Guidance for Safety Improvements on Local Roads

NCHRP Project 17-18(15)

January 2016

Submitted by:

CH2M

Traffic Safety Solutions, LLC

Acknowledgements

This volume of *NCHRP Report 500* was developed under NCHRP Project 17-18(15), the product of which is a series of implementation guides addressing the emphasis areas of the American Association of State Highway and Transportation Officials (AASHTO) *Strategic Highway Safety Plan*. The project was managed by CH2M.

Timothy Neuman of CH2M served as the overall project director for the team with John Nitzel as the manager. Richard Storm, also of CH2M, served as a technical specialist on the development of the guide.

The project team was organized around the specialized technical content contained in each guide. The following team of experts, selected based on their knowledge and expertise in this particular areas served as lead authors for this guide:

John Nitzel
CH2M

Richard Storm
CH2M

Jill Bartel
CH2M

Glenn Hansen
Traffic Safety Solutions

The prior volumes of *NCHRP Report 500* were the primary basis for this document. These volumes were initially utilized to develop the safety strategies and approaches contained herein. The project team is grateful to the following list of people and their agencies for supporting the project through their participation in workshops and meetings, as well as reviews of the Local Agency Guide:

Freeborn County, Minnesota
Susan G. Miller

Iowa Department of Transportation
Tom Welch*

NACE
Tony Giancola

California Highway Patrol
John Farrow

Capital District Transportation Committee, Albany, NY (DTCMPO)
Sandy Misiewicz

Harrison County, Logan, IA
Tom Stoner, PE

Cowlitz County, Kelso Washington
Kent Cash, PE

South Jersey Transportation Authority
Ed Conrow

Federal Highway Administration
Clayton Chen

Capitol Region Council of Governments, Hartford, CT
Jennifer Carrier

Fairfax County Police Department
Jesse Bowman

City of Surprise, AZ
Bob Maki

Richmond, CA Police Department
Andre Hill

Portland Area Comprehensive Transportation Committee (PACTS), Portland OR
Julia Dawson

Delaware Valley Regional Planning Commission

No Affiliation Available
Keith Sinclair
David Banks

* NCHRP Project 17-18 Panel Member

Contents

Attachments

Exhibits Page

Acronyms

4Es	engineering, enforcement, education, and emergency medical services
AASHTO	American Association of State Highway and Transportation Officials
CMF	crash modification factor
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
GIS	geographic information system
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
SHSP	Strategic Highway Safety Plan
TRB	Transportation Research Board

I. Summary

Introduction

Approximately 76 percent of the over 4 million miles of public roads in the United States are under the jurisdiction of cities/towns and counties, which includes urban and rural roads. In addition, approximately 5 percent of the remainder is under national park or national forest jurisdiction. In 2006 alone, approximately 38 percent of traffic fatalities occurred on roads controlled by local highway and transportation departments. Although this illustrates only a part of the highway safety picture and does not provide detail on injury and property damage only crashes, it is an indication of the potential magnitude of crash frequency on local roads.

With responsibility for over 80 percent of the country's roadways, the nation's non-state highway and transportation agencies have an enormous task to operate and maintain the local roadway system. Providing for the safety of the traveling public is only one of the responsibilities of local (non-state) transportation agencies and is a challenge given their limited resources.

Other safety challenges facing local agencies may include:

- The relatively small number of fatal or incapacitating-injury crashes that occur in an individual jurisdiction on a per-mile basis.
- Many miles of local roads are low-volume, which creates unique challenges for local agencies in funding, developing, and deploying safety countermeasures.
- Often local roads are constructed to lesser design standards than many state-maintained highways, possibly for budgetary reasons or because low volumes simply do not justify the additional expenditure to attain or meet higher design standards or guidelines.

To overcome these challenges and aid local agencies with their safety programs, this document was created as a companion to the others in the *NCHRP Report 500* series. The focus is on providing a set of safety countermeasures that are feasible and practical for smaller, local agencies with responsibility for the local roadway network in their county, township, municipality, etc.

Type of Issue Being Addressed

Addressing local road safety requires a more in-depth understanding of the types of fatal crashes and circumstances around them on local roads. Fatality Analysis Reporting System (FARS) data from 2004 offer insights on the characteristics of fatal crashes for the following basic conditions:

1. Urban vs. rural location

2. Intersections and driveway accesses (junctions), and roadway segments (that exclude intersections/driveways)
3. Roadway alignment, traffic control, and other geometric characteristics
4. Other contributing factors to a crash such as light condition, driver condition, and environmental conditions

As expected, there are different prominent crash types and safety concerns on urban local roads and rural local roads.

Urban Local Roads

The FARS data for urban local roads strongly suggest that in addition to reviewing motor vehicle crashes, it is important to address pedestrian and intersection-related incidents in urban areas. For all urban local roads, the three most common first harmful events are vehicle collision with a motor vehicle [in transport] (34 percent), vehicle collision with a pedestrian (19 percent), and vehicle collision with a tree (8 percent). Combined, pedestrian crashes (19 percent) and bicycle crashes (4 percent) account for nearly one-quarter of fatal crashes (23 percent) on urban local roads. These crash types comprise over three-quarters of the fatalities in urban areas. The data also show locations where specific crash types are more prominent on urban local roads.

Rural Local Roads

National fatal crash data for rural local roads offers insights on the nature of crashes on these roads and provides an example of potentially useful analyses an agency could perform with its own data. The three most common first harmful events are vehicle collisions with a motor vehicle [in transport] (26 percent), vehicle collisions with a tree (15 percent), and overturned vehicle (15 percent). In total, crashes involving a single vehicle running off the road and either overturning or striking a fixed object constitute over 55 percent of fatal crashes on rural local roads. The data also show locations where specific crash types are more prominent on rural local roads.

Summary of an Approach to Local Road Safety Issues

Agencies with the resources and data can conduct independent analyses similar to those described in this guide. In the absence of an agency-specific study, assuming the agency's roadway system is typical, the following should be the focus of safety efforts:

- For urban local roads, safety countermeasures that focus on:
  - Intersection crash patterns in such as multiple-vehicle patterns
  - Intersection crash patterns that are single-vehicle related such as pedestrian, bicycle, and fixed object crashes
  - Roadway segment crashes such as fixed object and pedestrian crashes
- For rural local roads, safety countermeasures that address run-off-the-road (lane-departure) crashes

The companion guide entitled *Local Highway Agency Safety Guides Safety Management Process* details a process to more effectively incorporate safety into local agency activities. The process can be used to systematically identify traffic safety issues for this guide.

Guidance for a Local Safety Process

The creation of a successful traffic safety management system or local safety process is key to a long-term effort to reduce crashes, especially those that are severe in nature. The seven steps of a successful safety process for local agencies are as follows:

1. Decide to make safety a priority
2. Define safety issues
3. Illustrate the results
4. Establish crash reduction goals
5. Find solutions to safety concerns
6. Put safety strategies into action
7. Monitor outcomes

Local agencies can be in various stages of development in the realm of traffic safety management. This seven-step framework provides the flexibility for a local agency to integrate anywhere in the process, or incorporate elements or items into the existing process the agency currently follows, according to their situation.

Local agencies that have successful safety efforts have in almost all cases used a systematic approach to solve traffic safety issues. These are considered "best practices." Following are examples of some of these approaches:

- Target the leading contributing factors to crashes
- Deploy safety strategies using a low-cost, proactive approach

Finding Solutions to Safety Concerns

A variety of approaches may be used to identify solutions (countermeasures) to safety concerns. How an analysis is conducted depends on the crash data available and how well it has been (or can be) integrated with roadway and traffic information. Following are examples of some of these approaches:

- Concentrate on severe crashes
- Separate rural and urban areas
- Identify any overrepresented safety emphasis areas
- Examine roadway segment and intersection safety separately
- Analyze crashes by road characteristics

- Review driving and environmental condition data
- Investigate contributing driver behavior to crashes

Description of Highway Safety Objectives and Strategies

Local agencies can use this guide to solve specific roadway safety issues following two basic steps.

Step 1 – Identify Highway Safety Objective(s) to Address the Crash Issue

A review of the data from the crash analyses for U.S. roads under the jurisdiction of local agencies identified six distinct areas of Highway Safety Objectives for reducing crashes. These Highway Safety Objectives are consistent with the safety emphasis areas developed by AASHTO in their *Strategic Highway Safety Plan*. These Highway Safety Objectives correspond to the AASHTO safety emphasis areas and are as follows:

I. Reduce Intersection Crashes

II. Keep Vehicles on the Roadway

III. Reduce Lane-Departure Crashes

IV. Reduce Pedestrian and Bicycle Crashes

V. Improve Enforcement and Education Programs

VI. Improve Emergency Medical Services

In addition, one Highway Safety Objective has been added:

VII. Innovative Safety Techniques

A local agency can use their safety data to follow this process to identify their own unique highway safety objectives. If an agency does this, it is recommended that the safety objectives be compared to those of their state Strategic Highway Safety Plan (SHSP) for compatibility and to assess if common issues exist.

Step 2 – Select Safety Strategies

The next step is to identify appropriate safety strategies. For the each of the objectives selected, the *NCHRP Report 500* guides were reviewed in detail to find appropriate strategies that fit the context and resources of local agencies. This selection concentrated on strategies that are low-cost, easy to implement, and proven to be effective and/or used and accepted by a significant number of agencies. These Highway Safety Objectives and Strategies include traditional engineering-related safety countermeasures and those that go beyond engineering solutions and include integrated and multidisciplinary (based on the 4Es – engineering, enforcement, education, and emergency medical services) approaches.

Details of the Highway Safety Objectives and Strategies

Attachment 1 lists the strategies for all seven Highway Safety Objectives that apply to local roads. The recommended use for these strategies is noted according to rural and urban areas. A wide range of strategies are included and they represent what can be called a set of safety tools for each Highway Safety Objective.

Attachment 2 contains summaries for each strategy and technique contained in the guide. They are organized by Highway Safety Objective. The strategies provide the most important information in a simple usable manner that can be quickly referenced and used by an agency.

Examples of How to Use This Guide to Address a Safety Issue

Several examples of how to use this guide to identify and develop safety solutions are provided. The examples cover typical situations where:

- A local agency may have developed a set of safety objectives and wants to address an identified crash reduction objective for a group of roads or a set of locations on their roadway system.
- An agency has not developed a set of safety objectives and may have a single location, or set of streets or locations, that have a safety issue.

The examples include crash data for hypothetical local agencies (such as a town or county). The crash modification factor (CMF) is then calculated (or estimated) for each strategy to determine how well a strategy will reduce a specific type of crash. The examples of safety issues and their accompanying strategies are as follows:

- Reducing intersection crashes
- Keeping vehicles on the roadway at curves
- Reducing pedestrian crashes along a roadway with no sidewalk or shoulder
- Implementing a speed management program for collector and local streets

II. Introduction

According to the Federal Highway Administration (FHWA), there are over 4 million miles of public roads in the United States with approximately 3.04 million miles (76 percent) under the ownership of a local agency (such as counties, municipalities, towns, and townships). Contained in this local agency maintained system, an estimated 2.18 million miles (54 percent of all U.S. public roads) are classified as rural roads and about 866,000 miles (22 percent of all U.S. public roads) are urban roads. Additionally, approximately 194,000 miles of roads (nearly 5 percent of total mileage) are listed as under the jurisdiction of a federal agency or other similar entity. These include roads in national parks, national forests, military bases, and on tribal lands, many having the same design and traffic characteristics as local roads. (1)

Data from the Fatality Analysis Reporting System (FARS) indicates that approximately 38 percent of all traffic fatalities (16,277) in 2006 occurred on roads under the jurisdiction of county, township, and municipal highway and transportation agencies. In 2006, another 1,835 fatalities (over 3 percent) occurred on roads classified with a jurisdiction as "Other," which is likely federal, tribal, etc. (2) While this illustrates only a part of the highway safety picture and does not provide detail on injury and property damage only crashes, it is an indication of the potential magnitude of crash frequency on local roads.

In recent years there has been a national renewed focus on the reduction of highway fatalities and injury crashes led by the American Association of State Highway and Transportation Officials (AASHTO), FHWA, the Transportation Research Board (TRB), and other transportation organizations. This has spurred the development of new resources for helping highway and transportation agencies to implement strategies to improve safety in their jurisdictions. Among the notable tools is the National Cooperative Highway Research Program (NCHRP) *Report 500* series of guides for the AASHTO *Strategic Highway Safety Plan* (SHSP). This series provides tried and proven strategies for each of 22 separate emphasis areas in the SHSP. However, this *Report 500* series guidance has been oriented towards larger agencies that have in-house transportation expertise, extensive and current databases, as well as more trained staff, additional funding resources, and the ability to research and deploy safety countermeasures.

