Road Safety Information Analysis

A Manual for Local Rural Road Owners

U.S. Department of Transportation
Federal Highway Administration

http://safety.fhwa.dot.gov
FHWA-SA-11-10

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-SA-11-10		

4. Title and Subtitle	5. Report Date
Roadway Safety Information Analysis: A Manual for Local Rural Road Owners	January 2011
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Golembiewski, G.A. and Chandler, B.	

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Science Applications International Corporation (SAIC) Mail Stop E-12-3 8301 Greensboro Drive McLean, VA 22102-3600	11. Contract or Grant No. DFTH61-05-D-00025, T-09-003

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Office of Safety Federal Highway Administration 1200 New Jersey Ave, SE Washington, DC 20590-9898	14. Sponsoring Agency Code HSSP

15. Supplementary Notes

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16. Abstract

According to the Federal Highway Administration, over 6 million lane-miles are in rural areas, and more than two-thirds of these rural roads are owned and operated by local entities. In 2008, 56 percent of highway fatalities occurred in rural areas. Rural areas face a number of highway safety challenges. Data is the foundation of any roadway safety improvement program and often this is lacking, especially in local rural areas.

This document was developed to provide data collection and analysis techniques as well as other processes applicable to the local practitioner to help improve the safety of local rural roads. The information will acquaint local practitioners – regardless of background or experience level – with the sources, calculations, tools, and methods to make data-supported decisions regarding local rural road safety.

17. Key Words	18. Distribution Statement
Data, Fatality, Injury, Traffic volumes, Rates, Segments, Corridors, Local rural roads, Trends, Field reviews, Implementation	No restrictions.

19. Security Clasif. (of this report)	20. Security Clasif. (of this page)	21. No. of Pages	21. Price
Unclassified	Unclassified	56	N/A

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1 Introduction

1.1. The Challenges on Local Rural Roads

In 2008, the Fatality Analysis Reporting System (FARS) indicated that 56 percent of the 37,261 fatalities on U.S. roadways occurred in rural areas.[1] Only 40 percent of all vehicles miles traveled nationally occur on rural roads, indicating the overrepresentation of severe rural traffic crashes.[2]

According to the Federal Highway Administration (FHWA), of the 8.4 million lane-miles of roads in the United States, over six million lane-miles are rural and more than two-thirds of these rural roads are owned and operated by local entities.[3] Rural areas face a number of highway safety challenges. For instance, rural crashes tend to be at relatively higher speeds than urban crashes; more victims of fatal crashes in rural areas were not wearing a safety belt at the time of the crash; and it can take first responders longer to arrive at the scene of a rural crash, requiring victims to wait longer for medical attention. Another challenge is that the geometry of many rural roads was never truly designed; instead, these roadways evolved over time – from dirt to gravel to pavement – without design upgrades or other safety improvements. Additionally, roadside hazards such as utility poles or trees close to the roadway as well as steep pavement drop-offs can contribute to severe crashes on rural roads.

1.2. Local and Rural Guides

This document is part of a series developed by FHWA to specifically address the safety issues experienced on local rural roadways. It was developed to provide processes and examples for typical information

1 National Highway Traffic Safety Administration, Traffic Safety Facts: 2008 Data (Washington, DC: 2009). Available at http://www-nrd.nhtsa.dot.gov/Pubs/811164.pdf.

2 Safe Transportation Research and Education Center (SafeTrec), Institute of Transportation Studies, University of California-Berkley, "Rural Road Safety website." Available at http://www.tsc.berkeley.edu/research/ruralroads.html.

3 U.S. Department of Transportation, Federal Highway Administration, Functional System Data: Lane-Miles by Functional System. , Highway Statistics Series, October 2008. Available at http://www.fhwa.dot.gov/policyinformation/statistics/hm60.cfm?hm_year=2007.

needs and analyses local practitioners can use to help improve the safety of local rural roads. Its purpose is to acquaint local practitioners– regardless of background or experience level– with the information sources, calculations, tools, and methods to make data-supported decisions regarding local rural road safety.

Highway safety planning and policy decisions are generally made based on data gathered at the State, county, and municipal levels. Regulations for safety-related Federal funding and safety plan development require data for the decision making process. At the local level, these data requirements might seem daunting, particularly as they relate to funding and staff time needed for data collection, analyses, and overall assessments of safety improvements. It is important to note that a data-supported approach can increase the effectiveness of the distribution of limited funds to improve safety on local rural roads.

Once safety information is collected and needs are identified, analysis can further support practitioners during countermeasure selection. Practitioners can then choose strategies that target the areas of need based on analysis of crash types and other data. When applied directly to appropriate locations (both those with a history of crashes and those without a history but with a potential for future crashes), these targeted countermeasures can significantly improve traffic safety on the roadway network.

Figure 1 depicts the steps for the data collection and analysis process. This process includes determining which information sources will be used, extracting and storing the data as appropriate, and conducting the appropriate analyses. The final step is to periodically review crash data to determine emerging trends and to assess the effectiveness of installed countermeasures.

Data collection and analysis should be the base of the safety management process. The importance of data should be clearly emphasized throughout all stages of a project's life cycle.

Step 1
Collect Safety, Roadway, and Exposure Information
(Manual: Section 2)

Information can be collected from:

- State and national crash databases
- Law enforcement crash reports
- Hospital records
- Observations by law enforcement and public works staff
- Public notifications
- State and local roadway databases
- Traffic count records

Step 2
Record Information for Safety Analysis
(Manual: Table 1)

Compile information in a table to determine if patterns emerge and to track responses to known crash locations.

Step 3
Analyze Data
(Manual: Section 3)

Data can be analyzed in the following ways, based on available information:

- Crash Frequency
- Crash Averaging
- Trend Analysis
- Crash Rate Calculations
- Identification of potential future crash locations

Step 4
Select Countermeasures
(Manual: Section 4)

Details from the crash data can provide clues about what treatments are the most appropriate. Based on the availability of data, different approaches can be taken:

- Systematic Approach
- Spot Location Approach
- Comprehensive Approach

Figure 1. Data Collection and Analysis Steps

2 Safety Information Collection

Several types of data are needed to develop an effective safety program. This information can assist agencies in identifying locations with safety issues, prioritizing locations, and identifying the most appropriate treatments. It is difficult to solve a problem until information is collected and analyzed to determine the nature of the problem. There are three common types of data needs for a safety project or program:

1. Crash data;
2. Roadway characteristic data; and
3. Exposure data.

2.1. Crash Data

Crash history data is the primary source of information regarding the traffic safety environment, driver behavior, and vehicle performance. In order to address safety problems, traffic safety data should be timely, accurate, complete, consistent, integrated, and accessible. Good quality data have the potential to improve problem identification, prioritization of project selection, and evaluation of the effectiveness of countermeasures.[4]

Compared to Federal and State safety professionals, local practitioners tend to be more aware of locations with a history of crashes within their own jurisdictions due to the size of the area and news-worthiness of local traffic crashes. This knowledge, coupled with actual crash data, can aid the practitioner in identifying factors contributing to crashes and allow them to choose improvements to address these issues. The primary sources of crash data for local practitioners include:

- Law enforcement crash reports;
- State crash database;
- Fatality Analysis Reporting System (FARS) database;
- Hospital data; and
- Public notification of safety concerns.

4 Federal Highway Administration, Crash Data Improvement Program Guide, April 2010. Available at: http://safety.fhwa.dot.gov/cdip/finalrpt04122010/index.cfm#toc

2.1.1. Law Enforcement Crash Reports

The primary and most comprehensive sources of information used to populate crash databases are the crash reports completed by State and local law enforcement organizations. Crash reports are the record of a traffic crash that has occurred on a public roadway. The format of the report varies by State, and sometimes by jurisdiction within a State. See Appendix A for an example of a State crash report.

Crash reports generally include the following information about the incident:

- Date & time of crash;
- Crash severity;
- Crash type;
- Location & roadway information;
- Weather;
- Number and types of vehicles involved;
- Driver information (e.g., name, age, gender); and
- Contributing circumstances.

By reviewing the information provided on crash reports over a period of time, recurring variables may be discovered to help pinpoint which factors are contributing to crashes.

The types of information collected and data collection methods used by law enforcement officers vary. Documentation methods among individual officers in the same jurisdiction also vary at times. The local practitioner should be aware of these variances during the review and analysis of crash reports.

There are a number of crash reporting issues that should be considered by law enforcement officers and safety practitioners when working with crash reports. These include:

Location Coding. Exact location of a crash is sometimes difficult to determine because the location of impact is often not where the vehicles come to rest. Referencing crash locations is often dependent on the level of technology used, the experience of the officers at the scene, and the approach used by the jurisdiction.

Typical methods include:

- Distance from known reference point;
- Street address;
- Milepost; and
- Global Positioning System (GPS) – latitude and longitude coordinates.

Limited resources often preclude the use of expensive technology, and reference points may be long distances apart, affecting accuracy. In a situation where GPS data is available, Geographic Information Systems (GIS) tools may be available to use these data for in-depth analysis and mapping.

Regardless of the method used, the location of each crash is an important data element for safety analysis.

Crash Type Definitions. Various jurisdictions may define crash report terms differently. For example, whereas rear-end and head-on crash types may be standard classifications in some areas, other regions may interpret these classifications differently or include additional classifications.

Threshold for Reportable Crashes and Severity Determination. States across the country use varying criteria to determine when a crash is deemed reportable and to define crash severity. Reportable crashes are crashes that include a fatality, injury, or property damage cost meeting a specified threshold. Most States have an estimated property damage cost threshold for a property damage only (PDO) crash to be considered reportable. In some States, if the vehicle can be driven away from the scene of the crash and no one is injured, it is not considered a reportable incident.

