Highway Safety Manual Lite

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Some of the Questions We Will Answer...

• What is the HSM (and what it is not)?
• Why do we need an HSM?
• What is the content within the HSM?
• How do we apply the HSM?
What are the safety issues and challenges specific to local agencies?
Self Introductions

- Name
- Employer
- What do you do?
- How is safety related to your job?
- Knowledge of the Highway Safety Manual (HSM)?
HSM Lite: Common Sense Safety Measures
HSM Lite – The Skinny

• Intended to assist government agencies with a discussion about roadway safety within their jurisdictions - who may or may not have a safety program and who may or may not have a strong sense of their crash data, traffic volumes or inventory of roadway characteristics.

• The release of the HSM, was seen as an opportunity to engage local government agencies in safety on the front end of the State DOT’s HSM implementation process. And even though there is a higher potential for a lack of safety and roadway data for many local jurisdictions, the Crash Modification Factors for various roadway features (Part C) and other safety countermeasures (Part D) provide high quality “take aways” from the Highway Safety Manual and the Crash Modification Clearinghouse that, in many cases, can be implemented as low cost safety countermeasures.

• HSM Lite is intended to convey this message in a straightforward manner.

• Common sense safety measures should be done as a healthy balance between reacting to existing safety problems/locations and proactively implementing treatments that are known to provide safer roadways and intersections.
## Fatal Crash Statistics (2009 Preliminary)

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>Delaware</th>
<th>Rhode Island</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fatalities</td>
<td>33,808</td>
<td>116</td>
<td>83</td>
</tr>
<tr>
<td>Fatality Rate (HMVMT)</td>
<td>1.14</td>
<td>1.28</td>
<td>1.01</td>
</tr>
<tr>
<td>Population</td>
<td>311,591,917</td>
<td>907,000</td>
<td>1,051,302</td>
</tr>
<tr>
<td>Roadway Departure</td>
<td>18,087 (53%)</td>
<td>56 (48%)</td>
<td>38 (46%)</td>
</tr>
<tr>
<td>Intersection</td>
<td>7,043 (21%)</td>
<td>26 (22%)</td>
<td>16 (19%)</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>4,092 (12%)</td>
<td>15 (13%)</td>
<td>16 (19%)</td>
</tr>
<tr>
<td>Speeding Related</td>
<td>10,591 (31%)</td>
<td>44 (38%)</td>
<td>28 (34%)</td>
</tr>
<tr>
<td>Alcohol Related</td>
<td>10,848 (32%)</td>
<td>45 (39%)</td>
<td>34 (41%)</td>
</tr>
<tr>
<td>Rural Road Fatality Rate</td>
<td>1.98</td>
<td>2.48</td>
<td>2.74</td>
</tr>
<tr>
<td>Rural Road Fatality Rate</td>
<td>0.72</td>
<td>0.76</td>
<td>0.80</td>
</tr>
<tr>
<td>Urban Road Fatality Rate</td>
<td>0.72</td>
<td>0.76</td>
<td>0.80</td>
</tr>
</tbody>
</table>
Highway Safety Philosophy

• There is no such thing as “absolute safety”
  - There is safety “risk” in all highway facilities

• Agencies try to operate and improve roads to the highest level that funding limitations allow
  - Safety risk is also due to factors over which transportation agencies have little control
    - User behavior
    - Environmental conditions
Formidable Safety Challenges

- Fatal and serious injury crashes are geographically dispersed making traditional “hot-spot” treatment approaches less effective.
- Finding effective “systematic” treatments with ever tighter fiscal constraints.
Reactive vs Proactive Approach to Safety

• Reactive – an agency “reacts” to a crash or history of crashes and implements a countermeasure

• Proactive – an agency seeks out locations that may be a higher risk (i.e. rural roads, curves, intersections) for crashes implements countermeasures to prevent crashes
Safety Trade-Offs?

What Do You Do?

Safety

Public Opinion
Costs
Capacity
Environment
Right-of-Way
“Road safety management is in transition. The transition is from action based on experience, intuition, judgment, and tradition, to action based on empirical evidence, science, and technology...”
The Highway Safety Manual...