The Challenge

With responsibility for over 80 percent of the country's roadways, the nation's non-state highway and transportation agencies have an enormous task to operate and maintain the local roadway system. Providing for the safety of the traveling public is only one of the responsibilities of local (non-state) transportation agencies and is a challenge given their limited resources.

Local agencies — including counties, cities, and townships, as well as tribal governments, park, and forest authorities — face many challenges implementing safety improvements, especially given their limited resources and extensive roadway networks. These challenges may include lack of in-house highway safety expertise, lack of data or ability to collect data, difficulty in identifying all of the stakeholders, insufficient funding, inability to include projects in a safety program, and inability to implement countermeasures. Other safety challenges facing local agencies may include:

- The relatively small number of fatal or incapacitating-injury crashes that occur in an individual jurisdiction. Based on the statistics cited above, there is one fatal crash annually for every 179 miles of local agency roadway. These few crashes, spread over many miles of roadways, may limit an agency's ability to gain a clear picture of specific safety concerns or locations on which to focus its safety resources.
- Many miles of local roads are low-volume, which creates unique challenges for local agencies. Even the size of local systems poses challenges. For example, the time to notify emergency medical services may significantly increase because of the time it takes for someone to discover and report the crash. Also, safety countermeasures may have a low benefit-to-cost ratio due to low traffic volumes, meaning rural safety projects don't compete well against other projects in more congested areas.
- Often local roads are constructed to lesser design standards than many state-maintained highways, possibly for budgetary reasons or because low volumes simply do not justify the additional expenditure to attain or meet higher design standards or guidelines. While higher standards do not guarantee safety, certain sets of circumstances on local roads (such as increased development and traffic growth) can lead to an increased risk for a severe crash on a road that may be not designed to accommodate a change that occurs.

Although state-level highway agencies also face many of these challenges, larger agencies traditionally have the advantage of access to wide range of safety improvement programs, and the programs are often of a much larger scale than is available or feasible for local agencies.

To overcome these challenges and aid local agencies with their safety programs, this document was created as a companion to the others in the *NCHRP Report 500* series. The focus is on providing a set of safety countermeasures that are feasible and practical for smaller, local agencies with responsibility for the local roadway network in their county, township, municipality, etc.

The *NCHRP Report 500* series includes "proven," "tried," and "experimental" safety strategies that are considered to be low-cost and readily implementable. For this guide, recognizing the limited resources of most local agencies, the selection of safety improvement strategies focuses on only those countermeasures that are generally proven to be effective and are relatively low-cost to implement.

Discussions for each strategy contained in this guide are primarily based on information available in the *NCHRP Report 500* series, but have been supplemented when newer information is available. In addition, the description for each strategy has been limited to one page, providing the most important information to users in a convenient concise manner. For more information about each strategy, users are directed to the *NCHRP Report 500* guides or other references listed.

References

(1) Federal Highway Administration. *Highway Statistics 2006*.
http://www.fhwa.dot.gov/policy/ohim/hs04/htm/hm20.htm

(2) National Highway Traffic Safety Administration. *Fatality Analysis Reporting System*. 2006.
http://www-fars.nhtsa.dot.gov

III. Type of Issue Being Addressed

Identifying and Describing Local Road Safety

In 2006, approximately 38 percent of all traffic fatalities in the U.S. occurred on roads under the jurisdiction of county, township, or municipal transportation agencies with another 3 percent of fatalities on roads classified as "Other" jurisdiction. (1)

Clearly, addressing local road safety requires a more in-depth understanding of the types of fatal crashes and circumstances around them on local roads. FARS data from 2004 (2, 3) offer insights on the characteristics of fatal crashes for the following basic conditions:

1. Urban vs. rural location
2. Intersections and driveway accesses (junctions), and roadway segments (that exclude intersections/driveways)
3. Roadway alignment, traffic control, and other geometric characteristics
4. Other contributing factors to a crash such as light condition, driver condition, and environmental conditions.

A local agency may find the information below useful to either compare their history of crashes, or lacking sufficient data use it as a basis for safety-based decision making.

Urban Local Road Safety Issues

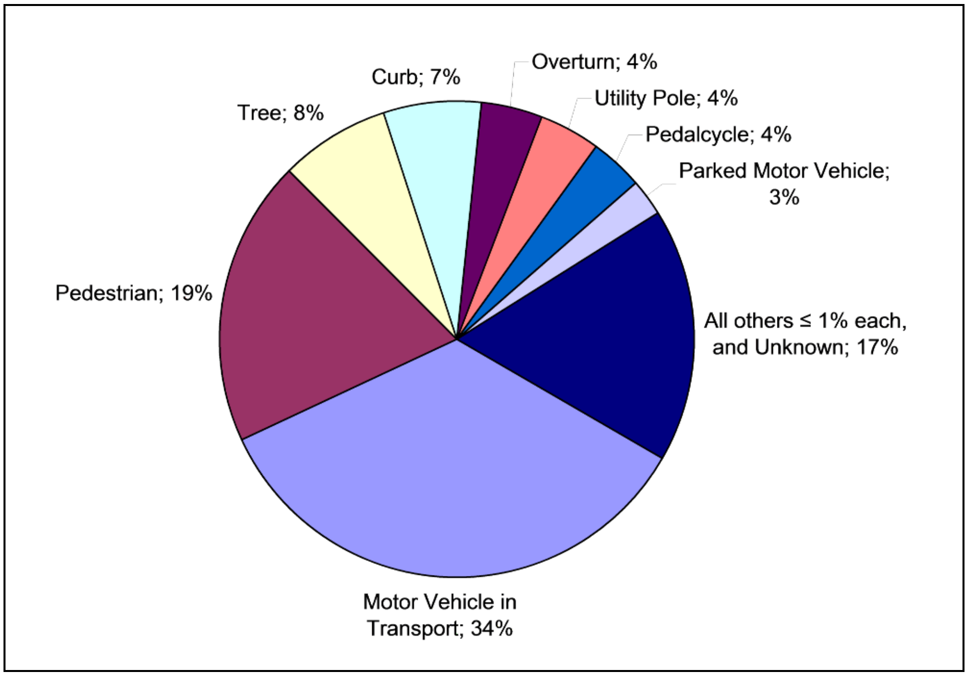
The FARS data for urban local roads strongly suggest that in addition to reviewing motor vehicle crashes, it is important to address pedestrian and intersection-related incidents in urban areas. This is discussed in more detail in the following subsections.

All Fatalities – Urban Local Roads

The distribution of urban local road fatalities by first harmful event is shown in Exhibit III-1. First harmful event is defined by the National Highway Traffic Safety Association (NHTSA) as the first event during a crash that caused injury or property damage. It is a useful way to describe the attributes and factors related to crash patterns.

Exhibit III-1 shows that, for all urban local roads, the three most common first harmful events are vehicle collision with a motor vehicle [in transport] (34 percent), vehicle collision with a pedestrian (19 percent), and vehicle collision with a tree (8 percent). In total, pedestrian and bicycle crashes account for nearly one-quarter of fatal crashes (23 percent) on urban local roads. These crash types comprise over three-quarters of the fatalities in urban areas.

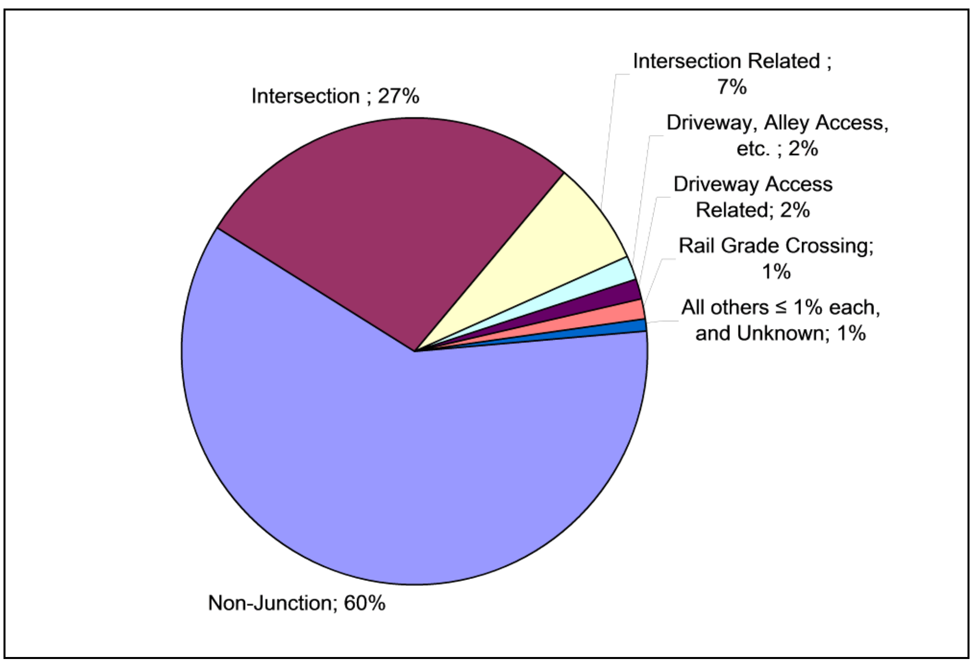
EXHIBIT III-1
Percentage of Fatalities by First Harmful Event on Urban Local Roads (2004)
(source: Traffic Safety Facts 2004, NHTSA)



Intersections and Driveways

Almost 40 percent of urban local road fatalities occur at intersections or driveway access points (junctions) (Exhibit III-2).

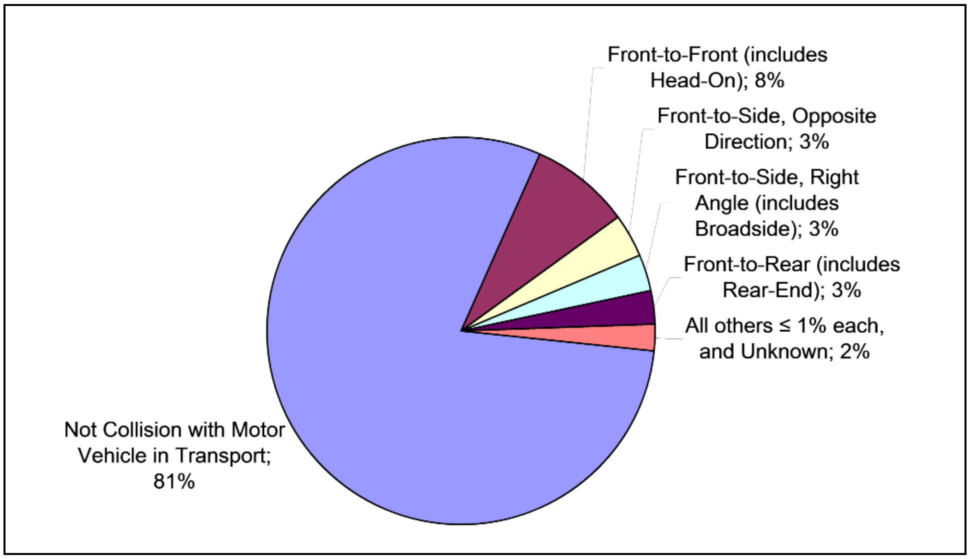
EXHIBIT III-2
Percentage of Fatalities by Relation to Intersections and Driveways on Urban Local Roads (2004)



Crashes on Roadway Segments

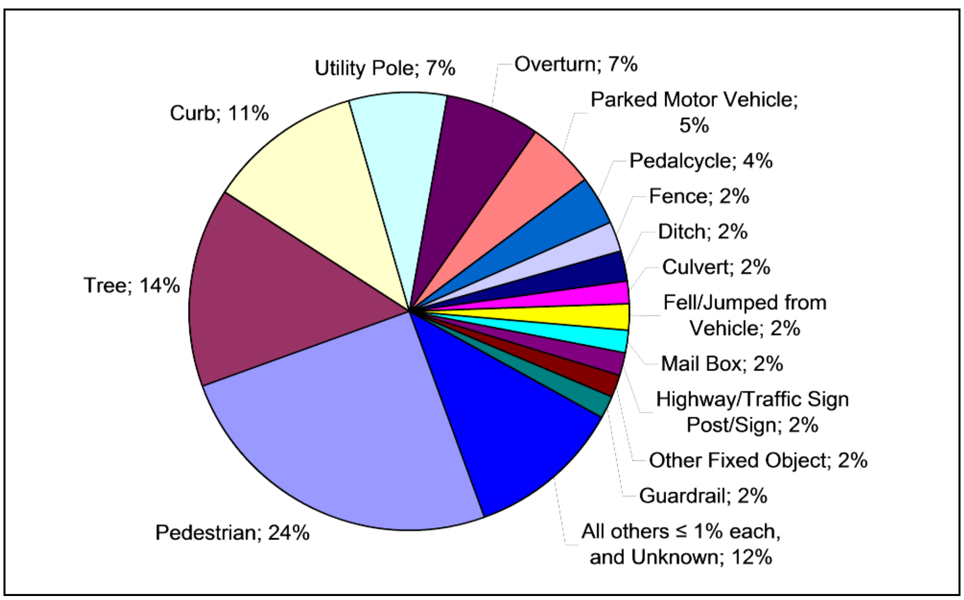
As shown in Exhibit III-2, 60 percent of urban local road fatalities occur on roadway segments (non-junction locations). Of these, 81 percent were single-vehicle collisions and 11 percent were head-on or opposite direction collisions (Exhibit III-3).