Jurisdictions are generally consistent with regard to the definition of a fatal crash; but as the severity of a crash diminishes, the classifications can vary by state. The severity of an injury crash is often difficult to determine at the scene and can be subjective based on the reporting officer if follow-up with hospital or Emergency Medical Services (EMS) is not conducted. Local practitioners should be aware of the issues in their States and local jurisdictions during crash data review and subsequent analysis.

Practitioners should also be aware that data issues such as missing, contradictory, and erroneous information have the potential to skew analysis and result in inefficient decision making. Coordination between law enforcement personnel and local road practitioners is important to ensure the efficient collection of crash data.

2.1.2. State Crash Database

Statewide crash databases typically offer comprehensive records on all reported crashes. They are compiled from State, county, and municipal law enforcement agencies submitting crash reports to a central State repository. State crash databases typically include the information collected at the scene of the incident.

However, State repositories can vary by agency, depending on the State. Data compilation and dissemination methods can also differ by State and not all States share their collected crash data with local jurisdictions. Moreover, local crash data in the repository can be incomplete. Local practitioners should be aware of the issues in their State and should identify the relevant points of contact necessary to obtain further information.

State data on crash types can provide clues regarding the potential for future severe crashes and countermeasures that could help. For example, if only non-injury roadway departure crashes have been recorded at a particular curve over a period of time, these incidents could be a precursor to a severe crash in the future if this location is not treated, since rural roadway departure crashes tend to be more severe than other types.

2.1.3. FARS Database

The Fatality Analysis Reporting System (FARS) is a national database of fatal crashes that occurred on the national public roadway network. It is maintained and operated by the National Highway Traffic Safety Administration (NHTSA).

FARS contains data derived from a census of all fatal traffic crashes within the 50 States, the District of Columbia, and Puerto Rico. FARS was developed to provide an overall measure of highway safety at the national level, to help identify traffic safety problems, to suggest solutions, and to help provide an objective basis upon which to evaluate the effectiveness of standards and highway safety programs among the States.[5]

Each State provides specific fatal crash information in a standard format to FARS. The data originate from State accident reports. Once collected by the FARS analysts, the data are recoded to match the standard FARS forms. FARS data are used to answer questions regarding the roadway, vehicle, and driver factors that contribute to traffic safety.[6] The benefit to the FARS data is that it includes information on every fatal crash that has occurred within a State; so if a jurisdiction has no other reliable source of data, FARS can provide a starting point.

The FARS dataset is limited to those crashes involving a fatality. In a local rural setting, fatal crashes are relatively rare and random; therefore, FARS data may not provide the best indication of locations with identifiable safety issues.

5 U.S. Department of Transportation, National Highway Transportation Safety Administration, "Fatality Analysis Reporting System Fatal Crash Data Overview" brochure, DOT HS 809726, April 2005.

6 U.S. Department of Transportation, National Highway Transportation Safety Administration, "Fatality Analysis Reporting System (FARS) Encyclopedia" web site, http://www-fars.nhtsa.dot.gov

2.1.4. Hospital Data

If on-scene crash data is unavailable, other potential sources of information are local Emergency Medical Services (EMS) and medical centers. EMS data can provide information regarding the locations and degree of EMS responses to traffic crashes. Similarly, hospitals may have some information available regarding emergency room visits or other admissions connected to traffic crashes. Due to a number of Federal and State regulations regarding the privacy of medical information, the availability of these data could be limited and will vary by State.

The Crash Outcome Data Evaluation System (CODES) links crash records to injury outcome records collected at the scene and en route by EMS; by hospital personnel after arrival at the emergency department or admission as an inpatient; or on the death certificate at the time of death. CODES is designed to foster and cultivate crash-outcome data linkages for highway safety applications by State and local practitioners.[7]

Analyses of linked data can help traffic safety professionals and coalitions to determine and implement data-driven traffic safety priorities. In many States, the State Department of Health (or similar agency) has access to the CODES linkage data, and this information in combination with the State crash database and FARS data, can be beneficial to local safety practitioners supporting safety initiatives.

2.1.5. Public Notification of Safety Concerns

Potential infrastructure issues, perceived safety concerns, or other traffic-related situations are sometimes reported to the local agency by citizens or citizen groups. The notification is typically delivered by telephone call or e-mail to the officials of a local jurisdiction, and a response is often requested.

The public official should compile records of these notifications so that multiple notifications of the same location can be identified. While this is primarily anecdotal information, public notifications can serve as indicators that a problem may exist and could warrant further review and analysis. Additionally, open communication with local citizens can help practitioners identify potential highway safety issues in the community.

Table 1 shows how a simple database could be designed to capture and store information from the various sources previously discussed. 2.2.

7 CODES data is collected in a limited number of states. Local practitioners should consult their State highway agency or Local Technical Assistance Program (LTAP) center for additional information.

Table 1. Sample Local Jurisdiction Crash Database

Intersection/ Location	Source of Information	Date (MM/ DD/YYYY)	Type of In-formation	Problem	Crash?
Intersection - Rt 123 and Fox Mill Road	Local Newspaper	3/8/2008	Citizen Complaint	Speeding	N
Route 123 West / 1/2 mile south of intersection with Fox Mill Road to intersection	Local Newspaper	12/1/2007	Citizen Complaint	Drivers losing control at curve	N
Intersection - Route 657 and Glade Drive	Local Police	2/1/2008	Police Report	Crash Report	Y
Route 657; 1/2 mile south of Glade Drive	Local Police	4/1/2008	Police Report		Y
Intersection - Route 657 and Clifton Road	State Police	10/4/2008	Police Report	Crash Report	Y
Clifton Road; South of Veirs Mill Road	State Police	11/11/2008	Police Report		Y
Intersection - Route 657 and Glade Drive	Local Police	11/12/2009	Police Report	Crash Report	Y
Route 657; 1/4 mile South of Glade Drive	Local Police	11/24/2009	Police Report		Y
Intersection - Middlebrook Pike and Waples Mill Road	Maintenance Crew	12/1/2009	Observation	Missing Stop Sign	N
Middlebrook Pike; 1 mile North of Running Cedar Road	Maintenance Crew	12/12/2009	Observation		N

Table 1. (continued) Sample Local Jurisdiction Crash Database

Nature of Crash	Crash Type	Time of Day (24 hr time)	Weather Conditions	Action?	Date of Action
NA	NA			Pending	
NA	NA			Pending	
Vehicle traveling North on Route 657 hit while making left turn onto Glade Drive	Right angle	7:22	Clear		
Driver hit tree on shoulder; single vehicle	Roadway departure; hit stationary object	23:03	Snow		
Vehicle traveling West on Clifton road rear-ended at intersection	Rear-end	19:21	Rain		
Driver ran off road on curve; exceeding posted speed	Roadway departure; on curve	12:23	Rain		
Vehicle traveling West on Glade collided with vehicle on Route 657	Right angle	10:06	Rain		
Driver ran off road; single vehicle	Roadway departure	23:04	Rain		
NA	NA			Replaced Stop Sign	12/19/2009
NA	NA			Advanced Curve Warning Sign Replaced	1/8/2010

2.2 Roadway Characteristic Data

It is also valuable to obtain information about the roadway infrastructure. The following roadway data are often used to assist practitioners in safety analyses:

- Roadway surface (dirt, aggregate, asphalt, concrete);
- Lane (number, width);
- Shoulder (type, width);
- Median (type, width);
- Roadway alignment (curve, straight);
- Intersection (number of legs, configuration); and
- Traffic control devices present (signs, pavement marking, traffic signals).

This information can be combined with crash data to help local practitioners identify appropriate locations and treatments to improve safety. For example, if a segment of roadway is experiencing a high number of roadway departure crashes, analysis of the inventory of roadway elements could reveal that the roadway does not have edgeline pavement markings. An appropriate countermeasure could be to install edgeline pavement markings to provide guidance to motorists to stay on the traveled way.

2.3. Exposure Data

The raw number of crashes can sometimes provide misleading information about the most appropriate locations for treatment. Introducing exposure data helps to create a more effective comparison of locations. Exposure data provide a common metric to the crash data so roadway segments and intersections can be compared more appropriately.

The two most common types of exposure data used are traffic volume and roadway miles.

1. **Traffic volume.** A count of the number of vehicles along a segment of road or entering an intersection can provide information to the practitioner for comparison. For example, if two intersections have the same number of crashes but different entering traffic volumes, the location with fewer vehicles (i.e., less exposure) will have a higher crash rate, meaning that vehicles were more likely to have experienced a crash at that location. This rate reflects the fact that an increase in the number of vehicles has an effect on the expected number of crashes.
2. **Roadway miles.** In many cases, traffic count data is not available and the cost to collect the information may be prohibitive for local jurisdictions. An alternative method for analyzing the data is to use the route's length in miles. If two roadways have a similar number of crashes but differing lengths, calculations will indicate the shorter road has experienced more crashes per mile.

3 Analyzing Data

Collected data should be analyzed and reviewed to identify locations with safety issues or locations with potential for future safety issues, and to select countermeasures to improve safety. Depending on the completeness, accuracy, and timeliness of available data, a local jurisdiction can analyze that information in a number of ways. Figure 2 shows the relationship between data availability and the analysis potential for improved safety-related decision-making.