- Provides a synthesis of validated highway safety research
- Facilitates explicit consideration of safety throughout the project development process
- Provides analytical tools for predicting the impact of decisions on road safety
- Provides a set of tools for Prediction of Crash Frequency and for Analysis of safety
The HSM describes the mathematical relationships for safety performance based upon exposure and roadway conditions.

The HSM is an analysis tool only; just like the HCM.

The HSM does not establish a legal standard of care.

The HSM does not create a public duty.

The HSM does not set any requirements or mandates, or tell you what to do.

The HSM does not contain “Warrants”, “Standards” nor “Best Practice” guidance.

The HSM does not supersede other publications that do.

HSM is like the Highway Capacity Manual

HSM is not Like the MUTCD & Green Book
Legal Context

Use is Protected Under Federal Law 23 USC Section 409: Discovery and admission as evidence of certain reports and surveys

The HSM was reviewed by the AASHTO Subcommittee on Legal Affairs and the TRB Committee on Tort Liability and Risk Management
Highway Safety has Two Dimensions

Nominal Safety
- Standards Compliance

Substantive Safety
- Expected or Actual Crash Frequency and Severity
Unlike Nominal Safety, Substantive Safety is a Continuum

Meeting standards does not necessarily make a highway safe
Substantive Safety may Vary when Nominal Safety Does Not

Existing Conditions

Alternative 1

Alternative 2

Alternative 3
Highway Safety Manual Organization

Part A: Introduction & Fundamentals

Part B: Safety Management Process

Part C: Predictive Methods

Part D: Crash Modification Factors
Knowledge Building

- Internal staff, consultants, and FLMA partners
- Safety partners (law enforcement, medical)
- External stakeholders
- General public
- Elected officials
Chapter 1 – Relating the HSM to the Project Development Process

Chapters 4 through 8 (Part B) can be used to identify locations most likely to experience crash reductions with improvements, diagnose individual sites, select the corresponding countermeasures, and conduct an economic evaluation to prioritize projects.

Chapters 5 through 7 (Part B) can be used to diagnose crash frequency and severity, select the countermeasures, and conduct an economic evaluation. During this process, Part D can be used to compare the effect on crash frequency of different design alternatives, and Part C can be used to predict future performance of an existing facility.
Chapter 1 – Relating the HSM to the Project Development Process

Chapters 6 and 7 (Part B) can be used for the selection and economic evaluation of countermeasures. During this process, Part D can be used to compare the effect on crash frequency of different design alternatives, and Part C can be used to predict future performance.

Chapters 5 through 7 (Part B) along with Part D can be used to monitor the crash frequency and severity for an existing roadway network, identify countermeasures to reduce crash frequency and severity, select countermeasures, and conduct an economic evaluation.

Chapter 9 (Part B) can be used to evaluate the effect of the countermeasures on crash frequency and severity and can contribute to the implementation of safety policy for future system planning.
Chapter 2 - Human Factors

- Role of Human Factors in Road Safety
- Driving Task Model
- Driver Characteristics and Limitations
- Impacts of Road Design on the Driver
Chapter 2 - Contributing Crash Factors

- Judgment errors
- Distractions
- Information overload
- Driver expectation violations
- Rules of the road violations
Driver Limitations:
► Perceive 2 or more events per second
► Make 1 to 3 decisions per second
► Take 30 to 120 actions per minute
► Commit at least one error every 2 minutes
► Are Involved in a hazardous situation every 2 hours
► Have 1 or 2 near collisions per month
► Average 1 crash every 6 years
Chapter 2 - Positive Guidance

**Primacy**
- Which information is the most important?

**Spreading**
- Provide information in small & manageable chunks

**Coding**
- Uniform traffic control devices – predictable shapes and colors

**Redundancy**
- Say the same thing in different ways
Clarify and Simplify Examples
Chapter 3 - Fundamentals

• Introduces basic concepts for understanding
  • Roadway Safety Management Techniques
  • Crash estimation methods
• ‘Crash Frequency’ (not rate)
• KABCO (Crash severity scale)
• ‘Safety Performance Functions’
• ‘Crash Modification Factors’
• ‘Standard Error’
• ‘Regression to the Mean’
• ‘Empirical Bayes (EB)’ Procedures
HSM Vol 1 (Part B) Road Safety Management Process