EXHIBIT III-3
Percentage of Roadway Segment Fatalities by Manner of Collision on Urban Local Roads (2004)



Clearly, single-vehicle run-off-the-road collisions represent the vast majority of urban fatalities occurring on roadway segments. Exhibit III-4 shows that three-quarters of these collisions involve the driver striking a fixed object such as a tree, culvert, utility pole, or sign. One-quarter of non-intersection fatalities on urban local roads involve pedestrians.

EXHIBIT III-4
Fatalities by First Harmful Event in Single-Vehicle Roadway Segment Crashes on Urban Local Roads (2004)



Crashes at Intersections

Looking specifically at intersection-related fatalities (Exhibit III-5), 39 percent were a right-angle collision and another 39 percent were single-vehicle crashes. The third most frequent crash type is a front-to-side, opposite direction crash. For intersections, this is typically a collision where a vehicle turning left is struck by or strikes a vehicle approaching from the opposite direction. The combination of right-angle and turning crashes illustrates the significance of crossing-path crashes for local agencies as related to fatal, urban intersection crashes.

EXHIBIT III-5
Percentage of Intersection Fatalities by Manner of Collision on Urban Local Roads (2004)

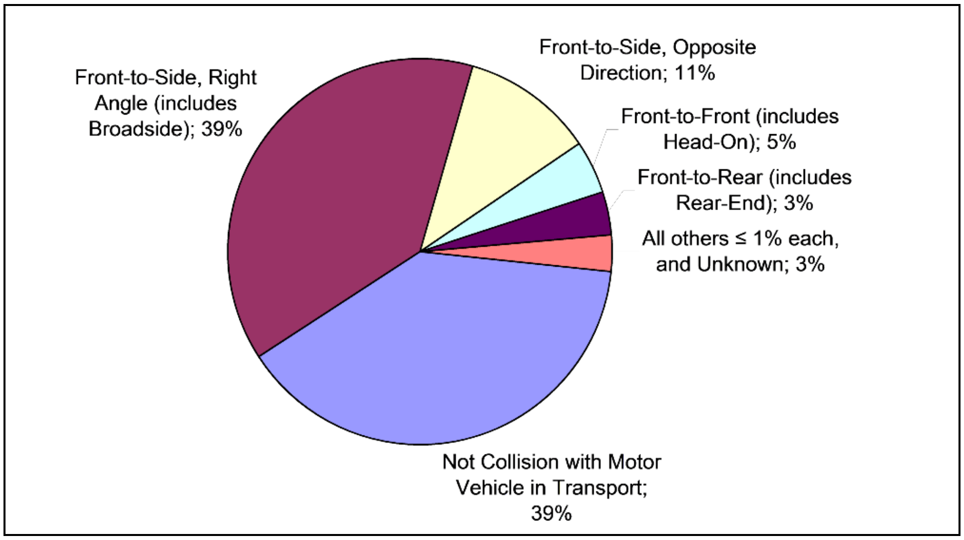
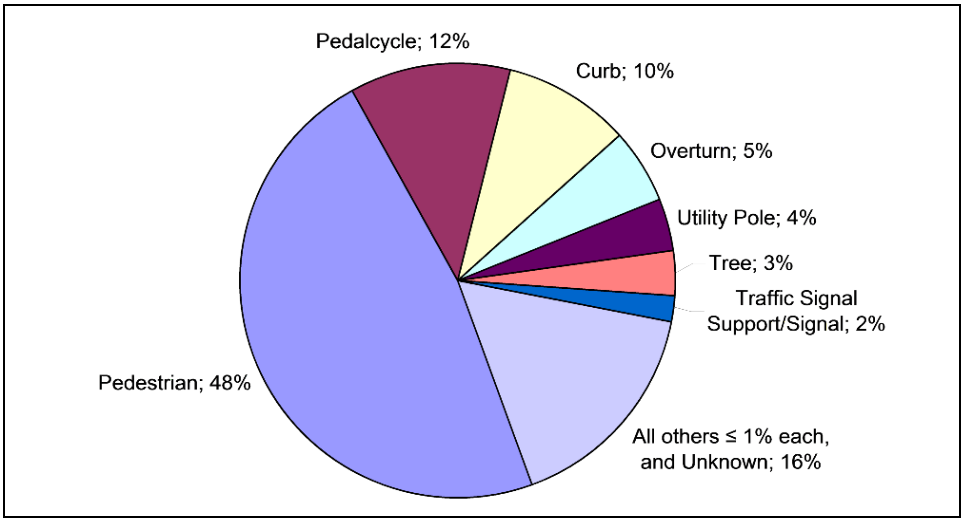


Exhibit III-6 is a closer look at the single-vehicle crashes at intersections. Collisions with pedestrians and bicycles combined account for 60 percent of these fatal crashes – 48 percent pedestrians and 12 percent bicycles. This reinforces the significance of pedestrian and bicycle crashes in urban areas, especially at intersections.

EXHIBIT III-6
Fatalities by First Harmful Event in Single-Vehicle Intersection Crashes on Urban Local Roads (2004)



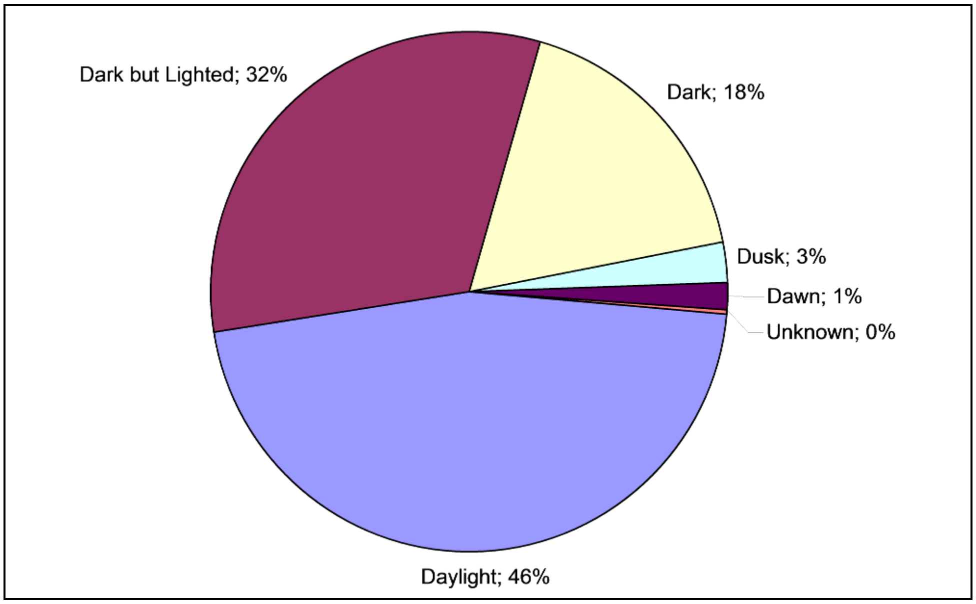
Crashes at Driveways

Where driveway crashes represent a significant number of crashes, the analysis completed for the intersection crashes can be repeated. For example, the FARS data revealed that the most common type of collision for driveway crashes was "not a collision with motor vehicle in transport," that is, single-vehicle crashes (42 percent), followed by right-angle crashes (30 percent). Of the single-vehicle urban driveway crashes, the most common first harmful events were collisions with pedestrians (47 percent) and bicyclists (19 percent).

Light Condition

Exhibit III-7 shows the distribution of urban local road fatalities by light condition. Seventy-eight percent of fatalities occurred when the light condition was reported as daylight or dark but lighted. As more traffic generally occurs during daylight hours, fatal crashes appear to be overrepresented at night.

EXHIBIT III-7
Percentage of Fatalities by Light Condition on Urban Local Roads (2004)



Alcohol Involvement

NHTSA estimates that 16,694 alcohol-related traffic fatalities (38 percent) occurred in 2004 on all highways. (4) NHTSA's analysis did not specifically identify how many crashes occurred on local roads, or separate them between rural and urban crashes. However, it is reasonable to assume that a similar percentage of alcohol-related traffic fatalities, 38 percent, occurred on local roads. If this is accurate, then approximately 6,300 alcohol-related traffic fatalities occurred on local roads in 2004.

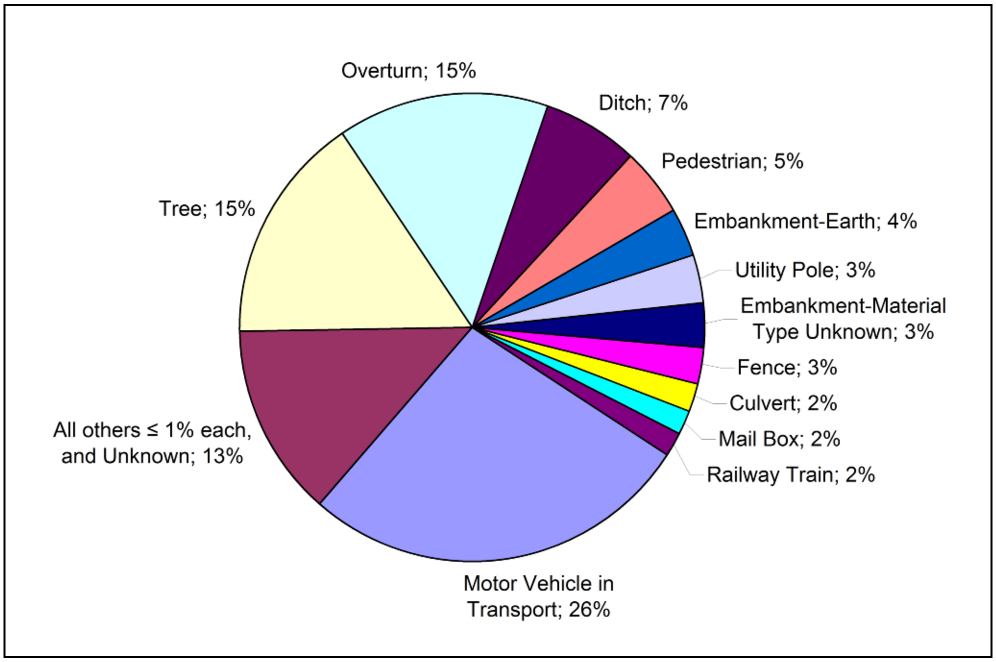
Rural Local Road Safety Issues

Similar to the evaluation of urban local roadways, a review of national fatal crash data for rural local roads was performed. National fatal crash data for rural local roads offers insights on the nature of crashes on these roads and provides an example of potentially useful analyses an agency could perform with its own data.

All Fatalities on Rural Local Roads

The distribution of rural local road fatalities by first harmful event is shown in Exhibit III-8. The three most common first harmful events are vehicle collisions with a motor vehicle [in transport] (26 percent), vehicle collisions with a tree (15 percent), and overturned vehicle (15 percent). (Overturning typically results from a single vehicle encounter with a steep slope or roadside ditch.) In total, crashes involving a single vehicle running off the road and either overturning or striking a fixed object constitute over 55 percent of fatal crashes on rural local roads.