In Figure 2, as more types of data become available to the safety practitioner (moving up in the figure on the left), the ability to perform more in-depth safety analyses is enhanced (the list on the right of the figure). For example, if only the county and route of a crash location are known, analysis is limited to analyses by county and route. But as more specific location information is collected and stored, including milepost location or GPS coordinates, options like pin map cluster analysis and location comparisons become available. If additional exposure and roadway characteristic information can be linked to the location (traffic counts, roadway width, shoulder type) then even more robust analyses can be performed.

As noted, several types of data analysis can be conducted to support roadway safety depending on available crash, roadway and exposure data. They include:

- Crash frequency;
- Crash averaging;
- Trend analysis; and
- Crash rates.

3.1. Crash Frequency

Crash frequency is one of the simplest forms of crash data analysis. It is defined as the number of crashes occurring within a specific jurisdiction, on a roadway segment, or at an intersection. Multiple crashes occurring at the same location over a period of time may be an indication of a safety issue and should be investigated and addressed appropriately. This is referred to as "clustering". Crashes can be clustered by route, specific location on that route, or by intersection.

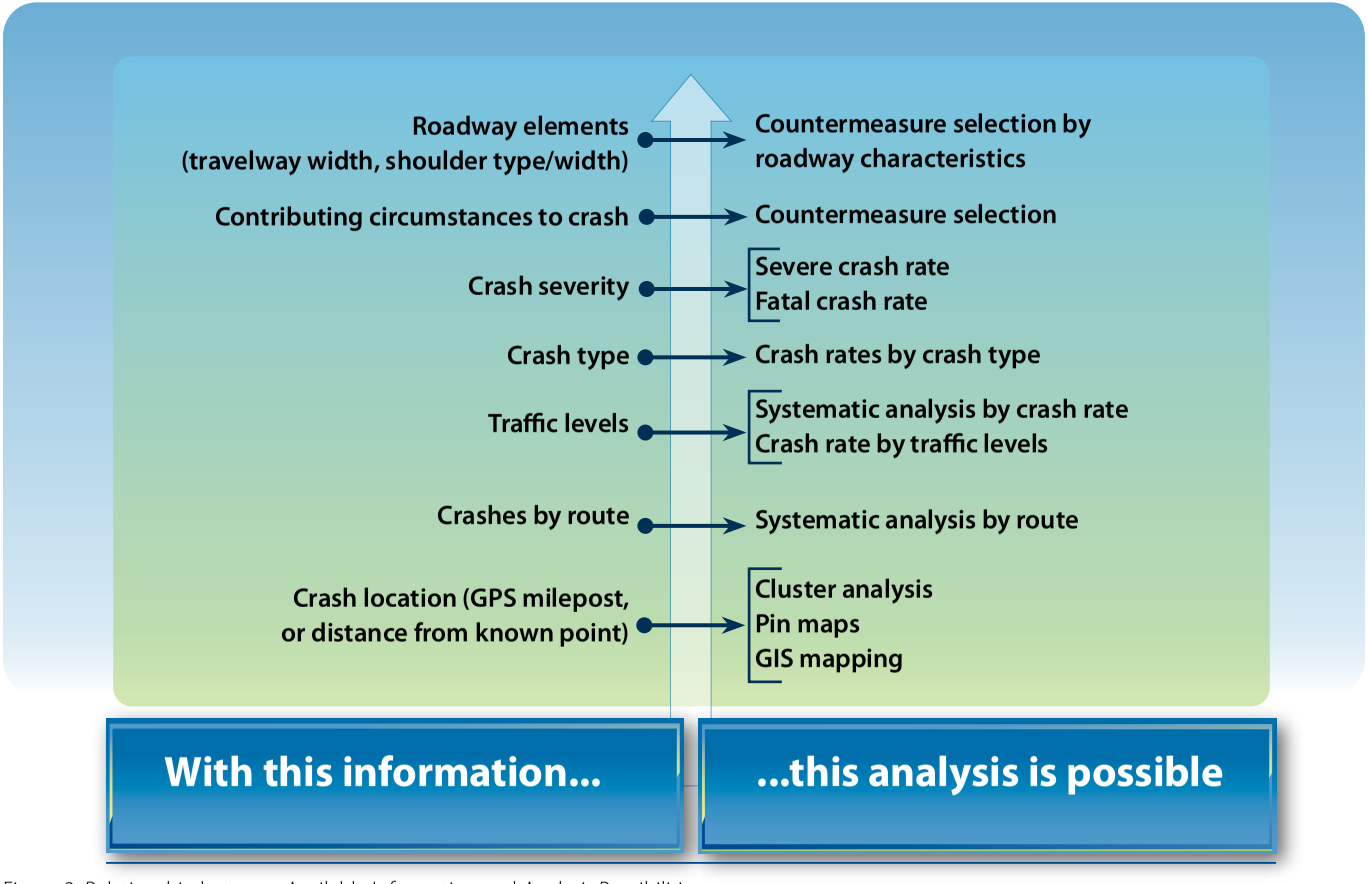

Figure 2. Relationship between Available Information and Analysis Possibilities

Example: County Road 220, in Potter's Grove, Rae County, is a 17-mile route that has 2,100 vehicles traveling on it each day. It had the following crash history over the past 5 years as shown in Table 2:

Year	Crashes
2005	2
2006	1
2007	6
2008	1
2009	2
5-year total	12

Table 2. Crash History for County Road 220[8]

Beyond looking at the raw number of crashes on a route, a practitioner can plot the crash locations on a pin map to determine clustering, as shown in Figure 3. Data from this figure indicate that the CR220 & 1st Street and CR220 & Main Street intersections appear to have experienced multiple crashes over the 5-year study period.

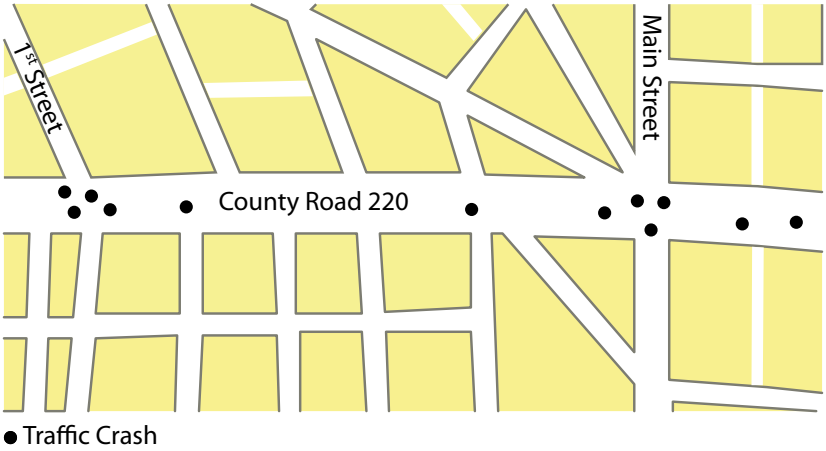

Figure 3. Location of Crashes on County Road 220

3.1.1. Crash Averaging

Crashes are relatively rare events, so it is important that a safety analysis includes an adequate time frame of study. Crash averaging allows the practitioner to normalize crash data over a longer period than one year

8 Data from this table will be used throughout this manual to illustrate different analysis methods.

to account for annual anomalies that can skew analyses. Due to the randomness of traffic crashes, it is likely that any one year could have a much higher or lower number of crashes than the typical year. A rule of thumb is to collect data from the previous 3 to 5 years, with 3 years as a working minimum. A longer period of time increases the statistical value of the data; however, if the period is too long, there is a chance that the situation (e.g., roadway configuration, traffic volume and patterns) may have changed.

For County Road 220 (Table 2, above), the 5-year average of crashes is calculated by adding the total crashes from 2005-2009 and dividing by the period of 5 years:

$$\frac{(2+1+6+1+2)}{5} = 2.4$$

Results show that County Road 220 averaged 2.4 crashes per year during that time period. Note that in 2007, the route experienced six crashes (five more than the year before and the year after), which might have caused the route to be "flagged" based on that single year of crashes. Averaging data across the 5-year analysis period provides a number more consistent with actual roadway conditions over time.

A Rolling Crash Average can also be used to achieve some normalcy from crash data. A Rolling Crash Average looks at the previous 3 to 5 years at more than one point in time. For example, the first data point could be 2001-2005 (a 5-year average). The next would be the 2002-2006 average, and so on. This technique further flattens the curve in an attempt to avoid inappropriate reaction to one or two statistically insignificant data points.

Year	Crashes	5-year period	Rolling Average
2001	1		
2002	3		
2003	2		
2004	0		
2005	2	2001-2005	1.6
2006	1	2002-2006	1.6
2007	6	2003-2007	2.2
2008	1	2004-2008	2.0
2009	2	2005-2009	2.4

Table 3. Rolling Crash Average for County Road 220

Table 3 shows that the rolling average of County Road 220 stayed relatively steady up to 2006, and then increased slightly from 2007 to 2009. A rolling average is commonly used to smooth out short-term fluctuations in the data and highlight longer-term trends. A study of the annual crashes shows one year with an atypically high number of crashes (six crashes in 2007). If crashes continue to hover near one or two crashes per year, the rolling average will quickly revert to that number as well.

The difference between looking at crashes per year and the rolling average, as shown in Table 3, is that the "peak" of the rolling average is only 2.4 versus six when looking at one year at a time. This supports a broader view of analysis by looking at the big picture and not focusing on a single data point.

3.1.2. Trend Analysis

A practitioner can also examine the trend of crashes over time to determine if crashes have been rising or falling. An increasing number of crashes may indicate an emerging safety issue. The crash history can be placed in a number of categories indicating both the number of crashes and the recent trend, such as:

- High and rising;
- High but falling;
- High and steady;
- Low but rising;
- Low and falling; and
- Low and steady.

