIRE. MIRE further breaks down each subcategory into individual data elements. For a complete listing of MIRE data elements, refer to the MIRE publication.

While the complete list of MIRE elements is rather extensive, there are a basic set of elements within MIRE called the Fundamental Data Elements (FDE) that an agency needs to conduct safety analyses regardless of the specific analysis tools used or methods applied. As discussed, the need for improved and more robust safety data is increasing due to the development of a new generation of safety data analysis tools and methods.

Linking Data Through A Referencing System

The types of road safety data presented in this unit are only useful as much as they are capable of being linked through a common geospatial relational location referencing system. States recognize that they must have a common relational location referencing system (i.e., geographic information system or linear referencing system) for all public roads if they are going to integrate different types of safety data. If all safety data are referenced to the same system, the road characteristics data can be linked with the crash data, which would permit the State to identify locations on all public roads where crash patterns are occurring that can be reduced through known countermeasures.

In most States, development of a common referencing system for all public roads will require significant effort and cooperation with local agencies. The Federal Highway Performance Monitoring System requires GIS-based referencing for all roads in the Federal-aid highway system, interstate highways, and public roads not classified as local roads or rural minor collectors.[7] However, significant travel occurs on local roads and rural minor collectors. Some local agencies have or are developing, their own GIS-based referencing systems for roads in their inventory data. Light detection and ranging (LIDAR) systems are often used to accurately survey the road network. The State should work with local agencies to incorporate these referencing systems into the State base map. Once the referencing systems are combined, attribute data for additional mileage can be added when either State or local agencies develop or expand inventories. Moreover, as stated above, this will lead to the ability to link crashes with inventory and traffic data, enabling the State to use the more advanced problem identification methods on more and more miles of public roads.

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[7] Memorandum on Geospatial Network for All Public Roads, Office of Highway Policy Information, August 7, 2012. Accessed October 2017 at https://www.fhwa.dot.gov/policyinformation/hpms/arnold.pdf

Conclusion

Data are crucial to improving road safety. Safety data consist of various kinds of data that can be used to identify safety problems and priorities so that safety partners in many agencies can address important issues. Data such as crash data, traffic volume data, and road characteristics data are often used and are critical for safety analysis by many agencies. Other data, such as conflict observations, emergency medical data, and citation data, can be useful in a supplemental role for specific studies. Regardless of the type of safety data, the quality of the data is vitally important. Agencies that collect safety data should strive to improve their timeliness, accuracy, completeness, uniformity, integration, and accessibility to maximize their potential to drive good decisions.

EXERCISES

- **SELECT** a scenario below. Assume that you are using crash data as your primary data to inform your decisions. Explain how each of the six quality criteria discussed in this chapter could affect your evaluation of the current safety situation and your recommendations.
    - You are prioritizing intersections in a city to be treated with enhanced visibility treatments, such as larger signs, wider markings, and additional signal heads.
    - You are developing a public outreach effort to communicate the need to yield to pedestrians at crosswalks. You wish to focus your efforts to the areas of the city where failing to yield to pedestrians is the most rampant.
    - You are recommending safety improvements to an interchange that was identified based on having a higher number of expected crashes than other interchanges of the same type.

  Given the scenario you selected above, how do you think the availability of other types of data could affect your recommendations? Such data may include any of the data types covered in Chapter 3.2. (e.g., EMS and hospital injury data, enforcement citations, public complaints, or other data). What additional information could this reveal?
- **IDENTIFY** programs or policies that exist in your state or local agency to improve data. This may include any of the types of safety data covered in Chapter 3.2.

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UNIT 4

Solving Safety Problems

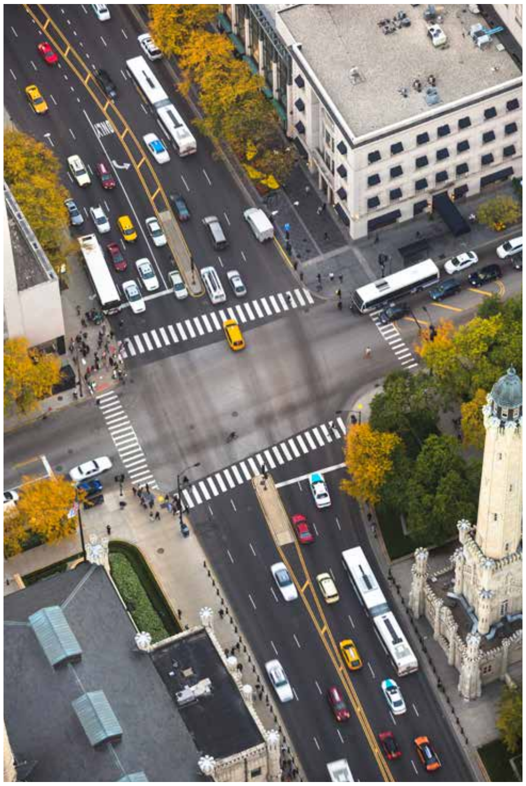
LEARNING OBJECTIVES

After reading the chapters and completing exercises in Unit 4, the reader will be able to:

- **IDENTIFY** three major components of road safety management
- **DEFINE** the process of conducting site-level and system-level safety management
- **USE** safety data to identify safety issues and develop strategies to solving those issues

Road Safety Management

Road safety management refers to the process of identifying safety problems, devising potential strategies to combat those safety problems, and selecting and implementing the strategies. Effective safety management is also proactive and looks for ways to prevent safety problems before they arise. High quality safety data should be used to determine the nature of the road safety problems and how best to solve them. As discussed in Unit 3, the clearest and most readily available indicators of road safety problems are crash data. These data can be used to identify safety problems on a large or a small scale. Other data, such as roadway characteristics, traffic volume, citations, and driver history, can be integrated with crash data to assist in identifying safety trends and high priority locations.



Data quality issues should not prevent a data-driven process

Every transportation agency will acknowledge that it does not have perfect data. All data have issues related to accuracy, coverage, timeliness, and other factors. One agency's crash data may have an incomplete record of low severity crashes. Another agency may have very little data on the traffic volume on low volume rural roads. However, data quality issues should not prevent a transportation agency from using the data to drive its safety management efforts. Even while the agency strives to improve its data, the data on hand should be used in the process of identifying safety problems and devising solutions to those problems.

Data needs for safety analysis

High quality safety analysis demands high quality data. Unfortunately, poor data availability and low quality limit the types of analyses that can be conducted. The data requirements depend on the type of analysis and what safety questions are being asked. Table 4-1 provides examples of various categories of safety analysis and lists the data that would be needed to conduct them.[1]

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[1] Applying Safety Data and Analysis to Performance-Based Transportation Planning, e-Guidebook, FHWA, http://safety.fhwa.dot.gov/tsp/fhwasa15089/appb.cfm

	SAFETY ANALYSIS QUESTION	DATA NEEDS
BENCHMARKING	How many fatalities and serious injuries are occurring in my area? How does this compare to other areas of my State?	**Total crashes** **Total fatalities and serious injuries** **High-level roadway data** — roadway ownership, functional classification **Agency geographic boundary information**
CRASH TRENDS AND CONTRIBUTING FACTORS	What type of road users are involved in crashes? When are the crashes occurring? What are the major contributing factors to crashes?	**Crash severity** — fatality, injury type, property damage only **Crash incidence data** — time of day, day, month, weather, etc. **Crash type** — road departure, intersection, head-on, angle, etc. **Contributing factors** — age, impairment, seatbelt usage, speed, etc.
SITES FOR SAFETY IMPROVEMENT	What locations (intersections or segments) show the most potential for safety improvements?	**Crash severity** **Crash location** **Roadway and roadside characteristics** — intersection control, number of lanes, presence and type of shoulder, presence and type of median, posted speed, horizontal and vertical alignment, etc. **Traffic volume data** — intersection total entering traffic volume, roadway segment volume per million vehicle miles. **Calibrated safety performance functions**, if predictive methods are used
SAFETY RISK FACTORS	What are the common characteristics of locations with crashes? What are the countermeasures to address these characteristics? How should we prioritize system-wide implementation?	**Crash severity** **Crash location** **Roadway and roadside characteristics** — intersection control, number of lanes, presence and type of shoulder, presence and type of median, posted speed, horizontal and vertical alignment, etc. **Traffic volume data** — intersection total entering traffic volume, roadway segment volume per million vehicle miles.

TABLE 4-1: Safety analysis categories, questions, tools and data needs.

Safety data as performance measures

A transportation agency has many types of data at its disposal for identifying safety problems, but the agency must select which type(s) of data will be the **performance measures** used to identify the road safety emphasis areas. Federal legislation has focused increasingly on fatal crashes and serious injury crashes as performance measures for road safety.

Table 4-2 provides examples of performance measures developed by the National Highway Traffic Safety Administration (NHTSA) and the Governors Highway Safety Association (GHSA) that could be used to identify safety priorities.[2] The sources of the data could be State crash data files, the Fatality Analysis Reporting System (FARS), surveys conducted by the State, or grant applications from law enforcement and other departments. The section on Network Screening in Chapter 11 presents a more detailed discussion of crash-based performance measures and how they can be used to identify sites that are high priority for safety treatment.

Performance measure

A numerical metric used to monitor changes in system condition and performance against established visions, goals, and objectives.

DESCRIPTION	SOURCES
Number of traffic fatalities (three-year or five-year moving averages)	FARS
Number of serious injuries in traffic crashes	State crash data files
Fatalities/VMT (including rural, urban, and total fatalities)	FARS, FHWA
Number of unrestrained passenger vehicle occupant fatalities, seat positions	FARS
Number of fatalities in crashes involving a driver or motorcycle operator with a blood alcohol concentration of .08 g/dL or higher	FARS
Number of speeding-related fatalities	FARS
Number of motorcyclist fatalities	FARS
Number of unhelmeted motorcyclist fatalities	FARS
Number of drivers 20 or younger involved in fatal crashes	FARS
Number of pedestrian fatalities	FARS
Observed seat belt use for passenger vehicles, front seat outboard occupants	Survey
Number of seat belt citations issued during grant-funded enforcement activities	Grant activity reporting
Number of impaired-driving arrests made during grant-funded enforcement activities	Grant activity reporting
Number of speed citations issued during grant-funded activities	Grant activity reporting

TABLE 4-2: Safety performance measures and data sources (*Source: NHTSA 2007*)

[2] National Highway Traffic Safety Administration (NHTSA). 2007. Performance Measures Discussion. 408 Team Document #005, October 29, 2007. National Highway Traffic Safety Administration.

Components of safety management

The safety management process can be viewed in three general components. These components are carried out by the agency (or agencies) responsible for managing the safety of the road system:

- **Identifying safety problems –** The agency uses crash data and other safety data to identify road safety problems or problem locations.
- **Developing potential safety strategies –** The agency develops potential strategies to address the identified safety problems. These strategies might also be referred to as countermeasures or treatments.
- **Selecting and implementing strategies –** The agency weighs the potential strategies and decides which ones to implement.

Levels of safety management

Although all road safety management follows the same three general components listed above, the specific steps of the safety management process will be different depending on the scope. The process might be intended to address specific site-level issues, such as crash patterns at high priority intersections, curves, or corridors. On a larger scale, the process might be intended to address system-level issues, such as problems that can be addressed by policies, design standards, or broad ranging campaigns of education or enforcement. The following chapters will discuss safety management for these two levels: Chapter 11 presents site-level safety management; Chapter 12 presents system-level safety management.

CHAPTER 11 UNIT 4: SOLVING SAFETY PROBLEMS

Site-Level Safety Management

Site-level safety management is the process of identifying and addressing safety issues at high priority **sites**. This contrasts with safety issues that are addressed for an entire transportation system (i.e., all roads in a city, county, or State). System-level safety management is covered in Chapter 12.

Site

A narrowly defined location of interest for safety analysis, such as an intersection, road section, interchange, or midblock crossing.

Agencies responsible for road safety often conduct some form of site-level safety management. They identify particular sites of concern and determine how best to address the safety problems at these priority sites. The methods of identifying priority sites and the safety strategies used to treat the sites differ according to the type of agency. A department of transportation (DOT) may install a sign or pavement marking; a law enforcement agency might increase enforcement in the area of the site. Regardless of the type of agency, it is important to conduct site-level safety management in a manner that uses good analysis methods driven by safety data.

Chapter 10 presented road safety management in terms of three general components:

- **Identifying safety problems**
- **Developing potential safety strategies**
- **Selecting and implementing strategies**

FIGURE 4-1: Schematic Illustrating the Steps of Site-level Safety Management

When discussing site-level safety management, these three components can be further divided into six distinct steps. This six-step process is common to the engineering discipline and is presented in Part B of the first edition of the Highway Safety Manual[3] (HSM). The process, shown in Figure 4-1, will be the framework for the discussion of site-level safety management in this chapter. The material presented in this chapter is based on the guidance presented in the HSM and material from a series of documents entitled "Reliability of Safety Management Methods" published by FHWA. These FHWA

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[3] Highway Safety Manual, First edition, American Association of State Highway Transportation Officials, 2010.

SAFETY MANAGEMENT COMPONENTS	STEPS OF SITE-LEVEL SAFETY MANAGEMENT
IDENTIFY SAFETY PROBLEMS	**Step 1. Network screening:** Identify locations that could benefit from treatments to reduce crash frequency and severity.
	Step 2. Diagnosis: Identify crash trends and patterns based on reported crashes, assess the crash types and severity levels, and study other elements that characterize the crashes.
DEVELOP POTENTIAL SAFETY SOLUTIONS	**Step 3. Countermeasure selection:** Identify appropriate countermeasures to target crash contributing factors and reduce crash frequency and severity at identified locations.
	Step 4. Economic appraisal: Estimate the economic benefit and cost associated with implementing a particular countermeasure or set of countermeasures.
SELECT AND IMPLEMENT STRATEGIES	**Step 5. Project prioritization:** Develop a prioritized list of safety improvement projects, considering available resources.
	Step 6. Safety effectiveness evaluation: Evaluate how a particular countermeasure (or group of countermeasures) has affected crash frequency and severity where it was installed.

TABLE 4-3: Steps of the Site-level Safety Management Process

documents provide in-depth guidance and examples on the following topics:

- **Network screening** – The network screening guide describes various methods and the latest tools to support network screening.[4]
- **Diagnosis** – The diagnosis information guide describes various methods and the latest tools to support diagnosis.[5]
- **Countermeasure selection** – The countermeasure selection information guide describes various methods and the latest tools to support countermeasure selection.[6]
- **Safety effectiveness evaluation** – The safety effectiveness evaluation guide describes various methods and the latest tools to support safety effectiveness evaluation.[7]
- **Systemic safety programs** – The systemic safety programs guide describes the state-of-the-practice and the latest tools to support systemic safety analysis.[8]

The six steps of the site-level safety management process relate to the three general components of safety management as shown in Table 4-3. Each step is presented in more detail through the following sections in this chapter.

[4] Srinivasan, R., F. Gross, B. Lan, G. Bahar (2016), *Reliability of Safety Management Methods: Network Screening*, Report No. FHWA-SA-16-037, Federal Highway Administration, Washington, D.C.

[5] Srinivasan, R., G. Bahar, F. Gross (2016), *Reliability of Safety Management Methods: Diagnosis*, Report No. FHWA-SA-16-038, Federal Highway Administration, Washington, D.C.

[6] Bahar, G. R. Srinivasan, F. Gross, (2016), *Reliability of Safety Management Methods: Countermeasure Selection*, Report No. FHWA-SA-16-039, Federal Highway Administration, Washington, D.C.

[7] Srinivasan, R., F. Gross, G. Bahar (2016), *Reliability of Safety Management Methods: Safety Effectiveness Evaluation*, Report No. FHWA-SA-16-040, Federal Highway Administration, Washington, D.C.

[8] See next page.

Step 1. Network screening

Network screening refers to the process of selecting high priority sites that need safety treatment, often through an analysis of crash data. There are many ways in which an agency can use crash data to prioritize sites, ranging from simplistic methods, which are easy to understand and implement but can be inaccurate or ineffective, to more advanced methods, which require statistical expertise and more data but provide a better prioritization of sites.

For many years, the most prevalent methods for ranking specific sites for safety improvements were based on historical crash data alone. Many agencies still use these methods to allocate their road safety funds. Agencies that prioritize sites by historical **crash frequency** identify those sites that have the highest number of crashes in a certain time period (typically three to five years). This serves to assist agencies in addressing the magnitude of the problem, that is, attempting to address the highest number of crashes. By its nature, this method typically identifies sites that have high amounts of traffic (either vehicles, pedestrians, or other road users). However, this method may miss abnormally hazardous sites that do not present a relatively large number of crashes. Another variation of the crash frequency method uses **crash severity**, in which agencies weight the crash frequency by giving greater weight to higher severity crashes. This method counteracts some of the bias in the crash frequency method. For example, a general high crash frequency may prioritize a busy intersection that has many crashes, but a closer examination reveals that most crashes are low speed, low severity rear-end crashes. The crash severity method would lower the priority of this intersection in favor of other sites where more serious crashes occur.

Some agencies prioritize sites by the historical **crash rate**. This method incorporates traffic volume to augment the crash data. The crash frequency at a site is divided by the traffic volume – either the annual average daily traffic (for road segments), total entering volume (for vehicle traffic at intersections), or other volumes, such as pedestrian crossing volume. The typical unit for this method is crashes per 100 million vehicle miles traveled for road segments or crashes per 100 million entering vehicles for intersections. Crash rate in these units is calculated as:

$$\text{Crash rate per 100 million vehicle miles traveled} = \frac{(C \times 100{,}000{,}000)}{(V \times 365 \times N \times L)}$$

C = Number of crashes in the study period

V = Traffic volumes using average annual daily traffic (AADT) volumes

N = Number of years of data

L = Length of the roadway segment in miles

This approach of prioritizing sites by crash rate serves to counteract the bias of crash frequency that overly prioritizes sites with high volume, since higher volume decreases the crash rate. However, it may inefficiently prioritize sites with very low volumes.

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(from previous page) Gross, F., T. Harmon, G. Bahar, K. Peach (2016), *Reliability of Safety Management Methods: Systemic Safety Programs*, Report No. FHWA-SA-16-041, Federal Highway Administration, Washington, D.C.

Crash frequency

The number of observed crashes per year.

Crash severity

The level of injury severity of the crash as an event, typically determined by the highest severity injury of any person involved in the crash.

Crash rate

The number of observed crashes per unit of traffic volume passing through the location.

Agencies might use a combination of these two methods. They may set a minimum crash rate to generate an initial list of priority sites and then prioritize that group by crash frequency or severity. Regardless, these simplistic methods are known to have potential biases. One of the most prevalent biases is that the crash history used to prioritize sites with these methods usually reflects only the short-term trend of crashes. Given that the year-to-year occurrence of crashes at a location is random, it can be the case that a short-term crash history (one to three years) may be relatively high, but in the long run (ten years), the crashes would return to a lower amount, even if no safety improvements were done. This effect creates selection bias or **regression-to-the-mean** (RTM) bias in the safety analysis of this location.

Regression-to-the-mean

The fact that a short term examination of crash history at a location is likely inaccurate (e.g., lower or higher than its true safety performance). When a longer time period of crash history is examined, the crash frequency will "regress" to its "mean" and provide a better picture of the long term average crash frequency.

As the years progressed, many transportation safety professionals recognized that while these simplistic methods did identify sites that benefited from safety improvement, they were not the locations where safety funds could be spent the most effectively. The selection of high crash sites was subject to RTM bias. Also, sites with high numbers of crashes were typically complex and required expensive reconstruction in order to reduce crashes appreciably. The question became, "How could road safety funds be spent in a way that provided the biggest bang for the buck?"

Comparing road segments by crash frequency and rate

Road Segment A: A three-mile section of road that has had **four** crashes over five years and has a traffic volume of **4,000** vehicles per day.

Road Segment B: A three-mile section of road that has had **10** crashes over five years and has a traffic volume of **12,000** vehicles per day.

If an agency is comparing these segments based on crash frequency, they would prioritize road segment B for having 10 crashes compared to road segment A which had four crashes.

If comparing these segments based on crash rate, the agency would calculate the crash rate of road segment A as (4 crashes x 100,000,000) / (4,000 vehicles per day x 365 x 5 years x 3 miles) = 18.2 crashes per 100 million vehicle miles traveled. Following the same calculation, road segment B has a rate of 15.2 crashes per 100 million vehicle miles traveled. According to crash rate, the agency would prioritize road segment A. The prioritization of these two segments changes when traffic volume is taken into account.

As the science of road safety advanced, researchers developed more advanced approaches for prioritizing sites for safety improvements. Dr. Ezra Hauer pushed forward a movement to identify "sites with promise."[9] The main idea was to identify sites that experienced more crashes than would be expected from a site with that particular set of characteristics. In many cases, these abnormally performing sites could be addressed with low cost safety treatments, such as larger signs or pavement markings with greater visibility. This approach uses statistical regression models that predict crashes for a given set of characteristics. These models demonstrate the advantage of bringing together different types of safety data, which in this case could include crash data, roadway characteristics, and traffic volume.

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[9] Hauer, E. (1997), *Observational Before After Studies in Road Safety*, Elsevier Science, New York.

The most basic of these regression methods calculates **predicted crashes**. This method requires information about certain geometric and operational characteristics, such as traffic volume, number of lanes, and type of road.

An SPF is developed or calibrated using data from an entire jurisdiction or State, so it is independent of the crash history of the specific site. This means that the predicted crash value is unaffected by the bias caused by RTM. Using SPFs, transportation agencies can predict crash values for many sites and prioritize the sites according to the highest predicted values. Another use of the predictive method is in systemic safety treatments, presented in Chapter 12 under Risk Based Prioritization.

Predicted crashes

The frequency of crashes per year that would be predicted for a site based on the result of a crash prediction model, called a safety performance function (SPF).

PERFORMANCE MEASURE	ACCOUNTS FOR TRAFFIC VOLUME	ACCOUNTS FOR RTM BIAS	ACCOUNTS FOR CRASH SEVERITY
1. Average crash frequency	*No*	*No*	*Not explicitly**
2. Crash rate	Yes	*No*	*Not explicitly**
3. Equivalent property damage only (EPDO) average crash frequency	*No*	*No*	Yes
4. Relative severity index	*No*	*No*	Yes
5. Critical rate	Yes	*No*	*Not explicitly**
6. Excess predicted average crash frequency using method of moments	*No*	*No*	*Not explicitly**
7. Level of service of safety	Yes	*No*	*Not explicitly**
8. Excess predicted average crash frequency using SPFs	Yes	*No*	*Not explicitly**
9. Probability of specific crash types exceeding threshold proportion	*No*	Not affected by RTM bias**	*Not explicitly**
10. Excess proportion of specific crash types	*No*	Not affected by RTM bias**	*Not explicitly**
11. Expected average crash frequency with empirical Bayes adjustments	Yes	Yes	*Not explicitly**
12. EPDO average crash frequency with EB adjustment	Yes	Yes	Yes
13. Excess expected average crash frequency with EB adjustment	Yes	Yes	*Not explicitly**

* While these measures do not explicitly mention severity, analysts can adapt any of the measures to consider any severity level.

** These two measures will not be affected by RTM only if they are based on data from a long time period.

TABLE 4-4: Performance Measures for Network Screening *(Source: Highway Safety Manual, 1st ed.)*

Where can I get safety performance functions for my State?

SPFs can be obtained in two ways:

1) SPFs can be developed from scratch using crash, roadway, and traffic volume data from roads and intersections in the State. This requires significant data to be collected on hundreds of sites. A statistical expert must use these data to develop SPFs that are tailor made for that State.

2) SPFs can be obtained from national resources, such as the HSM; then calibrated for the particular State of interest. This requires data to be collected on a smaller number of sites than is required for developing a new SPF.

The crashes predicted by the SPF are compared to the crashes observed on the State's roads, and an analyst calculates a calibration factor to adjust the SPF prediction appropriately for the State.

SPF development or calibration is typically handled by the State DOT. FHWA provides guidance on deciding between developing a new SPF or calibrating an existing one.[10] States that decide to develop new SPFs can refer to guidance in a related FHWA publication.[11] NCRHP provides guidance for those who decide to calibrate existing SPFs.[12]

The first edition of the HSM lists several benefits of the predictive method, including:

- RTM bias is addressed as the method concentrates on long-term expected average crash frequency rather than short-term observed crash frequency.
- Reliance on availability of limited crash data for any one site is reduced by incorporating predictive relationships based on data from many similar sites.
- The method accounts for the fundamentally nonlinear relationship between crash frequency and traffic volume.