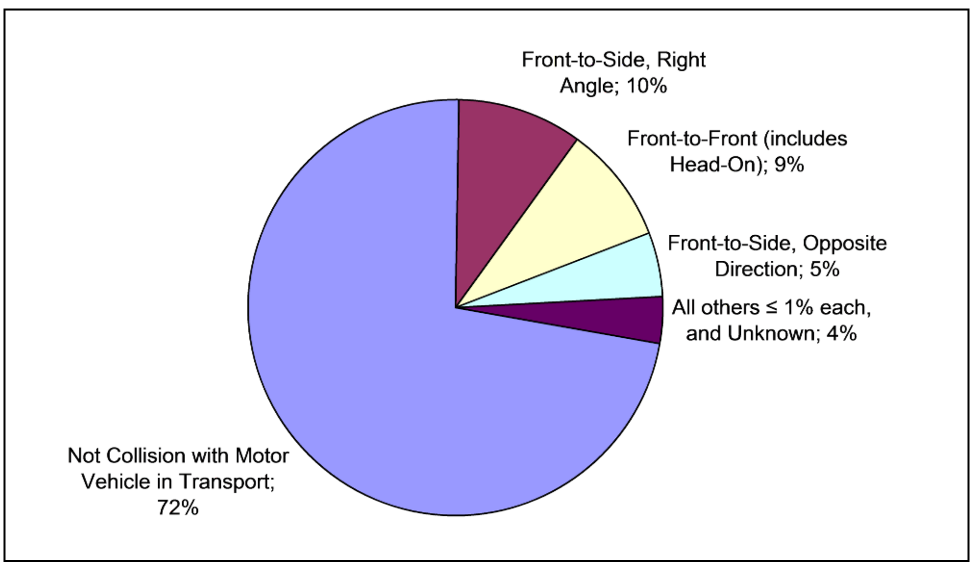
EXHIBIT III-8
Percentage of Fatalities by First Harmful Event on Rural Local Roads (2004)



Manner of Collision

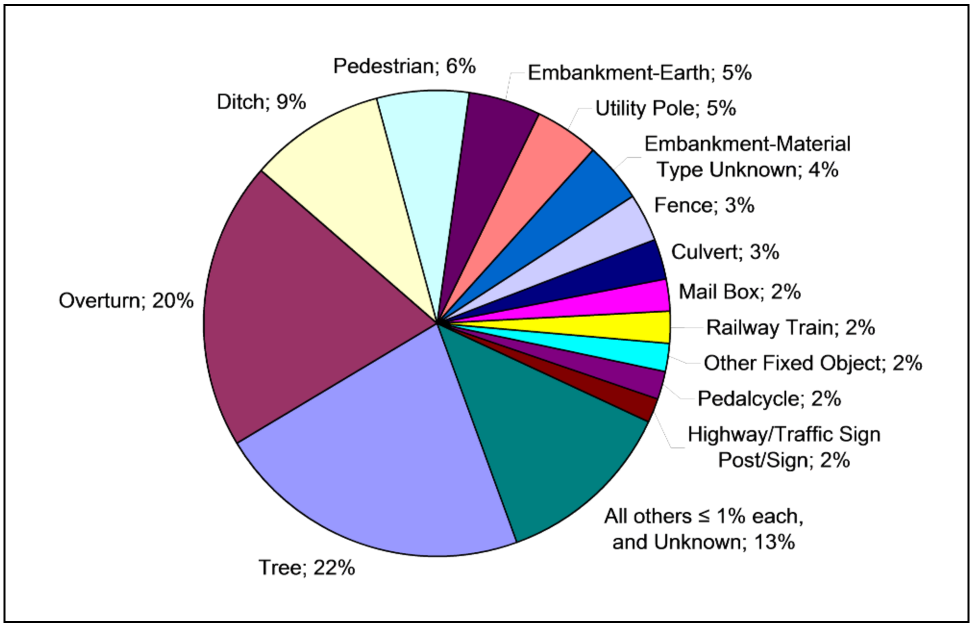
The magnitude of the single-vehicle, run-off-the-road safety concern is further illustrated in Exhibit III-9, which shows the manner of collision by first harmful event. Almost three-quarters (72 percent) of fatalities were a result of a crash with an object other than a motor vehicle in transport or a single-vehicle crash.

EXHIBIT III-9
Percentage of Fatalities by Manner of Collision on Rural Local Roads (2004)



Of the single-vehicle collisions, the distribution of first harmful event is shown in Exhibit III-10. The most common first harmful events in single-vehicle crashes on rural local roadways are collision with a tree (22 percent), overturning (20 percent), collision with a ditch (9 percent), and collision with a pedestrian (6 percent). Considering that another 9 percent of rural fatal crashes are head-on collisions (Exhibit III-9), road departure crashes account for at least 81 percent of single-vehicle fatal crashes on rural local roads.

EXHIBIT III-10
First Harmful Event in Single-Vehicle Crashes on Rural Local Roads (2004)



Crash Location

The distribution of rural local road fatalities by relation to junction (intersection and driveway accesses) is shown in Exhibit III-11. An overwhelming 80 percent of fatalities occurred in non-junction locations. Of the roadway segment (non-junction) crashes, over 80 percent were single-vehicle crashes (Exhibit III-12), followed by head-on collisions at 10 percent. Similar to all rural local road fatal crashes, collision with a tree, overturning, or collision with a ditch were the most common crash types for the single-vehicle collisions (Exhibit III-13).

EXHIBIT III-11
Percentage of Fatalities by Relation to Intersections and Driveways on Rural Local Roads (2004)

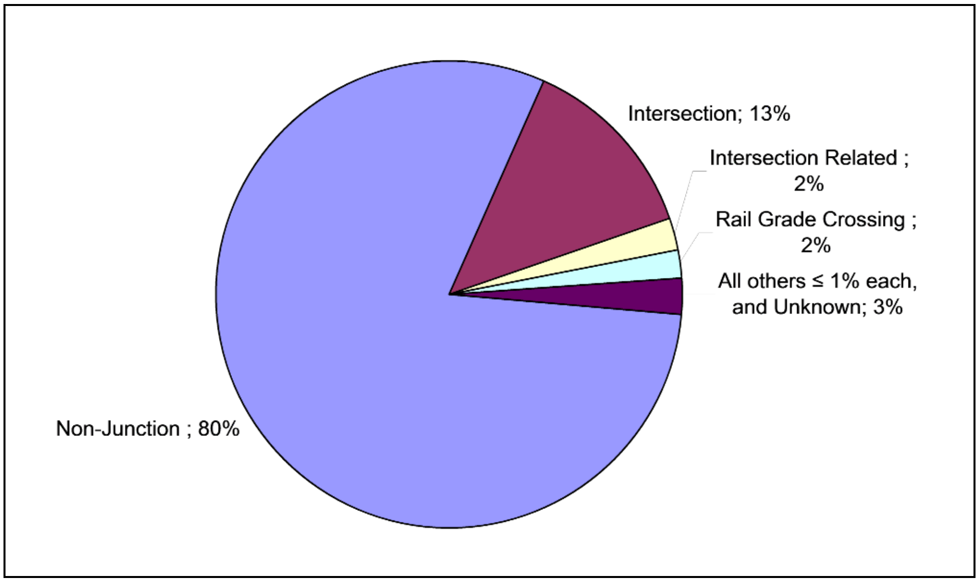


EXHIBIT III-12
Percentage of Roadway Segment Fatalities by Manner of Collision on Rural Local Roads (2004)

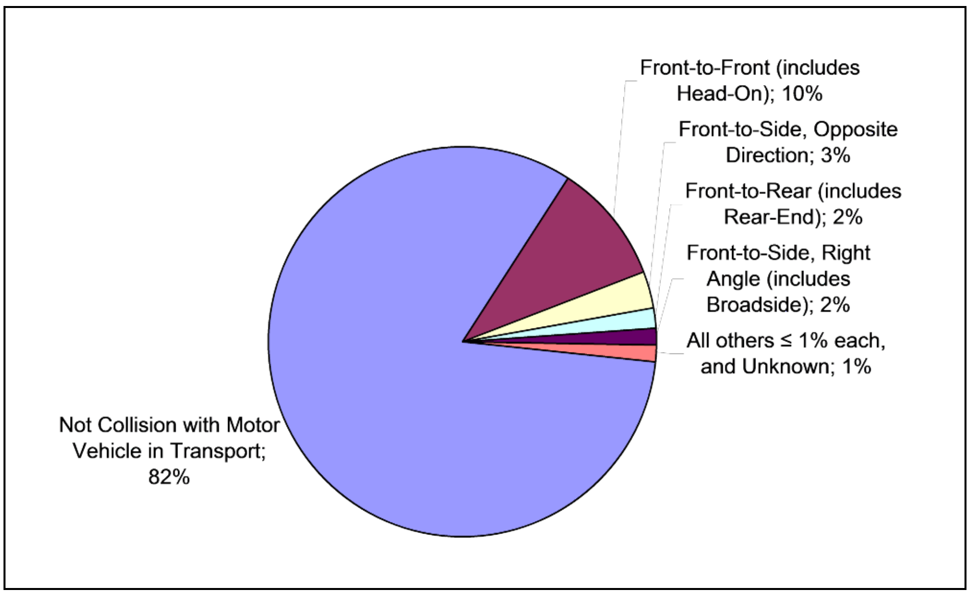
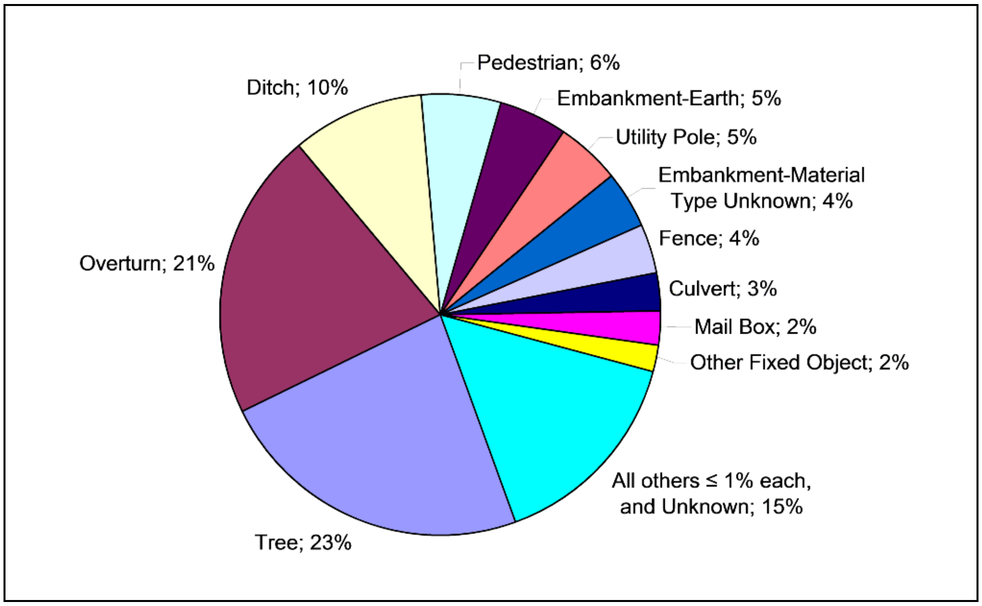


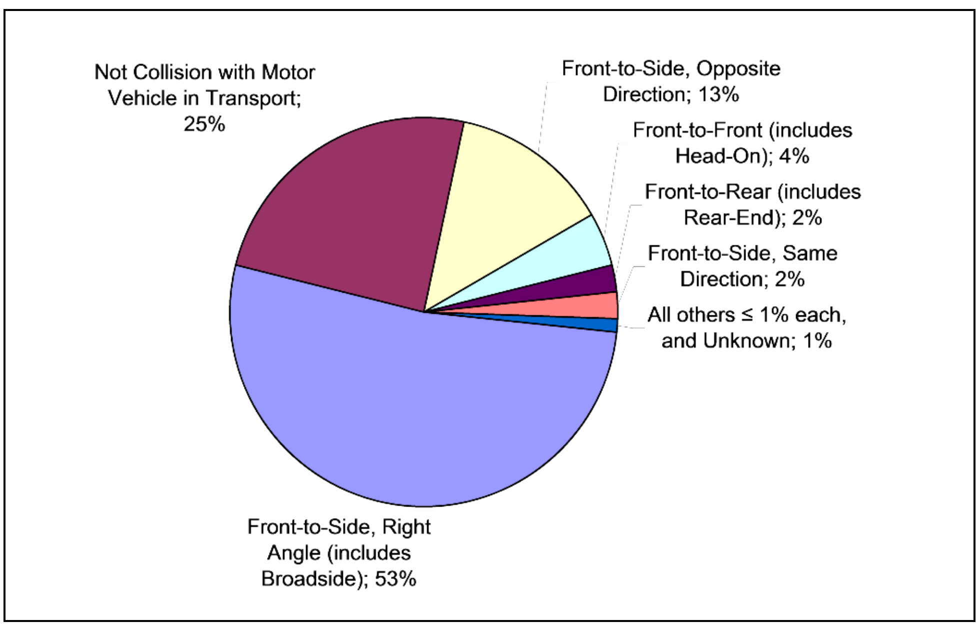
EXHIBIT III-13
Fatalities by First Harmful Event in Single-Vehicle, Non-Junction Crashes on Rural Local Roads (2004)



Intersections, Driveways, and Railroad Grade Crossings

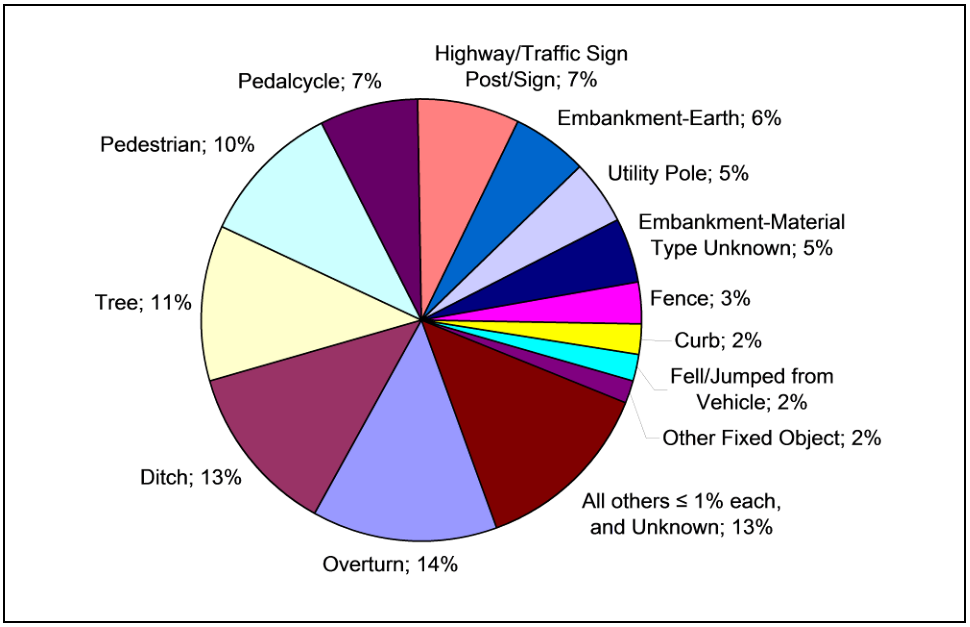
Twenty percent of rural road fatalities occurred at road junctions (intersections, driveways, and railroad grade crossings). Most of these crashes occurred at intersections. Exhibit III-14 shows the distribution of the manner of collision for the 15 percent of rural local road fatal crashes that occurred at intersections. Of these crashes, 53 percent were right-angle (broadside) collisions, and 25 percent were single-vehicle collisions.