For County Road 220, Figure 4 provides a graphic representation of the crashes from 2001-2009 and the trend for these crashes. The figure indicates the crash number fluctuates from year to year and the trend is rising. The linear trend line can be calculated by a computer software program (e.g., Microsoft Excel) to provide a general idea of the rise or fall of traffic crashes based on the patterns of change from year to year. In this case, it would be worthwhile for the practitioner to perform two additional steps:

1. Analyze the reason for the increase by reviewing the crash reports.
2. Note the trend for future analysis.

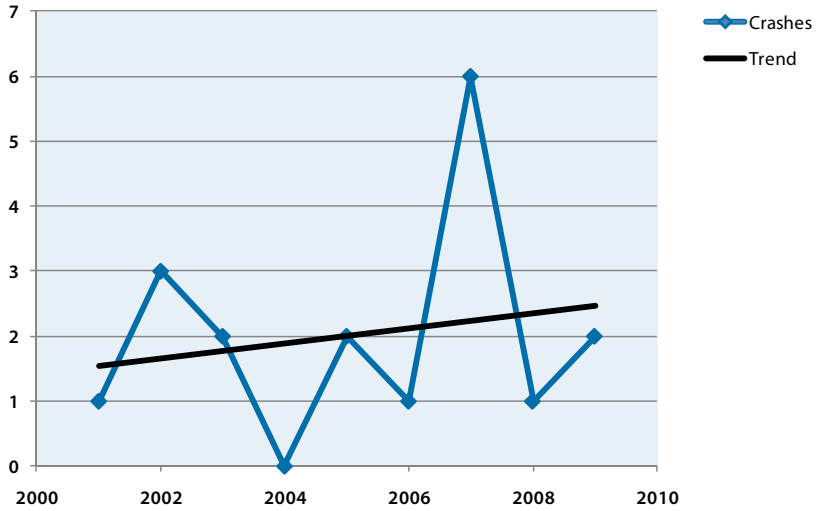

Figure 4. County Road 220 Crash Trends, 2001-2009

3.2. Crash Rates

Crash rate analysis of the relative safety of a segment or intersection takes into account exposure data. The crash rate is calculated to determine relative safety compared to other similar roadways, segments, or intersections. Crash rate analysis typically uses exposure data in the form of traffic volumes or roadway mileage.

Typically, traffic volumes are expressed in the form of Annual Daily Traffic (ADT). As discussed above, traffic volume data is not always available at the local jurisdiction level. In these cases, rates can be calculated using other exposure data, such as roadway length. Information may be available from other agencies including county traffic or maintenance; the Metropolitan Planning Organization (MPO); the Regional Planning Organization (RPO); or from the State database.

The benefit of crash rate analysis is that it provides a more effective comparison of similar locations with safety issues. This allows for prioritization of these locations when considering safety improvements with limited resources.

3.2.1. Road Segment Rate Calculation

The crash rate for road segments is calculated as:

Where:

$$R = \frac{100{,}000{,}000 \times C}{365 \times N \times V \times L}$$

R = Crash rate for the road segment expressed as crashes per 100 million vehicle-miles of travel (VMT).

C = Total number of crashes in the study period.

N = Number of years of data.

V = Number of vehicles per day (both directions).[9]

L = Length of the roadway segment in miles.

If County Road 220 was being assessed with the following values:

C = 12 crashes over the past 5 years on this segment.

N = 5 years of data.

V = 2,100 vehicles per day.

L = 17 miles.

The resulting segment crash rate would be:

$$R = \frac{100{,}000{,}000 \times 12}{365 \times 5 \times 2{,}100 \times 17} = 18.4 \text{ crashes per 100 million vehicle miles of travel on County Road 220}$$

Depending on the details of crash reporting methods and crash history in a particular jurisdiction, a value of 18.4 may or may not be cause for additional study. The most appropriate use of this crash rate is to determine the relative safety of a roadway segment when compared to similar segment within a specific jurisdiction.

3.2.2. Intersection Rate Calculation

The most common equation used to calculate a crash rate at an intersection is as follows:

9 It is possible that traffic counts by direction are available from different years. In this case, a growth factor should be applied to the earlier data (based on historic trends at that site) so that it will be consistent with the newer information.

Where:

$$R = \frac{1{,}000{,}000 \times C}{365 \times N \times V}$$

R = Crash rate for the intersection expressed as accidents per million entering vehicles (MEV).

C = Total number of intersection crashes in the study period.

N = Number of years of data.

V = Traffic volumes entering the intersection daily.[10]

If, for example, an intersection were being assessed with the following values:

C = 5 total crashes over the past 5 years.

N = 5 years of data.

V = 1,500 entering vehicles per day.

The resulting intersection crash rate would be:

$$R = \frac{1{,}000{,}000 \times 5}{365 \times 5 \times 1{,}500} = 1.82 \text{ crashes per million entering vehicles.}$$

Depending on the details of crash reporting methods and crash history in a particular jurisdiction, a value of 1.82 may or may not be cause for additional study. The most appropriate use of this crash rate is to determine the relative safety of an intersection when compared to similar intersections within a specific jurisdiction.

3.2.3. Crash Rates by Roadway Mileage

On many local roadways traffic volume information is not available. In these cases, other data can be used to make comparisons on a jurisdiction's system. As an example, route length can be used to develop a more accurate comparison of segment crashes than a simple crash frequency. Crashes per mile of roadway allow for an improved analysis across the system by improving the ability to compare crashes on roadways of differing lengths.

10 It is possible that traffic counts on the roadways in this analysis are available from different years. In this case, a growth factor should be applied to the data (based on historic trends at that site) so that it will be consistent with the newest available counts.

For example, two roadways could have the same number of crashes but different roadway lengths. In this case, traffic volume data is not available. By factoring in a measure of exposure (in this case route length), the calculation indicates that County Road 220 may be a more promising roadway for safety treatments.

A "crashes per mile" rate for road segments is calculated as:

Where:

$$R = \frac{C}{N \times L}$$

R = Crashes per mile for the road segment expressed as crashes per each 1 mile of roadway per year.

C = Total number of crashes in the study period.

N = Number of years of data.

L = Length of the roadway segment in miles.

If County Road 220 was being assessed with the following values:

C = 12 crashes over the past 5 years on this segment.

N = 5 years of data.

L = 17 miles.

The resulting segment crash rate would be:

If Route B was being assessed with the following values:

$$R = \frac{12}{5 \times 17}$$ = 0.14 crashes per mile per year on County Road 220.

C = 12 crashes over the past 5 years on this segment.

N = 5 years of data.

L = 26 miles.

The resulting segment crash rate would be:

$$R = \frac{12}{5 \times 26}$$ = 0.09 crashes per mile per year on County Road 305.

The most appropriate use of any crash rate is as a relative value to compare the safety of a segment or intersection to similar locations in a specific jurisdiction. As shown in Table 4, the crash rate of County Road 220 is higher than County Road 305 due to its shorter route length.

Roadway	Crashes (C)	Years of Data (N)	Length of segment (L)	Crashes per mile per year
County Road 220	12	5	17 miles	0.14
County Road 305	12	5	26 miles	0.09

Table 4. Route Comparison by Crashes per Mile

It is important to note that only roadways with similar cross-sections (e.g., two-lane, four-lane undivided, four-lane divided expressways) should be compared by section length.

3.2.4. Using Crash Rates

Crash rates can be used to compare the crash experience of similar locations in the jurisdiction, region, and state.[11] One method of comparing intersections or segments within a jurisdiction is to develop an average crash rate for the network. By calculating crash rates at a number of locations (intersections and segments) in the region, a baseline average for the comparison of future targeted locations can be developed. If resources are not available for this type of analysis, another source could be State highway agencies. State agencies typically develop average crash rates for different types of intersections and roadway segment cross-sections for statewide analyses.

3.3. Crash Severity

Knowledge of the severity of crashes in a jurisdiction can assist practitioners in determining their safety needs. For example, the frequency of crashes at urban intersections may be higher than at rural curves, but in many cases the rural curve crashes are more severe. In addition, if two similar locations had the exact same number of crashes, it may be appropriate to select the location with more severe crashes to address first.

11 Similar is defined as similar in cross section, relatively similar traffic volumes (even if counts are unavailable), and roadway use (i.e., arterial, collector, local).

3.4. Identifying Potential Crashes

Local jurisdictions often do not have access to all the data desired for safety analysis. While much of the discussion focuses on examining a location's crash history, it is also important to identify locations on local rural roads that show potential for future crashes. Identifying these locations and proactively implementing safety improvements can potentially save lives.

Identifying and addressing locations with potential safety issues and no crash history can be accomplished in the following steps:

1. Identify intersections and roadway segments with a relatively higher number of crashes than average in the jurisdiction, if available.
2. Examine crash reports to determine crash attributes, including the contributing circumstances to each crash.
3. Identify common attributes in these crashes.
    - » Human factor examples include driver distraction, alcohol use, speeding, and non-use of safety belts.
    - » Infrastructure examples include roadway geometry, design features, and traffic volume.
4. Identify other intersections and roadway segments on the network that have similar roadway features. Examples may include curves, intersections with poor sight distance, passing zones, and high traffic volume.
    - » Even though they have yet to experience crashes, the roadway attributes of these locations are similar to intersections and segments that are already experiencing crashes. This can be indicative of a location with a potential for future crashes.

5. Conduct a field review to assess the locations and determine need.
6. Implement low-cost safety improvements, as appropriate, at identified locations to prevent future crashes.