Part A

Network Screening (Ch. 4)

Part B

Diagnosis and Countermeasure Selection (Ch. 5 & 6)

Part C

Economic Appraisal and Prioritization (Ch. 7 & 8)

Part D

Safety Effectiveness Evaluation (Ch. 9)
Network screening is a process for reviewing a transportation network to identify and rank sites from most likely to least likely to realize a reduction in crash frequency with implementation of a countermeasure.

Determining the Network Screening Focus

Question
A State DOT has received a grant of funds for installing rumble strips on rural two-lane highways. How could State DOT staff screen their network to identify the best sites for installing the rumble strips?

Answer
State DOT staff would want to identify those sites that can possibly be improved by installing rumble strips. Therefore, assuming run-off-the-road crashes respond to rumble strips, staff would select a method that provides a ranking of sites with more run-off-the-road crashes than expected for sites with similar characteristics. The State DOT analysis would focus on only a subset of the total crash database—run-off-the-road crashes.
Chapter 5 - Diagnosis

Evaluating crash data and field conditions to identify crash patterns using:

• Crash data
• Historic site data
• Field conditions
• Other information
• How often do you look at crash data?
• How often do you look at crash diagrams?
• How often do you look at police/crash reports?
What can we Learn from a Crash Diagram?

Crash Summary
- Fatal: 0
- Injury: 4
- PDO: 10
- TOTAL: 14

LEGEND
Symbols and associated descriptions are shown in Figure 5-4.

Adapted from ITE Manual of Transportation Engineering Studies (4)
Figure 5-3. Example of an Intersection Collision Diagram
Chapter 6 – Select Countermeasures

• Identify contributing factors of crashes at a site
• Identify and select associated countermeasures to reduce crash frequency
Chapter 6 - 6.2.2 Contributing Factors for Consideration

Crashes on Roadway Segments

- Run-off-the-road
  - Inadequate lane width
  - Slippery pavement
  - Inadequate median width
  - Inadequate maintenance
  - Inadequate roadway shoulders
  - Poor delineation
  - Poor visibility
  - Excessive speed

Crashes at Signals

- Right-angle
  - Poor visibility of signals
  - Inadequate signal timing
  - Excessive speed
  - Slippery pavement
  - Inadequate sight distance
  - Drivers running red light
Chapter 7 – Economic Appraisal

• Evaluate benefits and costs of countermeasures
• Identify projects that are:
  • Cost-effective
  • Economically justified
Chapter 7 - Economic Appraisal Process

Figure 7-2. Economic Appraisal Process
**Chapter 7 - Societal Crash Cost Estimates by Crash Severity**

**CRASH SEVERITY LEVEL**

- **PDO (O)**: $7,400
- **Possible Injury (c)**: $44,900
- **Fatal & Injury (KAB)**: $158,200
- **Evident (B)**: $79,000
- **Disabling (A)**: $216,000
- **Fatal (K)**: $408,900

**COMPREHENSIVE CRASH COST**

$4,008,900
Chapter 8 - Prioritize Projects

- Evaluate economically justified improvements
  - At specific sites
  - Across multiple sites
- Identify a set of improvement projects to meet objectives
  - Cost
  - Mobility
  - Environmental impacts
## Chapter 8 - Prioritize Projects Example

### Table 8-2. Intersections and Roadway Segments Selected for Further Review

<table>
<thead>
<tr>
<th>Intersections</th>
<th>Traffic Control</th>
<th>Number of Approaches</th>
<th>Major AADT</th>
<th>Minor AADT</th>
<th>Urban/Rural</th>
<th>Crash Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>TWSC</td>
<td>4</td>
<td>22,100</td>
<td>1,650</td>
<td>U</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>TWSC</td>
<td>4</td>
<td>40,500</td>
<td>1,200</td>
<td>U</td>
<td>11</td>
</tr>
<tr>
<td>11</td>
<td>Signal</td>
<td>4</td>
<td>42,000</td>
<td>1,950</td>
<td>U</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>Signal</td>
<td>4</td>
<td>46,000</td>
<td>18,500</td>
<td>U</td>
<td>10</td>
</tr>
</tbody>
</table>