EXHIBIT III-14
Percentage of Intersection Fatalities by Manner of Collision on Rural Local Roads (2004)



Twenty-five percent of fatalities at intersection locations were a result of single-vehicle collisions. Exhibit III-15 shows the first harmful event in these single-vehicle collisions. Overturning, collision with a ditch, and collision with a tree are the three most common first harmful events. At rural local intersections, collisions with pedestrians and bicycles accounted for 17 percent of the fatal crashes, compared to 60 percent at local urban intersections.

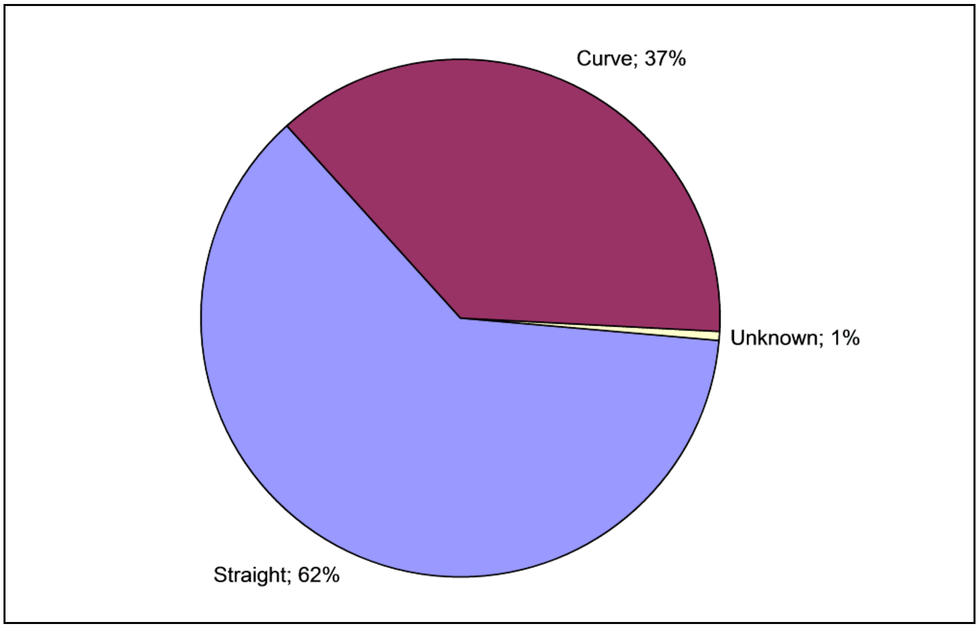
EXHIBIT III-15
Fatalities by First Harmful Event in Single-Vehicle Intersection Crashes on Rural Local Roads (2004)



Roadway Alignment

The distribution of rural local road fatalities by roadway alignment is shown in Exhibit III-16. Over one-third (37 percent) of rural local road fatalities on roadway segments occur at curves. Since the alignment of the roadway system is predominantly straight or tangent, fatal crashes are significantly over-represented on curves.

EXHIBIT III-16
Percentage of Fatalities by Roadway Alignment on Rural Local Roads (2004)

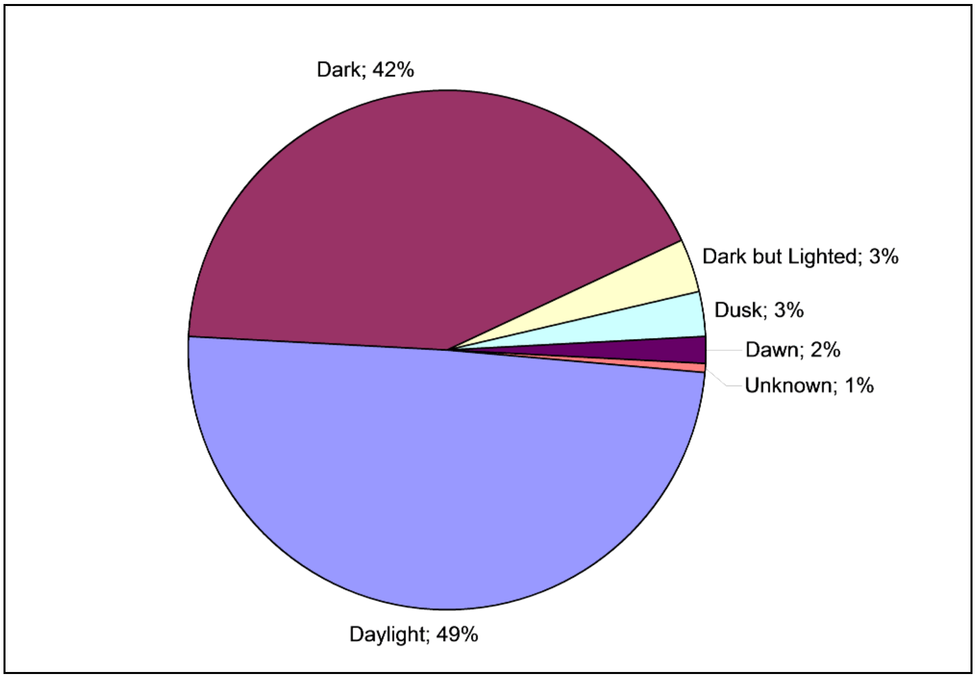


Light Condition

Exhibit III-17 shows the percentage of rural local road fatalities reported during daylight conditions (49 percent) is similar to what was found for urban roads (46 percent). However, dark but lighted, dropped from 32 percent for urban roads to just 3 percent for rural roads. Furthermore, dark (not lighted) went from 18 percent for urban roads up to 42 percent for rural roads.

A study completed for the Minnesota Department of Transportation used automatic traffic recorder stations around the state and solar tables to identify the amount of traffic that occurred during light and dark driving in rural Minnesota. (5) On both state and county highways, the data revealed that 77 percent of traffic was during light conditions and only 23 percent of traffic was at night. For this case, the data indicate that nighttime crashes are disproportionate to the number of vehicles travelling on the road.

EXHIBIT III-17
Percentage of Fatalities by Light Condition on Rural Local Roads (2004)



Summary of an Approach to Local Road Safety Issues

Agencies with the resources and data can conduct independent analyses similar to those cited in the preceding subsections. In the absence of an agency-specific study, assuming the agency's roadway system is typical, the following should be the focus of safety efforts:

- For urban local roads, safety countermeasures that focus on:
  - Intersection crash patterns in such as multiple-vehicle patterns (Exhibit III-5)
  - Intersection crash patterns that are single-vehicle related such as pedestrian, bicycle, and fixed object crashes (Exhibit III-6)
  - Roadway segment crashes such as fixed object and pedestrian crashes (Exhibit III-4)
- For rural local roads, safety countermeasures that address run-off-the-road (lane-departure) crashes that in many instances result in fixed object crashes (Exhibit III-10) or, to a lesser proportion, intersection crashes (Exhibits III-14 and III-15).

The companion guide entitled *Local Highway Agency Safety Guides Safety Management Process* details a process to more effectively incorporate safety into local agency activities. The process, such as the one identified in this section, can be used to systematically identify traffic safety issues for this guide.

This approach assists a local agency in the selection of the most suitable safety objectives and strategies. Furthermore, these analyses provide a framework that a local agency may use to evaluate their own crash data to identify key safety emphasis areas. Safety emphasis areas represent crash types and factors an agency may use to focus safety resources because of, for example, an overrepresentation in fatal and injury crashes. Agencies that have used a strategic highway planning process to select safety emphasis areas (for example, a state

Strategic Highway Safety Plan) may typically select a set of safety emphasis areas, say five. But the number of safety emphasis areas selected may range from three up to ten or more.

Of the other factors that might be considered, many tie in to non-engineering approaches, such as enforcement, and education strategies that can be implemented by a local agency by a cooperative approach between engineers, police, and public information professionals. The preceding example analyses should not be considered to be all inclusive of the factors that can be reviewed when performing a similar analysis for a specific agency. Other example potential crash factors to investigate include:

- Driver age (especially young or older drivers)
- Day of week when crashes occurred
- Time of day when crashes occurred
- Alcohol involvement
- Safety belt use
- Road surface and weather conditions
- Driver violations

References

(1) Federal Highway Administration. *Highway Statistics 2006*. http://www.fhwa.dot.gov/policy/ohim/hs04/htm/hm20.htm

(2) Bryer, Tom. "Local Road Fatalities." Unpublished white paper prepared for NCHRP. 2005.

(3) National Highway Traffic Safety Administration. *Fatality Analysis Reporting System*. 2004. http://www-fars.nhtsa.dot.gov

(4) National Highway Traffic Safety Administration. *Traffic Safety Fact Sheet (2004 Data): Alcohol*.

(5) Isebrands, Hillary, Shauna Hallmark, Zach Hans, Tom McDonald, Howard Preston, and Richard Storm. *Safety Impacts of Street Lighting at Isolated Rural Intersection – Part II, Year 1 Report*. Prepared for the Minnesota Department of Transportation and Minnesota Local Road Research Board, December 2004.

IV. Guidance for a Local Safety Process

The creation of a successful traffic safety management system or local safety process is key to a long-term effort to reduce crashes, especially those that are severe in nature.

As indicated in Section III, the companion guide for this document, entitled *Local Agency Guidance for a Transportation Safety Management Process* (*NCHRP Report 500*, Volume xx), details the recommended steps in implanting such a process. Following, in summary form, is a framework for a process that local governments may use to develop programs or projects to reduce crashes on their roads.

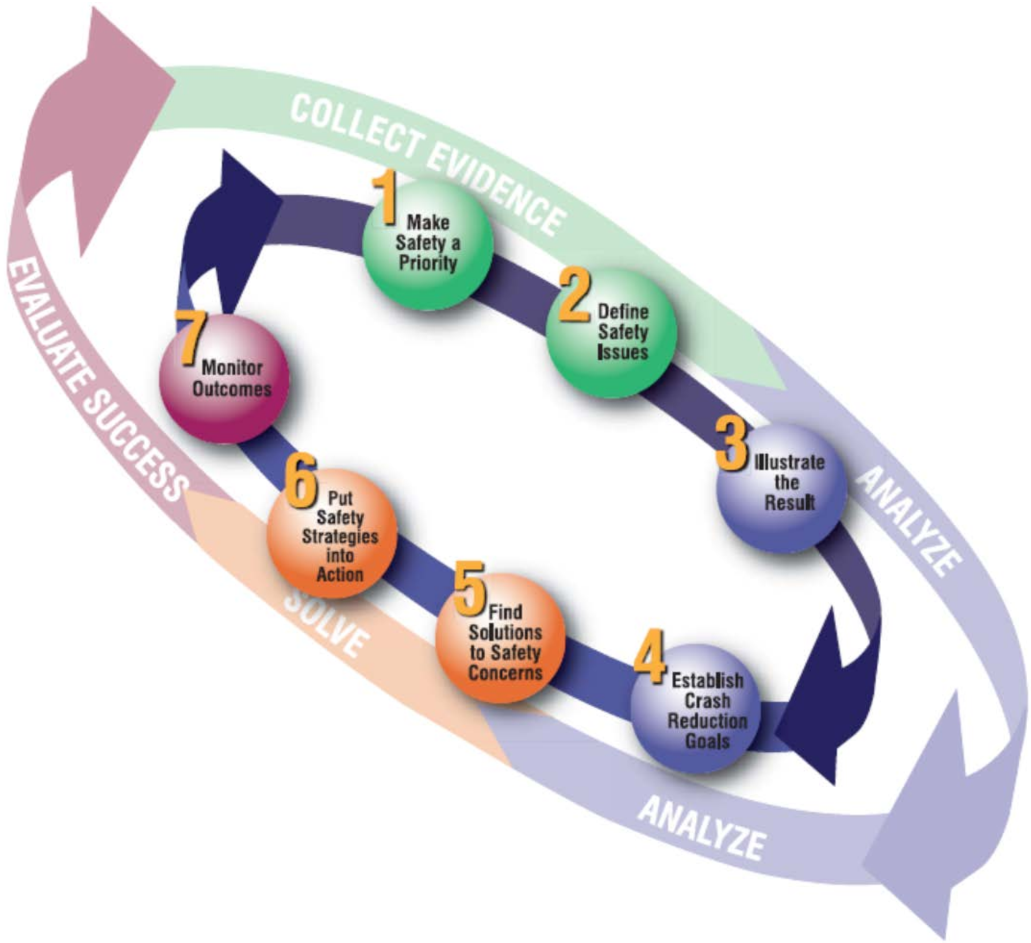
The process simplifies that taken from the *NCHRP Report 500* series, which includes an 11-step safety management process consistent with practices developed for the AASHTO *Strategic Highway Safety Plan*. (1) The seven steps of a successful safety process for local agencies are listed in Exhibit IV-1.