Federal and State studies have identified specific roadway features that can contribute to crashes. Additionally, these studies have identified tested and proven safety countermeasures to address these issues. Local practitioners should review available literature when considering these types of safety improvements on their network. See Appendix B for a list of resources.

3.5. Data Analysis Tools

Most States have developed data analysis tools that electronically analyze crash data and incorporate other types of data (e.g., roadway information, traffic volumes) to conduct comprehensive analyses. Often these tools are shared with local jurisdictions. For additional information, a local practitioner should contact the State highway agencies or State Local Technical Assistance Program (LTAP) center. Resources related to data analysis tools and methods currently in use are listed in Appendix B.

4 Countermeasure Selection

The results of data analysis will provide a summary of the crash frequency and rates on the roadway network and can highlight associated crash factors. The next step is to determine the most appropriate treatments to install to reduce the number and severity of crashes.

4.1. Types of Countermeasure Implementation

To make the most informed decisions regarding countermeasure selection, an agency should begin with the crash history data when available. Common crash types, the severity of the crashes, and the location of those crashes are important attributes of crash data for the countermeasure selection process.

There are three main types of countermeasure implementation approaches – systematic, spot location and comprehensive. The quality and availability of data can assist in determining the most appropriate implementation approach. The spot location approach is the most dependent on data availability and quality. The systematic implementation of safety countermeasures may be the most effective approach for those roadways that lack comprehensive data. Systematically applying safety treatments based on factors other than crash location can prevent future crashes for locations that have yet to experience them.

If roadway characteristic information is known, systematic solutions can be installed effectively, even if there are gaps in the crash data. Analysis shows that, in some situations, a high proportion of crashes tend to occur at locations that share common geometric or operational elements.[12] Installing the same countermeasure at multiple locations (where appropriate) could be an effective strategy to improve safety.

4.1.1. Systematic Approach

The basis for the systematic approach is not on specific crash locations, but on crash types and proven low-cost safety countermeasures. In one application of the systematic approach, common crash types are determined and countermeasures are selected that address the specific types. The network is screened for locations experiencing those crash types or that have the potential for them to occur. Selected safety solutions are then installed systematically at identified locations.

12 Low-Cost Safety Enhancements for Stop-Controlled and Signalized Intersections, Federal Highway Administration, FHWA-SA-09-020, May 2009.

Another application of the systematic approach begins with the selection of low-cost, effective countermeasures to common traffic safety issues. Once strategies are identified, the crash data system is searched to find locations where the countermeasure can be cost-effectively deployed. Estimates of the impacts of implementation can be made in terms of deployment cost and the benefits measured in traffic crash reduction.

Benefits of the systematic approach may include:

- **Widespread effect.** The systematic approach can impact safety issues at a large number of locations on an entire local roadway network.
- **Crash Prevention.** Jurisdictions can address potential future crashes using this approach. Using predominant crash types with a high or moderate level of crashes, an agency can address locations that have not yet experienced these crash types, but have similar characteristics to locations with such crash histories.
- **Cost-effectiveness.** Implementing low-cost solutions across an entire system can be a more cost-effective approach to addressing system-wide safety.
- **Reduced data needs.** The systematic approach can be used without a detailed crash history, reducing data needs.

Drawbacks of the systematic approach may include:

- **Justifying improvements can be difficult.** Because there is not always a direct correlation between crash location history and recommended treatments, it can be difficult to justify improvements at locations without crash history. The systematic approach will rarely include a recommendation for a large-scale safety improvement at a single location. Since these are the types of projects that often garner attention from decision makers, the media, elected officials, and the general public, it can require additional effort from safety professionals to explain the systematic approach and its benefits to those groups.

4.1.2. Spot Location Approach

The spot location approach has typically been based on an analysis of crash location history. Due to the fact that some locations in a jurisdiction will likely have a significantly higher number of crashes than most of the others, it is important to identify those locations and treat them accordingly.

The benefits to the spot location approach may include:

- **Focus on Demonstrated Needs.** The spot location approach focuses directly on locations with a history of crashes.

Drawbacks of the spot location approach may include:

- **Assumption that the past equals the future.** This approach assumes locations with a history of crashes will continue to have the same number and type of crashes in the future, if not treated.
- **Minimal overall benefit.** This approach often focuses on specific locations with crash history. As a result, potential benefits are limited.

The spot location approach to traffic safety can be implemented in parallel with the systematic approach to provide a combination of safety treatments in a jurisdiction. In addition, the spot location approach could be applied to those locations that have had low cost countermeasures installed systematically, but continue to show a higher than average crash rate.

4.1.3. Comprehensive Approach

The comprehensive approach introduces the concept of the "4 Es of Safety":

- Engineering;
- Enforcement;
- Education; and
- Emergency Medical Services.

This approach recognizes that not all locations can be addressed solely by infrastructure improvements.

Some locations will be identified that have frequent driving violations for which targeted enforcement is an appropriate countermeasure. In general, human behavior issues (e.g., speeding, aggressive driving, failure to wear safety belts, driving while impaired) are a factor in a high percentage of crashes. When locations are identified that have reports and observations of these violations, coordination with the appropriate law enforcement agencies is needed to deploy visible targeted enforcement to reduce the potential for future driving violations and related crashes. Additionally, educational efforts should supplement enforcement to improve the effect of each.

Using the example of County Road 220, analysis showed that five of the 12 crashes involved alcohol on a weekend evening. In this case, the practitioner should coordinate with the local law enforcement agency to consider additional alcohol-focused enforcement on the weekends on this roadway.

4.2. Incorporating Roadway Characteristics

Countermeasure selection is a data-driven process, focused on not only crash history, but also on roadway elements to determine the appropriate strategies. Roadway configuration contributing to crashes is often recorded in the crash database and/or police reports. Through examination of the reports or through field reviews these can be identified and factored into the countermeasure selection process. For example, County Road 220 had 12 crashes in the past 5 years. Further study of the crash database indicated that eight of those 12 crashes occurred at intersections. With this information available, the practitioner can implement countermeasures that address safety issues at intersections on this route, and potentially at similar locations on other routes within the jurisdiction.

Additional information on data analysis for selecting countermeasures to be considered can be found in Appendix B.

4.3. Countermeasure Evaluation

It is important to evaluate traffic safety treatments after installation to determine their effectiveness. The effort that goes into conducting the assessment will help guide future decisions regarding safety treatment implementation.

A record of crash histories and countermeasure installations forms the foundation for assessing how well implemented strategies have performed. It is important to keep a current list of installed countermeasures with documented "when/where/why" information. Periodic assessments will provide the necessary information to make informed decisions on whether each countermeasure contributed to an increase in safety, whether the countermeasure could or should be installed at other locations, and which factors may have contributed to the strategy's success.

To perform the assessment it is necessary to collect the required information for a certain amount of time after strategies were deployed at the intersection. The time period varies, but should be no less than one full year (with 3 years preferred). The most important information is crash data before and after implementation. Other information required may consist of public input and complaints, police reports, and observations from maintenance crews.

It is important to keep the list of deployed strategies up to date since it will serve as a record of countermeasure history. By using this type of system, assessment dates can be scheduled to review the crashes and other pertinent information at locations where treatments have been installed.

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5 Case Studies

This section contains descriptions of programs that illustrate the methods and processes used by State, district, and county staff to collaborate on improving data access and methods for conducting data analysis. These programs illustrate how improvements can be made. More examples are included in the sources listed in Appendix B.

The examples are shared in increasing order of the complexity of the data analysis method. The first two are basic examples using relatively simple equations to analyze route segments and intersections by the number and severity of traffic crashes. The third example provides an intermediate level of analysis, including crash rates in the calculations. The final example is more advanced, incorporating methodology from the recently-published Highway Safety Manual (HSM).

Basic Example:
Analysis of Roadway Departure Crashes on Local Roads

Oregon DOT

Description
In 2010 the Oregon DOT and FHWA began a project to analyze roadway departure crashes on both State and local roads. The result of the study would be a Roadway Departure Safety Implementation Plan designed to reduce roadway departure crashes.

In Oregon, spot location data (by milepost or GPS coordinate) was available for crashes that occur on State-maintained routes. However, this level of detail was unavailable for crashes occurring on locally maintained roadways. Crashes could be located on a certain roadway, but not at a point on that roadway. At the time of the data analysis, neither traffic volume counts nor the length of each roadway were available for local roads.

Methodology (Basic)
Oregon faced two significant limitations to the ability to analyze their roadway departure crash data on the local system. First, the lack of specific location and roadway attribute information on local roads made it impossible to pinpoint specific curves or sections of roadway for treatment. Second, not having traffic counts or roadway lengths made it impossible to calculate crash rates.

Due to these limitations, it was necessary to focus instead on the available information. The local road crashes did have information on the contributing circumstances of the crash, including the following:

- Run off road right;
- Run off road left;
- Head-on; and
- Opposite direction sideswipe.

The crashes also included the following additional information:

- Occurrence on a curve or straight section;
- Wet, ice-covered, or snow-covered pavement; and
- Lighting conditions (Day/Night).

Oregon DOT and FHWA used this information to identify systematic treatments for local roads, including curve signing and delineation, rumble strips, and tree removal. Cost estimates were based on an average length of 10 miles for each local road, which, when applied over the system, provided a sufficient estimate for preliminary program planning.

Next Steps

The Oregon DOT will proceed with low-cost safety treatments on the identified roadways based on the type of roadway departure crashes that occurred on each local road. They will also seek to improve data availability, starting with determining the length of each local roadway. Future efforts include determining the location of local road crashes along the roadway by coding all crashes by latitude and longitude.