Agencies can also use the predicted crashes in combination with actual crash history at the site of interest to calculate **expected crashes**. A method called empirical Bayes (EB) brings these two values together to reflect a crash frequency that incorporates the general crash prediction from the SPF with the real world experience of crash history at the site to provide an accurate estimation of how many crashes should be expected at the site (see more detailed discussion of the EB method later in this step). Some agencies may also calculate **excess crashes** as a measure for site prioritization. This is the difference between the expected crashes and the observed crash frequency at the site.

Performance measures in network screening

The key to effective network screening is selecting an appropriate performance measure. Network screening methods should appropriately account for three major factors that can affect the screening outcome:

- **Differences in traffic volumes**
- **Possible bias due to RTM**
- **Crash severity**

Table 4-4 lists the thirteen performance measures discussed in the HSM with an indication of their ability to account for these major factors. While some measures directly account for crash severity (e.g., relative severity index), analysts can adapt any of the measures to account for crash severity.

Expected crashes, excess crashes

See next page.

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[10] Srinivasan, R., D. Carter, and K.Bauer (2013), *Safety Performance Function Decision Guide: SPF Calibration vs SPF Development*, Report No. FHWA-SA-14-004, Federal Highway Administration, Washington, DC.

[11] R. Srinivasan and K. Bauer (2013), *Safety Performance Development Guide: Developing Jurisdiction-Specific SPFs*, Report FHWA-SA-14-005, Federal Highway Administration, Washington, DC

[12] Bahar, G (2014), *User's Guide to Develop Highway Safety Manual Safety Performance Function Calibration Factors*, HR 20-7(332), National Cooperative Highway Research Program, American Association of State Highway and Transportation Officials, Standing Committee on Traffic Safety, Washington, DC.

Accounting for differences in traffic volumes

As discussed earlier, analysts have traditionally used crash rates to account for differences in traffic volume among sites. Crash rate is the ratio of crash frequency to exposure, which is typically the traffic volume. Crash rates implicitly assume a linear relationship between crash frequency and traffic volume; however, many studies have shown that the relationship between crashes and traffic volume is nonlinear, and the shape of this relationship depends on the type of facility. Nonlinear relationships, such as SPFs, are more appropriate than linear relationships, such as crash rates to account for differences in traffic volume among sites.

SPFs are a more reliable method to account for differences in traffic volume among sites because they reflect the nonlinear relationship between crash frequency and traffic volume. The SPF is an equation that represents a best-fit model that relates annual observed crashes to the site characteristics including annual traffic volume and other site characteristics. Typically, SPFs are estimated for a particular crash type for a type of facility (e.g., run-off-road crashes on rural two

Expected crashes

The frequency of crashes per year that represents the combination of the predicted crashes and the observed crashes that actually occurred at the site.

Excess crashes

The difference between the expected crashes and the observed crash frequency at the site.

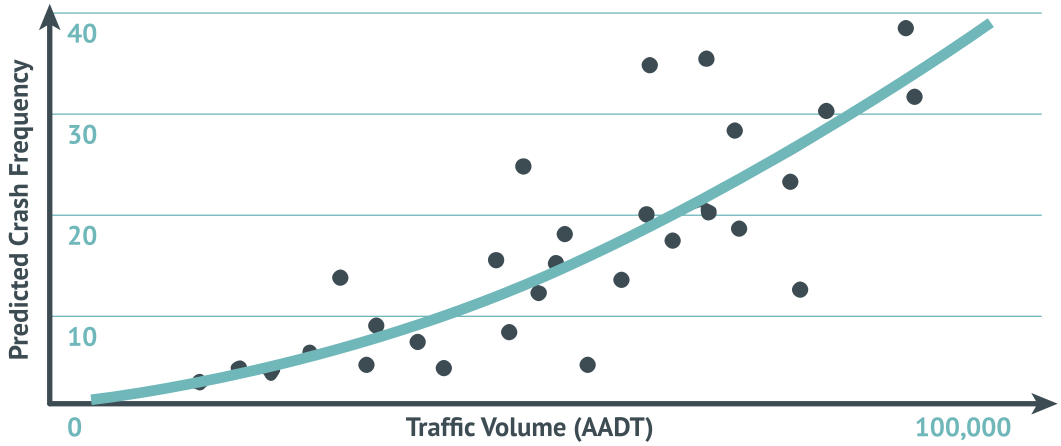

FIGURE 4-2: Example of SPF for multi-vehicle crashes on rural, 4-lane freeways

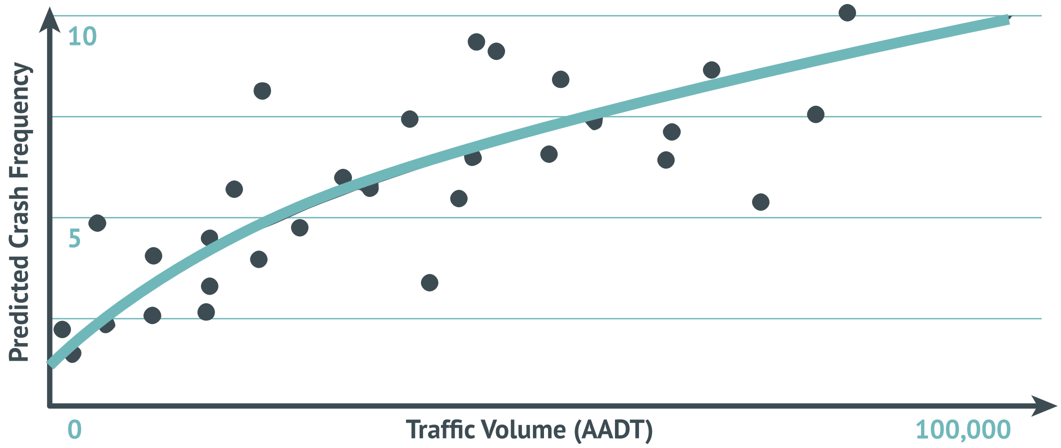

FIGURE 4-3: Example of SPF for single-vehicle crashes on rural, 4-lane freeways

lane roads) using data from an entire jurisdiction or State. Figure 4-2 and Figure 4-3 show example SPFs where the points represent observed crashes at specific traffic volumes for individual sites, and the solid line represents the best-fit model (i.e., the SPF). If the relationship between exposure and crash frequency were linear, then the solid line would be a straight line instead of a curve. These two figures also demonstrate the nature of SPFs – each curve is different. For the rural, four lane freeways used in this example, multi-vehicle crashes rise exponentially with more traffic volume (Figure 4-2) but single-vehicle crashes behave differently; they level off with increasing levels of traffic volume (Figure 4-3).

An SPF produces the average number of crashes that would be predicted for sites with a particular set of characteristics. By comparing a site's observed number of crashes with the predicted number of crashes from an SPF, it may be possible to identify sites that experience more crashes than one would expect from a site with that particular set of characteristics. Sites where the observed number of crashes is larger than the predicted number of crashes from an SPF warrant further review and diagnosis. Two measures in Table 4-4, level of service of safety (LOSS) and the excess predicted average crash frequency using SPFs, use the observed crash frequency and predicted frequency from an SPF to identify sites with promise.

Ideally, SPFs should be estimated using data from the same jurisdiction as the site(s) being studied.[13] However, that may not always be possible due to the availability of data or lack of statistical expertise. In that case, the SPFs developed from another jurisdiction could be calibrated using data from the jurisdiction with the study sites.[15]

SPF Example 1

Some States use Safety Analyst, a software tool from AASHTO, to identify sites that may benefit from a safety treatment.[14] The following is an SPF from Safety Analyst that predicts the total number of crashes on rural multilane divided roads:

$$\mathbf{P = L \times \mathit{e}^{-5.05} \times (AADT)^{0.66}}$$

P is the total number of crashes in one year on a segment of length **L**.

This is a relatively simple SPF where the predicted number of crashes per mile is a function of just AADT. For example, if the AADT is 45,000, then the predicted number of crashes for a one mile segment based on the SPF will be the following:

$$\mathbf{P = 1 \times e^{-5.05} \times 45000^{0.66}}$$
$$\mathbf{= 7.55 \text{ crashes per year}}$$

Avoiding bias due to regression-to-the-mean

As previously discussed, RTM describes the situation when periods with relatively high crash frequencies are followed by periods with relatively low crash frequencies simply due to the random nature of crashes. Figure 4-4 illustrates RTM, comparing the difference between short-term average and long-term average crash history.[16] Due to RTM, the short-term average is not a reliable estimate of the long-term crash propensity of a particular site. If an agency selects sites based

[13] R. Srinivasan and K. Bauer (2013), Safety Performance *Development Guide: Developing Jurisdiction-Specific SPFs*, Report FHWA-SA-14-005, Federal Highway Administration, Washington, DC.

[14] http://www.safetyanalyst.org/

[15] G. Bahar and E. Hauer (2014), *Users Guide to Develop HSM SPF Calibration Factors*, NCHRP Project 20-7(332).

[16] Susan Herbel, Lorrie Laing, Colleen McGovern (2010), *Highway Safety Improvement Program (HSIP) Manual*, FHWA-SA-09-029, Federal Highway Administration, Washington, DC.

SPF Example 2

Bauer and Harwood[17] provide a more complex SPF for fatal and injury crashes on rural two lane roads. This model provides a crash prediction that is more tailored to characteristics of the site, such as curve radius and vertical grade of the road:

$$N_{FI} = \exp[-8.76+1.00\times\ln(AADT)+0.044\times G+0.19\times\ln(2\times5730/R)\times I_{HC}$$
$$+4.52\times(1/R)(1/L_c)\times I_{HC}]$$

N_{FI} = fatal-and-injury crashes per mile per year
AADT = annual average daily traffic (vehicles/day)
G = absolute value of percent grade; 0% for level tangents; ≥ 1% otherwise
R = curve radius (ft); missing for tangents
I_{HC} = horizontal curve indicator: 1 for horizontal curves; 0 otherwise
L_C = horizontal curve length (mi); not applicable for tangents
ln = natural logarithm function

on high short-term average crash history, crashes at those sites may be lower in the following years due to RTM, even if the agency does not install countermeasures at those sites.

If RTM is not properly accounted for, sites with a randomly high count of crashes in the short term could be incorrectly identified as having a high potential for improvement, and vice versa. In this case, scarce resources may be inefficiently used on such sites while sites with a truly high potential for cost effective safety improvement remain unidentified.

One approach to address RTM bias is to use the EB method. The EB method is a statistical method that combines the observed crash frequency (obtained from crash reports) with the predicted crash frequency (derived from the appropriate SPF) to calculate the expected crash frequency for a site of interest. This method pulls the crash count towards the mean, accounting for the RTM bias.

The EB method is illustrated in Figure 4-5, which illustrates how the observed crash frequency is combined with the predicted crash frequency based on the SPF.[18] The

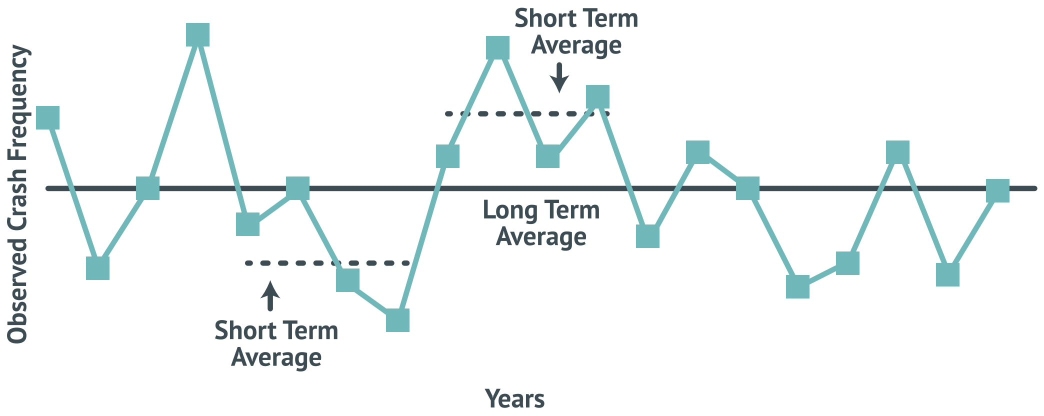

FIGURE 4-4: Chart to illustrate RTM phenomenon *(Source: HSIP Manual, 2010)*

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[17] Bauer, K. and Harwood, D., Safety Effects of Horizontal Curve and Grade Combinations on Two-Lane Highways, Federal Highway Administration, Report No. FHWA-HRT-13-077, January 2014.

[18] Susan Herbel, Lorrie Laing, Colleen McGovern (2010), *Highway Safety Improvement Program (HSIP) Manual*, FHWA-SA-09-029, Federal Highway Administration, Washington, DC.

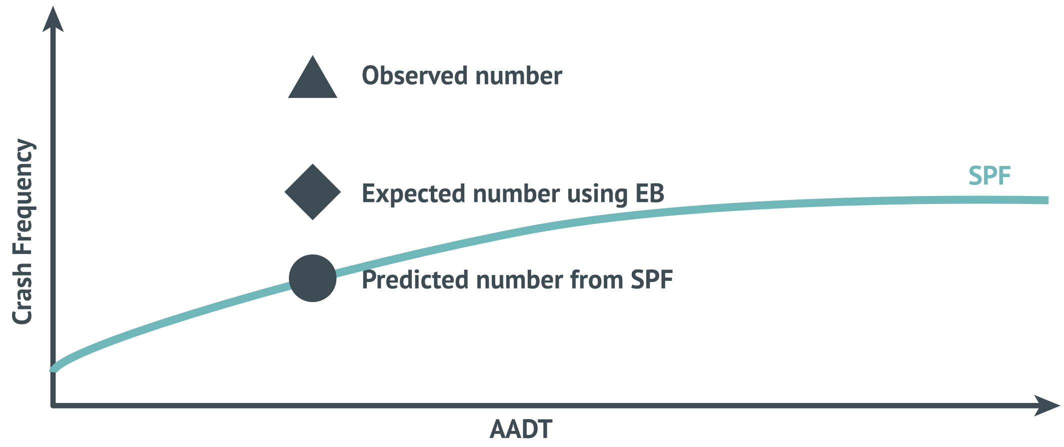


FIGURE 4-5: Schematic to illustrate the empirical Bayes method *(Source: HSIP Manual, 2010)*

EB method is applied to calculate an expected crash frequency or corrected value, which lies somewhere between the observed value and the predicted value from the SPF.

Mathematically, the expected number of crashes can be written as a function of the predicted value from the SPF and the observed crashes in the following manner:

Equation 1

$$N_{expected} = w \times N_{predicted} + (1 - w) \times N_{observed}$$

$N_{expected}$ = expected average crash frequency for a certain study period

w = weighted adjustment to be placed on the SPF prediction ($0 < w < 1$)

$N_{predicted}$ = predicted average crash frequency predicted using an SPF for the study period under the given conditions

$N_{observed}$ = observed crash frequency at the site over the study period

The weight w is a function of the predicted crash frequency ($N_{predicted}$) and a statistical parameter called the overdispersion parameter of the SPF. Procedures to estimate the expected average crash frequency are provided in Part B of the HSM. For example, if the observed crash frequency in a particular site was nine crashes per year, the predicted crash frequency from the SPF was 6.4 crashes per year, and the w was 0.3, then $N_{expected}$ will be as follows:

$$N_{expected} = 0.3 \times 6.4 + (1 - 0.3) \times 9$$
$$= 8.22 \text{ crashes per year}$$

We can prioritize sites by calculating the difference between the EB expected crashes at a particular site and the predicted crashes from an SPF. By comparing EB expected crashes at a particular site instead of observed crashes, we account for possible bias due to RTM.

The first eight measures presented in Table 4-4 do not account for possible bias due to RTM. Measure 9 (probability of specific crash types exceeding threshold proportion) and measure 10 (excess proportion of specific crash types) are not affected by RTM unless they are based on short-term crash history. Measure 11 (expected average crash frequency with EB adjustments), measure 12 (EPDO average crash frequency with EB adjustment), and measure 13 (excess expected average crash frequency with EB adjustment) account for possible bias due to RTM using the EB adjustments.

Accounting for crash severity

The severity of crashes at a location can (and should) have a bearing on the priority of the site for safety treatment. Three of the measures in Table 4-4, measure 3 (EPDO average crash frequency), measure 4 (relative severity index), and measure 12 (EPDO average crash frequency with EB adjustment), directly account for crash severity. Measures 3 and 12 use the EPDO method, which converts all crashes to a common unit, namely property damage only (PDO) crashes. Using these measures, the analyst assigns points to each crash based on its crash severity level. A PDO crash typically receives one point and the points increase as the severity of the crash increases.

While other measures do not explicitly mention severity, analysts can adapt any of the measures to consider any severity level. For example, an analyst could use crash frequency and focus on the frequency of fatal and severe injury crashes to priority rank sites. It is important to note that the severity distribution of crashes may be a function of site characteristics including AADT. For example, sections with higher AADT values may be associated with lower speeds and consequently fewer severe crashes.

Step 2. Diagnosis

Diagnosis is the second step in the roadway safety management process, following network screening. Diagnosis is the process of further investigating the sites and issues identified from network screening. The intent of diagnosis is to identify crash patterns and the factors that contribute to crashes at the identified sites. Thorough diagnosis can also identify potential safety issues that have not yet manifested in crashes. Diagnosis often involves a review of the crash history, traffic operations, and general site conditions. While safety professionals could review these data from the office, a field visit provides the opportunity to observe road user behavior and site characteristics that are not available in the data. Sometimes, safety professionals may also conduct a field review at night or at other times that crash history has indicated to be of concern. It is important to diagnose the cause of the problem before developing potential countermeasures, just as a doctor examines symptoms to diagnose an underlying disease before formulating a prescription. Otherwise, resources may be misallocated if a countermeasure that does not target the underlying issues is selected and implemented.

The Haddon Matrix is a framework to identify possible contributing factors (e.g., driver, vehicle, and roadway/environment) which are cross-referenced against possible crash conditions before, during, and after a crash to identify possible reasons for events. This comprehensive understanding of crash contributing factors is important for the diagnosis of safety problems. An example of the Haddon Matrix is presented later under Countermeasure Selection on page 4-20.

The HSM recommends that diagnosis include the following parts:

- **A review of safety data**
- **An assessment of supporting documentation**
- **An assessment of field conditions**

Safety data review

An analyst can conduct a detailed review of the crash data from police reports to identify patterns. This could involve reviewing the crash type, severity, sequence of events, and contributing circumstances. Different visualization tools, such pie charts, bar charts, or tabular summaries, can be used to display various crash statistics. In addition to reviewing descriptive statistics, analysts can use various methods to identify underlying safety issues based on the recognition of crash patterns.

One method would be to identify locations that have a proportion of a specific collision type relative to the total collisions that is higher than some average or threshold proportion value for similar road types. Kononov found that looking at the percentage distribution of collisions by collision type can reveal the "existence of collision patterns susceptible to correction" that may or may not be accompanied by the overrepresentation in expected or expected excess collisions.[19] Heydecker and Wu originally proposed this method.[20] The method is identical for different location types. However, only similar location types should be analyzed together because collision patterns will naturally differ. For example, the collision patterns are different for stop-controlled intersections, signalized intersections, and two-lane roads, so the method would be applied separately to the three types of facilities and separately for urban and rural environments. Another method would be to investigate sites that experience a gradual or sudden increase in mean collision frequency.[21]

Following the detailed review of the crash data, the analyst can create collision diagrams, condition diagrams, and crash maps to summarize the crash information by location. A collision diagram is a tool to identify and display crash patterns. Many resources, including the HSM, provide guidance on developing collision diagrams. Examples of collision diagrams are shown in Figure 4-6 and Figure 4-7. Each crash at the site is displayed according to where it occurred, what type of crash it was, how severe it was, and various other characteristics. An analyst uses symbols to visually represent many of these characteristics.

Condition diagrams include a drawing with information about the site characteristics including information about the roadway (e.g., number of lanes, presence of medians, pedestrian and bicycle facilities, shoulder information), surrounding land uses, and pavement conditions. Condition diagrams can be overlaid on top of collisions diagrams to gain further insight to the crash patterns.

Crash mapping involves the use of geographic information systems (GIS) to integrate information from the roadway network with information from geocoded crash data. If the geocoded crash data are

[19] Kononov, J. (2002), Identifying Locations with Potential for Collision Reductions: Use of Direct Diagnostics and Pattern Recognition Methodologies, *Transportation Research Record 1784*, pp. 153-158.

[20] Heydecker, B. J., and J. Wu (1991), Using the Information in Road Accident Records Proc., 19th PTRC Summer Annual Meeting, London.

[21] Hauer, E. (1996), Detection of Safety Deterioration in a Series of Accident Counts. *Transportation Research Record 1542*, 38-43.

Hauer, E. (1996), Statistical Test of the Difference between Expected Accident Frequencies, *Transportation Research Record 1542*, 24-29.

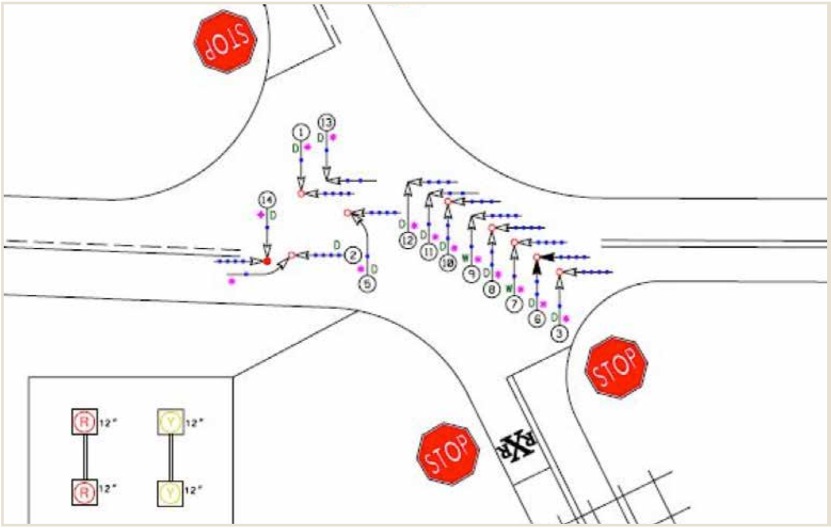
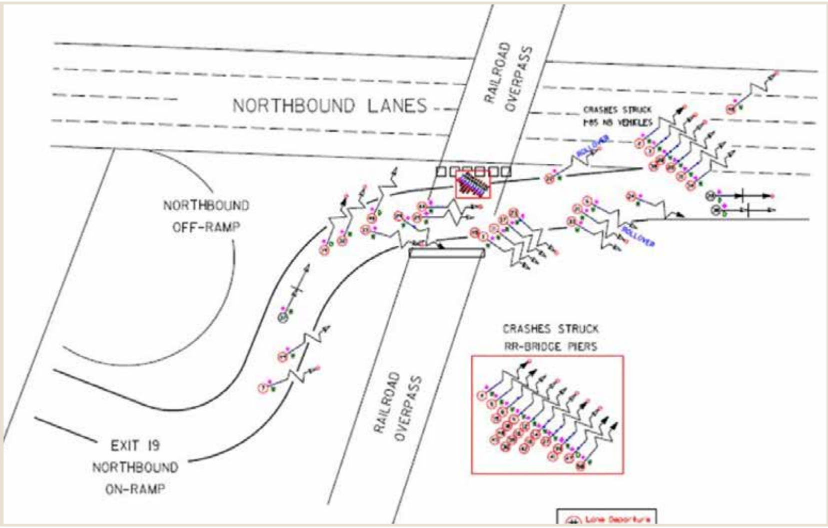


FIGURE 4-6: Example Collision Diagram at an Intersection

FIGURE 4-7: Example Collision Diagram at a Ramp



accurate, then crash mapping can provide valuable insights into crash locations and crash patterns.

Assess supporting documentation

This step involves a review of documented information about the site along with interviews of local transportation professionals to obtain additional perspectives on the safety data review from the previous step. Examples of supporting documentation include traffic volumes, construction plans and design criteria, photos and maintenance logs, weather patterns, and recent traffic studies in the area.

Assess field conditions

Field observations are useful for supplementing crash data and can help the analyst understand the behavior of drivers, pedestrians, and bicyclists. The first stage of the field investigation should be an on-site examination of a road user's experience. Those conducting the assessment should travel through the site at different times of the day using different modes of transportation (e.g., driving, walking, and bicycling). Assessors should observe the mix of vehicle traffic and other road users. They should also observe traffic movements, conflicts, and

ROAD SAFETY AUDIT	TRADITIONAL SAFETY REVIEW
Independent, multi-disciplinary team	Safety review team within the project team with only safety and/or design experience
Considers all potential road users (pedestrians, bicyclists, motor vehicles, transit users)	Often concentrates only on motor vehicles
Accounts for road user capabilities and limitations	Safety reviews do not normally consider human factor issues
Always generates a formal report	Often does not generate a formal report
Always generates a formal response report	Often does not generate a formal response report

TABLE 4-5: Differences between Road Safety Audit and Traditional Road Safety Review *(Source: FHWA)*

operating speeds. Those conducting the field review could determine whether the road and intersection characteristics are consistent with driver expectation and if roadside recovery zones are clear and traversable.