EXHIBIT IV-1
Key Steps in a Safety Process for Local Agencies

Step	Action
1	Decide to make safety a priority
2	Define safety issues
3	Illustrate the results
4	Establish crash reduction goals
5	Find solutions to safety concerns
6	Put safety strategies into action
7	Monitor outcomes

These seven steps are shown graphically in Exhibit IV-2. As illustrated, an effective safety process is self-reinforcing and self-sustaining in nature. Investments in safety are confirmed for their effectiveness, which in turn influences future decisions and investments. This process, successfully applied over time, will allow an agency to reach their fatal-crash reduction goals.

EXHIBIT IV-2
Safety Process for Local Agencies



Local agencies can be in various stages of development in the realm of traffic safety management. For example, a local agency may currently have no safety process or management capability, or an agency may have an ongoing process that needs only to be updated to select new strategies or programs.

The framework provides the flexibility for a local agency to integrate anywhere in the process shown, or incorporate elements or items shown into the existing process the agency currently follows according to their situation. For example, an agency may already have a crash data base (part of Step 2 – Define Safety Issues), have developed a stakeholder process (Step 2), and mapped crash data (Step 3 – Illustrate the Results). But they may not have completely accomplished Step 1 – Making Safety a Priority or established crash reduction goals (Step 4). The reader should refer to the companion guide for more details.

This document, *Guidance for Safety Improvements on Local Roads*, primarily focuses on Steps 5 and 6 (as shown in Exhibit IV-2). The effective use of this guide is a function of first successfully completing earlier steps; that is, obtaining, analyzing, and interpreting safety data. Armed with specific data and information on crashes in a jurisdiction, agencies can successfully focus their efforts:

Local agencies that have successful safety efforts have in almost all cases used a systematic approach to solve traffic safety issues. These are considered "best practices." Following are examples of some of these approaches:

- **Target the Leading Contributing Factors to Crashes:** Safety funds are limited and should be used to address the most important safety emphasis areas or contributing factors. A review of crash data can be used to identify the top safety emphasis areas in an agency's jurisdiction, say three to five. The AASHTO *Strategic Highway Safety Plan* (SHSP) (1) lists 22 emphasis areas that an agency could evaluate and rank before selecting.
  Another approach to selecting safety emphasis areas is to choose from those included in their state's SHSP (most of which are modeled after the AASHTO SHSP). Regardless of the selection method, the safety emphasis areas should address most frequent severe crashes (those crashes resulting in one or more fatalities and/or incapacitating injuries) on an agency's roadway network.
- **Deploy Safety Strategies Using a Low-Cost, Proactive Approach:** Especially in rural areas, severe crashes on local agency roads are often spread over many miles, with few, if any, locations where multiple severe crashes have occurred. Some proven, low-cost strategies can be widely deployed in a programmatic manner. For example, a low-cost, well-designed, proactive approach should systematically address all roadways, beginning at locations that have a high crash frequency/rate or other associated risk factors (for example, a higher-volume road with narrow shoulders and minimal clear zones).

Finding Solutions to Safety Concerns

There are a variety of approaches that may be used to identify solutions (countermeasures) to safety concerns (Step 5). How an analysis is conducted will depend on the crash data available and how well it has been (or can be) integrated with roadway and traffic information. Following are examples of some of these approaches:

- **Concentrate on Severe Crashes:** The focus of the current federal legislation and guidance is on reducing the number of severe crashes, especially fatal and incapacitating-injury crashes. In many instances the most severe crashes have different contributing factors and characteristics than minor injury and property damage crashes. Thus, including all crashes in an analysis can lead to the potential selection of strategies and locations that may not efficiently address the most common factors in severe crashes. Typically, many local agencies have few fatal and incapacitating-injury crashes on an annual basis. This can make the identification of their patterns and factors difficult, if not impossible. To overcome this issue, local agencies may find it necessary to use additional years of data (say, five or more years instead of only three), expand the sample for analysis to include moderate or minor injury crashes, or a combination of both. A key consideration is to keep a focus as much as possible on the severe crashes.

- **Separate Rural and Urban Areas:** For agencies that have both urban and rural areas, it is better to separate the analyses if possible, since the two areas often have different patterns of crashes and issues. Section III described the differences typically found between rural and urban roads and intersections in terms of fatal crash frequency.

- **Identify Any Overrepresented Safety Emphasis Areas:** As safety funds are limited, it is a good practice to identify crash types (safety emphasis areas) that represent the largest proportion of severe crashes. The selection of an agency's safety emphasis areas (discussed earlier in this section) typically represents an entire jurisdiction, but this analysis can also be utilized if a safety emphasis area is are equally important in both rural and urban areas.

- **Examine Roadway Segment and Intersection Safety Separately:** Another possible analysis is to identify the roadway characteristics of where fatal and incapacitating-injury crashes are occurring. For example, it is typically desirable to separate intersections and roadway segments since the characteristics of crashes for these two roadway elements have different characteristics and, therefore, safety countermeasures may differ. State departments of transportation and some larger local agencies may have the ability to link crash data and roadway characteristics (geometric information) in a geographic information system (GIS) database or a common data file such as a management system. For many local agencies this will not be possible, in which case it may be necessary to rely on roadway element information recorded by the reporting officer on the crash report form.

- **Analyze Crashes by Road Characteristics:** Typical roadway segment characteristics that might be analyzed include functional class; number of lanes; posted speed limit; roadway width; type of shoulder; width and type of median, alignment (tangent versus horizontal curves) and grade; and traffic volume. Intersection characteristics could include traffic control devices, presence of turn lanes, entering volumes, intersection lighting, or any other data of interest and available in the crash report.

- **Review Driving and Environmental Condition Data:** In addition to the roadway segment and intersection geometry, review the driving conditions at the time of the crash, such as weather, road surface, and light. If a specific environmental condition is overrepresented, especially when compared to all crashes, this may indicate what type of strategies would be more beneficial. For example, a disproportionate number of nighttime road departure crashes could indicate a need for improved pavement markings (for example, lane lines to provide enhanced retroreflectivity).

- **Investigate Contributing Driver Behavior to Crashes:** Even though street and roadway agencies do not typically address driver behavior, this will help identify areas where transportation and highway agencies can work with law enforcement and public education. For example, a higher rate of fatalities due to lack of safety restraint use on rural roads in a jurisdiction would indicate a potential need for increased enforcement on these roadways or perhaps a locally targeted public information campaign on the importance of seat belt usage.

References

(1) American Association of State Highway and Transportation Officials (AASHTO). *Strategic Highway Safety Plan*. February 2005.

V. Description of Highway Safety Objectives and Strategies

This section outlines how this guide may be used by a local agency to solve specific roadway safety issues. The organization and safety strategies contained in this guide are then outlined. The following steps can be followed and are discussed in detail:

- Step 1 – Identify crash issue and identify which Highway Safety Objective applies.
- Step 2 – For each Highway Safety Objective, select one or more safety strategies that can address the crash issue.
- Details of Highway Safety Objectives and Strategies.

Step 1 – Identify Highway Safety Objective(s) to Address the Crash Issue

Section III used national fatal crash data from the FARS database pertaining to the local roads category to identify crash types according to urban and rural conditions, by road type, collision type, intersection or non-intersection, and by other conditions that were prominent for local roads.

A review of the data from the crash analyses for U.S. roads under the jurisdiction of local agencies identified six distinct areas of Highway Safety Objectives for reducing crashes. These Highway Safety Objectives are consistent with the safety emphasis areas developed by AASHTO in their *Strategic Highway Safety Plan*. (1) These Highway Safety Objectives are as follows (the corresponding AASHTO safety emphasis area is shown in parenthesis):

I. Reduce Intersection Crashes (Improve the Design and Operation of Highway Intersections)

II. Keep Vehicles on the Roadway (same as AASHTO)

III. Reduce Lane-Departure Crashes (Minimize the Consequences of Leaving the Road)

IV. Reduce Pedestrian and Bicycle Crashes (Make Walking and Street Crossing Safer, and Ensure Safer Bicycle Travel)

V. Improve Enforcement and Education Programs

VI. Improve Emergency Medical Services (Enhancing Emergency Medical Capabilities to Increase Survivability)

In addition, one Highway Safety Objective has been added. This group, which will be discussed later in more depth, is entitled:

VII. Innovative Safety Techniques (Adds New Techniques)

As suggested earlier, a local agency using their safety data can follow this process to identify their own unique highway safety objectives. If an agency does this, it is recommended that the safety objectives be compared to those of their state Strategic Highway Safety Plan (SHSP) for compatibility and to assess if common issues exist.

The Safety Objectives are described in more detail in the following subsections.

Objective I – Reduce Intersection Crashes

The purpose of this objective and the listed safety strategies is to reduce vehicle collisions at an intersection. The following approaches are used:

- Eliminate or minimize conflict points.
- Improve visibility at an intersection.
- Improve driver awareness of the situation.
- Improve the design and traffic operation.

For intersection strategies that reduce vehicle collisions with pedestrians or bicyclists, refer to Objective IV.

Objective II – Keep Vehicles on the Roadway

The purpose of this objective is to describe safety strategies that prevent a vehicle from leaving its travel lane and straying out of the lane to the right side or into oncoming traffic. Many of the strategies presented either:

- Keep vehicles in their travel lane using enhanced traffic control devices, such as pavement markings that alert drivers to current and upcoming road characteristics.
- Warn drivers that they have strayed out of their lane by using improved design treatments.

Objective III – Reduce Lane-Departure Crashes

The purpose of this objective is to outline strategies to improve safety when a vehicle has left its lane and is on the roadside. The strategies include the following:

- Preventing the vehicle from colliding with a fixed object or oncoming traffic.
- Minimizing the severity of a fixed object collision.
- Reducing the potential for a vehicle rollover or a head-on crash.

Objective IV – Reduce Pedestrian and Bicycle Crashes

Pedestrians and bicyclists can be severely injured if involved a collision with a motor vehicle. This objective is intended to prevent such a crash from happening. Strategies include the following:

- Separate motorized and non-motorized traffic.
- Reduce speeds of vehicles.

- Increase a pedestrian and bicyclist's visibility, and their visibility to drivers.
- Provide traffic calming.

Objective V – Improve Enforcement and Education Programs

Education programs and enforcement of driving laws and regulations is a vital part to any program to improve traffic safety. This objective describes information about enforcement and education programs that address primarily the following four aspects of driver-related issues:

- Aggressive driving/speeding.
- Seat belt use.
- Impaired driving.
- Coordination of enforcement and education to increase their effectiveness of each program and overall safety initiatives.

The principles outlined for these strategies can be adapted to other situations and driver-related issues.

Objective VI – Improve Emergency Medical Services

The strategies outlined focus on techniques that can be used by local agency emergency medical response providers and focus on the following three approaches:

- Improve incident location methods to get a timely medical response.
- Provide an appropriate response to a crash scene to improve the survival of a victim.
- Set up traffic management at a crash scene to reduce secondary collisions and injuries.

Objective VII – Innovative Safety Techniques

The safety strategies described include a variety of approaches that are new and emerging. The following innovative safety strategies are examples and illustrative of the current progress in the highway safety area:

- Improved or more efficient approaches to crash data collection.
- Targeted public education efforts.
- Team crash review efforts.
- Improved design at stops for public transit users.
- Education of maintenance workers on better safety practices.