### Table 8-3. Summary of Countermeasure, Crash Reduction, and Cost Estimates for Selected Intersections and Roadway Segments

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Countermeasure</th>
<th>Present Value of Crash Reduction</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Single-Lane Roundabout</td>
<td>$33,437,850</td>
<td>$695,000</td>
</tr>
<tr>
<td>7</td>
<td>Add Right-Turn Lane</td>
<td>$1,200,000</td>
<td>$200,000</td>
</tr>
<tr>
<td>11</td>
<td>Add Protected Left-Turn Lane</td>
<td>$1,400,000</td>
<td>$230,000</td>
</tr>
<tr>
<td>12</td>
<td>Install Red Light Cameras</td>
<td>$1,800,000</td>
<td>$100,000</td>
</tr>
</tbody>
</table>

### Table 8-5. Cost-Effectiveness Evaluation

<table>
<thead>
<tr>
<th>Project</th>
<th>Total</th>
<th>Cost</th>
<th>Cost Effectiveness (Cost/Crash Reduced)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection 2</td>
<td>47</td>
<td>$695,000</td>
<td>$14,800</td>
</tr>
<tr>
<td>Intersection 7</td>
<td>6</td>
<td>$200,000</td>
<td>$33,300</td>
</tr>
<tr>
<td>Intersection 11</td>
<td>7</td>
<td>$230,000</td>
<td>$32,900</td>
</tr>
<tr>
<td>Intersection 12</td>
<td>9</td>
<td>$100,000</td>
<td>$11,100</td>
</tr>
</tbody>
</table>
• Evaluating effectiveness of a countermeasure at one or more sites

• Crash reduction
  ▪ Frequency
  ▪ Severity
• Evaluating a single project at a specific site to determine the safety effectiveness of that specific project,
• Evaluating a group of similar projects to document the safety effectiveness of those projects,
• Evaluating a group of similar projects for the specific purpose of quantifying a CMF for a countermeasure,
• Assessing the overall safety effectiveness of specific types of projects or countermeasures in comparison to their costs.
Part C introduces techniques for predicting crashes on two-lane rural highways, multilane rural highways, and urban and suburban arterials. This material is particularly useful for estimating expected average crash frequency of new facilities under design and of existing facilities under extensive re-design. It facilitates a proactive approach to considering safety before crashes occur.
HSM Vol 2 (Part C) Predictive Methods

- **Part A**
  - Rural Two-lane Roads (Ch. 10)

- **Part B**
  - Rural Multi-lane Roads (Ch. 11)

- **Part C**
  - Urban Suburban Arterials (Ch. 12)
Key Components to Applying the Predictive Methods

- Traffic volumes (AADT)
- Roadway characteristics
- Crash data
Divide Road Into Homogeneous Segments

Segment 1 (Curve)  
Length = 0.30 mi

Segment 2 (Tangent)  
Length = 0.21 mi

Segment 3 (Tangent + Grade)  
Length = 0.23 mi

Segment 4 (Curve)  
Length = 0.28 mi

Intersection 1

Intersection 2
Predicted Crash Frequency (Crash Prediction Model)

\[ N_{\text{predicted}} = \text{SPF} \times (\text{CMF}_1 \times \text{CMF}_2 \times \ldots) \times C \]

where:

- \( N_{\text{predicted}} \) = crashes per year
- SPF = Safety Performance Function
- CMF = Crash Modification Factors
- C = Local Calibration Factor
What are Safety Performance Functions (SPF)?

An equation used to estimate or predict the expected average crash frequency per year at a location as a function of traffic volume and in some cases roadway or intersection characteristics.