Road safety audits

One method to assess field conditions is a road safety audit (RSA). This is the formal safety performance examination of an existing or future road or intersection by an independent, multidisciplinary team. An RSA qualitatively estimates and reports on existing and potential road safety issues and identifies opportunities for safety improvements for all road users. FHWA encourages States, local jurisdictions and tribal governments to integrate RSAs into the project development process for new roads and intersections and to conduct RSAs on existing ones.

The purpose of an RSA is to answer the following questions:

- **What elements of the road may present a safety concern, and to what extent, to which road users, and under what circumstances?**
- **What opportunities exist to eliminate or mitigate identified safety concerns?**

The multidisciplinary audit team consists of people who represent different areas of expertise, such as engineering (e.g., design, traffic, and maintenance), law enforcement, safety educators, public officials, community traffic safety advocates, and others. Any phase of project development (planning, preliminary engineering, design, construction) and any sized project from minor intersection and roadway retrofits to mega-projects are eligible for an RSA.

Most State DOTs have established safety review processes. However, RSAs and a traditional safety reviews are different. Table 4-5 shows the difference between an RSA and a traditional safety review.[22]

[22] "Road Safety Audits (RSA)," accessed August 7, 2013, http://safety.fhwa.dot.gov/rsa/

International Road Assessment Programme

The International Road Assessment Programme (iRAP) conducts safety inspections on high-risk roads in more than 70 countries. The iRAP inspectors perform a detailed road survey, focusing on road attributes that are known to be associated with crash risk. These include intersection design, number of lanes, roadside hazards, and provisions for pedestrian crossings. The inspectors use these data to develop a star rating, which reflects the level of safety of the road, and provide detailed feedback to the government agency in the form of an assessment report. iRAP also provides a Road Safety Toolkit, which helps engineers, planners, and policy makers develop safety plans for all road users.[23]

Step 3. Countermeasure selection

After diagnosing the safety issues at the site, analysts select countermeasures to address the contributing factors for observed crashes. The first part of countermeasure selection is to identify countermeasures to target the underlying safety issues. Analysts can use tools like the Haddon Matrix and resources like the NCHRP Report 500 series to identify targeted countermeasures to address or mitigate underlying contributing factors.

Identifying contributing factors

The Haddon Matrix is a tool originally developed for injury prevention, but it is directly applicable to highway safety in both diagnosis and countermeasure selection.[24] The Haddon Matrix is useful to gain a comprehensive understanding of crash contributing factors. Analysts can use the Haddon Matrix to identify human, vehicle, and roadway factors contributing to the frequency and severity of crashes prior to, during, and after the crash event. Then, analysts can identify targeted reactive and proactive countermeasures to address or mitigate the underlying contributing factors for the given site. Chapter 6 of the 1st edition of the HSM provides further discussion of the Haddon Matrix.

The Haddon Matrix is comprised of nine cells to identify human, vehicle, and roadway factors contributing to the target crash type or severity outcome before, during, and after the crash. Pre-crash factors speak to the factors or actions prior to the crash that contributed to the occurrence of the crash. Crash factors speak to those factors or actions that occurred at the moment of the crash. Post-crash factors speak to factors that come into play after the crash that affect the severity of the injuries or speed of response. Examples of human factors include fatigue, inattention, age, and failure to wear a seat belt. Vehicle factors include bald tires, airbag operations, and worn brakes. Examples of roadway factors include pavement friction, weather, grade, and limited sight distance.

Table 4-6 is an example application of the Haddon Matrix from the Highway Safety Improvement Program (HSIP) Manual for crashes in an urban area.[25] The top-left cell identifies driver behaviors or characteristics that may contribute to the likelihood or the severity of a collision, such as poor vision or reaction time, alcohol consumption, speeding, and risk taking. These

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[23] http://www.irap.net/

http://toolkit.irap.org/

[24] Haddon, W., Jr. (1972). A logical framework for categorizing highway safety phenomena and activity. *Journal of Trauma* 12: 193–207.

[25] Susan Herbel, Lorrie Laing, Colleen McGovern (2010), *Highway Safety Improvement Program (HSIP) Manual*, FHWA-SA-09-029, Federal Highway Administration, Washington, DC.

factors should be considered when selecting countermeasures. For example, based on these human factors, successful countermeasures may be those that improve visibility or reduce speeding. The matrix in its entirety provides a range of potential issues that can be addressed through a variety of countermeasures including education, enforcement, engineering, and emergency response solutions.

Countermeasure resources and tools

Diagnosing a roadway safety problem and identifying effective countermeasures is a skill developed through education, training, research, and experience. Many resources are available to help transportation professionals analyze and develop countermeasures. Since the transportation field continuously generates new knowledge and countermeasure approaches, it is important to stay informed of the available resources and tools.[26]

Some of the most useful resources and tools for countermeasure guidance and selection are listed below (alphabetically):

- **Bicycle Safety Guide and Countermeasure Selection System (BIKESAFE, www.pedbikesafe.org/bikesafe)** – This resource provides practitioners with the latest information available for improving the safety and mobility of those who bike. The online tools provide the user with a list of possible engineering, education, or enforcement treatments to improve bicycle safety and/or mobility based on user input about a specific location.
- **Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices** – This document serves as a basic reference to help state

PERIOD	HUMAN	VEHICLE/ EQUIPMENT	PHYSICAL ENVIRONMENT	SOCIO-ECONOMIC
PRE-CRASH	Poor vision or reaction time, alcohol, speeding, risk taking	Failed brakes, missing lights, lack of warning systems	Narrow shoulders, ill-timed signals	Cultural norms permitting speeding, red light running, DUI
CRASH	Failure to use occupant restraints	Malfunctioning safety belts, poorly engineered air bags	Poorly designed guardrails	Lack of vehicle design regulations
POST-CRASH	High susceptibility, alcohol	Poorly designed fuel tanks	Poor emergency communication systems	Lack of support for EMS and trauma systems

TABLE 4-6: Haddon Matrix for crashes in an urban area *(Source: HSIP Manual)*

[26] *Highway Safety Improvement Program Manual.* Federal Highway Administration, Washington, D.C., 2010, Chapter 3

highway safety offices (SHSOs) select effective, evidence-based countermeasures for traffic safety problem areas related to user behaviors, such as alcohol-impaired and drugged driving, seat belts and child restraints, and aggressive driving and speeding.[27]

- **Crash Modification Factors Clearinghouse (www.cmfclearinghouse.org)** – This website offers transportation professionals a central, online repository of crash modification factors (CMFs) that indicate the safety effect on crashes due to infrastructure improvements. The website also provides additional information and resources related to CMFs. This site is funded by FHWA.
- **FHWA Proven Countermeasures (safety.fhwa.dot.gov/provencountermeasures)** – FHWA regularly compiles a list of countermeasures that have been shown to be effective in reducing crashes but have yet to be widely applied on a national basis.
- **Handbook for Designing Roadways for the Aging Population (safety.fhwa.dot.gov/older_users/handbook)** – This FHWA guide provides practitioners with a practical information source that links aging road user performance to highway design, operational, and traffic engineering features. This handbook supplements existing standards and guidelines in the areas of highway geometry, operations, and traffic control devices.[28]
- **Highway Safety Manual (www.highwaysafetymanual.org)** – This document provides science-based knowledge and tools to conduct safety analyses, allowing for safety to be quantitatively evaluated alongside other transportation performance measures, such as traffic operations, environmental impacts, and construction costs.
- **National Cooperative Highway Research Program (NCHRP) Report 500 Series (safety.transportation.org/guides.aspx)** – This resource is a collection of 23 reports in which relevant information is assembled into single concise volumes, each pertaining to specific types of highway crashes (e.g., run-off-the-road, head-on) or contributing factors (e.g., aggressive driving) related to behaviors, vehicles, and roadways. Countermeasures are categorized as proven, tried, and experimental.
- **Pedestrian Safety Guide and Countermeasure Selection System (PEDSAFE, www.pedbikesafe.org/pedsafe)** – This resource provides practitioners with the latest information available for improving the safety and mobility of those who walk. The online tools provide the user with a list of possible engineering, education, or enforcement treatments to improve pedestrian safety and/or mobility based on user input about a specific location.

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[27] Goodwin, A., Thomas, L., Kirley, B., Hall, W., O'Brien, N., & Hill, K. (2015). *Countermeasures that work: A highway safety countermeasure guide for State highway safety offices*, Eighth edition. (Report No. DOT HS 812 202). Washington, DC: National Highway Traffic Safety Administration. Accessed February 2017 at www.nhtsa.gov/staticfiles/nti/pdf/812202-CountermeasuresThatWork8th.pdf

[28] Brewer, M., D. Murillo, A. Pate (2014). *Handbook for Designing Roadways for the Aging Population*, Report No. FHWA-SA-14-015, Federal Highway Administration, Washington, D.C.

Identifying and selecting countermeasures

After identifying potential countermeasures to target the underlying issues, safety professionals must estimate the safety impact of countermeasures, individually and in combination. It is important to consider positive and negative safety impacts. Subsequent steps of the roadway safety management process (i.e., economic appraisal and project prioritization) include the consideration of other parameters, such as constructability, environmental impacts, and cost.

The agency that will be making the final decision on countermeasure selection should make sure to coordinate with other safety partners to ensure that the countermeasure is appropriate for all parties. For example, a DOT should coordinate with law enforcement and emergency response to make sure that a proposed engineering installation will interfere with enforcement activities or impede emergency responders.

For infrastructure improvements, CMFs associated with different countermeasures provide a mechanism for determining the safety effect of different countermeasures. A CMF is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site.

- If the CMF for a particular treatment is less than 1.0, then that countermeasure is expected to reduce crashes.
- If the CMF for a particular treatment is greater than 1.0, then that countermeasure is expected to increase crashes.
- A CMF of 1.0 implies that a countermeasure will not have any effect on safety.

Guidance on CMF application

FHWA provides an extensive selection of guidance on selecting and applying CMFs through the CMF Clearinghouse (**www.cmfclearinghouse.org**). They present answers to frequently asked questions, such as "How can I apply multiple CMFs?" and "How do I choose between CMFs in my search results that have the same star rating but different CMF values?" The website also houses an archive of annual webinars in which experienced CMF users talk about issues related to applying CMFs in real world situations.

For example, if the expected number of crashes without a countermeasure is 5.6 crashes per year, and the CMF for the particular countermeasure is 0.8, then the expected number of crashes with the countermeasure is:

5.6 crashes per year x 0.8 =
4.48 crashes per year

It is important to recognize that some countermeasures may decrease some types of crashes but increase other types. For example, installing a traffic signal would be expected to decrease severe collisions, such as right angle and left turn crashes, but it would be expected to increase less severe crashes, such as rear ends.

The CMF Clearinghouse and the first edition of the HSM provide CMFs for a variety of countermeasures.[29] Only those CMFs that passed a set of inclusion criteria based on quality and reliability were included in the HSM. The CMFs in the clearinghouse

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[29] www.cmfclearinghouse.org

are provided for any published study, regardless of quality, and are continuously updated based on the latest research. The CMFs in the clearinghouse are reviewed and given a star quality rating ranging from one to five stars, based on the quality of the study. Higher stars imply a better quality CMF.

CMFs should be applied to situations that closely match those from which the CMF was developed. Several variables can be used to match a CMF to a given scenario including roadway type, area type, segment or intersection geometry, intersection traffic control, and traffic volume. However, it is critical for practitioners to use engineering judgment when a CMF is not available for the situations encountered as there are some cases for which a CMF that was developed for different conditions might be the best available.

Step 4. Economic appraisal

An economic appraisal of alternative countermeasures should be conducted to ensure that safety funds are being used as efficiently as possible. This appraisal helps transportation agencies achieve their desired safety performance the fastest and at the lowest possible cost. An agency can compare

Calculating benefits due to crash reduction

A city has a stop-controlled intersection with an expected crash frequency of 10 crashes per year, consisting of one A-injury crash, one B-injury crash, two C-injury crashes, and six PDO crashes.

The city is considering installing a roundabout at the intersection. Based on a search of the FHWA CMF Clearinghouse, they decide that they will use a CMF of 0.19 in the calculation of the crash reduction benefit.[30] This CMF applies only to serious and minor injury crashes, so they do not use it to estimate any reduction to fatal or PDO crashes (see note).

They multiply the CMF by the expected crashes before roundabout installation to determine the expected crashes after installation:

CRASH SEVERITY		FATAL	A-INJURY	B-INJURY	C-INJURY	PDO
I	**Expected Crashes per Year before Roundabout**	0	1	1	2	6
II	**CMF**	N/A	0.19	0.19	0.19	N/A
III	**Expected Crashes per Year after Roundabout (I x II)**	0	0.19	0.19	0.38	6
IV	**Crash reduction benefit (I minus III)**	**0**	**0.81**	**0.81**	**1.62**	**0**

Thus, the benefit of a roundabout installation is expected to be a reduction of 0.81 A-injury crashes, 0.81 B-injury crashes, and 1.62 C-injury crashes per year.

NOTE: A roundabout would also likely bring a reduction to fatal and PDO crashes (i.e., additional CMFs could be incorporated), but the example has been simplified to a single CMF for illustration purposes.

[30] Rodegerdts et al., "NCHRP Report 572: Applying Roundabouts in the United States." Washington, D.C., Transportation Research Board, National Research Council, (2007)

the benefits expected from the countermeasure to the estimated costs of the countermeasure.

Some safety countermeasures have a higher-cost value than others. Geometric improvements to the road, such as straightening a tight curve to reduce run-off-road crashes, tend to be very expensive. Installing a curve warning sign and in curve delineation may address the same problem, but at a much lower cost. Although both countermeasures address the same problem, the actual safety benefit may not be the same. Safety professionals take the relative costs and benefits into consideration when prioritizing among countermeasures. Part of calculating the cost of a countermeasure is considering how those costs vary over time, while taking into consideration any maintenance costs and long term effectiveness.

Estimating benefits

The primary benefit of a countermeasure is a reduction in crash frequency or severity. To estimate the safety benefits, a safety professional should use CMFs, such as those discussed in the countermeasure selection step. CMFs can be applied to the actual crashes or expected crashes based on the EB method. Expected crashes are preferred because they account for possible bias due to RTM. The estimated change in crashes represents the expected benefit from the countermeasure.

For each proposed countermeasure, the change in crash frequency and/or severity needs to be converted to monetary value, based on the monetary value of the type of crashes reduced. This monetary value is also called the crash cost. Crash costs are based on costs to society, such as lost productivity, medical costs, legal and court costs, emergency service costs, insurance administration costs, congestion costs, property damage, and workplace losses.[31]

INJURY SEVERITY LEVEL	COMPREHENSIVE CRASH COST
Fatality (K)	$4,008,900
Disabling Injury (A)	$216,000
Evident Injury (B)	$79,000
Fatal/Injury (K/A/B)	$158,200
Possible Injury (C)	$44,900
PDO (O)	$7,400

TABLE 4-7: Crash Costs by Severity Level in the Highway Safety Manual, 1st ed.

The benefit from the countermeasure is the sum of the crash costs for crashes prevented by the countermeasure. Assigning costs to crashes is a topic that is under constant discussion and revision nationwide. States differ widely in the dollar amount that they assign to crashes, though all States apply higher values to more severe crashes. The CMF Clearinghouse provides a synthesis of crash costs that are used by various States.[32]

Additionally, the first edition of the HSM provided a list of crash costs by severity level (Table 4-7). However, since the publication of the first HSM in 2010, the USDOT has issued periodic recommendations that dramatically raised the values. For instance, the monetary value of a

[31] Blincoe, L. J., Miller, T. R., Zaloshnja, E., and Lawrence, B. A. The economic and societal impact of motor vehicle crashes, 2010. (Revised), National Highway Traffic Safety Administration, Report No. DOT HS 812 013, Washington, DC, May 2015.

[32] http://www.cmfclearinghouse.org/resources_servlifecrashcostguide.cfm

fatal crash was listed as $4 million in the HSM, but recommended as over $9 million in a 2013 policy memo from USDOT.[33]

Although countermeasures are primarily expected to reduce crashes, there might be other benefits, including reduced travel times or lower fuel consumption. For example, a roundabout can decrease total delay at an intersection if applied and configured properly. An AASHTO publication provides guidance on estimating these other non-safety benefits.[34]

Estimating costs

The costs of the proposed countermeasure include the startup cost and the ongoing operational and maintenance costs. These costs can usually be estimated based on costs of materials, labor cost per person-hour, cost of additional right-of-way, and past experience with similar countermeasures. Table 4-8 illustrates the types of startup and ongoing costs that would be incurred for various countermeasures.

Service life

Another important consideration when calculating the benefits and costs of a countermeasure is the length of time that the countermeasure will last. This is referred to as the service life. Countermeasures, such as road edgelines or pavement reflectors, will have a much shorter service life (e.g., three to five years) than countermeasures, such as traffic signal installation or sidewalk construction (e.g., 20 years or more). Many States have a standard list of the service life values used for common countermeasures. The CMF Clearinghouse provides a survey of service life values used by various States for many different countermeasures.[35]

Calculating monetary benefit of crash reduction

The previous example showed that a city calculated a crash savings of 0.81 A-injury crashes, 0.81 B-injury crashes, and 1.62 C-injury crashes per year by installing a roundabout. The city has examined guidance from the HSM, guidance from USDOT, and experiences of other cities and States and determined a standard set of crash costs they will use for all benefit/cost calculations. They apply these costs to determine the monetary benefit of the expected crash reductions:

	CRASH SEVERITY	FATAL	A-INJURY	B-INJURY	C-INJURY	PDO
IV	**Crash Reduction Benefit**	0	0.81	0.81	1.62	0
V	**This City's Standard Crash Cost**	$5 mil	$400,000	$100,000	$60,000	$10,000
VI	**Monetary benefit of crash reduction (IV x V)**	**0**	**$324,000**	**$81,000**	**$97,200**	**0**

Thus, the city expects a total monetary benefit of $324,000+$81,000+$97,200 = **$502,000** per year due to reduction in crashes.

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[33] Trottenberg, Polly, and Robert Rivkin, "Revised Departmental Guidance 2013: Treatment of the Value of Preventing Fatalities and Injuries," USDOT Office of the Secretary of Transportation, 2013.

[34] User and Non-User Benefit Analysis for Highways, American Association of State Highway Transportation Officials, September 2010

[35] http://www.cmfclearinghouse.org/resources_servlifecrashcostguide.cfm

COUNTERMEASURE	STARTUP COST	ONGOING COST DURING SERVICE LIFE
Install curve warning sign	**Low –** sign material, minimal labor for installation	**None**
Install roundabout	**High –** Design plan, purchase of additional right-of-way, material, labor, traffic control during construction	**Low –** maintenance of grass and decorative vegetation
Install traffic signal	**High –** Timing plan, material, labor for installation, traffic control during construction	**Moderate –** electricity, bulb replacements, repairs, modifications to timing

TABLE 4-8: Examples of Countermeasure Costs

The service life is used in the calculation of the present value of the benefits and costs of the proposed countermeasure. The calculation of present value includes a discount rate that reflects the time value of money (i.e., present dollars are worth more than future dollars). Present value of countermeasure benefits is calculated as follows:

$$PV = A \times \frac{(1+i)^{y}-1}{i \times (1+i)^{y}}$$

PV = present value of benefits

A = annual benefit (i.e., monetary value of crashes prevented)

i = discount rate

y = service life of countermeasure

Calculating present value in this way assumes a uniform annual benefit. The HSIP Manual demonstrates how to calculate present value if the benefits or costs each year are not the same.[36]

The present value of annual costs (i.e., operational and maintenance costs) can be calculated in the same manner as for benefits. However, for costs, the final present value must also include the startup cost in the year of installation (see examples in Table 4-8).

Calculating the present value of a crash reduction benefit

From the previous example, the city plans to install a roundabout and expects to see a benefit from crash reductions resulting in savings of $502,000 per year. They estimate that the roundabout will have a service life of 20 years and they determine that a discount rate of 5% is appropriate. They calculate the present value of benefits as:

$$PV = \$502{,}000 \times \frac{(1+0.05)^{20}-1}{0.05 \times (1+0.05)^{20}}$$

$$= \$6{,}256{,}030$$

Methods for economic appraisal

There are several methods for using the values of estimated benefits and costs to evaluate the economic effectiveness of safety improvement projects at a particular site. In particular, these methods

[36] Herbel, Susan, Lorrie Laing, Colleen McGovern, Highway Safety Improvement Program (HSIP) Manual, Federal Highway Administration, FHWA-SA-09-029, January 2010

are useful in situations where a safety professional is considering several alternatives and desires to choose the countermeasure with the greatest benefit for the cost.

The HSIP Manual contains guidance on three methods – net present value, benefit/cost ratio, and cost effectiveness index.[37] Net present value (NPV) is generally regarded as the most economically appropriate method, though the other two methods have certain advantages, as discussed below. The following sections provide quoted guidance from the HSIP Manual on economic appraisal.

Net Present Value

The NPV method, also called the net present worth (NPW) method, expresses the difference between the present values of benefits and costs of a safety improvement project. The NPV method has two basic functions: 1) determining which countermeasure(s) is/are most cost efficient based on the highest NPV and 2) determining whether a countermeasure's benefits are greater than its costs (i.e., the project has a NPV greater than zero).

The formula for NPV is:

$$NPV = PVB - PVC$$

PVB = Present value of benefits

PVC = Present value of costs

A countermeasure will result in a net benefit if the NPV is greater than zero. Table 4-9 summarizes the NPV calculations of four alternative countermeasures.

For Alternative A, the NPV can be calculated as follows:

$$NPV = \$1{,}800{,}268 - \$500{,}000 = \$1{,}300{,}268$$

The same calculation is performed for the other three countermeasure alternatives, and rank each countermeasure based on its NPV. As shown, all four alternatives are economically justified with a NPV greater than zero. However, Alternative B has the greatest NPV for this site based on this method.

Benefit/Cost Ratio and Analysis

The benefit/cost ratio (BCR) is the ratio of the present value of a project's benefits to the present value of a project's costs.

ALTERNATIVE COUNTERMEASURE	PRESENT VALUE OF BENEFITS (I)	PRESENT VALUE OF COSTS (II)	NET PRESENT VALUE (I-II)	ALTERNATIVE RANK
A	$1,800,268	$500,000	$1,300,268	3
B	$3,255,892	$1,200,000	$2,055,892	1
C	$3,958,768	$2,100,000	$1,858,768	2
D	$2,566,476	$1,270,000	$1,296,476	4

TABLE 4-9: Net Present Value *(Source: HSIP Manual, Chapter 4)*

[37] Herbel, Susan, Lorrie Laing, Colleen McGovern, Highway Safety Improvement Program (HSIP) Manual, Federal Highway Administration, FHWA-SA-09-029, January 2010.

The formula for BCR is:

$$BCR = PVB / PVC$$

PVB = Present value of benefits

PVC = Present value of costs

Table 4-10 shows an example of using BCR to prioritize four alternatives.

A project with a BCR greater than 1.0 indicates that the benefits outweigh the costs. However, the BCR is not applicable for comparing various countermeasures or multiple projects at various sites; this requires an incremental benefit/cost analysis.

An incremental benefit/cost analysis provides a basis of comparison of the benefits of a project for the dollars invested. It allows the analyst to compare the economic effectiveness of one project against another; however, it does not consider budget constraints. Optimization methods are best for prioritizing projects based on monetary constraints. An in-depth explanation of incremental benefit/cost analysis and an example is provided in Chapter 4 of the HSIP Manual.

When conducting a benefit/cost analysis, transportation professionals compare all of the benefits associated with a countermeasure (e.g., crash reduction), expressed in monetary terms, to the cost of implementing the countermeasure. A benefit/cost analysis provides a quantitative measure to help safety professionals prioritize countermeasures or projects and optimize the return on investment.