Step 2 – Select Safety Strategies

The next step is to identify appropriate safety strategies. For the each of the objectives selected, the *NCHRP Report 500* guides were reviewed in detail to find appropriate strategies that fit the context and resources of local agencies. This selection concentrated on strategies that are:

- Low-cost
- Easy to implement.
- Proven to be effective and/or used and accepted by a significant number of agencies.

The Highway Safety Objectives and Strategies contained in this document include traditional engineering-related safety countermeasures and those that go beyond engineering solutions and include integrated and multidisciplinary (4E) approaches. All solutions to transportation safety can be implemented by a local agency.

The 4Es of highway safety are:

- Engineering
- Enforcement
- Education
- Emergency medical services

Highway Safety Objectives I through IV include strategies based on traditional engineering-related strategies. Highway Safety Objectives V through VII include driver education, law enforcement, and emergency medical response strategies.

The strategies listed in Objective VII – Innovative Safety Techniques have been successfully used by one or more agencies and are applicable to the safety issues faced by local agencies. Due to their limited use at this time, these techniques are still considered to be experimental. But, because of their potential benefit, they have been included and described in summary form.

Details of the Highway Safety Objectives and Strategies

List of Highway Safety Objectives and Strategies

The table in Attachment 1 lists the strategies for all seven Highway Safety Objectives that apply to local roads. The recommended use for these strategies is noted according to rural and urban areas. This grouping matches the analysis of crash data discussed in Section III of this report.

In the real world, it is not always simple for an agency to specifically define rural and urban areas. The intent of this grouping of safety strategies is to assist an agency to more effectively matching strategies in a more appropriate context.

A wide range of strategies are included and they represent what can be called a set of safety tools for each Highway Safety Objective.

Also shown in Attachment 1 is the applicability of a strategy to a road classification according to arterial, collector, and local road. These road classifications are general in nature and are intended to assist an agency in better matching a strategy with the context of a road type.

Details of Strategies

Attachment 2 contains summaries for each strategy and technique contained in the guide. They are organized by Highway Safety Objective.

The strategies, typically one page in length, provide the most important information in a simple usable manner that can be quickly referenced and used by an agency. For additional information, readers are encouraged to refer each strategy's listed reference(s); typically the *NCHRP Report 500* guides.

The safety strategies provided in Attachment 2 have the following information for the user. A more detailed explanation of this information is provided in the following subsections:

- An overview of the strategy and what types of approaches or safety solutions are available if this strategy is used.
  A strategy may list a number of approaches, since similar techniques have been grouped together for the convenience of the local agency user.

- The type of crashes the strategy reduces.
  The type of crashes that the specific strategy mitigates is discussed. In most cases, more than one strategy might be considered and selected by a local agency.

- What are the issues to implement a strategy in terms of time, costs, and other concerns.
  The issues are briefly described and can vary by situation. Specific cost information is not included except in general terms. Many agencies have their own cost data or use information from a state department of transportation.

- Where the strategy should be used.
  These are recommendations and may vary by agency context.

- The best known information about safety effectiveness of the strategy is shown; if the quantitative effect is known, it is included.
  Where possible quantitative (numerical) estimates of the effectiveness of a safety strategy are given, and are shown in most cases as a crash modification factor (CMF). A CMF is defined as a quantitative value that expresses the expected change in the number of crashes due to the use of a strategy. A CMF is expressed as a decimal number and can range from greater than zero and less than or greater than 1.0. The implications of CMF ranges of are:

  – If the value of a CMF is 1.00, there is no change in the number crashes for the application of a strategy compared to the existing situation or condition. This implies there is no change in the safety effect of a selected strategy.

– If the value of a CMF is less than 1.00, the use of a strategy reduces the estimated number of crashes compared to the existing situation. This indicates an improvement in safety.

– If the value of a CMF is greater than 1.00, the selection of a strategy increases the estimated number of crashes compared to the existing situation. This indicates a reduction in safety. In this document, there are few examples of strategies that have such a CMF value.

For some quantified values of strategies, CMFs are not shown but instead the safety effectiveness is described by the "percent reduction in crashes." The percent reduction in crashes relates to a CMF in the following way:

$$\text{CMF} = 1.00 - (\text{percent reduction in crashes} \div 100)$$

For example if the percent reduction is 30 percent for a safety strategy, then the CMF is as follows:

$$\text{CMF} = 1.00 - (30 \div 100) = 1.00 - 0.30 = 0.70$$

- Where to get more information on the strategy.
  Usually reference is made more details that are in the *NCHRP Report 500* guides, which can be referenced at http://safety.transportation.org/

References

(1) American Association of State Highway and Transportation Officials (AASHTO). *Strategic Highway Safety Plan*. February 2005.

(2) Transportation Research Board (TRB). *NCHRP Report 500*, Volume 1-xx.

VI. Examples of How to Use This Guide to Address a Safety Issue

This section contains examples of how to use this guide to identify and develop safety solutions. The examples cover typical situations where:

- A local agency may have developed a set of safety objectives and wants to address an identified crash reduction objective for a group of roads or a set of locations on their roadway system. Examples 1 and 2 illustrate how to use this guide for defined safety objectives.

  Refer Objectives I through V in subsection *Step 1 – Identify Highway Safety Objective(s) to Address the Crash Issue* (in Section V) for examples of safety objectives and Section III for how these safety objectives can be identified.

- An agency has not developed a set of safety objectives and may have a single location, or set of streets or locations, that have a safety issue. Examples 3 and 4 illustrate how these types of situations may be handled.

Reminder

Where possible, quantitative (numerical) estimates of the safety effectiveness of a strategy are given, and are shown in most cases as a crash modification factor (CMF). A CMF is defined as a quantitative value that expresses the expected change in the number of crashes due to the use of a strategy. A CMF is expressed as a decimal number and can range from greater than zero and less than or greater than 1.0. The implications of CMF ranges of are:

- If the value of a CMF is 1.00, there is no change in the number crashes for the application of a strategy compared to the existing situation or condition. This implies there is no change in the safety effect of a selected strategy.
- If the value of a CMF is less than 1.00, the use of a strategy reduces the estimated number of crashes compared to the existing situation. This indicates an improvement in safety.
- If the value of a CMF is greater than 1.00, the selection of a strategy increases the estimated number of crashes compared to the existing situation. This indicates a reduction in safety. In this document, there are few examples of strategies that have such a CMF value.

For some quantified values of strategies, CMFs are not shown but instead the safety effectiveness is described by the "percent reduction in crashes." The percent reduction in crashes relates to a CMF in the following way:

$$1.00 - (\text{percent reduction in crashes} \div 100)$$

For example, if the percent reduction is 30 percent for a safety strategy, then the CMF is:

$$1.00 - (30 \div 100) = 1.00 - 0.30 = 0.70$$

Example 1: Reducing Intersection Crashes

Smith County's highway safety objective is to reduce intersection crashes. Based on crash data, the County determined that intersection crashes represent 40 percent of all crashes in the county. They have looked at the crash patterns where arterials intersect with other streets (such as collectors or local streets) and have compiled a list of 10 intersections with the highest number of crashes as their target safety locations.

Given the following information:

- Crash type – turning vehicles at an intersection. The identified crash pattern involves a vehicle turning left from the main street to the side street and this vehicle is rear ended. There is also a pattern of left-turning vehicles colliding with an oncoming vehicle on the arterial street.
- The locations identified are all on rural routes.
- The subject intersections are on an arterial (major street) and the side streets are collectors or local streets (minor street).
- Existing intersection control, minor streets are stop controlled.
- Intersections have no left-turn lanes, no lighting, with minimal signing and pavement markings.
- The first intersection to be evaluated has eight crashes per year, on average, for the most recent 3 years of data are available.
- On the average per year, four of these crashes occur at night and four crashes occur during the day.

Then determine:

- Which safety strategies might be applicable to reduce intersection crashes due to the identified crash patterns.
- If a crash modification factor (CMF) is known, estimate the change in the number of crashes and the predicted reduction in crashes using one or more strategies.
- If a CMF is not known, and it is not possible to predict a change in crashes, discuss the safety effects of the selected strategy.

Procedure:

Review the intersection-related strategies for safety effectiveness.

1. Knowing that the safety objective is to reduce intersection crashes, refer to Attachment A, *Objectives and Strategies Table*. See Objective I: Reduce Intersection Crashes. Review all 14 intersection-related strategies and assess which ones apply to the identified patterns of:

    - Rear-end crash involving a vehicle turning left from the main street to the side street.
    - Left-turning vehicles colliding with an oncoming vehicle.

2. Select the strategies that relate to an intersection that is controlled by STOP signs on the minor street approaches.

Smith County considered four potential strategies, which apply to this type of intersection control and crash patterns:

- Strategy I.1: Provide Left-Turn Lanes or Right-Turn Lanes and Enhancements
- Strategy I.5: Improve Intersection Visibility with Signing and Delineation
- Strategy I.6: Improve Intersection Visibility with Pavement Markings
- Strategy I.7: Improve Nighttime Visibility of Intersection with Street Lighting

3. Review the four applicable strategies and assess their safety effectiveness. These strategies are evaluated in the following subsections in the order of greatest to least safety effectiveness. Those strategies that give a crash reduction in terms of a crash modification factor (CMF) are discussed first.

Strategy I.1: Provide Left-Turn Lanes or Right-Turn Lanes and Enhancements

For this example, assume that only a left-turn lane is being considered with no enhancements. As indicated in the description for this strategy, the installation of left-turn lanes on the major street would address the targeted crash patterns, and is applicable to rural areas on arterials as well.

A CMF that is applicable to Smith County's situation is highlighted in the following table (from Strategy I.1).

Effectiveness

Crash modification factors (CMFs) for installation of turn lanes on major road approaches:

Turn Type	Area	Intersection		CMF Approaches	
		Type	Control	One	Two
Left	Rural	3 Leg	STOP	0.56	N/A
Left	Rural	3 Leg	Signal	0.85	N/A
Left	Rural	4 Leg	STOP	0.72	0.52
Left	Rural	4 Leg	Signal	0.82	0.67
Left	Urban	3 Leg	STOP	0.67	N/A
Left	Urban	3 Leg	Signal	0.93	NA
Left	Urban	4 Leg	STOP	0.73	0.53
Left	Urban	4 Leg	Signal	0.90	0.81
Right	Both	Any	STOP	0.86	0.74
Right	Both	Any	Signal	0.96	0.92
N/A = not available					

As indicated in the table, if left-turn lanes are installed at this intersection, a CMF of 0.52 is estimated.

Using the CMF, calculate the number of estimated crashes at the intersection with the installation of new left-turn lanes (assume 8 crashes/year before installation):

$$0.52 \times (8 \text{ crashes/year}) = 4.2 \text{ crashes/year}$$

Calculate the resulting reduction in crashes at the intersection:

8 – 4.2 = 3.8 fewer crashes/year

Strategy I.7: Improve Nighttime Visibility of Intersection with Lighting

The installation of street lighting can reduce nighttime intersection crashes, such as rear-end crashes. This strategy is applicable for rural arterials as well.

A variety of studies have been conducted to assess the safety effectiveness of street lighting. As indicated in Strategy I.7, installing street lights at rural intersections results in a 25- to 50-percent reduction in nighttime crashes. The safety effectiveness may also vary according to the number of lights installed.

For this example, assume that one street light will be installed. Also assume a conservative 30-percent reduction in nighttime crashes.

Since no CMF is available for this strategy, calculate the CMF using a 30-percent reduction in crashes:

1.00 – (percent reduction in crashes ÷ 100)

1.00 – (30 ÷ 100)

1.00 – 0.3 = 0.7

Using this CMF, calculate the estimated number of crashes at the intersection with the installation of a street light (assume 4 nighttime crashes/year before installation):

0.7 × (4 nighttime crashes/year) = 2.8 crashes/year

Calculate the resulting reduction in nighttime crashes at the intersection:

4 – 2.8 = 1.2 fewer nighttime crashes/year

Calculate the overall (day and night) estimated number of crashes at the intersection with the installation of a streetlight:

daytime crashes + nighttime crashes with street lighting

4 + 2.8 = 6.8 total crashes/year

Combined Safety Treatments – Strategy I.1: Left-Turn Lanes and Strategy I.7: Street Lighting

Because more comprehensive safety improvements are desired and funds are available, Smith County decides to implement more than one safety strategy to achieve a greater safety benefit. In this case, both strategies have CMFs. This allows the combined safety effect of installing left-turn lanes on the major street and providing street lighting at the intersection to be estimated.

The CMFs for each strategy are:

0.52 for installing left-turn lanes

0.7 for installing street lighting

Since nighttime crashes are the only type correctible by street lighting, the CMFs must be applied in three steps. To get the combined effect, the number of crashes is multiplied by both CMFs.