Mathematical Regression Models for Roadway Segments and Intersections:

- Developed from data for a number of similar sites
- Developed for specific site types and “base conditions”
- Function of only a few variables, primarily AADT
- Used to calculate the expected crash frequency (crashes/year) for a set of base geometric and traffic control conditions
Safety Performance Function (SPF)

SPF = Best Fit Line

Crashes per Year vs. Annual Average Daily Traffic
Example Safety Performance Functions

Two lane rural road - Segment SPF:

\[ N_{SPF\,rs} = AADT \times L \times (365 \times 10^{-6}) \times e^{-0.312} \]

AADT = Annual Average Daily Traffic
L = Length of Segment

Rural Multi-lane Road - 4 legged, minor leg stop control Intersection SPF:

\[ N_{SPF\,int} = e^{[a + b \ln(AADT_{maj}) + c \ln(AADT_{min})]} \]

Where \( a, b \) and \( c \) vary for intersection type and traffic control and are given in the HSM
What is the Purpose of *Crash Modification Factors* (CMF)?

Crash modification factor (CMF)—an index of how much crash experience is expected to change following a modification in design or traffic control. CMF is the ratio between the number of crashes per unit of time expected after a modification or measure is implemented and the number of crashes per unit of time estimated if the change does not take place.

- Adjusts the calculated SPF predicted value for base conditions to *actual or proposed conditions*
- Accounts for the difference between base conditions and site specific conditions
Crash Modification Factors (CMFs)

Crash Modification Factors are used to adjust the calculated SPF predicted value for base conditions to actual or proposed conditions.

- **CMF = 1.0**: Meets base conditions or the treatment has no effect on the expected crash frequency.
- **CMF < 1.0**: The treatment may reduce the expected crash frequency.
- **CMF > 1.0**: The treatment may increase the expected crash frequency.

\[
CMF = 1 - CRF
\]
Calibration of SPFs

Local Calibration Factor \((C_r \text{ or } C_i)\)

- Adjust HSM SPF-derived crash estimates to reflect local conditions
- Provide method to address for local variations such as:
  - Climate,
  - Driver populations,
  - Animal populations,
  - Crash Reporting Thresholds, and
  - Crash Reporting System Procedures
Empirical Bayes (EB) Methodology - method used to combine observed crash frequency data for a given site with predicted crash frequency data from many similar sites to estimate its expected crash frequency.

- Reduces effects of regression-to-the-mean (if we do not account for RTM, we cannot say the crash difference is due to the treatment)
- Pairs predicted crashes with observed crashes to improve the reliability of the crash frequency estimate (corrects for unusual crash trends)
- Both SPF and crash data must be available
- See HSM Part C - Appendix A
Natural Variability in Crash Frequency
Regression to the Mean – Example

Site Selected for Treatment due to Short-Term Trend

Expected Average Crash Frequency (Without Treatment)

RTM Reduction

Before

AFTER

Perceived Effectiveness of Treatment

Actual Reduction due to Treatment
Chapter 10 Rural Two-Lane Road Segments and Intersections
Chapter 10 Base Conditions for Rural Two-Lane Segments

<table>
<thead>
<tr>
<th>Base Condition</th>
<th>Measurement</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Width (LW)</td>
<td>12 ft</td>
<td>1.00</td>
</tr>
<tr>
<td>Shoulder Width (SW)</td>
<td>6 ft</td>
<td>1.00</td>
</tr>
<tr>
<td>Shoulder Type</td>
<td>paved</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadside Hazard Rating (1-7)</td>
<td>3</td>
<td>1.00</td>
</tr>
<tr>
<td>Driveway Density (DD)</td>
<td>5 per mile</td>
<td>1.00</td>
</tr>
<tr>
<td>Horizontal Curves</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Vertical Curves</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Passing Lane</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Centerline Rumble Strips</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Grade</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>TWLTL</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Lighting</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Automated Speed Enforcement</td>
<td>None</td>
<td>1.00</td>
</tr>
</tbody>
</table>
## Chapter 10 Base Conditions for Rural Two-Lane Road Intersections