Cost-Effectiveness Index

In situations where it is not possible or practical to monetize countermeasure benefits, transportation professionals can use the cost-effectiveness index method in lieu of the NPV or BCR. Cost-effectiveness is simply the amount of money invested divided by the crashes reduced. The result is a number that represents the cost of the avoided crashes of a certain countermeasure. The countermeasure with the lowest value is the most cost-effective and therefore ranked first.

$$\text{Cost-Effectiveness Index} = PVC/CR$$

PVC = Present value of project cost

ALTERNATIVE COUNTERMEASURE	PRESENT VALUE OF BENEFITS (I)	PRESENT VALUE OF COSTS (II)	BENEFIT/ COST RATIO (I/II)	ALTERNATIVE RANK
A	$1,800,268	$500,000	3.6	1
B	$3,255,892	$1,200,000	2.7	2
C	$3,958,768	$2,100,000	1.9	4
D	$2,566,476	$1,270,000	2.0	3

TABLE 4-10: Example of Benefit/Cost Ratio Prioritization *(Source: HSIP Manual, Chapter 4)*

ALTERNATIVE COUNTERMEASURE	PRESENT VALUE OF COSTS	TOTAL CRASH REDUCTION	COST-EFFECTIVENESS INDEX	ALTERNATIVE RANK
A	$500,000	43	$11,628	1
B	$1,200,000	63	$19,048	3
C	$2,100,000	70	$30,000	4
D	$1,270,000	73	$17,397	2

TABLE 4-11: Cost-Effectiveness Index *(Source: HSIP Manual, Chapter 4)*

CR = Total crash reduction

The Cost-Effectiveness Index is a simple and quick method that provides an indication of a project's value. Transportation professionals can use this formula and compare its results with other safety improvement projects. The Cost-Effectiveness Index method, however, does not account for value differences between reductions in fatal crashes compared to injury crashes, and whether a project is economically justified.[38]

Table 4-11 summarizes the calculations using the cost-effectiveness index method to rank alternative countermeasures, given the present value of the costs and the total crash reduction.

For Alternative A, calculate the cost-effectiveness index as follows:

Cost-effectiveness index = 500,000/43 = 11,628

Calculate the Cost-Effectiveness Index for the remaining alternatives and rank each countermeasure based on its Cost-Effectiveness Index value. With this method, the lowest index is the highest priority and therefore ranked first. Alternative A is ranked first, since it has the lowest cost associated with each crash reduction.

The above example uses the number of crashes to determine the cost-effectiveness index. Transportation professionals can use this same method using EPDO crash numbers, which has the advantage of considering severity.

Step 5. Project prioritization

If a transportation agency is considering installing countermeasures at one or more sites out of a group of potential sites, they will need to prioritize which projects they will implement. Ideally, the agency would implement all projects that bring a safety benefit (e.g., all those with a NPV greater than zero or a BCR greater than one). However, all agencies work within a limited budget and must prioritize where safety funds are spent.

The agency can use steps 1 through 4 of this process to determine which countermeasure(s) would be used at each potential treatment

[38] *Highway Safety Improvement Program Manual.* Federal Highway Administration (Washington D.C., 2010), Chapter 4

site and to conduct an economic appraisal of the expected effect of the countermeasure. The next step is to determine project priorities. The HSM discusses how projects can be prioritized by economic effectiveness, incremental benefit/cost analysis, or various optimization methods.

Prioritizing by economic effectiveness

Projects can be prioritized by ranking projects or project alternatives by the economic appraisal values produced in step 4. An agency might select those projects with the highest NPV, the highest BCR, or the highest cost effectiveness index. When using NPV the goal of a safety professional should be to implement all projects that have an NPV greater than zero, since each one brings a safety benefit. However, this is not possible since funds are limited, thus the goal should be to implement the group of projects that have the greatest combined NPV when added together (NPV is an additive property). Maximizing the NPV of a group of projects is different from prioritizing projects with high NPV. In other words, it may be best to implement numerous low cost projects with low NPV than one high cost project with a high NPV – but not higher than the NPV of all the low cost projects added up.

Prioritizing by incremental benefit/cost analysis

This method involves ranking all projects with benefit cost ratio greater than 1.0 in increasing order of their estimated cost. An analyst calculates an incremental BCR as such:

$$\text{Incremental BCR} = \frac{(\text{Benefit of Project A} - \text{Benefit of Project B})}{(\text{Cost of Project A} - \text{Cost of Project B})}$$

If the incremental BCR is greater than 1.0, the project with the higher cost is compared to the next project on this list; however, if the incremental BCR is less than 1.0, the project with the lower cost is compared to the next project on the list. This process is repeated and the project selected in the last pairing is the considered the best economic investment.

Prioritizing by optimization methods

Optimization methods take into account certain constraints when prioritizing projects. Linear programming, integer programming, and dynamic programming (refer to Chapter 8, Appendix A, HSM, 2010) are optimization methods consistent with an incremental benefit/cost analysis, but they also account for budget constraints in the development of the project list. These optimization methods are more likely to be incorporated into a software package, rather than manually calculated. Multi-objective resource allocation is another optimization method. It incorporates nonmonetary elements (including decision factors not related to safety) into the prioritization process.

Safety professionals may use software applications to select and rank countermeasures. The SafetyAnalyst tool from AASHTO includes economic appraisal and priority ranking tools.[39] The economic appraisal tool calculates

[39] http://www.safetyanalyst.org/

the BCR and other metrics for a set of countermeasures. The priority-ranking tool ranks proposed improvement projects based on the benefit and cost estimates from the economic appraisal tool. The priority-ranking tool can also determine an optimal set of projects to maximize safety benefits.

Step 6. Safety effectiveness evaluation

Once a countermeasure has been implemented at a site, or group of sites, it is important to determine whether it was effective in addressing the safety problem. For a safety professional to evaluate the countermeasure, he or she must determine how the countermeasure affected the frequency, type, and severity of crashes. For example, did the installation of a roundabout reduce the frequency of angle crashes? If so, by how much? Did it cause an increase to any other types of crashes? A countermeasure evaluation can result in a CMF for the countermeasure, which quantifies the effect on crashes (see CMF discussion in Step 4).

Two documents entitled A Guide to Developing Quality Crash Modification Factors[40] (from FHWA) and Recommended Protocols for Developing Crash Modification Factors[41] (from NCHRP) provide guidance on the different methods for conducting evaluations. The following is an overview of study designs and methods for conducting evaluations.

Categories of Study Designs

Study designs fall into two broad categories – experimental and observational. Experimental studies are conducted when sites are selected at random for treatment. There is general consensus that experimental studies are the most rigorous way to establish causality.[42] In contrast, observational studies are conducted when sites are not selected as part of an experiment but selected for other reasons including

[40] Gross, F., B. Persaud, and C. Lyon (2010), *A Guide for Developing Quality Crash Modification Factors*, Report FHWA-SA-10-032, Federal Highway Administration, Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.

[41] Carter, D., R. Srinivasan, F. Gross, and F. Council (2012), *Recommended Protocols for Developing Crash Modification Factors*, Prepared as part of NCHRP Project 20-07 (Task 314), Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.

[42] Elvik, R. (2011a), Assessing Causality in Multivariate Accident Models, *Accident Analysis and Prevention*, Vol. 43, pp. 253-264.

safety. Truly experimental studies are not common in road safety partly because of potential liability considerations (i.e., a random selection may result in an agency being held liable for failing to treat some sites that have demonstrated high crash history). Observational studies are more common in countermeasure evaluations because most transportation agencies prioritize installation sites based on some kind of past safety performance (see Step 1, Network Screening).

Observational studies of countermeasures can be broadly classified into cross-sectional studies and before-after studies. In cross-sectional studies, an analyst compares a group of sites with a certain feature to a group of sites without that feature. For example, an analyst might compare the safety performance of a group of stop-controlled intersections to that of a group of yield-controlled intersections to determine the effect of the type of traffic control on crashes. Cross-sectional studies can also be thought of as "with/without" studies. In before-after studies, an analyst takes a group of sites and compares the safety performance in the period before a countermeasure is implemented to the period after the countermeasure is implemented. For example, in a before-after study, an analyst could evaluate the effect of converting a stop-controlled intersection to a roundabout by comparing safety data before the roundabout conversion to the safety data afterwards.

CMFs that result from cross-sectional studies are not considered to be as robust as those resulting from a before-after study. In a typical before-after study, an analyst deals with same roadway unit located in a particular place, most likely used by the same road users during the before and after period. Since most of these factors can be assumed to be constant or almost constant in the before and after periods, they are less likely to cause significant biases. On the other hand, "cross-sectional studies compare different roads, used by different road users, located at different places and subject to different weather conditions. Besides, these roads will differ in very many other ways that are not measured."[43] However, there are issues in both types of studies that need to be addressed, and they are briefly discussed below.

Cross sectional studies

Analysts use cross-sectional studies to compare the safety of a group of sites with a feature with the safety of a group of sites without that feature. The resulting CMF can be derived by taking the ratio of the average crash frequency of sites with the feature to the average crash frequency of sites without the feature. For this method to work, the two groups of sites should be similar in their characteristics except for the feature. In practice, this is difficult to accomplish and multiple variable regression models are used. These cross-sectional models are also called SPFs. The coefficients of the variables from these equations are used to estimate the CMF associated with a treatment.

Guidance from FHWA on developing CMFs says that "the basic issue with the cross-sectional design is

[43] Elvik, R. (2011a), Assessing Causality in Multivariate Accident Models, *Accident Analysis and Prevention*, Vol. 43, pp. 253-264.

Using cross-sectional modeling to calculate a CMF for widening shoulders

A CMF can be obtained from a cross sectional model. Suppose the intent is to estimate the CMF for shoulder width based on the following SPF, which was estimated to predict the number of crashes per mile per year on rural two-lane roads in mountainous roads with paved shoulders (Appendix B of Srinivasan and Carter, 2011[44]):

$$Y = \exp\left[\, 0.8727 + 0.4414 \times \ln\left(\frac{AADT}{10000}\right) + 0.4293 \times \left(\frac{AADT}{10000}\right) -0.0164 \times SW \,\right]$$

Where, AADT is the annual average daily traffic and SW is the width of the paved shoulder in feet. If the intent is to estimate the CMF of changing the shoulder width from three to six feet, then the CMF can be estimated as the ratio of the predicted number of crashes when the shoulder width is six feet to the predicted number of crashes when the shoulder width is three feet:

$$CMF = \frac{\exp\left[\, 0.8727 + 0.4414 \times \ln\left(\frac{AADT}{10000}\right) + 0.4293 \times \left(\frac{AADT}{10000}\right) -0.0164 \times 6 \,\right]}{\exp\left[\, 0.8727 + 0.4414 \times \ln\left(\frac{AADT}{10000}\right) + 0.4293 \times \left(\frac{AADT}{10000}\right) -0.0164 \times 3 \,\right]}$$

This ratio simplifies to:

$$CMF = \exp\,[-0.0164 \times (6-3)\,] = 0.952$$

This CMF of 0.952 indicates that changing the shoulder width from three to six feet would be expected to reduce crashes (since the CMF is less than 1.0). Specifically, the expected change in crashes would be a 4.8% reduction (1.0 – 0.952 x 100 = 4.8).

However, it is important to recognize that this CMF of 0.952 is the midpoint in a range of possible values (i.e., the confidence interval). This range can be calculated by using the standard deviation of the CMF. In order to estimate the standard deviation, the standard error of the coefficient of SW is needed, which was reported to be 0.0015 in the original study. The high and low ends of the confidence interval are calculated using -0.0164+0.0015, and then using -0.0165-0.0015, and the difference between the two is divided by two. The equation is given below:

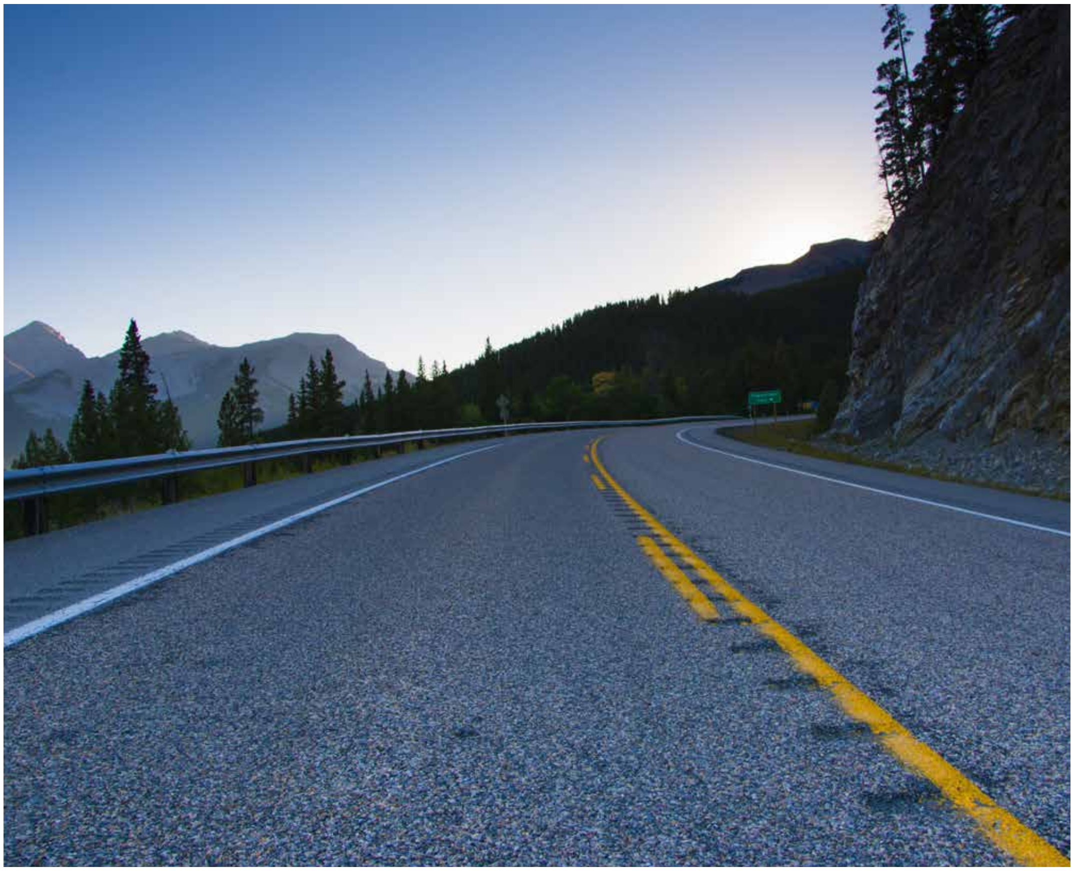
$$StDev(CMF) = \frac{\exp\,[-0.0164+0.0015 \times (6-3)\,] - \exp\,[-0.0164-0.0015 \times (6-3)\,]}{2} = 0.004$$

The approximate 95% confidence interval for the CMF is (0.952-1.96×0.004, 0.952+1.96×0.004), which translates to a range of 0.944 to 0.960. Since the entire 95% confidence interval is below 1.0, the CMF is statistically significant, thereby indicating that widening the shoulder from three to six feet is very likely to reduce crashes.

that the comparison is between two distinct groups of sites. As such, the observed difference in crash experience can be due to known or unknown factors, other than the feature of interest. Known factors, such as traffic volume or geometric characteristics, can be controlled for in principle by estimating a multiple variable regression model and inferring the CMF for a feature from its coefficient. However, the issue is not completely resolved since it is difficult to properly account for unknown, or known but unmeasured, factors. For these reasons, caution needs to be exercised in making inferences about CMFs derived from cross-sectional designs. Where there are sufficient applications of a specific countermeasure, the before-after design is clearly preferred."[45]

[44] Srinivasan, R. and D. Carter (2011), *Development of Safety Performance Functions for North Carolina*, Report FHWA/NC/2010-09, Submitted to NCDOT, December 2011.

[45] Gross, F., B. Persaud, and C. Lyon (2010), *A Guide for Developing Quality Crash Modification Factors*, Report FHWA-SA-10-032, Federal Highway Administration, Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.



One way to account for some of the limitations of cross-sectional regression models is to use the propensity scores-potential outcome method. This method uses the "individual traits of a site to calculate its propensity score, defined as a measure of the likelihood of that site receiving a specific treatment. Sites with and without the treatment are then matched based on their propensity scores."[46] The matched data are then used to estimate a cross sectional regression model. The propensity score method has been shown to reduce selection bias by accounting for the non-random assignment of treatment sites.[47] Recently, the propensity score method is starting to be used in place of traditional cross-sectional methods to conduct evaluations.[48]

Other types of cross-sectional methods include case control and cohort methods. "Case-control studies select sites based on outcome status (e.g., crash or no crash) and then determine the prior treatment (or risk factor) status within each outcome group."[49] Another critical component of many case-control studies is the matching of cases with controls in order to control for the effect of confounding factors. In cohort studies, sites are assigned to a particular cohort based on current treatment status and followed over time to observe exposure and event frequency. One cohort may include the treatment and the other may be a control group without the treatment. The time to a crash in these groups is used to determine a relative risk, which is the percentage change in the probability of a crash given the treatment.[50]

[46] Gooch, J.P., Gayah, V.V., and Donnell, E.T. (2016), Quantifying the Safety Effects of Horizontal Curves on Two-Way, Two-Lane Rural Roads, *Accident Analysis and Prevention*, Vol. 92, pp. 71-81.

[47] Holmes, W.M., (2013). *Using Propensity Scores in Quasi-Experimental Designs*. SAGE Publications.

[48] Wood, J., Porter, R., (2013). Safety impacts of design exceptions on non-freeway segments. *Transport. Res. Rec.: J. Transport.* Res. Board 2358, 29–37.

[49] Gross, F., B. Persaud, and C. Lyon (2010), *A Guide for Developing Quality Crash Modification Factors*, Report FHWA-SA-10-032, Federal Highway Administration, Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.

[50] See next page.

Before after studies

An analyst can use a before-after study to evaluate a countermeasure by comparing the crashes before the countermeasure was installed to the crashes after installation. This study design is advantageous because the only change that has occurred at the site is the countermeasure installation (assuming the analyst has researched the site histories to discard any sites at which other significant changes occurred).

There are issues for consideration with this study design as well. The analyst must know when the countermeasure was installed and must have data, such as crash and traffic volume, available in the before and after periods. For high-cost, high-profile countermeasures, such as road widening or traffic signal installation, the installation records will be readily available. However, for low-cost countermeasures, such as sign installations, there may be little to no documentation on when they were installed.

The analyst might simply compare the number of crashes per year before the countermeasure to the number of crashes per year after the countermeasure, known as a simple or naïve before-after evaluation. Although a simple before-after evaluation can be done easily using only crash data, it is prone to significant bias. One of the most influential biases for this method is the possible bias due to RTM. As discussed earlier, RTM describes a situation in which crash rates are artificially high during the before period and would have been reduced even without an improvement to the site. Programs focused on high-hazard locations are vulnerable to the RTM bias. This potential bias is greatest when sites are chosen because of their extreme value (e.g., high number of crashes or crash rate) in a given time period. A simple before-after evaluation has a high likelihood of showing a much greater benefit from the safety treatment than actually occurred.

As discussed earlier under the network screening section, the EB method is one of the methods that has been found to be effective in dealing with the possible bias due to RTM. The following steps are needed to conduct an EB before-after evaluation:

1. **IDENTIFY** a reference group of sites without the treatment, but similar to the treatment sites in terms of the major factors that affect crash risk including traffic volume and other site characteristics. One way to identify a reference group that is similar to the treatment is to use the propensity score method discussed earlier under cross-sectional studies.
2. Using data from the reference site, **ESTIMATE** SPFs using data from the reference sites relating crashes to independent variables, such as traffic volume and other site characteristics. As discussed in the following steps, SPFs are used in the EB method to predict the average number of crashes based on AADT and site characteristics. By selecting the reference group to be similar to the treatment group in terms of the major risk factors, we can reduce the possible bias due to confounding on these predictions.

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Carter, D., R. Srinivasan, F. Gross, and F. Council (2012), *Recommended Protocols for Developing Crash Modification Factors*, Prepared as part of NCHRP Project 20-07 (Task 314), Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.

Using an EB before-after evaluation to develop a CMF for signal phasing changes

This example is an illustration of an EB before-after evaluation that was conducted as part of NCHRP Project 17-35.[51] The countermeasure was a change from permissive to protected-permissive left turn phasing at signalized intersections in North Carolina. Data from twelve locations were used in this evaluation. A reference group of 49 signalized intersections was identified for the development of SPFs. The analysis looked at total intersection crashes, injury and fatal crashes, rear end crashes, and left turn opposing through (LTOT) crashes. In this example, only the data for LTOT crashes will be used.

The SPF for LTOT crashes based on the data from the reference group was:

$$\text{LTOT crashes/intersection/year} = e^{-0.3696}\,(\text{MajAADT}/10000)^{0.5564}\,e^{0.6585\times(\text{MinAADT}/10000)}$$

Where, MajAADT is the major road AADT and the MinAADT is the minor road AADT. The overdispersion parameter (k) for this SPF was 0.5641.

In the first site of this study, there were 10 observed crashes in the before period (X_b), and the predicted number of crashes from the SPF in the before period was 5.535 (P_b). The formula for obtaining the EB estimate of the expected crashes in the before period (EB_b) is as follows:

$$EB_b = w \times P_b + (1 - w) \times X_b$$

Where, X_b is the observed crashes in the before period, and w is the EB weight that is calculated as follows:

$$w = \frac{1}{(1 + k \times P_b)}$$

Where, k is the overdispersion parameter for the estimated SPF.

In this example:

$$w = \frac{1}{(1 + 0.5641 \times 5.535)} = 0.243$$

The EB estimate of the crashes in the before period (EB_b) = 5.535*0.243 + 10*(1-0.243) = 8.917 crashes.

The predicted number of crashes from the SPF in the after period was 11.391 (P_a).

The formula for the EB expected number of crashes that would have occurred in the after period had there been no countermeasure is given by:

$$\pi = EB_b \times (P_a / P_b)$$

In this example, the EB expected number of crashes in the after period had the countermeasure not been implemented (π) is equal to:

$$8.917 \times (11.391 / 5.535) = 18.350 \text{ crashes}$$

The variance of this expected number of crashes is also estimated in this step:

$$Var(\pi) = \pi \times (P_a / P_b) \times (1 - w)$$

Where, P_a is the SPF predictions in the after period. In this example, the variance of $\pi\pi$ is estimated as follows:

$$Var(\pi) = 18.350 \times (11.391 / 5.535) \times (1 - 0.243) = 28.603$$

This process was repeated for all 12 sites. Based on the data for all the 12 sites that were used in the evaluation, the actual crashes in the after period were 115, the EB expected crashes had the countermeasure not been implemented was 131.933 with a variance of 140.080.

(continued on next page)

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Srinivasan, R. et al., *Evaluation of Safety Strategies at Signalized Intersections*, NCHRP Report 705, Washington, DC.

The formula for the CMF and its standard deviation (StDev) are as follows:

$$\mathrm{CMF} = \frac{\dfrac{\lambda_{sum}}{\pi_{sum}}}{1 + \dfrac{\mathrm{Var}(\pi_{sum})^{2}}{\pi^{2}_{sum}}}$$

$$\mathrm{StDev}(\mathrm{CMF}) = \sqrt{\frac{\mathrm{CMF}^{2}\ \dfrac{\mathrm{Var}(\lambda_{sum})}{\lambda^{2}_{sum}} + \dfrac{\mathrm{Var}(\pi_{sum})}{\pi^{2}_{sum}}}{\left(1 + \dfrac{\mathrm{Var}(\pi_{sum})}{\pi^{2}_{sum}}\right)^{2}}}$$

Where, λ_{sum} is the total number of crashes that occurred in the after period, for all the treated sites in the sample, π_{sum} is the total number of expected crashes in the after period had the countermeasure not been implemented, and Var represents the variance. Since crashes are assumed to be Poisson distributed, $\mathrm{Var}(\lambda_{sum})$ is usually assumed to be equal to λ_{sum}. So, $(\mathrm{Var}(\lambda_{sum}))/(\lambda_{sum}^{2})$ will be equal to $1/\lambda_{sum}$.

In this example, the overall CMF was calculated as:

$$\mathrm{CMF} = \frac{\dfrac{115}{131.933}}{1 + \dfrac{140.080}{131.933^{2}}} = 0.865$$

This CMF of 0.865 indicates that the countermeasure (changing from permissive to protected-permissive left turn phasing) would decrease crashes, since the CMF is less than 1.0. It would be expected to decrease crashes by 13.5% (1.0 – 0.865 x 100 = 13.5).

Again, it is important to recognize that the CMF is the midpoint of a range of possible values (i.e., the confidence interval). The standard deviation of the CMF can be estimated as follows:

$$\mathrm{StDev}(\mathrm{CMF}) = \sqrt{\frac{0.865^{2}\left(\dfrac{1}{115} + \dfrac{140.080}{131.933^{2}}\right)}{\left(1 + \dfrac{140.080}{131.933^{2}}\right)^{2}}}$$

$$= 0.111$$

Based on this standard deviation of the CMF, the approximate 95% confidence interval is (0.865-1.96×0.111, 0.865+1.96×0.111), which translates to a range of 0.647 to 1.083. Since this confidence interval includes values greater than 1.0, the CMF is not statistically different from 1.0 at the 95% confidence level. This indicates that there is less confidence that this countermeasure will reduce crashes compared to a countermeasure whose CMF is significantly different from 1.0.