1. Calculate the combined effect of both strategies on nighttime crashes (assume 4 crashes occur at night):

   4 × 0.52 × 0.7 = 1.5 nighttime crashes/year

2. Calculate the effect of both strategies on daytime crashes (assume 4 crashes occur during the day). Since street lighting has no effect on daytime crashes, only apply the CMF for installing left-turn lanes. Thus:

   4 × 0.52 = 2.1 daytime crashes/year

3. Combine the number of nighttime and daytime crashes to obtain the resulting total crashes when both strategies are applied.

   1.5 + 2.1 = 3.6 total crashes/year

Strategy I.6: Improve Intersection Visibility with Pavement Markings

This strategy uses pavement markings to alert drivers when they are approaching an intersection. It targets reducing rear-end crashes that are due to drivers not being aware of an intersection ahead.

For this example (based on a recent study), the use of STOP AHEAD pavement markings was estimated to provide a 15-percent reduction in intersection crashes.

Calculate the CMF using a 15-percent reduction in crashes:

1.00 – (percent reduction in crashes ÷ 100)

1.00 – (15 ÷ 100)

1.00 – 0.15 = 0.85

Using this CMF, calculate the estimated number of crashes at the intersection with the installation of STOP AHEAD pavement markings (assume 8 crashes/year before installation):

0.85 × (8 crashes/year) = 6.8 crashes/year

Calculate the resulting reduction in crashes at the intersection after to the installation of STOP AHEAD pavement markings:

8 – 6.8 = 1.2 fewer crashes/year

Strategy I.5: Improve Intersection Visibility with Signing and Delineation

Smith County decides to use larger warning signs and possibly activated flashing beacons to alert drivers when they are approaching an intersection. Strategy I.5 targets reducing rear-end crashes that are due to drivers not being aware of an intersection ahead.

For this strategy there are not any quantitative estimates of the safety benefits. Crash reports should be reviewed to determine if either one of the drivers was not aware of the intersection.

Summary

The four strategies selected for consideration provide the estimated safety benefits in the following table. Smith County should review the other nine intersections to determine the safety benefits, review available resources, and can make a more comparative analysis using a benefit-cost analysis.

Strategy Number	Approach	Number of Crashes/Year
	Crashes per year before safety enhancements	8
I.1	Provide Left-Turn and Right-Turn Lanes and Enhancements	4.2
I.7	Improve Nighttime Visibility of Intersection with Street Lighting	6.8
I.1, I.7	Combined Safety Treatments – Left-Turn Lanes and Street Lighting	3.6
I.6	Improve Intersection Visibility with Pavement Markings	6.8
I.5	Improve Intersection Visibility with Signing and Delineation	N/A
N/A = not able to quantify safety effects		

Example 2: Keeping Vehicles on the Roadway at Curves

Angel County's highway safety objective is to keep vehicles on the roadway at curves. The County reviewed rural road crashes using an approach similar to that followed in Section III of this guide. They found that lane-departure crashes accounted for 48 percent of the crashes that resulted in fatal and incapacitating injuries on rural roads. Crashes on curves accounted for a large proportion of these crashes.

Based on a more detailed review of crash data on curves, Angel County determined that 10 percent of these crashes (fatal, injury, and property damage only crashes) occur at the top 15 ranked curves and that 22 percent of all fatal and injury crashes occur at the top 15 locations. From this data, the County wants to focus on crashes at curves as a safety objective.

Given the following information:

- Crash types – run-off-the-road, head-on, and sideswipe (opposing direction).
- The locations identified are all on rural routes.
- The curves on the average have a shorter length and smaller average curve radius than average curves in the state.
- Curves have minimal signing and pavement markings.
- None of the curves have pavement edge drop-offs.
- At the highest-ranked curve, there were 2 fatal crashes and 7 injury crashes in the past 2 years, and 4 property damage only crashes, for a total of 13 crashes.

Then determine:

- Which safety strategies might be applicable to crashes due to the identified crash patterns on curves.
- Using crash modification factor (CMF) information, estimate the change in the number of crashes and the predicted reduction in crashes using one or more strategies.

Procedure:

Review the roadway-related strategies for safety effectiveness.

1. Knowing that the safety objective is to reduce crashes by keeping vehicles on the roadway at curves, refer to Attachment A, *Objectives and Strategies Table*. See Objective II: Keep Vehicles on the Roadway.

   Angel County considered four potential strategies, which apply to this type of roadway control and the observed crash patterns:

   - Strategy II.1: Improve Advanced Curve Warning and Curve Delineation
   - Strategy II.2: Improve Pavement Markings and Delineation
   - Strategy II.3: Install Shoulder, Edge Line, or Centerline Rumble Strips
   - Strategy II.4: Minimize or Eliminate Pavement Edge Drop-offs

The County reviewed the four strategies. Since current signing was limited on the curves, they elected to focus initially on improving advance warning signs and curve delineation. These enhancements included the use of larger and brighter Curve warning signs; advisory speed signs; and the installation of larger chevron signs and delineators. Advisory speeds for the curves were checked using ball bank indicators.

Studies show that the safety effectiveness of installing the appropriate signs and delineations can reduce crashes by:

- 15 percent for run-off-the- road crashes by installing post-mounted delineators.
- 22 percent by installing Curve warning signs and advisory speed plaques.

2. Looking at the top-ranked curve, which had a total of 13 crashes in 2 years (an average of 6.5 crashes/year), determine the combined safety benefit of installing post-mounted delineators and enhanced curve signing.

   Since no CMF is available for this strategy, calculate the CMF for a 15-percent reduction in crashes based on the installation of post-mounted delineators:

   1.00 – (percent reduction in crashes ÷ 100)

   1.00 – (15 ÷ 100)

   1.00 – 0.15 = 0.85

   a. Calculate the CMF for a 22-percent (using Curve warning signs and advisory speed plaques) reduction in crashes:

      1.00 – (percent reduction in crashes ÷ 100)

      1.00 – (22 ÷ 100)

      1.00 – 0.22 = 0.78

   b. In 2 years there were 2 fatal and 7 injury crashes, or 4.5 fatal or injury crashes/year and 6.5 total crashes/year. Calculate the estimated number of fatal and injury crashes on a curve using both strategies:

      fatal or injury crashes/year × percent reduction in crashes using delineators × percent reduction in crashes using signs

      4.5 × 0.85 × 0.78 = 3.0 fatal or injury crashes/year

   c. Calculate the total number of crashes on a curve using both strategies:

      total crashes/year × percent reduction in crashes using delineators × percent reduction in crashes using signs

      6.5 × 0.85 × 0.78 = 4.3 total crashes/year

   d. Calculate the resulting reduction in fatal-injury crashes on the roadway curve after to the installation of post-mounted delineators and Curve warning signs and advisory speed plaques:

      4.5 – 3.0 = 1.5 fewer fatal or injury crashes/year

e. Calculate the resulting reduction in the number of total crashes on the roadway curve after to the installation of post-mounted delineators and Curve warning signs and advisory speed plaques:

6.5 – 4.3 = 2.2 fewer total crashes/year

Example 3: Reducing Pedestrian Crashes along a Roadway with No Sidewalk or Shoulder

The Village of Sunrise has experienced several pedestrian crashes in the past 2 years along several collector streets that have no sidewalk or shoulder. Their safety objective is to reduce this type of crash.

Given the following information:

- Crash types – Pedestrian crashes occurred as a pedestrian was walking on or immediately adjacent to the street. In the last 3 years, 6 pedestrian crashes have occurred, 3 on each street.
- The locations where pedestrian crashes have occurred are both collector streets in an urban setting.
- The speed limit on the two streets of concern is 40 mph.
- There are currently no sidewalks on the collector streets, and the existing shoulder for the roadway is minimal or non-existent.
- The area along the routes is residential with parks and schools in the vicinity.

Then determine:

- At least one safety strategy that might be applicable to reduce pedestrian crashes due to the identified crash patterns.
- Using estimates of the predicted reduction in crashes, find an estimated crash modification factor (CMF) and predict the safety effectiveness of the strategy.

Procedure:

Review the roadway-related strategies for safety effectiveness.

1. Knowing that the safety objective is to reduce pedestrian crashes, refer to Attachment A, *Objectives and Strategies Table*. See Objective IV: Reduce Pedestrian and Bicycle Crashes.

   The Village of Sunrise considered Strategy IV.1: Provide Sidewalks/Walkways and Curb Ramps, which outlines current information about the safety effectiveness of providing sidewalks for pedestrians.

2. As outlined in Strategy IV.1, the presence of sidewalks along a road (compared to having no sidewalks or walkways) reduces the risk of pedestrian crashes by 50 to 90 percent. Higher speed limits on the roadway increases the risk to pedestrians where there are not designated walking areas. While safety data varies on their effectiveness, it is possible to estimate the range of the safety benefit of installing sidewalks.

a. Since no CMF is available for this strategy, calculate the estimated CMFs for each end of the given range of safety effectiveness – 50-percent and 90-percent reduction in pedestrian crashes (in areas where no sidewalks exist):

   1.00 – (percent reduction in crashes ÷ 100)

   1.00 – (50 ÷ 100) = 1.00 – 0.50 = 0.50 (low end of safety effectiveness range)

   1.00 – (90 ÷ 100) = 1.00 – 0.90 = 0.10 (high end of safety effectiveness range)

b. In 3 years there were 6 pedestrian crashes, or an average of 2 crashes/year. Calculate the estimated number of crashes along the roadway with the installation of sidewalks to reduce pedestrian crashes using the estimated CMF of 0.50 (50-percent reduction in pedestrian crashes):

   crashes/year × 50-percent reduction in crashes

   2 × 0.50 = 1.0 pedestrian crash/year

   Calculate the estimated number of crashes along the roadway with the installation of sidewalks to reduce pedestrian crashes using the estimated CMF of 0.10 (90-percent reduction in pedestrian crashes):

   crashes/year × 90-percent reduction in crashes

   2 × 0.10 = 0.2 pedestrian crash/year

c. Calculate the resulting reduction in the number of pedestrian crashes on the roadway after to the installation of sidewalks or wider shoulders:

   2 – 1.0 = 1 fewer pedestrian crash/year (low end of safety effectiveness range)

   2 – 0.2 = 1.8 fewer pedestrian crashes/year (high end of safety effectiveness range)

   Over 3 years, the cumulative reduction is estimated to be 3 to 5.4 fewer pedestrian crashes on these collector streets.

Example 4: Implementing a Speed Management Program for Collector and Local Streets

In recent years, the Village of Cupcake, West Dakota, has received a number of complaints from citizens and neighborhood associations about speeding on Village streets. These complaints have mostly been about speeding collector streets that abut residential areas and on local streets next to parks.

Given the following information:

- The Village reviewed their crash reports for collector and local streets. They found that in 45 percent of the fatal and incapacitating injury crashes, one or more of drivers involved was speeding.
- The mayor of Cupcake formed a multidisciplinary task force of staff from public works, law enforcement, and public information to develop solutions to the issue.
- Due to decreases in revenue, the Village has found it necessary to reduce the number of law enforcement officers and has reduced, but not eliminated, traffic and speed enforcement efforts.
- Recently, the State of West Dakota passed legislation that authorized local entities to enact and implement automated enforcement programs such as automated speed enforcement. The law stipulates that a program can be implemented if a community does the following, which in effect are a set of good practices for such a program:
  - Identify that speeding is a safety issue and identify specific locations where speeding is a safety issue
  - A local entity passes appropriate local statutes enabling automated enforcement efforts.
  - Before implementing an automated enforcement program, the local entity review posted speed limits, signing, and institute a public awareness program related to speeding and the program operation.
  - The automated enforcement program be part of an adopted overall enforcement program
  - The equipment should be attended by an individual unless it is only being used for speed measurements or another non-enforcement effort.
  - Periodic evaluations of the program are required.

Then determine:

- At least one safety strategy or program that might be applicable to reduce crashes due to speed related crash patterns.
- Using the best-available information, estimate the predicted reduction in crashes based on the proposed efforts. For many enforcement, education, and emergency medical services programs, there are no CMFs available because current studies have not determined precise estimates of the safety effectiveness.

Procedure:

Review the speed management strategies for safety effectiveness.

1. Knowing that the safety objective is to implement a speed management program, refer to Attachment A, *Objectives and Strategies Table*. See Objective V: Enforcement and Education, which outlines strategies related to reducing crashes due to speed. Strategy V.2: Better Manage Vehicle Speeds outlines the elements of such a program.
2. The Village of Cupcake public works, legal staff, and law enforcement staff reviewed the crash history and the new state legislation in the context of their resources and needs. As a result, the Village is developing a speed management program for consideration by the Village and citizens.
3. As outlined in Strategy V.2, the effectiveness of a speed management program can reduce injury and fatal crashes by 20 to 25 percent, if properly designed and managed. Due to lack of precision in this estimate, a CMF cannot be accurately determined. However, research has indicated that well-designed and effectively implemented speed management programs improve safety on roadways.