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Basic Example:
Data Analysis at the Regional Planning Level

Mid-Ohio Regional Planning Commission

Description

Crash data in Ohio often lack important information, such as accurate locations, safety belt use, and contributing crash factors. Inconsistent location reporting also has compromised the ability to direct safety resources to the most hazardous locations. Law enforcement officers often indicate crash location by noting the closest intersection or nearest point on the road centerline file rather than by latitude and longitude. As a result, the State's Strategic Highway Safety Plan (SHSP) identified traffic records as an area in need of improvement. The Mid-Ohio Regional Planning Commission (MORPC) took up the challenge to improve data collection by proposing an "Interagency Safety Partner Program" that would inform law enforcement of the need for high quality crash data and explain how these data are used to identify multidisciplinary transportation safety countermeasures.

MORPC partnered with local engineers, the Safe Communities program, the municipal court, and City of Columbus police to provide educational information regarding the current crash reporting process and discuss the balance between the high demands of reporting and the limited resources dedicated to it. Workshops were held with those groups to provide practical examples of work products that utilize crash statistics, which helped officers understand why information in crash reports is crucial for improving transportation safety. The RPC also explained how road safety improvements would reduce traffic crashes and potentially free up law enforcement resources. One key areas addressed was the lack of accurate crash data with regard to crash locations, crash types, and behavioral issues.

To address this issue on the state level, the Department of Public Safety developed an electronic crash reporting software that is made available for free to every law enforcement agency in Ohio, along with free training on how to use it. Currently about 25 percent of crashes are reported electronically by 150 agencies.

Methodology (Basic)

The data are used to create a list of Ohio's high crash locations which are prioritized for consideration for treatments to reduce crashes, injuries, and fatalities. The methodology used is summarized below:

MORPC's Ranking Steps

1) Determine top 100 intersections by frequency via GIS;
2) Calculate severity index and crash rate for each;
3) Provide ranks for each of these 3 variables, with 1 = worst location;
4) Add ranks to determine overall rank;
5) The intersection with the overall lowest score is considered the worst.

Crash frequency is defined as the total number of crashes occurring at each intersection.

$$Crash\ frequency = N$$

N = Total number of crashes at the particular location

Crash severity index gives an indication of the crash severity at each intersection. Obviously, fatal and injury crashes are more severe than property-damage only (PDO) crashes and are weighted accordingly in the following equation:

$$Severity\ Index = \frac{12 * F + 3 * I + 1 * PDO}{N}$$

F = Total number of fatal crashes at the particular location

I = Total number of injury crashes at the particular location

N = Total number of crashes at the particular location

Crash rate *(per million entering vehicles)* takes into account the total number of crashes compared to the average traffic volume entering the intersection.

$$Crash\ Rate = \frac{N}{(\sum ADT) * 3\ years * 365\ days * 10^{-6}}$$

∑ADT = Sum of average daily traffic entering the intersection

N = Total number of crashes at the particular location

Figure 5. MORPC's Ranking Steps.

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Intermediate Example:
High Risk Rural Roads Methodology with Less-than-perfect Data

New Jersey

Description

The High Risk Rural Roads Program (HRRRP) is an initiative of the Highway Safety Improvement Program (HSIP) in direct response to the unique challenges faced by local, rural road owners. Through this program, money is set aside for each state to construct and make operational improvements on high risk rural roads. In New Jersey, utilizing the authorized budget allocations has been difficult. The data necessary to calculate traditional crash rates are not available for local, rural roads, so the State could not determine what segments qualified under this program.

Methodology (Intermediate)

New Jersey has many sources of good information, but it is incomplete for more advanced analysis. For example, there is a standardized crash report form that is compliant with the Model Minimum Uniform Crash Criteria (MMUCC)[13] with an average 300,000 reportable crashes per year, but only 60 to 70 percent of the database entries have a map location. The state also has a roadway database (straight line diagrams) that is nearly compliant with the Model Inventory of Roadway Elements (MIRE)[14], but most roads below the State level are missing traffic volume data. This makes calculation of traditional crash rates on rural roads difficult.

In 2007, the Transportation Safety Resource Center (TSRC) was asked to help brainstorm a way to determine segments that would qualify under the HRRRP funding given the State's data limitations. TSRC developed an initial procedure that used functional class, speed limit, number of lanes, presence of shoulder, and crash locations. The output

13 The MMUCC Guideline presents a model minimum set of uniform data elements for describing a traffic crash. States are encouraged to adopt as many recommended MMUCC data elements as possible when they next update their State's official accident report. Additional information is available at http://www.mmucc.us.

14 The MIRE Guideline includes a listing of roadway inventory and traffic elements critical to safety management of all streets and highways across the country. By collecting roadway elements, a highway agency will have a more complete set of the safety and operations components of the streets and highways it owns and maintains. Additional information is available at http://www.mireinfo.org.

included segments labeled as high risk based on crash rates. In 2010, that procedure was updated to include crash severity and trending over six years of crash data. The following is the methodology used in New Jersey and approved by the FHWA Division office:

1. *Divide all rural roads into similar cross-sections based on functional classification, number of lanes, speed limit, and presence of shoulders. This was done by the Metropolitan Planning Organization (MPO) for the State of New Jersey since three MPOs cover the entire state.*
    a. Creating similar cross sections negates the need for AADT data since similar cross sections are assumed to have similar volumes of traffic. This assumption ameliorated the lack of AADT issue.
2. Individual crash rates were then calculated for each segment using the following formula:

$$\mathbf{CR_{segment}} = \frac{\mathbf{5(F) + 4(II) + 3(MI) + 2(I) + PDO}}{\mathbf{L}}$$

Where:

CR = Crash rate.

F = Number of Fatal crashes.

II = Number of Incapacitating Injury crashes.

MI = Number of Moderate Injury crashes.

I = Number of Injury crashes.

PDO = Number of Property Damage Only crashes.

L = Length of segment in miles.

The above elements were taken from "Occupant Physical Condition" on New Jersey's crash report form – the most severe value was assigned to the entire crash. If occupant physical condition was missing, the severity value of the crash was assigned (Fatal = F, Injury = I, PDO = PDO). In the case for injury, the lowest injury value was used; fatal and property damage only crashes remained the same.

3. Next, an aggregate average for each cross-section was calculated. For example, all of the segments with the same functional class, speed limit, number of lanes and presence of shoulder were averaged to find a MPO average crash rate for that cross-section.

$$CR_{MPO} = \frac{CR_1 + CR_2 + \ldots CR\chi}{\chi}$$

Functional Class	# Lanes	Speed	Shoulder	Crash Rate	Fatal	Injury	PDO
7	2	30	0	16.318	1	12	26
7	2	30	1	9.524	0	1	3
7	2	35	0	7.965	0	4	5
7	2	35	1	5.392	0	1	10
7	2	40	0	9.355	0	8	22
7	2	40	1	7.695	0	18	62
7	2	45	0	7.611	2	29	79
7	2	45	1	11.869	2	104	219

Table 5. Partial listing of MPO crash rate averages by cross section

4. Lastly, individual segment rates were compared to the corresponding MPO average rate. If the individual rate was higher than the average rate, it was flagged as high risk. If it was lower, it was not. From this, an output of the high risk rural road segments was provided to each MPO to implement as they saw fit.

IF $CR_1 > CR_{MPO}$, *then* CR_1 = *high risk.*

IF $CR_1 < CR_{MPO}$, *then* $CR_1 \neq$ *high risk.*

Note: This can be done two ways depending upon available data:

1) The above procedure can be done for a three (3) year period.

2) Or, the above can be done to six (6) years, using the first three (3) years as 'before' and the last three (3) years as 'after'. This yields the following breakdown of high risk segments:

a. Segments that were high risk before and after – worsening condition.
b. Segments that were only high risk after – worsening condition.
c. Segments that were high risk before and after – improving condition.

The benefit to doing this is to add information for prioritization purposes – making of short lists.

Next Steps

In order to proceed, it was necessary to gain approval from the FHWA Division Office for this new process. Once approved, an output list for each MPO was produced that included all roadway segments in their individual regions that were considered high risk. From there, each MPO was responsible for developing a short list that would be submitted for HRRR funds. An example of this success can be found in the NJTPA case study listed in FHWA's report entitled Implementing the High Risk Rural Roads Program, FHWA-SA-10-012.[15]

Contact

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15 FHWA-SA-10-012 can be accessed at http://safety.fhwa.dot.gov/local_rural/training/fhwasa10012.

Advanced Example: Predictive Method Analysis using the Highway Safety Manual[16]

Missoula, Montana

Background, Issues, and Objectives:

The Russell Street corridor in Missoula, Montana, is 1.5 miles long, connecting residential and industrial uses across a river to the downtown business district. It is an important vehicle and bicycle commuter route. The average daily traffic volume along this route ranges from 20,000 to 25,000 vehicles per day. The corridor has received funding for major geometric improvements. This study was conducted to evaluate the traffic operations and safety impacts of various design alternatives for the entire corridor. Several options were considered as part of the project, including converting the 2-3 lane roadway to a five-lane road, or converting the roadway to a three-lane road. Each case would include a mix of traffic signals and roundabouts at the intersections. This project example demonstrates the quantitative safety analysis of two alternatives on a small portion of the corridor.