3. In estimating SPFs, **CALIBRATE** annual SPF multipliers to account for the temporal effects (e.g., variation in weather, demography, and crash reporting) on safety. The annual SPF multiplier is the ratio of the observed crashes to the predicted crashes from the SPF. In using the annual SPF multipliers from the SPFs to account for temporal effects, it is assumed that the trends in the crash counts are similar in the treatment and reference groups.
4. **USE** the SPFs, annual SPF multipliers, and data on traffic volumes for each year in the before period for each treatment site to estimate the number of crashes that would be predicted for the before period in each site.
5. **CALCULATE** the EB estimate of the expected crashes in the before period at each treatment site as the weighted sum of the actual crashes in the before period and predicted crashes from Step 4.
6. For each treatment site, **ESTIMATE** the product of the EB estimate of the expected crashes in the before period and the SPF predictions for the after period divided by these predictions for the before period. This is the EB expected number of crashes that would have occurred had there been no treatment. The variance of this expected number of crashes is also estimated in this step.

The expected number of crashes without the treatment along with the variance of this parameter and the number of reported crashes after the treatment is used to calculate the CMF and the standard deviation of the CMF. This procedure is repeated for each treated site. Once CMFs have been calculated for each individual site in a group of treated sites, the CMFs can be combined to calculate the overall effectiveness of the countermeasure. More details on this procedure are provided in the previously mentioned guidance documents.[52,53]

In some cases, treatments may be installed system-wide for a particular type of facility. For example, a jurisdiction may decide to increase the retroreflectivity of all their stop signs. Since sites are not specifically selected based on their crash history, the bias due to RTM is minimal. However, it is still necessary to account for changes in traffic volume and other trends. To evaluate the safety of such installations, an EB method could still be used, and while a reference group is not necessary, a comparison group is necessary in order to account for trends. SPFs can be estimated using the before-data from the treatment sites and these SPFs can be used to account for changes in traffic volumes. In addition, SPFs could be estimated for a group of comparison sites and the annual factors from these SPFs can be used to account for trends. Further details about such evaluations can be found elsewhere.[54]

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[52] Gross, F., B. Persaud, and C. Lyon (2010), *A Guide for Developing Quality Crash Modification Factors*, Report FHWA-SA-10-032, Federal Highway Administration, Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.

[53] Carter, D., R. Srinivasan, F. Gross, and F. Council (2012), *Recommended Protocols for Developing Crash Modification Factors*, Prepared as part of NCHRP Project 20-07 (Task 314), Washington, D.C. Available at http://www.cmfclearinghouse.org/resources_develop.cfm. Accessed July 2016.

[54] B. Persaud and C. Lyon (2007), Empirical Bayes Before After Studies: Lessons Learned from Two Decades of Experience and Future Directions, *Accident Analysis and Prevention*, 39(3):546-55.

System-Level Safety Management

System-level safety management involves addressing road safety issues that affect the broad transportation system, as opposed to treating specific high priority sites. The size and scope of the transportation system depends on the agency or jurisdiction. For a State DOT, the transportation system would consist of all State-owned roads, signals, bridges, and other features across the entire State, whereas the transportation system for a town would consist of a much smaller area and roadway network. Road safety at a system-level often has to do with policies, whether design policies for the construction and operation of roads and intersections, driver policies for licensing, or vehicle policies that require certain safety technologies. Other system-level efforts would include broad media or enforcement campaigns.

Recall that Chapter 10 presented road safety management in terms of three general components:

- **Identifying safety problems**
- **Developing potential safety strategies**
- **Selecting and implementing strategies**

This chapter will discuss how each of these components can be addressed at a system-level.

System-wide vs. systemic?

System-wide is a general term that refers to treating safety issues across an entire transportation system using policies or campaigns. Systemic is a more specific term that refers to identifying a subset of a transportation system based on risk factors and implementing safety efforts that address the particular characteristics of that subset.
See page 4-41 for more discussion on the systemic approach.

Identifying safety problems

To identify safety problems on a system-level, safety professionals analyze safety data that apply to the entire jurisdiction. They examine crash data and link crashes to other safety data to determine the nature and locations of safety problems. Problem identification on a system-level involves identifying crash trends and using risk-based methods to prioritize safety efforts.

Identifying crash type trends

Safety professionals can examine crash types and contributing factors to determine the nature of crashes within their agency's jurisdiction. This type of examination may reveal crash trends, such as those related to alcohol involvement, seat belt use, driver age, or vulnerable road users. For example, crash data might show that crashes involving unbelted occupants have been increasing over the past several years, or it might show that the number of crashes involving unbelted occupants is significantly higher than other nearby agencies, such as adjacent counties or States. This would lead an agency to consider how to increase seat belt use, perhaps through media campaigns, increased enforcement, or educational campaigns in schools. This type of agency-wide analysis of crash data can demonstrate broad scale trends that need to be addressed through broad scale efforts.

It is important that safety professionals are specific when identifying safety problems in crash trends. For example, "crashes involving teen drivers" is not defined well enough, because the causes of crashes for 16 year-olds is markedly different from those of older, more experienced teens. Crashes in which teens are victims of other drivers' errors require different solutions from those where the teen was at fault. Similarly, the cause of crashes depends greatly on the specific time, place and driving environment. A better target crash type would be "crashes occurring between 7-9 a.m. involving 16-year old drivers."

Example of safety problem identification in State Highway Safety Plans

A good example of identifying safety problems from crash type trends can be seen in how States develop **strategic highway safety plans** (SHSPs). The development of a SHSP involves the identification of safety problems on the State and local roads. A State analyzes safety data to determine the priorities, referred to as emphasis areas. The analysis can involve an examination of crash proportions between categories of crashes, crash trends, crash severity (e.g., fatal and serious injury), or more advanced crash modeling techniques. As presented in the call-out boxes, Ohio and Florida conducted analyses of their crash data and identified areas of concern.

Strategic highway safety plan

A statewide-coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads.

Florida's emphasis on motorcyclist safety

The State of Florida examined its crash data to identify emphasis areas in the development of their SHSP in 2012. One area that continued to be a focus was motorcyclist safety. The data indicated that crashes involving motorcycles had decreased somewhat during the time period analyzed (2006 to 1010) but remained a significant portion of the crashes on Florida roads. Florida's safety professionals recognized that since Florida hosts numerous national motorcycle events, the state's SHSP should have motorcycle safety as an emphasis area.

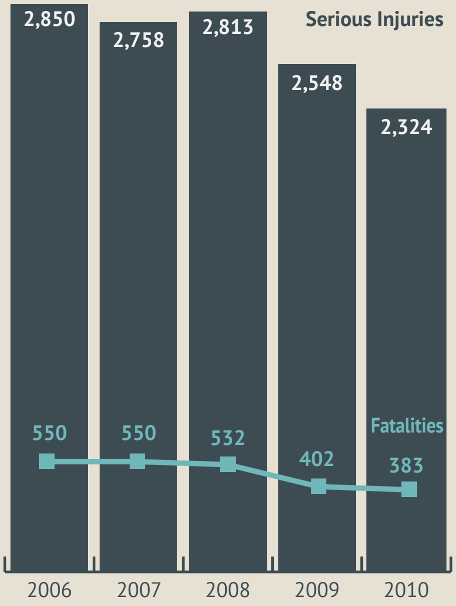

FIGURE 4-8. Florida motorcycle crash trend 2006-2010

Ohio's emphasis on older driver safety

Ohio developed a SHSP in 2014 in which they identified fifteen emphasis areas. One of the emphasis areas was the safety of older drivers (65 and older). The crash data showed that older driver-related crashes accounted for 18% of highway deaths and 16% of serious injuries. They recognized that these numbers would likely increase with an aging population. The crash trends over the time period examined (2003 to 2013) showed a slight upward trend to older driver serious injuries and a slight downward trend to older driver fatalities. This contrasted to other types of crashes that experienced significant declines. These reasons motivated Ohio to make older driver safety an emphasis area in their 2014 SHSP.

Risk based prioritization – the systemic approach

Chapter 11 presented various methods of selecting high priority sites through a process of network screening based on crash data. Many safety professionals recognize that this process of identifying specific locations using past crash data does not adequately address the fact that there may be locations that pose a safety threat but have not yet experienced many (or any) crashes. This recognition led to an increased use of risk-based prioritization, also called the **systemic** approach.[55]

In this approach, a transportation agency identifies priority locations based on the presence of risk factors rather than crashes. In the medical field, doctors pay attention to factors that may elevate a person's risk for disease. A history of smoking, poor eating habits, and a lack of exercise may indicate a higher-than-average risk for heart disease, even if the person has not yet experienced heart problems. Similarly, a section of road with certain characteristics, such as sharp curvature, old pavement, or lack of visibility, may be at risk for run-off-road crashes, even if none have occurred yet. Agencies can be proactive in their approach to safety management by identifying and treating these sites before crashes occur. These treatments are often low cost, such as signs and markings, so many systemic-identified locations can be treated within an agency's limited budget.

An agency using the systemic approach selects the focus crash type(s) and identifies risk factors associated with the focus crashes. Risk factors are site characteristics (e.g., design and operational features) that are common across

Systemic

The process of identifying road or intersection characteristics that increase the risk of crashes and selecting locations for safety treatment based on the presence of these risk factors.

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[55] http://safety.fhwa.dot.gov/systemic/

locations with the focus crash type(s). The agency can identify risk factors by analyzing crash data from their jurisdiction or by reviewing previous research studies. Using the list of risk factors as a guide, the agency identifies a list of sites with those specific characteristics, and then develops targeted treatments to address or mitigate the specific risk factors. The agency can apply crash history and other thresholds to reduce the list of sites based on available resources and program objectives.

The systemic approach has two attractive features. First, an agency can employ the systemic approach even for roads or intersections where crash data are not fully available (e.g., where location accuracy is questionable or underreporting is a problem). For instance, locating crashes accurately and precisely in rural areas or on non-State owned urban roads can be difficult. Second, the systemic approach is useful for treating safety issues where crashes are highly dispersed, such as on rural or low volume roads. Specifically, agencies can use the systemic approach to address existing and potential safety issues across a large portion of the network (e.g., shoulder rumble strips on all rural, two-lane roads with a certain shoulder width and traffic volume level).

Developing potential safety strategies

After safety professionals analyze data and identify safety problems, they must develop potential strategies to address the problems. It is important to engage safety stakeholders and other partners when selecting potential strategies as they may provide unique perspectives. Safety professionals should seek to involve local officials, citizens, and safety partners to produce effective multidisciplinary strategies. For example, addressing a particular safety problem with law enforcement and education can be far more economical than implementing a multimillion-dollar engineering fix. On the other hand, law enforcement tends to be effective only during the time in which it is active, so a more permanent engineering measure may be needed in some cases. It is often the case that a combination of strategies is necessary to effectively address the multitude of contributing factors.

On a system level, agencies must think broadly across the many disciplines represented by those who have a stake in road safety. Potential strategies might address infrastructure policies and practices (e.g., design standards, speed limits, etc.) or they may be directed at specific population focused efforts (e.g., seat belt laws, helmet laws, young driver restrictions, etc.).

Just as the identification of problems was based on safety data, so too must the development and selection of strategies be driven by the data. If an agency identified concerning trends in certain types of crashes, then they should further examine the crash data to determine how best to address the safety problem. For example, Figure 4-9 shows an example of alcohol-related crashes where an agency identified a spike in frequency (or high pole) of crashes occurring near 2:00 AM. Further examination revealed that bars in

Case Study: Systemic Analysis in Thurston County, Washington

The Thurston County Public Works Department in Washington conducted a systemic safety analysis for their road network. Based on a review of severe crashes, Thurston County decided to focus on roadway departure crashes in horizontal curves on arterial and collector roadways when it found that:

1. Most of the severe crashes occurred due to roadway departures, and that
2. 81% of the severe curve /roadway departure crashes occurred on arterial and collector roads. Because this effort coincided with ongoing efforts to identify and upgrade warning signs for horizontal curves on their County road system, Thurston County chose to focus on currently signed horizontal curves.

Thurston County accessed an inventory of their roads and intersections through a database maintained by the Statewide County Road Advisory Board. In addition, Thurston County assembled crash data for the 2006-to-2010 timeframe from the Washington State DOT crash database. They linked the road, intersection, and curve data with crash data and used these data to identify risk factors. Thurston County assembled a list of 19 potential risk factors and then performed a descriptive statistics analysis to identify 9 risk factors for use in screening and prioritizing candidate locations. The identified risk factors were:

- **Roadway class of major rural collector**
- **Presence of an intersection**
- **Traffic volume of 3,000 to 7,500 annual average daily traffic**
- **Edge clearance rating of 3**
- **Paved shoulders equal to or greater than 4 feet in width**
- **Presence of a vertical curve**
- **Consecutive horizontal curves (windy roads)**
- **Speed differential between posted approach speed and curve advisory speed of 0, 5, and 10 miles per hour**
- **Presence of a visual trap (a minor road on the tangent extended)**

Thurston County decided that a risk factor could be worth one point or a one-half point. Those factors present in at least 30% of the severe (fatal and injury) crashes and overrepresented by at least 10% (when comparing the proportion of all locations with the proportion of severe crash locations) were used as a guideline to have a high confidence and assigned one point in the risk assessment process. The risk factors that had a lower confidence in their relative data were assigned one-half point.

Thurston County then tallied the number of risk factors present for each of the curves. The risk factor totals for the ten curves with the highest scores ranged from 4.5 to 6.0. All 270 signed curves were prioritized for potential low cost safety investments. They identified the following low-cost, low-maintenance countermeasures with documented crash reductions to implement at the selected locations:

- **Traffic signs** – enhanced curve delineation with the addition of chevrons and larger advance warning signs
- **Pavement markings** – dotted extension lines at intersections and recessed raised pavement markers
- **Shoulder rumble strips**
- **Roadside improvements** – object removal, guardrail, and slope flattening

Systemic analysis provided Thurston County a proactive, data-driven, and defensible approach to identifying curves for improvement prior to a severe crash occurring, rather than reacting after an incident has occurred.[56]

[56] "Thurston County, Washington, Public Works Department Applies Systemic Safety Project Selection Tool" FHWA-SA-13-026, June 2013. http://safety.fhwa.dot.gov/systemic/

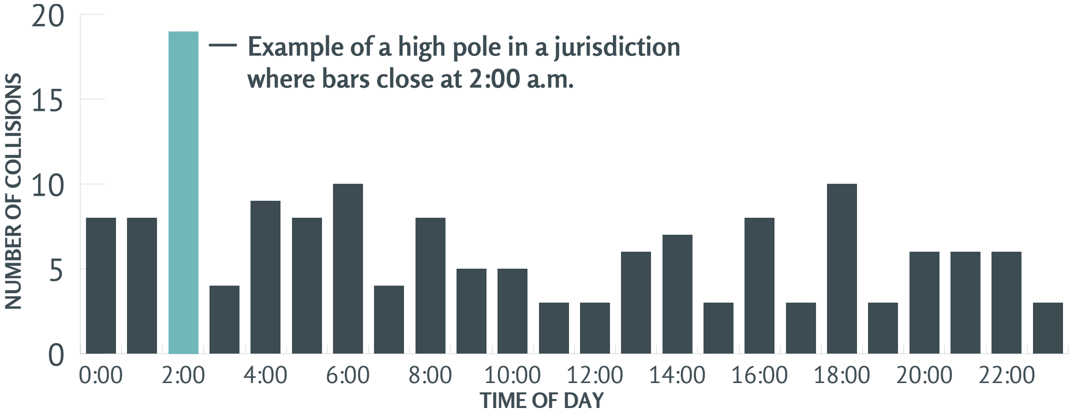

FIGURE 4-9. Example of "high pole" in crash data *(Source: NCHRP Report 501)*

that jurisdiction closed at 2:00 AM. This could lead to potential strategies, such as increased enforcement of impaired driving at that time of night and in the vicinity of bars.

It is also important to use the data to determine the necessary scope of the intervention. If the data show that the problem exists year-round, then the solution needs to match that. For example, a "safe ride program" for drinkers to get home on New Year's Eve is not going to significantly impact the problem of impaired driving overall.

Critical thinking is needed to develop effective solutions to the safety problems at hand. Analysts should look for characteristics of crash trends that could be addressed by practical strategies. An NCHRP report on an integrated safety management process states that safety professionals should use safety data to perform "further analyses of those characteristics that are found to be significantly or practically over-represented on a percentage or rate basis."[57] The report gives a set of guidelines to be considered in analyzing crash data to identify trends and develop potential safety strategies:

Consider How Specific Behaviors Influence the Safety Problem

Safety professionals must identify and target road user behaviors that contribute to the identified safety problem. The target behavior should be specific. For example, "safe driving" is not a specific behavior that can be changed because it involves a number of different behaviors. However, "speeding on Main Street" is a specific behavior that can be targeted. It is also important to consider the factors influencing this behavior. Why are people speeding on Main Street? Which social, cultural, or environmental factors are influencing this behavior? Does it vary by time of day or week, perhaps reflecting the kind of drivers who are speeding?

1. **ASK** the questions, "Is this information sufficient for action item development? If not, what further information is needed to act on this finding?"
2. **CONSIDER** cross tabulations of two variables within the subset of data that pertains to the activities under consideration if one or more of the following types of conditions hold:
   - If the activities are time critical (e.g., all selective

[57] Bahar, G., M. Masliah, C. Mollett, and B. Persaud, Integrated Safety Management Process, National Cooperative Highway Research Program, Report 501, Transportation Research Board of the National Academies, Washington, D.C., 2003

enforcement strategies), perform a time-of-day by day-of-the-week analysis. As an example, alcohol-related crashes will likely be over-represented in the early morning and on weekend days. A logical approach is to perform a cross tabulation of time-of day by day-of-the-week to determine the best times and days for driving under the influence (DUI) selective enforcement. The goal of the procedure at this point is to determine additional details (who, what, where, when, and how) for those crash types identified by the analyses performed to this point.

- If the over-represented variable is not constant over all crash severities, cross tabulate the variable by severity (e.g., nighttime, rural, and older-driver crashes tend to be more severe).
- If the activities can be targeted to geographic location, age group, gender, race, or any other demographic factor within the crash records, consider these variables for cross tabulation with other over-represented variables.

3. **CONSIDER** creating subsets of the data for additional comparisons where activities are to be targeted to a particular subgroup of the population. For example, insight into a graduated driver's license strategy can be obtained by comparing 16-year-old causal driver crashes against 17- to 20-year-old causal driver crashes. As another example, insight into youth alcohol enforcement activities can be attained by comparing alcohol-related crashes of 16- to 20-year-old causal drivers against alcohol-related crashes of their 21-year-old and older counterparts. Each of these types of comparisons can show differences between the respective subpopulations.
4. **USE** the results of each analysis to determine what further information is needed before the best decision can be made, and repeat the analysis with the additional information.
5. **PERSIST** and maintain a thread of evidence until the information available has been exhausted. If the information generated indicates a significant factor, create further subsets of the data (e.g., youth-pedestrian crashes), and repeat the entire analysis.
6. **REJECT** any strategies and activities at this point that the data clearly show to be counterproductive (i.e., activities that will consume resources that could be better applied elsewhere). Maintain a list of all potential strategies and corresponding activities that will be subjected to further analysis in the optimization procedure.[58]

Many system-level safety strategies focus on behaviors of drivers and other road users. Resources like Countermeasures That Work provide a useful listing of potential safety strategies for system-level safety management.[59] The excerpt from *Countermeasures That Work* in

[58] Bahar, G., M. Masliah, C. Mollett, and B. Persaud, Integrated Safety Management Process, National Cooperative Highway Research Program, Report 501, Transportation Research Board of the National Academies, Washington, D.C., 2003

[59] Goodwin, A., Thomas, L., Kirley, B., Hall, W., O'Brien, N., & Hill, K. *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*, Eighth edition, National Highway Traffic Safety Administration, Report No. DOT HS 812 202, Washington, DC, 2015.

FIGURE 4-10. Potential Safety Strategies to Address Speeding and Aggressive Driving

1. Laws

COUNTERMEASURE	EFFECTIVENESS	COST	USE	TIME
1.1 Speed limits	★★★★★†	$	High	Short
1.2 Aggressive driving laws	★☆☆☆☆	$	Low	Short

† When enforced and obeyed

2. Enforcement

COUNTERMEASURE	EFFECTIVENESS	COST	USE	TIME
2.1 Automated enforcement	★★★★★	$$$†	Medium	Medium
2.2 High-visibility enforcement	★★☆☆☆	$$$	Low††	Medium
2.3 Other enforcement methods	★★☆☆☆	Varies	Unknown	Varies

† Can be covered by income from citations

†† For aggressive driving, but use of short-term, high-visibility enforcement campaigns for speeding is more widespread

3. Penalties and Adjudication

COUNTERMEASURE	EFFECTIVENESS	COST	USE	TIME
3.1 Penalty types and levels	★★☆☆☆	Varies	High	Low
3.2 Diversion and plea agreements	★☆☆☆☆	Varies	Unknown	Varies

4. Communications and Outreach

COUNTERMEASURE	EFFECTIVENESS	COST	USE	TIME
4.1 Public Information supporting enforcement	★★★☆☆	Varies	Medium	Medium

Effectiveness:

★★★★★	Demonstrated to be effective by several high-quality evaluations with consistent results
★★★★☆	Demonstrated to be effective in certain situations
★★★☆☆	Likely to be effective based on balance of evidence from high-quality evaluations or other sources
★★☆☆☆	Effectiveness still undetermined; different methods of implementing this countermeasure produce different results
★☆☆☆☆	Limited or no high-quality evaluation evidence

Figure 4-10 gives a list of potential strategies for addressing speeding-related crashes, from either laws, enforcement, penalties and adjudication, or communications and outreach. The list also includes an indication of the effectiveness, cost, current usage, and time of each strategy, which are all important considerations when selecting safety strategies to implement.

If the agency identifies safety problems from a systemic analysis, the potential safety strategies should address the types of crashes that were related to the roadway characteristic risk factors. These strategies may often be engineering improvements related to the risk factors. For example, if an examination of crash trends may highlight run-off-road crashes, and a systemic analysis would identify the type(s) of road on which run-off-road crashes are likely to occur. Table 4-12 shows a list of potential safety strategies that could be implemented for engineering treatments for a run-off-road crash problem. In a systemic approach, these engineering treatments would be implemented across some or all roads meeting the risk factors that increase the likelihood of run-off-road crashes.

Example of system-level safety strategies in state highway safety plans

SHSPs provide many good examples of system-level strategies that address safety problems identified through analysis of crash and other safety data. The previous section showed how Ohio and Florida had identified safety priorities on older drivers and motorcyclists, respectively. The SHSPs from these States also demonstrated the types of safety strategies each State intended to pursue to combat the safety problems in these areas.

Florida's strategies for motorcyclist safety

After identifying motorcyclist safety as an emphasis area in their 2012 SHSP, Florida identified a list of strategies to address motorcyclist safety. Example strategies include:

- **Promote personal protective gear and its value in reducing motorcyclist injury levels and increasing rider conspicuity**
- **Promote adequate rider training and preparation to new and experienced motorcycle riders by qualified instructors at State-approved training centers**
- **Incorporate motorcycle-friendly policies and practices into roadway design, traffic control, construction, operation, and maintenance**
- **Develop and implement communications strategies that target high-risk populations and improve public awareness of motorcycle crash problems and programs.**

Selecting and implementing strategies

A transportation agency must determine which of the potential strategies they will implement to address the identified safety problems. Since system-level safety solutions can involve broad changes to policies, design practices, or jurisdiction-wide road user behavior, there are different issues to consider compared to implementing a safety countermeasure at a specific

OBJECTIVES	COUNTERMEASURES	RELATIVE COST TO IMPLEMENT AND OPERATE	EFFECTIVE-NESS
15.1 A: KEEP VEHICLES FROM ENCROACHING ON THE ROADSIDE	15.1A1: Install shoulder rumble strips	Low	Tried
	15.1 A2: Install edgelines "profile marking", edgeline rumble strips or modified shoulder rumble strips on section with narrow or no paved shoulders	Low	Experimental
	15.1 A5: Provide improved highway geometry for horizontal curves	High	Proven
	15.1 A6: Provide enhanced pavement markings	Low	Tried
	15.1 A7: Provide skid-resistance pavement surfaces	Moderate	Proven
15.1 B: MINIMIZE THE LIKELIHOOD OF CRASHING INTO AN OBJECT OR OVERTURNING IF THE VEHICLE TRAVELS OFF THE SHOULDER	15.1 B1: Design safer slopes and ditches to prevent rollovers	Moderate	Proven
	15.1 B2: Remove/relocate objects in hazardous locations	Moderate to High	Proven
15.1 C: REDUCE THE SEVERITY OF THE CRASH	15.1 C1: Improve design of roadside hardware	Moderate to High	Tried
	15.1 C2: Improve design and application of barrier and attenuation systems	Moderate to High	Tried

TABLE 4-12. Potential Safety Strategies for Run-Off-Road Crashes *(Source: NCHRP 500, Volume 6)*

location. Many more people will be affected by the system-level changes. This carries great promise in that safety might be improved across an entire system, but it also carries unique challenges.

Agencies will need to consider the following questions when selecting strategies to implement:

- **Safety effectiveness** – How likely will it address the safety problem?
- **Public acceptance** – How will the strategy be accepted by the public? What kind of marketing will be needed to communicate the intent and benefit of the strategy?
- **Stakeholders and partners** – Which parties will need to be involved in implementing the strategy?
- **Cost efficiency** – What kind of return on the dollar would be expected?
- **Time** – How long will it take to implement the strategy?

Communication is critically important for system-level safety strategies. Both the general public and road users affected by the strategy must understand the benefits. Other public agencies may need to integrate their efforts with the proposed safety strategy. Administrators, lawmakers, and other key decision-making personnel must understand how the strategy will improve road safety for their constituency and bring an overall financial benefit. Unit 5 provides more discussion on communication, marketing, and outreach for agencies who seek to implement system-level safety strategies.

Ohio's strategies for older driver safety

Ohio identified three strategies to address the older driver emphasis area in their 2014 SHSP:

- Coordinate older driver messages developed by multi-agency communication committee.
- Create a comprehensive and coordinated outreach effort that educates older drivers and their caregivers on driving risks and remedies.
- Encourage roadway design and engineering measures that reduce the risks of traffic crashes for older drivers.

Evaluating a system-level strategy (e.g., program or intervention) to determine its effectiveness is a critical but often overlooked step. The transportation agency in charge should evaluate the effect of the safety strategy using good quality data; ideally the same type of data that was used to identify the safety problem initially. If a program or intervention is not effective, the overseeing agency should consider why this might be the case. Can the program be improved, or should other approaches be considered instead? If successful, how can the intervention be institutionalized to ensure long term support (and therefore lasting change)? Finally, it is important to remember that success or failure in one location does not guarantee the same results at a different location.

Example of System-Level Safety Management

The following provides an example of using system-level safety management to address a specific problem. This example demonstrates the three general components of safety management presented in this unit.

1. Identify the safety problem.

County A noticed a large number of crashes involving 16–17 year old drivers occurring weekdays between 11:00am and 1:00pm. Neighboring counties have not experienced this problem. County officials coordinate with school district staff to tackle this issue.

In exploring the problem, the officials discover that County A is the only jurisdiction that has an open campus lunch policy allowing students to leave school during their lunch period. Allowing teens to leave campus during lunch means there are many young, inexperienced drivers on the roads at the same time. They may be carrying additional passengers which research has established leads to an increased risk of a fatal crash.[60,61] The brief lunch period also results in pressure to get back in time for the next class. Combined, these factors lead to a risky driving situation and an increased risk of crashing.

2. Develop potential safety strategies.

In this situation, an informational approach that simply tells teenagers about the problem would likely not make a difference. Teens are not crashing because they lack information about the importance of safe driving or the consequences of unsafe driving. Teens are crashing largely because they lack the driving experience that equips most drivers to intuitively/near instantaneously do the things necessary to avoid crashing. Because of this, changing the environment is more likely to be effective.

The officials recognize that eliminating the policy that allows students to leave campus during lunch would lead to a reduction in crashes during this time. This policy would eliminate exposure to the risky driving situation and reduce the potential for crashes.

3. Select and implement strategies.

The school districts accordingly eliminate the policy allowing students to leave campus during lunch. They recognize that this policy change should be evaluated to determine its safety effect. Crash data would be needed to examine whether the closed school lunch policy has an effect on weekday crashes between 11:00am and 1:00pm. However, it will take many years to accumulate enough data for this evaluation. In this example, there is a proxy measure that can be used in the interim. A before and after observational survey with an appropriate control could quantify the number of students leaving campus during lunch before and after the change. In this case the officials know that the proxy measure (reduced driving from 11:00am to 1:00 pm) is a guaranteed indicator of crash reduction for this specific problem. However, it is not often the case that proxy measures are so closely aligned to the outcome of interest.

[60] Tefft B.C., Williams A.F., & Grabowski J.G. (2013). Teen driver risk in relation to age and number of passengers, United States, 2007-2010. Traffic Injury Prevention, 14, 283-292.

[61] Chen, L., Baker, S.P., Braver, E.R., & Li, G. (2000). Carrying Passengers as a Risk Factor for Crashes Fatal to 16- and 17-Year-Old Drivers. Journal of the American Medical Association, 283, 1578-1582.

Unit Summary

Solving road safety problems requires a comprehensive process to identify safety problems, develop potential safety strategies, and select and implement those strategies. To get the most effective results, this process must be based on solid safety data, particularly good quality crash data. The methods of undertaking the safety management process will depend on the scope of the effort.

Safety management of individual sites involves a six-step process of screening the network for high-priority sites, diagnosing the safety issues at those sites, selecting appropriate countermeasures, conducting an economic appraisal for all options, prioritizing the countermeasure projects based on estimated costs and benefits, and evaluating the countermeasure performance afterwards. Safety management at a system-level involves identifying safety problems by examining crash trends or using a systemic approach to identifying high-risk road characteristics. State agencies who are developing system-wide safety strategies must examine the data trends and the road users involved. They must consider factors, such as how system-wide policies and programs will be accepted by the public and who will be the partners to involve in implementing the safety strategy.

EXERCISES

- **PRESENT** an example road safety problem and compare and contrast the ways in which the problem could be addressed at a system-level vs. site-level.

- Your state has a small, rural, mountainous county where a large number of motorcycle crashes are happening. The crash rate per registered motorcycle in this county is nearly 10 times the state average. Upon further investigation you learn that this county is a popular motorcycling tourist destination. People come from all over the country to ride the curvy mountain roads. In fact, the majority of people involved in crashes are not from that area at all. Clusters of crashes occur on certain curves. What are some approaches that could be used to reduce crashes in this county? How could these approaches be evaluated? In particular, **DETAIL** how you would apply the three major components described in this unit:

  - Identify the safety problem
  - Develop potential safety strategies
  - Selecting and implement strategies

  When you work through this process, recall the discussion of human behavior from Unit 2. What are possible behaviors leading to the safety problem? What other factors could be influencing this behavior? How does this affect your identification and selection of potential safety strategies?

- If possible, **OBTAIN** three to five years of crash data for an intersection or section of road in your area. You will likely need to contact the controlling agency – the State DOT, county, or city. Describe how you would apply the steps in Chapter 11 on site-level safety management to this location (the network screening step would not apply since this location is already identified). Consider safety strategies across a range of disciplines (e.g., engineering, law enforcement, public communication and education, etc.).

- This exercise should be conducting using the Excel spreadsheet that accompanies this book. The goal of this exercise is to **USE** selected performance metrics to create a ranked list of sites for further investigation as part of a network screening effort. The Excel spreadsheet includes nearly 1,400 intersections, or sites. Each site has a unique ID number, traffic volume data, and other information about its location and characteristics. Three performance metrics have been calculated for each site. These have been calculated using five years of data (2010-2014) and one year of data (2014), resulting in a total of six performance metrics per site. Your assignment is to rank the sites using these various performance metrics and document the results. Document the twenty highest priority sites based on each method. Use the results to answer the following questions:

  - What were some of the sites that routinely ranked in the top twenty? What were some of their characteristics (volumes, number of lanes, stop/signal control)?
  - Were there any sites that were only occasionally present in the top twenty? What were some characteristics of these sites?

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UNIT 5

Implementing Road Safety Efforts

LEARNING OBJECTIVES

After reading the chapters and completing exercises in Unit 5, the reader will be able to:

- **IDENTIFY** the current road safety partner agencies and define their role in addressing safety problems
- **DEFINE** three areas of road safety research
- **DEFINE** the characteristics of strategic communications
- **RECOGNIZE** potential avenues for advancing road safety efforts

CHAPTER 13

IMPLEMENTING ROAD SAFETY EFFORTS

Who Does What

The greatest gains in road safety occur when transportation agencies work together rather than tackling problems alone. This can be challenging given the fragmented nature of transportation governance in the U.S. There are numerous agencies operating in different focus areas and at different levels. This chapter presents an overview of the various agencies and organizations that have a direct hand in advancing road safety and the initiatives that they undertake.

U.S. transportation agencies are typically structured around particular focus areas, such as roadway, vehicles, or road users. This approach is also seen on the international scale – the United Nations (U.N.) used a generalization called the "Five Pillar" structure as part of the Decade of Action for Road Safety. [1] The U.N. recognized that efforts to improve road safety must address various pillars including road safety management, safer roads and mobility, safer vehicles, safer road users, and better post-crash response. [2]

Likewise, U.S. transportation agencies are organized to address focus areas that are similar in theme to the U.N. five pillars, though not the same. Table 5-1 shows how agencies at all levels (Federal, State, and local) address five focus areas in road safety.

FOCUS AREA	FEDERAL	STATE	LOCAL
Road Design / Environment	Federal Highway Administration	Departments of transportation	City public works Metropolitan/rural planning organizations
Road User Behavior	National Highway Traffic Safety Administration Federal Motor Carrier Safety Administration	Highway safety offices Departments of motor vehicles Health departments	*No specific agency*
Vehicle Design / Technology		Departments of motor vehicles	*No specific agency*
Law Enforcement	*No specific agency*	State police / highway patrol	Police departments
Transit Safety	Federal Transit Administration	*No specific agency*	Metropolitan planning organizations Municipal transit agencies

TABLE 5-1: Transportation Agencies by Focus Area

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[1] United Nations, A/RES/64/255, Geneva, 2010

[2] Global Status Report on Road Safety 2013: Supporting a Decade of Action, World Health Organization, ISBN 978 92 4 156456 4, 2013.

Federal Agencies

The Federal role in implementing road safety initiative is carried out largely through the U.S. Department of Transportation (USDOT) and the many agencies under that department. These agencies are each tasked with a specific focus area as the Federal Government seeks to address safety issues for various modes of travel. These agencies include:

- **Federal Highway Administration**
- **National Highway Traffic Safety Administration**
- **Federal Motor Carrier Safety Administration**
- **Federal Transit Administration**
- **Federal Railroad Administration**

Federal Highway Administration

www.fhwa.dot.gov

Focus Area: Road Design and Environment

The Federal Highway Administration (FHWA) works to reduce highway fatalities through partnerships with State and local agencies, community groups, and private industry. The FHWA Office of Safety advocates designs and technologies that improve road safety and administers safety programs, such as the Highway Safety Improvement Program (HSIP). FHWA's Resource Center also provides technical assistance, technology deployment, and training. FHWA has a significant role in safety research through the Office of Safety Research and Development, which develops and implements safety innovations through teams of research engineers, scientists, and psychologists.

In addition, FHWA oversees the Local and Tribal Technical Assistance Program (LTAP/TTAP), which provides information and training programs to local agencies and Native American Indian tribes to improve road safety.[3] Further, FHWA maintains division offices in each state to deliver assistance to partners and customers in highway transportation and safety services at the State level.

National Highway Traffic Safety Administration

www.nhtsa.gov

Focus Areas: Road User Behavior and Vehicle Design and Technology

The National Highway Traffic Safety Administration (NHTSA) focuses on the safety of the vehicle, driver, and road user. NHTSA investigates safety defects in motor vehicles, establishes and enforces safety performance standards for motor vehicles and motor vehicle equipment, sets and enforces fuel economy standards, collects data, and conducts research on driver behavior and traffic safety, and helps states and local communities reduce the threat of impaired driving and other dangerous road user behaviors.

NHTSA carries out research and demonstration programs in many behavioral areas including impaired driving, occupant protection, speed management (shared with FHWA), pedestrian, motorcycle and bicycle safety, older and younger road users, drowsy, and distracted driving. NHTSA is also the lead Federal agency for emergency medical services (EMS) and 9-1-1 systems.

[3] "About the National Program," last updated June 20, 2013, accessed June 20, 2013, http://www.ltap.org/about/.

[4] "Who We Are and What We Do," accessed June 20, 2013, https://www.nhtsa.gov/about-nhtsa.

Federal Motor Carrier Safety Administration

www.fmcsa.dot.gov

Focus Areas: Road User Behavior and Vehicle Design and Technology

The Federal Motor Carrier Safety Administration (FMCSA) focuses on reducing crashes, injuries, and fatalities involving commercial use of large trucks and buses. FMCSA develops and enforces research-based regulations that balance safety and efficiency. The agency manages safety information systems to enforce safety regulations with regards to drivers who have high risk in factors, such as health, age, experience, and education.

FMCSA also targets educational messages to carriers, commercial drivers, and the public.[5] Some key programs administered by the agency include:

- **Commercial Driver's License Program:** FMCSA develops, monitors, and ensures compliance with the commercial driving licensing standards for drivers, carriers, and States.
- **Motor Carrier Safety Identification and Information Systems:** FMCSA provides safety data, State and national crash statistics, current analysis results, and detailed motor carrier safety performance data to industry and the public. This data allows Federal and State enforcement officials to target inspections and investigations on higher risk carriers, vehicles, and drivers.
- **Safety education and outreach:** FMCSA implements educational strategies to increase motor carrier compliance with the safety regulations and reduce the likelihood of a commercial vehicle crash. Messages are aimed at all highway users including passenger car drivers, truck drivers, pedestrians, and bicyclists.[6]

The Federal Motor Carrier Safety Administration develops, monitors, and ensures compliance with commercial driving licensing standards.

[5] "About FMCSA," accessed June 20, 2013, https://www.fmcsa.dot.gov/mission/about-us.

[6] "Key FMCSA Programs," accessed October 15, 2013, https://www.fmcsa.dot.gov/mission/we-are-fmcsa-brochure.

The Federal Transit Administration seeks to improve public transportation, such as buses.

Federal Transit Administration

www.transit.dot.gov

Focus Area: Transit Safety

The Federal Transit Administration (FTA) seeks to improve public transportation by assisting State and local governments with planning, implementation, and financing of public transportation projects.[7] FTA manages many transit-oriented safety programs including:

- **Bus and Bus Facilities:** This program provides capital funding to replace, rehabilitate, and purchase buses and related equipment and to construct bus-related facilities.
- **Public Transportation Emergency Relief Program:** This program helps States and public transportation systems pay for protecting, repairing, and/or replacing equipment and facilities that may suffer or have suffered serious damage because of an emergency including natural disasters.
- **Research, Development, Demonstration, and Deployment Projects:** This program supports research activities that improve the safety, reliability, efficiency, and sustainability of public transportation.
- **Transit Safety and Oversight:** FTA has the authority to establish and enforce a new comprehensive framework to oversee the safety of public transportation throughout the United States as it pertains to heavy rail, light rail, buses, ferries, and streetcars.[8]

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[7] "Federal Transit Administration," last updated September 6, 2013, https://www.usa.gov/federal-agencies/federal-transit-administration.

[8] "MAP-21 Programs," accessed October 16, 2013, https://www.transit.dot.gov/regulations-and-guidance/legislation/map-21/map-21-program-fact-sheets.

Federal Safety Programs

Federal agencies advance road safety through numerous programs and initiatives. Federal programs can be very influential due to large funding sources provided by Federal legislation. These funds are often distributed to State and local levels to implement various improvements to roads and intersections.

Specific funding programs can change with each new piece of transportation legislation. However, it may be useful to look at an overview of some of the types of current and past funding programs. Below are listed a few programs that have been widely used through the years to develop and implement improvements to road safety:

- **Highway Safety Improvement Program (FHWA)**
- **Traffic Records Improvement Grants (NHTSA)**
- **Safety Data Improvement Program Grant (FMCSA)**

Highway Safety Improvement Program (FHWA)

HSIP is a Federal program focused on infrastructure improvements that will lead to significant reduction in traffic fatalities and serious injuries on all public roads. HSIP is Federally funded and administered by FHWA, but it is implemented by the State departments of transportation per the strategies laid out in the State's Strategic Highway Safety Plan (SHSP). Funding is provided for safety-related infrastructure improvements, such as sidewalks, traffic calming, or signing upgrades. The States are required to develop a **data-driven**, strategic approach for improving highway safety through the implementation of such infrastructure improvements.[9] States are also required to report to the U.S. Secretary of Transportation on progress made implementing highway safety improvements and the extent to which fatalities and serious injuries on all public roads have been reduced.

Traffic Records Improvement Grants (NHTSA)

NHTSA administers Federal funding to encourage States to implement programs that will improve the timeliness, accuracy, completeness, uniformity, integration, and accessibility of State data used in traffic safety programs. The Federal SAFETEA-LU legislation established this program of incentive grants, and the funding continued under subsequent legislation. The funds were to be used to evaluate the effectiveness of efforts to make safety data improvements, to link safety data systems within the State, and to improve the compatibility of the State data system with national data systems and data systems of other States. A State may use these grant funds only to implement such data improvement programs. To qualify, a State must meet certain requirements including a functioning Traffic Records Coordinating Committee (TRCC), a strategic plan to address data deficiencies, and a regular traffic records assessment.[10]

Safety Data Improvement Program Grant (FMCSA)

The Safety Data Improvement Program (SaDIP), administered by FMCSA, provides financial and

Data-driven

An approach of which the priorities are determined by examination of crash data or other objective and reliable safety data, rather than priorities set by preferences of a few parties, current "hot" topics, or high profile rare events.

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[9] Source: "Highway Safety Improvement Program (HSIP)," accessed August 12, 2013, http://safety.fhwa.dot.gov/hsip/ and "HSIP History," accessed August 12, 2013, http://safety.fhwa.dot.gov/hsip/gen_info/hsip_history.cfm.

[10] NHTSA, Section 408 SAFETEA-LU Fact Sheet, https://one.nhtsa.gov/Laws-&-Regulations/Section-408-SAFETEA%E2%80%93LU-Fact-Sheet

technical assistance to States to improve data collected on truck and bus crashes that result in injuries or fatalities. The assistance is provided to State departments of public safety, departments of transportation, or State law enforcement agencies. SaDIP funds have been used to hire staff to code safety performance data, purchase software for field data collection, and revise outdated crash forms.

FMCSA maintains the Motor Carrier Management Information System (MCMIS) and supplies access to the system for designated employees in each State through SAFETYNET, an online network of safety data. States use MCMIS and SAFETYNET to enter data on motor carriers, drivers, compliance reviews, inspections, and crashes. At the national level, FMCSA uses the data to characterize the safety experience of commercial motor vehicles, and to help States with the task of identifying high risk carriers and drivers. The data are also used by motor carrier companies, safety researchers, advocacy groups, insurance companies, the public, and a variety of other entities.

State Agencies

All fifty States, the District of Columbia, and Puerto Rico administer road safety programs. State agencies administer roadway systems, driver licensing, injury prevention programs, traffic law enforcement, and other road safety activities. However, assignment of these responsibilities varies widely from State to State. In many cases, two or three government agencies are responsible for most or all of these activities. Other States distribute these responsibilities to numerous agencies and offices. Regardless of how these responsibilities are distributed, States share a vital role in improving road safety for all citizens.

In general, State agencies that address road safety issues include:

- State departments of transportation
- State highway safety offices
- State departments of motor vehicles
- State highway patrols
- State health departments

State departments of transportation oversee design, construction, maintenance, and operation of roads.

State Departments of Transportation

Focus Area: Road Design and Environment

Each State has a department of transportation (DOT), which oversees the design, construction, maintenance, and operation of the State's roads. This agency may also be called the State Highway Administration or Department of Roads. State DOTs have many official responsibilities. For highway safety issues, State DOTs have official transportation planning, programming, and project implementation responsibility. These agencies typically oversee all Interstate highways and most primary highways (State highways). State DOTs focus on roadway safety, and thus work in direct partnership with FHWA. They serve as liaisons between the Federal and local transportation agencies and provide resources and technical assistance to local agencies. State DOTs coordinate the use of Federal HSIP funds to improve roads and intersections on the local level.

In some States, the DOT administers, maintains, and operates county and city streets or secondary roads. State DOTs also work cooperatively with tolling authorities, ports, local agencies, and special districts that own, operate, or maintain portions of the transportation network.

The State DOT typically leads the development of the SHSP, a statewide-coordinated safety plan that provides a comprehensive framework for reducing highway fatalities and serious injuries on all public roads. The State DOT also develops long-range (20 to 30 year) transportation plans and short range (five to 10 year) plans that outline the vision of the transportation network and which projects will be constructed to fulfill that vision.

State Highway Safety Offices

Focus Area: Road User Behavior

State Highway Safety Offices (SHSOs) administer a variety of national highway safety grant programs authorized and funded through Federal legislation.[11] The governor of each State appoints a highway safety representative to administer the Federal Highway Safety Grant Program and numerous other highway safety programs designated by Congress. The governor's representative promotes safety initiatives in the State, such as high visibility enforcement campaigns like Click It or Ticket.

The State Highway Safety Office focuses on behavioral aspects of roadway users, and thus works in direct partnership with NHTSA. Safety programs implemented by the SHSO include:

- Encouraging safety belt, child car seat, and helmet use
- Discouraging impaired driving
- Promoting motorcycle safety
- Improving the skills of younger and older drivers

State Departments of Motor Vehicles

Focus Area: Vehicle Design and Technology

State Departments of Motor Vehicles

[11] "SHSO Programs & Funding," accessed June 20, 2013, http://www.ghsa.org/about/federal-grant-programs.

Coordinated

People from many agencies come together to develop an SHSP, including those from the department of transportation, department of motor vehicles, state highway patrol, public health, universities, and others.

Comprehensive

Using all types of strategies to improve road safety, such as infrastructure improvements, law enforcement, and campaigns to change driver behavior. This is seen in the types of crashes which serve as the focus areas of an SHSP, such as speeding related crashes, which are most effectively addressed through a combination of speed enforcement, engineering modifications, and behavioral campaigns.


State highway patrols enforce motor vehicle laws and regulations, investigate crashes, and work to identify enforcement needs.

(DMVs) administer State programs for driver licensing, and automobile inspection and registration. Generally, DMVs reside either within the State DOT or a department of public safety. A few States have a cabinet-level DMV.

The DMV is responsible for identifying at-risk drivers and maintaining driver records. The agency also implements driver license standards, monitors graduated licensing programs, and establishes requirements for driver education. Some State DMVs also serve as the primary owners of the statewide crash data.

State Highway Patrols

Focus Area: Law Enforcement

State highway patrols (also known as State police and State patrols) operate in every State except Hawaii. State police patrol highways and enforce motor vehicle laws and regulations.

State law enforcement agencies play an important role in reducing the frequency and severity of crashes. At the scene of crashes, State police direct traffic, administer first aid, call for emergency equipment, write traffic citations, and complete crash reports.

State highway patrols also investigate motor vehicle crashes, which are important sources of State and Federal crash data. They work closely with State highway safety representatives to identify enforcement needs. They play a vital role in implementing impaired driving laws, safety belt use, and other safety programs. Certain troopers in the State highway patrol are tasked with inspecting large trucks to ensure the driver and the vehicle comply with safety regulations, such as vehicle size and weight, driver hours of service, and medical fitness.

State Health Departments

Focus Area: Road User Behavior

State health departments also play an important role in reducing crash severity. These agencies are typically responsible for statewide trauma center planning. State health departments provide training, certification, and technical assistance for EMS providers, administer injury prevention programs, and maintain trauma and injury databases. Some State health departments coordinate with other public agencies and community groups to promote young driver safety, older driver safety, child passenger safety, and pedestrian and bicycle safety.

State Safety Plans and Programs

State agencies use numerous approaches to improve road safety within their State. Often, they seek to identify State-specific safety issues and direct Federal or State funding to solve those issues. State agencies take the lead in developing statewide safety plans or programs, many of which are encouraged or required by the Federal Government. Although States differ in their specific safety improvement efforts, the following plans or programs are developed in every State:

- **Strategic Highway Safety Plan**
- **Long Range Transportation Plan**
- **Statewide Transportation Improvement Program**
- **Railway-Highway Crossing Program**
- **Highway Safety Program**

Although the HSIP was previously covered under Federal safety programs, it should be noted that the State plays the major role in selecting locations that need safety improvement, designing, and implementing the safety improvement, and reporting annually on all the HSIP funded projects that were constructed that year.