Data Requirements:

Segments

- Segment Length (miles).
- Through Lanes (number).
- Median Type (divided/undivided).
- Median Width (feet).
- On-Street Parking (yes/no).
- Fixed Object Density (obj/mile).
- Average Offset of Fixed Objects (feet).
- Roadway Lighting (yes/no).
- Speed Limit (mph).
- Traffic Volume (veh/day).
- Number/Types of Driveways.

Intersections

- Number of Intersection Legs (number).
- Traffic Control (signal, stop, roundabout).
- Left Turn Lanes and Phasing (protected, permitted, protected/permitted).
- Right Turn Lanes and Control of Right Turn (permitted on red, prohibited on red).
- Lighting (yes/no).
- Maximum Number of Traffic Lanes. Crossed by Pedestrians (number).
- Nearby Bus Stops, Schools, and Alcohol Sales Establishments (number).
- Entering Traffic Volumes (veh/day).
- Pedestrian Activity (yes/no).

16 Adapted from "An Introduction to the Highway Safety Manual," AASHTO, 2010.

Analysis Methodology Overview:
The crash frequency for each segment and intersection is predicted using an iterative 18-step method in Highway Safety Manual - Chapter 12: Urban/Suburban Arterials. In summary, this method consists of initially calculating multiple- and single-vehicle fatal/injury and property damage only crashes; these values are added to obtain base predicted vehicle crashes. The next step is to adjust the base predicted vehicle crashes with crash modification factors (CMFs) based on the roadway characteristics. Finally, this value is added to predicted bicycle and pedestrian crashes. If a calibration factor was available, or historical data was available to apply the Empirical Bayes method, these two steps would be included. The base equation and a sample calculation using the base equation for prediced average crash frequency is shown below. Sample calculations are shown for the Main Street/3rd Street intersection no-build conditions.

$$N_{bi} = N_{spf\,int} \times (CMF_{1i} \times CMF_{2i} \times \ldots CMF_{6i}) \times C$$

$$N_{bi} = 12.97 \times (0.66 \times 0.96 \times 0.88 \times 1.00 \times 0.91 \times 1.00) = 6.63 \text{ crashes/year}.$$

Where:

N_{bi} = *Predicted average crash frequency for an intersection.*
$N_{spf\,int}$ = *Predicted average crash frequency for base conditions (Nspf int = 12.97, see below).*

$CMF_{1i} - CMF_{6i}$ = *Crash modification factors for left-turn lanes (CMF_{1i} = 0.66), left-turn phasing (CMF_{2i} = 0.96), right-turn lanes (CMF_{3i} = 0.88), right-turn-on-red (CMF_{4i} = 1.00), lighting (CMF_{5i} = 0.91), and red light camera (CMF_{6i} = 1.00).*

C = Calibration factor (C = 1.00).

Note, as this is a multi-step process there are multiple equations that are used to calculate $N_{spf\,int}$, these steps are not detailed in this example. A sample equation used in that process for the Main Street/3rd Street intersection no-build condition is illustrated below. Results are shown in Table 6.

$$N'_{bimv(FI)} = exp(a + b \times ln(AADT_{maj}) + c \times ln(AADT_{min}))$$

$$N'_{bimv(FI)} = exp(-13.14 + 1.18 \times ln(33{,}910) + 0.22 \times ln(25{,}790)) = 4.07\ crashes/year.$$

Where:

$N'_{bimv(FI)}$ = *Multiple vehicle intersection fatal/injury crashes.*

a, b, and c = Regression coefficients (-13.14, 1.18, and 0.22 for 4-leg signalized intersections).

$AADT_{maj}$ = *Annual average daily traffic on major road (33,910).*

$AADT_{min}$ = *Annual average daily traffic on minor road (25,790).*

Results:

- Changes in crash frequencies are quantified and compared to the no-build scenario, as shown in Table 6. The resulting forecast crash frequencies for Alternatives 1 and 2, 15.7 and 25.8 crashes respectively, are compared to the no-build crash frequency, 29.6. The difference is quantified as a percentage.
- The change in crash frequency can now be considered as one of the trade-offs similar to traffic operations, environmental impacts and pedestrian and bicycle mobility.

	2035 Forecast Crash Frequency (Crashes/Year[1])								
	No-Build			Alternative 1 (Mix 3 and 5-Lane)			Alternative 2 (5-Lane)		
Intersection/ Segment[2]	Facility	AADT[4]	Crashes/ Year	Facility	AADT[4]	Crashes/ Year	Facility	AADT[4]	Crashes/ Year
Int: Main & Oak	Stop	35,730/ 3,650	3.26	Roundabout	35,730/ 3,650	1.67	Signal	39,080/ 5,280	6.93
Seg: Oak to 3rd St.	3-Lane	34,580	8.30	3-Lane	34,580	5.74	5-Lane	38,150	9.32
Int: Main & 3rd	Signal	33,910/ 25,790	6.63	Roundabout	33,910/ 25,790	3.43	Roundabout	36,900/ 29,400	3.86
Seg: 3rd to 5th	5-Lane	33,270	5.05	5-Lane	33,270	1.51	5-Lane	37,310	1.74
Int: Main & 5th	Signal	33,200/ 5,940	6.40	Roundabout	33,200/ 5,940	3.32	Roundabout	37,860/ 7,230	3.99
UNCALIBRATED Total Prediction	29.6			15.7			25.8		
Change Relative to No-Build				47% Decrease			13% Decrease[3]		

1 Total Crashes Per Year

2 For the purposes of presenting the results, crashes estimated for minor street intersections along the two segments (Oak St. to 3rd St. and 3rd St. to 5th St.) were added into the segment crash totals.

3 Under the 5-lane scenario, the corridor has more capacity, therefore more regional traffic is drawn to this corridor. The decrease shown is for overall crashes, so a normalized analysis would show a slightly greater decrease.

4 Major Street AADT/Minor Street AADT for intersections

Table 6. Forecast Crash Frequency for Russell Street Project Alternatives

6. Summary

Highway safety decisions are generally made based on data. Regulations for safety-related Federal funding and safety plan development require data for the decision making process. Recent national initiatives, such as State-level Strategic Highway Safety Plans (SHSPs) and the High Risk Rural Roads Program (HRRRP) have contributed to improved rural road safety by fostering the implementation of effective countermeasures. One aspect of this Federal support is an emphasis on data-driven processes to help jurisdictions determine the best course of action for making safety decisions on local road networks. For example, the HRRRP requires that rural major collectors, minor collectors, and local roads exhibit a history of crashes above the statewide average or are expected to experience a higher-than-average number of crashes in the future to be eligible for Federal funding.

At the local level, these data requirements can seem daunting, particularly as they relate to funding and staff time needed for data collection, analyses, and overall assessments of safety improvements. It is important to note that a data-supported approach can increase the effectiveness of the distribution of limited funds to improve safety on local rural roads.

A comprehensive set of crash data is desirable for effective roadway analysis and countermeasure selection, but a lack of such databases should not deter road safety practitioners from addressing safety issues on their roadways. The types of information that should be collected for roadway safety analysis include crash data (location, type, severity, roadway conditions, weather, time of day, day of week, month), exposure, and roadway elements. The primary sources of these data are local law enforcement crash reports, emergency medical service information, and State and Federal databases. In addition, observational data often serves as an important supplement to formal data sources.

Collected data should be analyzed to identify locations with safety issues or locations with potential for safety issues, and to select countermeasures to improve safety. Depending on the completeness, accuracy, and timeliness of available data, a local jurisdiction can analyze that information in a number of ways. Analyses can range

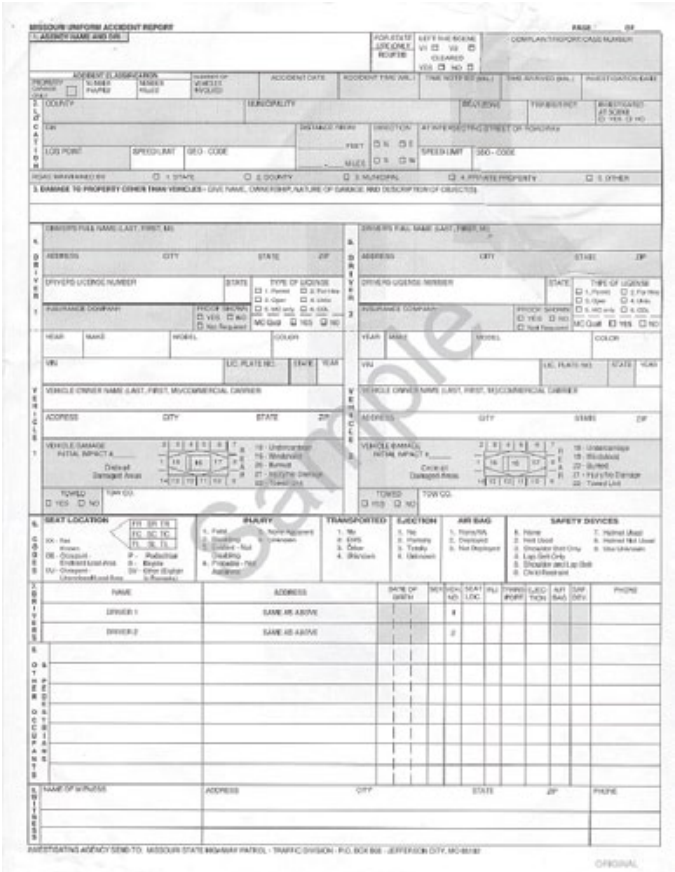
from simple cluster analysis to more advanced calculations of crash rates, determination of crashes by type and severity, and analysis of combinations of contributing factors and roadway elements. By using a data-driven approach, local practitioners will have the information to make informed decisions about the type and location of strategies to optimize effectiveness. Many states have developed data analysis tools; these are often shared with local practitioners to assist their local road safety programs.