Strategic Highway Safety Plan

A State's SHSP is a statewide-**coordinated** safety plan that provides a **comprehensive** framework for reducing highway fatalities and serious injuries on all public roads. An SHSP identifies a State's key safety needs and guides investment decisions toward strategies with the highest potential to save lives and prevent injuries. Since 2005, Federal legislation has required States to develop, implement,evaluate, and update their SHSP.[12,13]

The State DOT develops an SHSP in a cooperative process with local, State, Federal, tribal, and private sector safety stakeholders. It is a data-driven, multi-year plan that establishes statewide goals, objectives, and key emphasis areas. The development of an SHSP provides a venue for highway safety partners in the State to align goals, leverage resources (i.e., combine Federal and State resources), and collectively address the State's safety challenges.[14]

An ideal SHSP meets several criteria:

- It addresses engineering, management, operation, education, enforcement, and emergency service elements of highway safety as key factors in evaluating highway projects.
- It considers safety needs of, and high-fatality segments of, all public roads.
- It considers the results of State, regional, or local transportation and highway safety planning processes.
- It describes strategies to reduce or eliminate safety hazards.
- It gains approval of the governor of the State or a responsible State agency.[15]

As mentioned on page 5-5, in order to spend HSIP funds, a State must have a current SHSP, produce a program of projects or strategies to reduce safety problems, and evaluate the SHSP on a regular basis.[16]

Coordinated, Comprehensive

See previous page.

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[12] "Strategic Highway Safety Plans: A Champion's Guidebook to Saving Lives 2nd ed.," Federal Highway Administration (Washington, D.C., October 2012), History and Background, http://safety.fhwa.dot.gov/hsip/shsp/guidebook/ovrvw.cfm

[13] [14] "Strategic Highway Safety Plan (SHSP)," accessed August 13, 2013, http://safety.fhwa.dot.gov/hsip/shsp/

[15] "Map-21," Title 23 U.S.C. (2012), accessed August 19, 2013, http://www.gpo.gov/fdsys/pkg/PLAW-112publ141/pdf/PLAW-112publ141.pdf

[16] "Highway Safety Improvement Plan (HSIP)," accessed August 14, 2013, http://www.fhwa.dot.gov/map21/hsip.cfm.

Long-Range Transportation Plans

Long-range transportation plans (LRTPs) identify transportation goals, objectives, needs, and performance measures over a 20- to 25-year horizon and provide policy and strategy recommendations for accommodating those needs. LRTPs are prepared at both the State and MPO level. LRTPs are fiscally-unconstrained and typically present a systems-level approach that considers roadways, transit, pedestrian, and bicycle facilities. LRTP's have wide scopes; the components of the plan may be policy-oriented and strategic or focused on specific projects. The types of improvements range widely, as well. Safety-focused improvements in a LRTP may be directed at infrastructure, such as building new interchanges or bringing certain highways up to current design standards, or behavioral efforts, such as addressing seat belt use or aggressive driving.

Statewide Transportation Improvement Programs

The Statewide Transportation Improvement Program (STIP) identifies the funding and scheduling of transportation projects throughout the State that support the goals identified in the LRTP. STIPs are short-range (typically an outlook of five to ten years) and fiscally constrained, meaning that the projects must have designated funding. While many STIP projects are constructed for capacity or mobility reasons (i.e., build a bypass or widen a road), there are also STIP projects that are focused on improving safety, such as widening shoulders or installing rumble strips. Projects included in STIPs must have identified funding sources (e.g., HSIP, State, or local funding). The State DOT identifies projects in areas outside MPOs, such as rural areas and smaller urban jurisdictions, for inclusion in the STIP.[17]

Railway-Highway Crossings Program

The Railway-Highway Crossings Program funds safety improvements to reduce the number of fatalities, injuries, and crashes at public grade crossings.[18] A grade crossing is a location where a public highway, road, street, or private roadway (including associated sidewalks and pathways) crosses a railroad track at the same level as the street. These locations are high-risk spots for road users. The United States has more than 200,000 grade crossings.[19] Types of crossing improvements that the Railway-Highway Crossings Program implements include:

- **Crossing approach improvements:** projects such as channelization, new or upgraded signals on the approach, guardrail, pedestrian/bicycle path improvements near the crossing, and illumination
- **Crossing warning sign and pavement marking Improvements:** projects such as signs, pavement markings, and/or delineation where these project activities are the predominant safety improvements
- **Active grade crossing equipment installation/upgrade:** projects such as new or upgraded flashing lights and gates, track circuitry,

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[17] Title 49, United States Code, § 5304

[18] "Railway-Highway Crossings Program," accessed August 9, 2013, http://www.fhwa.dot.gov/map21/rhc.cfm.

[19] Railroad-Highway Grade Crossing Handbook 2nd ed. Federal Highway Administration (Washington D.C., August 2007)

The Railway-Highway Crossings Program funds safety improvements at crossings.

wayside horns, and signal improvements such as railway-highway signal interconnection and pre-emption.[20]

Highway Safety Program

Each State administers a Highway Safety Program, approved by the U.S. Secretary of Transportation. The program is designed to reduce deaths and injuries on the road by targeting user behavior through education and enforcement campaigns.[21] The State conducts this program through the State highway safety office. A State is eligible for SHSP grants by having and implementing an approved Highway Safety Plan (HSP). The HSP establishes goals, performance measures, targets, strategies, and projects to improve highway safety in the State. It also documents the State's efforts to coordinate with the goals and strategies in the SHSP. However, the Highway Safety Program is distinct from an SHSP. SHSPs target improvements to infrastructure and road users, and are broad in content and context, while highway safety programs focus more on road user behavior.[22] An HSP might address issues such as excess speeds, proper use of occupant protection devices, driving while impaired, and quality of traffic records data.[23]

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[20] "Railway-Highway Crossings Program Reporting Guidance," accessed August 9, 2013, http://www.fhwa.dot.gov/map21/guidance/guiderhcp.cfm.

[21] [23] "MAP-21," Title 23, U.S.C. (2012), accessed August 16, 2013, http://www.fhwa.dot.gov/map21/docs/title23usc.pdf, Sec. 402.

[22] "MAP-21," Title 23, U.S.C. (2012), accessed August 16, 2013, http://www.fhwa.dot.gov/map21/docs/title23usc.pdf, Sec. 148.

Local Agencies

Local agencies, such as city and county governments, play an important role in improving road safety and identifying and selecting transportation projects. These agencies that administer roads at the local level may be called by various names: public road agency, department of public works, departments of transportation, or road commissions. Due to their smaller size, many local agencies may not have a staff member who is specifically focused on road safety. The urban nature of their jurisdiction naturally causes their efforts to be focused on different types of road safety topics than a State DOT. For example, a city transportation department would typically focus on urban elements such as sidewalks, transit accommodations, and high density access management, where as a State DOT would typically be focused on more rural elements, such as high speed curves and isolated intersections.

Most safety issues for local streets, intersections, or corridors are the responsibility of the city or county government. These agencies supplement State laws, establish traffic laws in their jurisdictions, and determine penalties for noncompliance. Local law enforcement agencies investigate crashes and submit crash data to State and Federal agencies. City and county planning and engineering staff help plan and design roads, bike lanes, and sidewalks. Many local police departments partner with State police to implement impaired driving, work zone safety, motorcycle safety, heavy truck, and safety belt education and enforcement programs. In some States, the State DOT owns many of the major roads in the city and may coordinate with the local agency to identify potential safety improvements and get them installed. Many local agencies also collaborate with the State DOT to develop a Local Road Safety Plan.

Charlotte Pedestrian Safety

The City of Charlotte developed its Transportation Action Plan (TAP) in 2011 to describe how to reach its safety and mobility transportation goals. The plan emphasized the safety of all road users and included objectives such as constructing 375 miles of new sidewalk by 2035.[24] To support the goal of pedestrian safety, Charlotte developed Charlotte WALKS, the city's first comprehensive Pedestrian Plan. This plan identified new strategies to meet the pedestrian safety and walkability goals in Charlotte's TAP.[25]

At the regional level, metropolitan planning organizations (MPOs) plan, program, and coordinate Federal highway and transit investments. When an urban area meets certain minimum characteristics (e.g., population), Federal law requires the creation of an MPO for the region to qualify for Federal highway or transit funds in urbanized areas. MPOs do not typically own or operate the transportation systems in their jurisdiction. MPOs play a coordination and consensus-building role in planning and programming funds for capital improvements, maintenance, and operations. MPOs involve local transportation providers in the planning process by coordinating with transit agencies, State and local highway departments, airport authorities, maritime operators, rail-freight operators, Amtrak, port operators, private providers of public transportation, and others within the MPO region.[26]

[24] The City of Charlotte Transportation Action Plan Policy Document, 5 Year Update, August 22, 2011.

[25] http://charlottenc.gov/Transportation/Programs/Pages/default.aspx

[26] The Transportation Planning Process Briefing Book, Federal Highway Administration and Federal Transit Administration, 2015 Update, http://www.fhwa.dot.gov/planning/publications/briefing_book/fhwahep15048.pdf

Other Safety Partners

Although government agencies have the support of large budgets and institutional authority to implement improvements to road safety, they are not the only entities working to improve road safety. Government agencies work with partners from a variety of fields to improve the nation's roadways including those in private industry, special interest groups, and professional organizations.

Private industry

Automobile Manufacturers

Auto manufacturers have a critical effect on road safety by designing vehicles that assist the driver in avoiding crashes and that absorb energy in crashes that do occur. Federal standards stipulate that vehicles must have certain safety improvements, such as seat belts, air bags, and electronic stability control.[27] However, auto manufacturers have also implemented various non-required safety improvements. These improvements typically make use of emerging technologies or materials.

For instance, in the early 2000's, auto manufacturers began manufacturing vehicles that had "smart" technologies to improve safety, such as collision warnings and assisted braking. These technologies, which were not required by the government, addressed some of the most common crash types, such as rear end crashes. These improvements also set the stage for more advanced automated vehicle designs and technologies.

Insurance Companies

Insurance companies often assist in identifying ways to improve safety on the nation's roads. The most notable organization in this respect is the Insurance Institute for Highway Safety (IIHS) and its sister organization, the Highway Loss Data Institute (HLDI). These are organizations that study road safety issues and use insurance data to provide data-based evidence of safety by vehicle make and model. These organizations are funded by a pooled group of insurance companies and associations. IIHS runs the Vehicle Research Center, which conducts crash tests of many vehicle types to encourage auto manufacturers to produce safer vehicles and inform the consumer on vehicle safety ratings.

[27] Title 49 of the United States Code, Chapter 301, Motor Vehicle Safety; and Federal Motor Vehicle Safety Standard (FMVSS) No. 218

Special interest groups

Special interest groups are associations of individuals or organizations that promote their common interests by influencing the legislative process at the local, State, and/or Federal levels of government. Many interest groups also serve other functions, such as providing services and information to their members. Interest groups fill a vital role in advancing the cause of safety-related legislation.

A few examples of road safety-focused interest groups include the AAA Foundation for Traffic Safety, National Safety Council, Mothers Against Drunk Driving (MADD), the American Council of the Blind, and the National Federation of the Blind. There are many other interest groups involved in influencing transportation and safety legislation. These groups engage in a variety of activities, such as sponsoring independent research and evaluation, mobilizing citizens to contact their legislators in support of or against certain pieces of legislation, and disseminating policy reports in support of or against legislation affecting the safety of the road users they represent.

Professional organizations

Professional organizations bring together road safety professionals from common backgrounds or spheres of influence to foster discussion and advancement of safety issues. Members of these organizations who recognize emerging road safety issues can use the power of the group to advocate legislation or sponsor research to address these issues.

American Council of the Blind (ACB) and National Federation of the Blind (NFB)

The ACB and NFB represent the interests of people who are blind or visually impaired. These organizations work to inform legislators, city and State agencies, and the public about road safety issues that are unique to individuals with visual impairment. They promote policies and practices that assist visually impaired individuals in traveling safety and independently. These include enhancements, such as auditory stop announcements on buses and accessible pushbuttons that provide information about street crossing signals.

These organizations often hold regular conferences that allow safety professionals to network, share ideas, and gain knowledge from others in their field. The organizations also provide training opportunities that help advance and disseminate road safety knowledge.

There are many professional organizations covering many disciplines that relate to road safety. While this textbook is not intended to provide an encyclopedic listing, a few examples are listed below.

American Association of State Highway Transportation Officials (AASHTO)

AASHTO members consist of representatives from highway and transportation departments in the 50 States, the District of Columbia, and Puerto Rico. AASHTO provides tools such as Safety Analyst, an analytical software package, and publishes the Highway Safety Manual, which provides an analytical and quantitative framework for analyzing a road's safety performance. AASHTO focuses on emerging safety issues through its Standing Committee on Highway Traffic Safety. AASHTO inspired the development of a national safety plan called Toward Zero Deaths, committed to reducing the number of highway fatalities to zero.

Institute of Transportation Engineers (ITE)

ITE is an association of transportation professionals who are responsible for meeting mobility and safety needs. ITE promotes professional development of its members and facilitates the application of technology and scientific principles to the safety of ground transportation. ITE's Transportation Safety Council covers issues, such as roadside safety, pedestrian and bicyclist safety, and work zone safety.

Association of Transportation Safety Information Professionals (ATSIP)

ATSIP focuses on data and is the leading advocate for improving the quality and use of transportation safety information. ATSIP furthers the development and sharing of traffic records system procedures, tools, and professionalism. Its goal is to improve the quality of safety data and encourage their use in safety programs and policies.

Governors Highway Safety Association (GHSA)

GHSA represents the State and territorial highway safety offices that implement programs to address behavioral highway safety issues including occupant protection, impaired driving, and speeding. GHSA provides leadership and advocacy for the States and territories to improve traffic safety, influence national policy, enhance program management, and promote best practices.

International Organizations

As of 2017, there is no U.S. organization that combines the narrow focus of improving road safety and a broad multidisciplinary approach. The current inventory of U.S. professional organizations is usually specific to a type of discipline, such as engineering or behavioral science. Looking beyond the U.S. borders shows that other countries have formed organizations that bring together many different disciplines to address road safety including the following:

- World Road Association (PIARC, after its former name Permanent International Association of Road Congresses), **www.piarc.org/en/**
- La Prévention Routière Internationale (PRI), **www.lapri.org**
- United Nations Road Safety Collaboration, **www.who.int/roadsafety/en/**
- Global Road Safety Partnership, **www.grsproadsafety.org**
- International Road Federation, **www.irf.global**

EXERCISES

- **RESEARCH** a recent road safety project in your city, county, State, or region. Identify the roles and responsibilities of the Federal, State, and/or local governmental agencies in the project. Prepare a brief report for a class presentation.
- **USE** your local, State, or regional highway department's website to determine its most pressing road safety concerns. Prepare a brief report that explains the concerns, how the agency identified them, the proposed remedies, and the agency's next steps.
- **PREPARE** a brief presentation that summarizes how your local government administers roadway programs. Identify the form of government (city, county, municipality, parish, etc.), the local agencies, and their responsibilities to roadway safety programs.
- **RESEARCH** a private or nonprofit interest group that works to improve road safety. Prepare a class presentation that includes a brief history of the interest group, a synopsis of important and successful campaigns, and a summary of its current work. Some examples of private or nonprofit interest groups include the Automobile Association of America (AAA), Mothers against Drunk Driving (MADD), the Insurance Institute for Highway Safety (IIHS), and the American Bikers Aimed Toward Education (ABATE), and many others.
- **RESEARCH** your local, State, or regional transportation safety planning group. Prepare a brief report that identifies the group's current safety goal(s), explains how the group plans to alleviate the safety challenge(s), and describes the group's strategic communications plan.
- **RESEARCH** a private sector or industry association that works to improve road safety. Prepare a class presentation that includes a brief history of the interest group, a synopsis of important and successful campaigns, and a summary of its current work. Some examples of private sector or industry associations include the American Insurance Association (AIA), the American Traffic Safety Services Association (ATSSA), the American Road and Transportation Builders Association (ARTBA), the National Association of County Engineers (NACE), the American Public Works Association (APWA), and many others.
- **FIND OUT** how professional associations like the National League of Cities, the American Association of State Highway Transportation Officials (AASHTO), the Governor's Highway Safety Association (GHSA), and the Standing Committee on Highway Traffic Safety (SCOHTS) influence road safety policy. What are some examples of past successful campaigns?
- Using the State DOT website, **RESEARCH** your home State's Highway Safety Program. Prepare a brief presentation that identifies the State and describes how it is working to improve roadway safety. You may want to focus on the State's efforts with a particular road user or road safety provider. Be sure to include details about how the State identified the safety challenge(s), how the State chose its countermeasure(s), and how its efforts measure against national performance criteria.

Road Safety Research

Road safety practitioners are constantly seeking the most effective means for preventing injuries and fatalities on the road. To accomplish this, they need to understand the nature of the road safety problems and which behavioral or infrastructure countermeasures are the best at addressing these problems. When weighing two possible safety treatments, they need to know which one is more effective (would prevent more crashes) and more efficient (preventing crashes at a lower cost). Additionally, safety practitioners work with a limited budget, so they need to know which safety treatment is more cost effective, that is, how many crashes can be prevented for the same dollar spent. These goals lead to many questions, such as:

- What age range should be targeted in a young driver safety program?
- What is an effective strategy for preventing run-off-road crashes?
- How many crashes would be expected on one type of road versus another type?
- How many serious injuries could be prevented by installing additional safety measures at a signalized intersection?

Research is the key to answering these questions and providing quality information to the safety practitioner. Unit 3 of this textbook provides a look at the various types of safety data and how they can be used together. Good research analyzes one or more kinds of safety data to gain knowledge on ways to prevent crashes or decrease injuries when crashes do occur.

General Types of Road Safety Research

The intention of this chapter is not to summarize the entire field of road safety research, but rather to provide an overview that will show what types of research have been conducted within the topic of road safety.

	RESEARCH QUESTION EXAMPLES	
	PROBLEM IDENTIFICATION	**EVALUATION**
PERSON	What are characteristics of crashes involving teen drivers?	What is the safety effect of instituting a graduated driver license law?
	What type of driver is overrepresented in alcohol-related crashes?	Has the arrival of ride-sharing apps in cities reduced alcohol-related crashes?
VEHICLE	What models of vehicle are more prone to run-off-road crashes?	What is the effect of an antilock braking system on run-off-road crashes?
	What factors are associated with large truck-related crashes?	What is the effect of airbags on injury severity?
ROAD ENVIRONMENT	What road features are associated with run-off-road crashes?	What is the safety effect of installing rumble strips?
	How does lane width influence driver speed?	What is the safety effect of narrowing lanes on urban roads?
	Are some land development patterns riskier from a safety standpoint?	What is the safety effect of controlling road access in dense urban areas?

TABLE 5-2: Safety Research Categorization

One way that these road safety research projects can be generally categorized is by grouping them by the safety factor they address: the person, the vehicle, or the roadway. For each of these categories, safety research typically focuses either on identifying safety problems or on evaluating solutions to safety problems. Table 5-2 demonstrates this classification of safety research areas and provides example questions that would drive research studies in each area.

While this chapter presents road safety research in terms of identifying problems or evaluating solutions, researchers also play key roles in developing new solutions to road safety problems. For example, the Florida Department of Transportation (FDOT) was experiencing thousands of crashes, including many fatalities, in construction work zones and sought an alternative to the traditional work-zone barrier. University of Florida civil engineering researchers hired by FDOT developed a new type of portable temporary low-profile barrier that can redirect cars and small trucks, preventing them from crashing into the work zone and protecting the passengers in the vehicle. The barrier was advantageous in that it could be broken down into small inexpensive segments that are easy to install and move around.[26] Additional research was carried out to evaluate this new type of barrier in terms of criteria like crash performance and durability.

[26] University of Florida, Office of Technology Licensing, “Portable Temporary Low-Profile Barrier (PTB) for Roadside Safety”, UF #11052, US Patent 6,767,158

Examples of Road Safety Research

The following sections provide descriptions and examples of research studies. These examples will give the reader a look at the types of studies that are conducted within each of the six categories shown in Table 5-2.

Research on the Person

Problem Identification

The IIHS sponsored a study to examine the characteristics of crashes involving 16-year old drivers. The researchers used crash data from NHTSA's General Estimates System (a national crash database built on sampling from police agencies around the U.S.). They compared crash involvement of sixteen-year-olds to that of other age categories of drivers and found that sixteen-year-olds were more likely to be involved in single-vehicle crashes and night time crashes (6:00pm to 11:59pm). Sixteen-year-olds were also more likely to have received a moving violation and been at fault for a crash. They were also more likely to be accompanied by other teenage passengers. Researchers also found some indications that drivers with less on-the-road experience (females in this study) were proportionately more involved in crashes.[28]

Evaluation of Solutions

In 1997, Michigan instituted its Graduated Driver Licensing (GDL) program to address the high rate of fatal crashes involving teen drivers. This program required teen drivers to gain driving experience under relatively low risk conditions before obtaining full driving privileges. A new driver would progress through Level 1 (a learner's stage requiring extensive supervised practice), Level 2 (an intermediate stage which prohibited teenage passengers and driving at night), and Level 3 (full licensure with no restrictions). NHTSA funded a group of researchers to evaluate the effect of the GDL program on the crash risk of 16-year-old drivers. The researchers examined Michigan statewide crash data from 1996 (pre-GDL) and 1998 and 1999 (post-GDL). They analyzed the pre-GDL and post-GDL rates of 16-year-old drivers involved in crashes by unit of the statewide population. Researchers also compared to crash rates of drivers over age 25 to control for any other trends. They found that the overall crash risk for 16-year-old drivers decreased 25% by the year 1999 (two years after GDL was implemented). They also found significant reductions in many specific crash types, such as night crashes and single vehicle crashes. These findings showed a significant benefit to the GDL program and served to support GDL implementation in other States.[29]

Research on the Vehicle

Problem Identification

The design of a vehicle, particularly how well it protects the occupants in the event of a crash, can have a significant effect on injuries sustained in the crash. A group of researchers from the IIHS investigated the relation of vehicle roof strength to occupant injury during crashes. They examined crash data from fourteen States

[28] Ulmer, Robert G., Allan F. Williams, and David F. Preusser, Crash Involvements of 16-Year-Old Drivers, Journal of Safety Research, Vol. 28, No. 2, pp 97-103, 1997. http://www.sciencedirect.com/science/article/pii/S0022437596000412

[29] Shope, J., L. Molnar, M. Elliott, P. Waller. Graduated Driver Licensing in Michigan: Early Impact on Motor Vehicle Crashes Among 16-Year-Old Drivers. Journal of the American Medical Association, Vol. 286, No. 13, October, 2001. http://jama.jamanetwork.com/article.aspx?articleid=194251

for single-vehicle rollover crashes involving midsize SUVs. They also used a rating of roof strength for each vehicle type in the crash data. Their findings showed that the crush resistance of a vehicle's roof was strongly related to the risk of fatal or incapacitating injury to the occupants. This research identified one statistically significant factor (roof strength) in the severity of rollover crashes. The researchers also recommended the study of other vehicle factors to determine their effect on the severity of rollover crashes.[30]

Evaluation of Solutions

Anti lock braking system (ABS) is a technology that was developed to combat the problem of drivers losing control of their vehicle during hard braking due to locked wheels. ABS modulates braking power to prevent a vehicle's wheels from locking up. Since this technology requires drivers to employ it correctly (i.e., step and hold on the brake rather than pumping), the Federal Government conducted a public information campaign in 1995 to inform drivers how to use ABS correctly. The NHTSA sponsored a study that took a long term look at the effect of ABS from 1995 to 2007. The researchers used crash data from two Federal databases (the Fatality Analysis Reporting System and the General Estimates System of the National Automotive Sampling System) to estimate the long-term effectiveness of ABS for passenger cars, light trucks, and vans. They found that ABS reduced fatal crashes with pedestrians but increased fatal run-off-road crashes. ABS proved to be quite effective in reducing nonfatal crashes in all types of vehicles. This result is for the ABS alone; the authors recognized that electronic stability control (a technology which automatically applies brakes to individual wheels to keep the driver on the road) would soon be paired with ABS for potentially greater crash reductions.[31]

Research on the Road Environment

Problem Identification

Curves on the road, both horizontal and vertical, are known to be problem spots for road safety. They are particularly concerning when they occur together, such as a horizontal curve at the peak of a hill. FHWA sponsored a study to identify and quantify the road and curve characteristics that are associated with higher instances of crashes. The researchers examined curves in Washington State using crash data and roadway characteristics contained in the Highway Safety Information System (HSIS). They analyzed locations where horizontal and vertical curves occurred independently, as well as locations where both occurred in the same place. The researchers developed equations that predicted the effect on crash frequency for each type of curve combination. These predictive equations included road and curve characteristics found to affect the frequency of crashes. These characteristics included the sharpness of the vertical curve and the radius of the horizontal curve.[32]

Evaluation of Solutions

Rumble strips are expected to decrease crashes by generating noise to alert sleepy or inattentive drivers that they are about to leave

[30] Brumbelow, M., E. Teoh, D. Zuby, and A. McCartt. Roof Strength and Injury Risk in Rollover Crashes. Traffic Injury Prevention, 10:252-265, 2009. DOI: 10.1080/15389580902781343

[31] Kahane, C., and J. Dang. The Long-Term Effect of ABS in Passenger Cars and LTVs. National Highway Traffic Safety Administration, Report DOT HS 811 182, August 2009.