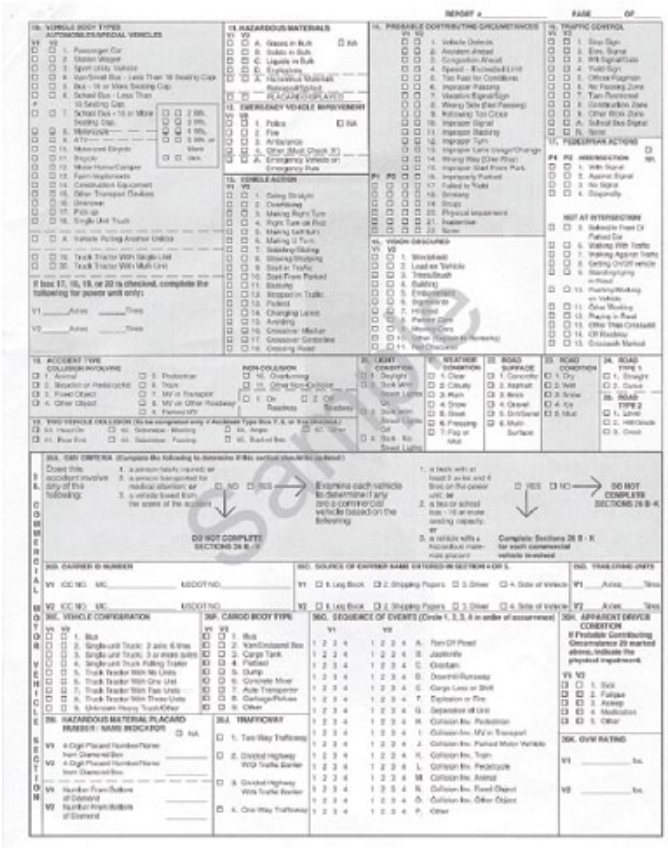
Crash data, when available, can assist practitioners in making the most informed decisions regarding countermeasure selection. Common crash types, the severity of the crashes, and the location of those crashes are some important attributes of crash data for the countermeasure selection process. There are three main types of countermeasure implementation approaches – spot location, systematic, and comprehensive. The quality and availability of data can assist in determining the implementation approach undertaken. The spot location approach is the most dependent on data availability and quality. The systematic implementation of safety countermeasures may be the most effective approach for those roadways that lack comprehensive data. Analysis shows a high proportion of crashes tend to occur at locations that share common geometric or operational elements. Installing the same countermeasure at multiple locations, where appropriate, could be an effective strategy to improve safety on the overall network.

The effectiveness of specific road safety countermeasures is important to an overall safety program at any level, due to resource limitations of highway agencies. The assessment will help guide future decisions regarding the selection and implementation of safety countermeasures. Looking at the number and type of crashes before and after the implementation of a safety strategy will provide a basic effectiveness of the strategy. However, to understand the full effect, changes in traffic volumes and roadway attributes should be considered.

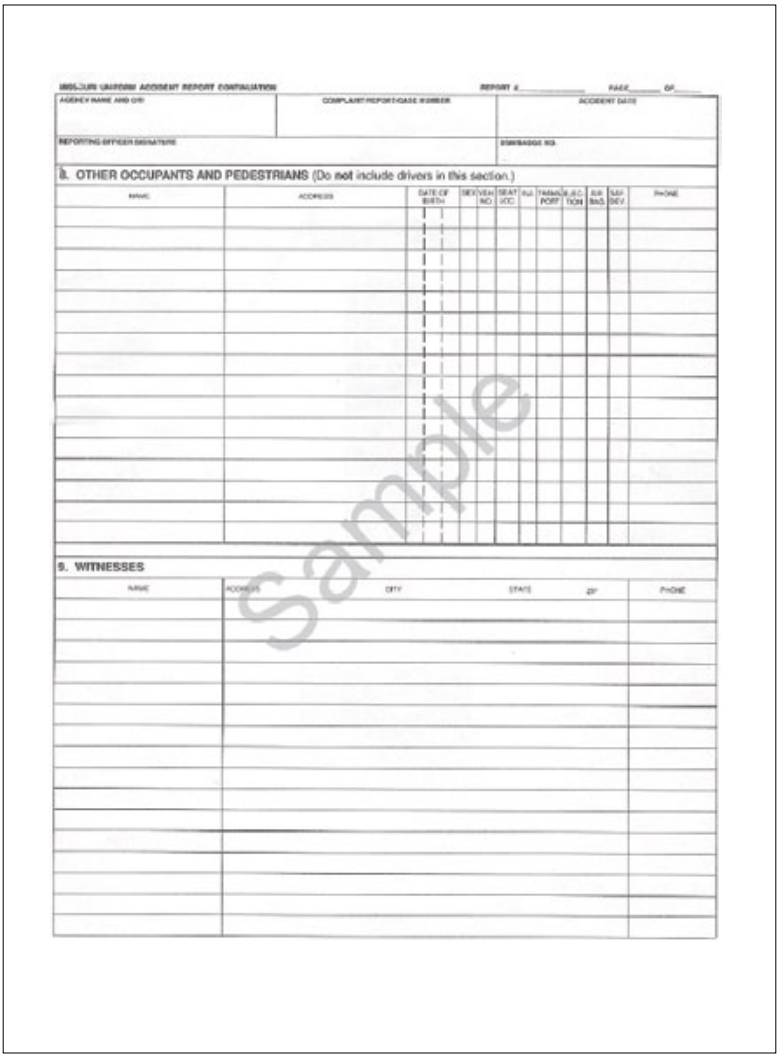
Local highway agencies have unique responsibilities and challenges related to the safety of their roadway system. By beginning any traffic safety effort by first looking at the data, those agencies will be in a better position to address their highway safety needs.

Appendix A. State Crash Report Example






REPORT #
PAGE
OF
V1
V2
V3
V4
If Department elects to use the I.T.E. symbols, refer to Appendix A in the Missouri Uniform Accident Report Preparation Manual.
INDICATE ROAD NAMES
DIAGRAM NOT TO SCALE
Sample
PHOTOS
RECONSTRUCTION



UNIFORM TRAFFIC ACCIDENT REPORT CONTINUATION — REPORT #_____ PAGE_____ OF_____

AGENCY NAME AND ORI	COMPLAINT/REPORT/CASE NUMBER	ACCIDENT DATE
REPORTING OFFICER SIGNATURE		STAR/BADGE NO.

8. OTHER OCCUPANTS AND PEDESTRIANS (Do **not** include drivers in this section.)

NAME	ADDRESS	DATE OF BIRTH	SEX	VEH NO.	SEAT LOC	INJ	TRANS PORT	EJECTION	AIR BAG	SAF DEV	PHONE

9. WITNESSES

NAME	ADDRESS	CITY	STATE	ZIP	PHONE

Appendix B. Resources

Analytical Tools/Methods

Federal Highway Administration, *Highway Safety Facts and Statistics website*. Available at *http://safety.fhwa.dot.gov/facts_stats/*.

Green, E.R. and Agent, K.R., *Crash Rates at Intersections*, University of Kentucky College of Engineering, Kentucky Transportation Center. Research Report KTC-03-21/SPR258-03-2I (2003). Available at *http://www.ktc.uky.edu/Reports/KTC_03_21_SPR258_03_2I.pdf*.

Gross, F. and Yunk, K. U.S. "Using CRFs to Improve Highway Safety." Department of Transportation, Federal Highway Administration, *Public Roads*, May/June 2009, pp. 26-31. Available at *http://www.fhwa.dot.gov/publications/publicroads/09june/04.cfm*.

Federal Highway Administration, "Desktop Reference for Crash Reduction Factors." (Washington, DC: 2007). Available at *http://www.ite.org/safety/issuebriefs/Desktop%20Reference%20Complete.pdf*.

Federal Highway Administration, *Crash Reduction Factors website*. Available at *http://safety.fhwa.dot.gov/tools/crf/*.

Federal Highway Administration, Crash Modifications Factors Clearinghouse website. Available at *http://www.cmfclearinghouse.org/*.

NCHRP Report 500 Series: Guide for Implementation of the AASHTO Strategic Highway Safety Plan

Relevant information is assembled into single concise volumes, each pertaining to specific types of highway crashes or contributing factors. Data-focused volumes include:

"Volume 19: A Guide for Collecting and Analyzing Safety Highway Safety Data." *http://safety.transportation.org/guides.aspx?cid=40*.

"Volume 21: Safety Data and Analysis in Developing Emphasis Area Plans" *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_500v21.pdf*.

"NCHRP – Synthesis 321: Roadway Safety Tools for Local Agencies: A Synthesis of Highway Practice" *http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_321.pdf*.

Databases

National Highway Traffic Safety Administration, Center for Statistics and Analysis, *Fatality Analysis Reporting System (FARS)*. Available at *http://www-fars.nhtsa.dot.gov/Main/index.aspx*.

National Highway Traffic Safety Administration, *Crash Outcome Data Evaluation System (CODES)*. Available at *http://www.nhtsa.gov/Data/State+Data+Program+&+CODES*.

State and Local Programs and Initiatives

Iowa Department of Transportation. Crash Analysis. Accessed at: *http://www.intrans.iastate.edu/pubs/traffichandbook/5CrashAnalysis.pdf*.

For More Information

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Federal Highway Administration
1200 New Jersey Ave, SE
Washington, DC 20590-9898
http://safety.fhwa.dot.gov

FHWA-SA-11-10