[32] Bauer, K.M. and Harwood, D.W. Safety Effects of Horizontal Curve and Grade Combinations on Rural Two-Lane Highways, Report No. FHWA-HRT-13-077, Federal Highway Administration, Washington, DC, 2013.

the travel lane. Rumble strips on both the centerline and shoulder ensure that drivers are alerted no matter which side of the lane they depart. FHWA, through a pooled fund from 38 States, conducted a study to determine the safety effect of installing centerline and shoulder rumble strips on rural two-lane roads. The researchers gathered data on roads in three States and compared crash performance for roads where the rumble strips were installed versus roads without rumble strips. The analysis showed that the combined rumble strip strategy was effective at reducing crashes. As expected, the greatest crash reductions were for crash types that were related to lane departure including head-on crashes (37% decrease), run-off-road crashes (26% decrease), and sideswipe-opposite-direction crashes (24% decrease).[35]

How Research Affects Implementation: Motorcycle Helmets

Motorcycle helmets are now a common road safety element to reduce serious head injuries, but they were not always so. The original interest in motorcycle helmets began when Colonel T.E. Lawrence (better known as Lawrence of Arabia) died after suffering a head injury in a motorcycle crash. One of the physicians who attended him, Hugh Cairns, was moved by the incident and began studying the prevalence of head injuries among motorcyclists in the British Army. His work ultimately led to helmets becoming mandatory in the British Army and the U.K.

Early motorcycle helmets were leather caps that did little to protect riders. Then in the 1950s, Roth and Lombard came up with the idea of using a crushable, energy absorbing material (Styrofoam) inside the helmet. A study in 1957 by a physician named George Snively helped this new type of helmet take hold through unusual means – testing six popular motorcycle helmets on human cadavers. The Roth and Lombard helmet with the protective lining was by far the most effective in preventing head injuries.

Many more studies have documented the effectiveness of motorcycle helmets. This eventually led to standards for motorcycle helmets and universal helmet laws.[33,34]

Major Road Safety Research Sponsors and Research Programs

Most road safety research is funded by the government, through state or federal agencies. However, some research is also funded by privately run companies or foundations. The organizations that sponsor research projects are often focused on one category of research. The list below presents a look at some of the major research sponsors and their area of focus in road safety research.

Federal Research Sponsors

Federal Highway Administration

FHWA sponsors research studies on a variety of road safety topics, and their primary focus is on the roadway or the built environment. This research investigates the impact of road characteristics on

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[33] Maartens, N., A. Wills, and C. Adams. Lawrence of Arabia, Sir Hugh Cairns, and the Origin of Motorcycle Helmets. Neurosurgery, Vol. 50, No. 1, January 2002.

[34] Liu, B., R. Ivers, R. Norton, S. Blows, S.K. Lo. Helmets for preventing injury in motorcycle riders (review). The Cochrane Collaboration, John Wiley and Sons, Ltd. January 2008. DOI: 10.1002/14651858.CD004333.pub3

[35] Lyon, Craig; Bhagwant Persaud; and Kimberly Eccles. "Safety Evaluation of Centerline Plus Shoulder Rumble Strips." Federal Highway Administration, Report FHWA-HRT-15-048, 2015.

road safety and seeks solutions to known safety problems. The FHWA Offices of Safety and Safety Research and Development conduct research to address issues including driver interaction with the roadway, intersection safety, pedestrian and bicycle safety, and keeping vehicles on the roadway.[36] The FHWA Turner-Fairbank Research Center houses more than 20 laboratories, data centers, and support facilities, and conducts applied and exploratory advanced research in road safety, among other topics. Additionally, FHWA staff participates and provides input to many other venues of research around the nation.

National Highway Traffic Safety Administration

NHTSA studies behaviors and attitudes in road safety, focusing on drivers, passengers, pedestrians, and motorcyclists. Research sponsored by NHTSA identifies and measures behaviors involved in crashes or associated with injuries, and develops and refines countermeasures to deter unsafe behaviors and promote safe alternatives. The research topics include occupant protection, distracted driving, motorcycle safety, speeding, and young drivers.[37]

Transportation Research Board

The Transportation Research Board (TRB) is part of the National Academies of Sciences and provides advice to the nation and informs public policy decisions. TRB plays a major role in road safety research. It hosts an annual meeting where transportation professionals

How Research Affects Implementation: Safety Edge^{SM}

The ultimate intent of safety research is to provide solid data to affect the way that safety measures are carried out in the real world. The development of Safety Edge^{SM} is a good example of this.

Drivers who run off the road and then try to regain control often go too far and over-steer, leading to veering into the opposite lane or running off the road on the other side. This problem is made worse when the soil is eroded away from the pavement edge, creating a drop off. This safety concern was recognized in the 1980s, and the 1989 AASHTO Roadside Design Guide included a recommendation for adding a sloped edge to the pavement to assist drivers in regaining control onto the roadway. A few States attempted this treatment, but it was not widely implemented. Through the following years, other research showed a correlation between drop off crashes and fatalities.

In the early 2000s, several States (Georgia, New York, Colorado, and Indiana) decided to install several miles of the sloped edge as demonstration project. The FHWA sponsored a research study to evaluate the effect of the sloped edge, now called Safety Edge^{SM}, on run-off-road crashes. The results showed a positive effect, and this finding swayed many safety offices in favor of the treatment. Those now in favor of Safety Edge^{SM} worked to get other offices, such as pavement offices, on board with the idea. Eventually it became a widespread practice, and by 2015, forty States required Safety Edge^{SM} to some degree in their design policies.[38]

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[36] https://www.fhwa.dot.gov/research/tfhrc/programs/safety/index.cfm

[37] https://www.nhtsa.gov/research-data

[38] Graham, J.L., Richard, K.R. , O'Laughlin, M.K., Harwood, D.W., "Safety Evaluation of the Safety Edge Treatment" Report No. FHWA-HRT-11-024, Federal Highway Administration, Washington, DC. (2011) http://www.fhwa.dot.gov/publications/research/safety/11024/11024.pdf

from around the world present new research on many different transportation topics. The papers presented at the annual meeting are peer-reviewed, and a portion of them are published in the Transportation Research Record.

TRB also maintains standing committees that provide direction to the research field and assist in disseminating research findings. Committees such as Transportation Safety Management, Highway Safety Performance, Pedestrians, Occupant Protection, and many others specifically address topics related to road safety. TRB manages the National Cooperative Highway Research Program (NCHRP), described below.

State Research Sponsors

American Association of State Highway Transportation Officials (AASHTO)

AASHTO is the organization behind NCHRP. The NCHRP funds many road safety research projects each year on a variety of topics that are integral to the State departments of transportation (DOTs) and transportation professionals at all levels of government and the private sector. The NCHRP is administered by the Transportation Research Board (TRB) and sponsored by individual State departments of transportation. The research projects are conducted in cooperation with FHWA (FHWA). Individual projects are conducted by contractors with oversight provided by volunteer panels of expert stakeholders. NCHRP projects cover a wide range of highway topics, but there is a specific focus area for safety.[39] AASHTO also maintains several committees that oversee road safety topics including the Standing Committee on Highway Traffic Safety and the Subcommittee on Safety Management. These groups decide which research topics should be prioritized for funding under NCHRP.

Other Research Sponsors

Although the majority of road safety research is funded by government sources, private companies and organizations also participate in funding road safety research. Prominent examples of these are the IIHS and the American Automobile Association Foundation for Traffic Safety.

State Research Programs

In addition to participating in large scale research efforts, such as NCHRP, State departments of transportation often fund road safety research projects on topics that are of particular interest to their State. They use portions from Federal funds that are specially designated for research projects. Every State has a different process for how the research projects are conceived and conducted, but a common arrangement is that the State DOT contracts with universities in the State to conduct the research. The research topics typically pertain to current road safety issues that are high priority within the State or issues related to geography, terrain, weather, driver population, or other such factors that may be particular to that State. For example, a State in a snowy climate may sponsor a research project on how snowplowing affects the visibility and durability of in-pavement reflective markers.

[39] http://www.trb.org/NCHRP/NCHRP.aspx

Strategic Communications

A key part of many efforts to improve road safety is sharing safety messages through strategic communications. This chapter provides an outline of the most basic elements of strategic communications that transportation safety professionals should use when working with their communications teams to craft and disseminate messages that seek to improve traffic safety culture. As mentioned in Unit 1, strategic communications programs like public education campaigns are commonly used to improve road user attitudes and awareness.

A strategic communications program involves elements of communications, marketing, and public outreach. These components often overlap and are not easily separated into distinct categories with unique functions. Strategic communications is more than the sum of its parts. Rather, it is a structured methodology that fuses messaging with marketing while garnering public support.

Several examples demonstrate that strategic communications can result in behavioral changes. An effort in the late 1980s to stop impaired driving resulted in substantial decreases in Driving Under the Influence (DUI) citations. NHTSA saw successful results from the implementation of the "Buckle Up America Campaign" and the National Safety Council's "Airbag and Seat Belt Safety Campaign" and the high-visibility public information program "Click It or Ticket" safety belt enforcement campaign. Strategic communications was a key element of all of these efforts.

Public education campaigns like this one are commonly used to improve road user attitudes and awareness. *(Source: NHTSA)*

Other examples of communications efforts include:

- Campaigns with careful pre-testing and delineation of a target group that receives the messages.
- Longer-term programs that deliver a message in sufficient intensity over time.

- Education programs built around behavioral change models, using interactive methods to teach skills to resist social influences through role playing.
- Public information campaigns that accompany other ongoing prevention activities.
- Programs conducted as part of a broader community effort or in support of law enforcement.

An effective strategic communications program, like any effective endeavor, needs a plan. The following are key steps in developing a strategic communications plan that every road safety professional should know:

1. **Develop objectives**
2. **Identify target audience**
3. **Design messaging**
4. **Select communications channels**
5. **Determine budget and resources**
6. **Measure results**

Each step of this communications plan outline is discussed in the sections below.

1. Develop Objectives

The first phase in creating a strategic communications plan is to determine objectives. A well-designed communications strategy may achieve multiple goals, such as informing the public about transportation safety issues, educating key political leaders on their roles in saving lives, and encouraging active participation from safety partners.

To develop objectives, safety professionals must start by defining what "success" should look like. Important questions include:

- What are we trying to achieve?
- Do we want people to take a new action, or do we want people to modify an old behavior?
- How do we know when we have achieved our goal (i.e., what are our target metrics)?

Establishing measurable goals is an important piece that should be not be overlooked. Having a target or measurable goal (metric) makes it simpler to gauge the success of a campaign.

2. Identify Target Audience

After developing communications objectives, the next step is deciding what populations to target. For example, safety professionals must decide if the program should be aimed at the general public or a specific sub-set of the population, such as young drivers, pedestrians, or people who drive aggressively. A message could also be aimed at road safety professionals and government officials. In addition to a target audience or audiences, secondary audiences may be included. For instance, if the program targets young drivers, a secondary audience may include the parents of these novice drivers.

3. Design Messaging

Once safety professionals identify the target audience, they must determine what the message will be. A key step is to define the problem that needs to be solved in order to craft the message. Messaging should be designed so that it encourages specific actions, and draws upon established

Watch for Me NC

Watch for Me NC is a comprehensive program run by the North Carolina Department of Transportation (NCDOT) in partnership with local communities. It is aimed at reducing the number of pedestrians and bicyclists crashes.

The Watch for Me NC program involves two key elements: 1) safety and educational messages directed toward drivers, pedestrians, and bicyclists, and 2) enforcement efforts by area police to crack down on some of the violations of traffic safety laws. Local programs are typically led by municipal, county, or regional government staff with the involvement of many others including pedestrian and bicycle advocates, city planners, law enforcement agencies, engineers, public health professionals, elected officials, school administrators and others.

All North Carolina communities are encouraged to use Watch for Me NC campaign materials to improve pedestrian and bicyclist safety in their communities.

(Source: Watch for Me NC)

objectives to determine what those actions should be. Designing the message will bring about questions like these: "Is the intended action a change in safety funding or policies? Or is the goal a change in user behavior?" Focusing efforts on strategies that connect with the target audience is particularly important in today's environment of tight budgets and scarce resources.

After message development, safety professionals should consider pre-testing the message with the target audience. A pre-test can identify points of view of the target audience, provide unexpected insights or reactions that can help further refine messaging, and help determine if the communications plan will improve the chance of accomplishing the stated objectives.

4. Select Communications Channels

Carefully crafted messages need to be conveyed through appropriate channels in order to be effective. Communications channels include the personal and the non-personal. Personal channels include the advocate channel (advocates championing the objectives of a campaign), expert channel (independent experts making statements to the target audience), and social channel (word of mouth communications). Non-personal channels include media, events, and public outreach – examples of common non-personal dissemination techniques include, but are not limited to, the following:

- Brochures

- Conferences/workshops
- Dynamic message signs
- Media advisories
- New media (e.g., blogs, podcasts, Facebook pages)
- News media events
- Newsletters and press releases
- Public service announcements
- Print, radio, and television advertising
- Social media
- Websites

Safety professionals must work with the communications team to determine the right media mix, which is the combination of communication channels needed to meet communications objectives. Together they must figure out which channels -- personal and/or non-personnel – and which tactics will help meet the stated road safety goals. For example, personal channels may work well with government officials, while non-personnel channels may work best with reaching out to the public. Also, a detailed timeline of channels and tactics to employ, is crucial for implementing a strategic communications plan.

5. Determine Budget and Resources

Implementing a comprehensive communications program requires resources like money, staff, and time. Therefore, developing a budget for the program is an integral part of carrying out the plan. Safety professionals should consider every element of the proposed plan, and make sure there are resources to cover them all. For instance, it may be necessary to hire an outside firm to help develop and refine messages and tactics, and that should be factored into the budget. All program expenses should be tracked to determine how well the budget has been met when measuring results.

6. Measure Results

Evaluation of a strategic communications program is essential. Without evaluation, current programs may waste resources and fail to contribute to a road safety program's goals. Evaluations help safety professionals learn from outcomes and help them allocate funds in the most efficient manner. If a program does not meet expected metrics, they should re-examine the program and/or move the resources to other efforts.

To measure the results of the program, safety professionals must go back to the objectives and pre-determined measurable goals and targets. The original questions in Step 1 will guide the evaluation of the success of the program. Surveys, focus groups, and/or one-on-one interviews are often good ways of measuring the performance of a strategic communications program.

As far as data allow, safety professionals should also attempt to compare the effectiveness of communication campaigns in the same way that they compare the performance of traditional infrastructure countermeasures. The comparison will help identify campaigns that are both effective and efficient.

Advancing Road Safety

This chapter covers the crucial role that safety leaders, champions, and coalitions play in road safety management. While the various agencies and organizations involved in road safety bring unique and valuable perspectives to the problem of road safety, they also bring competing philosophies and problem-solving approaches. Bringing these various entities together to develop and implement an effective road safety program is a challenge.

The major topics include:

- **Leaders**
- **Champions**
- **Coalitions**

Leaders

Leadership is essential in any field, but it is particularly important in road safety for three major reasons:

- The safety field is diverse. It draws on the skills of educators, politicians, advocates, bureaucrats, public servants, and others. These groups sometimes work in harmony, but too often, they work in isolation. Leaders are necessary for cohesion in a complex, multi-stakeholder environment.
- A great deal of technical knowledge is available in the safety field regarding the most effective means of addressing the contributing factors to crashes. However, technical knowledge is not sufficient for change to occur. Leadership is necessary to ensure technical knowledge is used.
- Road safety programs and projects compete with other public sector priorities. Without strong leaders to support the safety cause, public sector decision makers might not consider or prioritize safety.

Leadership Activities

Leaders are an instrumental part of any planning process, and road safety programs are no exception. Leaders bring people together, provide essential direction, and motivate people to participate in and implement the program. Leaders should be engaged and actively involved in the process.

Consider a few examples of leadership in safety:

- State DOT leaders decide that reducing fatal and serious crashes should be the first priority of the department. They garner staff support to make funding and structural changes to the organization to support the shift in priorities.
- Law enforcement officers develop new incentive programs to encourage officers to identify and arrest impaired drivers. They successfully sell the program to their managers.

Leaders bring people together, provide essential direction, and motivate people.

- A trauma nurse initiates a "teachable moments" campaign in which nurses teach patients about the risks associated with drinking and driving.
- A mayor recognizes that many streets in her city are not suitable for safe travel by pedestrians and garners support and funding from the city council to build sidewalks and improve the safety of transit stops.

In each of these examples, the leaders recognized a need for change, acted on the need, and inspired others to follow. Anyone with drive, dedication, and a good idea can lead.

Leadership Traits and Skills

Good leaders influence policy direction, set priorities, and define performance expectations. They energize the road safety process and see to it that a plan is developed, and once developed, is implemented. They are risk takers, problems solvers, and creative thinkers committed to doing what is necessary to advance the cause, which sometimes means breaking traditional institutional barriers and balancing competing agency priorities.

Leaders are often known as program managers, and their activities keep the implementation process on track. They manage the process and attend to the day-to-day tasks of arranging, facilitating, and documenting meetings, tracking progress, and moving discrete activities through to completion.

Leaders are needed throughout all stages of road safety development, implementation, and evaluation. They communicate the safety vision and support a collaborative framework that enables safety stakeholders to participate actively in implementation.

Leadership Development

To expand leadership support, begin with the safety partners already committed to the safety concept and process. Encourage the leadership of those partners to contact their peers, explain the significance of their efforts, and marshal support. Their endorsement of the safety vision should include encouraging staff to stay engaged and building relationships across organizational boundaries and traditional areas of responsibility.

Leadership support affects agencies or organizations internally by granting permission to dedicate time and resources to the safety effort. It also holds those responsible for safety accountable. Leadership should recognize that this is an ongoing process and institutionalize the change in the safety decision-making culture.

The safety program manager may perform either as a part- or full-time permanent role; experience demonstrates a dedicated role is preferable.

Champions

Successful road safety programs call for at least one champion to assist in gathering all critical safety partners into a collaborative group. Champions provide enthusiasm and support for the safety programs.

Like leaders, champions must be credible and accountable, have excellent interpersonal and organizational skills, and be skilled expediters.

Champion Activities

Safety champions help secure the necessary leadership, resources, visibility, support, and commitment of all partners. Sometimes the DOT leadership, or the leadership of the primary sponsoring agency, appoints the champion. A safety champion can reside at any level within the organizational structure and can perform various functions.

For example, a safety champion may lead the executive committee that meets periodically to solve problems, remove barriers, track progress, and recommend further action. The role of the executive committee is to decide which projects or strategies are funded based on input from the emphasis area teams, and to prioritize them based on benefit/cost analysis, expected fatality reductions, and the extent to which they address the project's goals and objectives.

Where relationships are not fully developed, the champion may have to put in additional effort to keep the full range of safety partners committed and actively participating.

Champion Traits and Skills

FHWA published the "Strategic Highway Safety Plan Implementation Process Model" that identifies two types of transportation safety champions.[39] The first have access to resources and the ability to implement change. In other words, they may not be involved in the day-to-day management responsibility for program development and implementation, but they are able to "move mountains" in terms of resource allocation and policy support. The second are leaders who inspire others to follow their direction. These champions are people who provide enthusiasm and support to transportation project implementation. They tend to be subject matter experts and highly respected within their own agencies and in the safety community.

Succession Planning

All agencies and organizations undergo staff changes, and it is essential to train the leaders of tomorrow to ensure that the focus on safety continues into the future. This can be accomplished by assigning leadership responsibilities for program implementation to newer staff and by ensuring that all staff have opportunities to engage and lead during meetings and other activities.

To ensure continuity when an individual champion or leader retires, takes a position in another organization, or moves out of State, a systematic approach to identifying their replacement is necessary. The selection process should be based on individual skills, leadership traits, and the position held within a stakeholder organization. One way to institutionalize the selection of safety committee members is to link their selection to the position they hold within the stakeholder organization. For example, whoever assumes the previous safety champion or committee member's position should also become the new committee member.

[39] http://safety.fhwa.dot.gov/hsip/shsp/

Coalitions

Safety partners and organizations bring unique and valuable perspectives to bear on the transportation safety problem. However, differing philosophies, competing priorities, and varying business cultures may make collaboration a challenge. Coalitions are an opportunity for road safety leaders and champions to bring together the various disciplines and agencies and focus on the shared goal of reducing crashes. Whether coalitions are short-term, long-term, or permanent, they offer road safety collaborators the prospect of solving complex issues through partnerships.

Safety Partners

The organizational structure of agencies and interagency working relationships are important factors to consider when bringing safety partners together. Rather than create entirely new committees, a champion should build upon existing relationships, interagency working groups, and committees.

Many States have functioning transportation safety committees, such as a TRCC, an Executive Committee for Highway Safety, or a Towards Zero Deaths (TZD) coalition. Regardless of how safety partners are brought together and organized to contribute to the safety process, champions should look for ways to expand membership to include a broad range of partners, such as insurance, trucking and motor coach companies, fire and rescue, local businesses, and others.

When States implement the Federally required SHSPs, their safety partners typically include those that are Federally required, such as EMS providers, health and education departments, Motor Carrier Safety Assistance Program (MCSAP) managers, local agencies, tribal governments, special interest groups (e.g., MADD), and others.

With an emphasis on wide-ranging collaboration that includes many external partners, it can be easy to overlook the importance of broad DOT involvement, as well. Early involvement of planning, design, operations, and maintenance will enhance the implementation of safety strategies, especially if they are new or experimental.

Some champions bring partners together by convening a safety summit or meeting. This could be a large initial kickoff meeting or a meeting of the safety working group or steering committee. It provides an opportunity to learn about each of the safety partner priorities and understand what they contribute. Coalitions should give participants the opportunity to describe their safety concerns and current programs. This may advance the discussion of critical safety issues, identify opportunities, and forge an agreement on how to proceed.

Benefits of Collaboration

Engineering, planning, emergency response, and behavioral approaches all have roles to play in addressing road safety. Professionals in these various disciplines have different skill sets, and they approach solutions using different methods. Dramatic improvements in roadway safety are more likely to result through a combination of techniques than from techniques from a single discipline. This need for multidisciplinary solutions necessitates collaboration.

Unit Summary

Improving road safety is a complex endeavor requiring the knowledge and expertise of a wide range of professionals. Road safety improvement is a joint effort across many Federal, State, and local agencies, each with their own particular focus area.

Federal agencies often play a role in providing funding and national cooperation for focused road safety efforts. State and local agencies implement road safety improvements, either for roads and intersections in their jurisdiction, or on the road users themselves. The efforts of these government agencies is supported by a broad base of road safety research, which provides knowledge on identifying safety problems or evaluating potential solutions. Strategic communications allow all road safety partners to be effective in their efforts to improve road safety, either in communicating to the public or to transportation professionals.

Leadership is essential in the road safety field. The diversity of the field, the importance of coordination among disciplines, and the need to defend safety programs among a host of competing public sector priorities all contribute to the need for strong leadership. Successfully implementing road safety efforts relies on safety champions and coalitions that bring together safety partners from all agencies and disciplines.

EXERCISES

- **IDENTIFY** a road safety leader in your community, State, or region. Determine the leader's area(s) of concern, observe how the leader engages with the transportation safety community, and assess the leader's success. Write a brief report summarizing your research. Include an explanation for why or why not the leader was successful.
- FHWA has explicitly stated that a "safety champion" should lead safety efforts, specifically development of State SHSPs. Using your home State's DOT website, **RESEARCH** past or present safety champions. Prepare a brief class presentation that identifies the champion, explains why he or she was chosen for the role, what the requirements of the position were, and what projects the State implemented under the champion's guidance. Be sure to include an assessment of the champion's tenure.
- Coalition building requires a thoughtful, reasoned approach. **CHOOSE** an important road safety issue that the transportation community is still studying. Propose a list of coalition members that could best approach the issue from all available disciplines and interests. Be sure to keep the list reasonable. In a report, summarize the safety issue and introduce the coalition members. Explain why each member is critical to the coalition and the expectations for each member's contributions.

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Road Safety Fundamentals is available for free at:
https://rspcb.safety.fhwa.dot.gov/rsf/

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