<table>
<thead>
<tr>
<th>Base Condition</th>
<th>Measurement</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skew Angle</td>
<td>none</td>
<td>1.00</td>
</tr>
<tr>
<td>Presence of Left Turn Lane</td>
<td>none</td>
<td>1.00</td>
</tr>
<tr>
<td>Presence of Right Turn Lane</td>
<td>none</td>
<td>1.00</td>
</tr>
<tr>
<td>Lighting</td>
<td>none</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Step 1 Calculate SPF:

\[ N_{(\text{Rural 2-lane})} = \text{AADT} \times L \times (365 \times 10^{-6}) \times e^{-0.312} \]

**AADT** = Annual Average Daily Traffic

**L** = Length of Segment

AADT range from zero to 17,800 vehicles per day

AADT = 2,000

Length of Segment = 2 miles

\[ N_{\text{spf/rs}} = 2,000 \times 2 \times 365 \times 10^{-6} \times e^{-0.312} \]

= 1.07 crashes/year or ~ 1 crash every year
Applying the HSM

Step 2 Identify the Roadway Characteristics and find Applicable CMF in HSM

<table>
<thead>
<tr>
<th>Base Condition</th>
<th>Existing Roadway</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 ft</td>
<td>Lane Width</td>
</tr>
<tr>
<td>10 ft</td>
<td></td>
</tr>
<tr>
<td>6 ft</td>
<td>Shoulder Width</td>
</tr>
<tr>
<td>4 ft</td>
<td></td>
</tr>
<tr>
<td>Paved</td>
<td>Shoulder Type</td>
</tr>
<tr>
<td></td>
<td>Gravel</td>
</tr>
</tbody>
</table>
Table 10-8. CMF for Lane Width on Roadway Segments (CMF_{ra})

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>AADT (vehicles per day)</th>
<th>&lt; 400</th>
<th>400 to 2000</th>
<th>&gt; 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 ft or less</td>
<td>1.05</td>
<td>1.05 + 2.81 \times 10^{-4} (AADT - 400)</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>10 ft</td>
<td>1.02</td>
<td>1.02 + 1.75 \times 10^{-4} (AADT - 400)</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>11 ft</td>
<td>1.01</td>
<td>1.01 + 2.5 \times 10^{-5} (AADT - 400)</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>12 ft or more</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

Note: The collision types related to lane width to which this CMF applies include single-vehicle run-off-the-road and multiple-vehicle head-on, opposite-direction sideswipe, and same-direction sideswipe crashes.
Table 10-9. CMF for Shoulder Width on Roadway Segments (CMF<sub>wa</sub>)

<table>
<thead>
<tr>
<th>Shoulder Width</th>
<th>AADT (vehicles per day)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 400</td>
<td>400 to 2000</td>
</tr>
<tr>
<td>0 ft</td>
<td>1.10</td>
<td>1.10 + 2.5 × 10&lt;sup&gt;-4&lt;/sup&gt; (AADT - 400)</td>
</tr>
<tr>
<td>2 ft</td>
<td>1.07</td>
<td>1.07 + 1.43 × 10&lt;sup&gt;-4&lt;/sup&gt; (AADT - 400)</td>
</tr>
<tr>
<td>4 ft</td>
<td>1.02</td>
<td>1.02 + 8.125 × 10&lt;sup&gt;-5&lt;/sup&gt; (AADT - 400)</td>
</tr>
<tr>
<td>6 ft</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>8 ft or more</td>
<td>0.98</td>
<td>0.98 + 6.875 × 10&lt;sup&gt;-5&lt;/sup&gt; (AADT - 400)</td>
</tr>
</tbody>
</table>

Note: The collision types related to shoulder width to which this CMF applies include single-vehicle run-off the-road and multiple-vehicle head-on, opposite-direction sideswipe, and same-direction sideswipe crashes.
Applying the HSM

Step 3  Find/Calculate CMF’s and Apply to SPF:

AADT = 2,000 and Length of Segment = 2 miles

<table>
<thead>
<tr>
<th>Base Condition</th>
<th>Existing Roadway</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 ft</td>
<td>Lane Width</td>
<td>10 ft</td>
</tr>
<tr>
<td>6 ft</td>
<td>Shoulder Width</td>
<td>2 ft</td>
</tr>
<tr>
<td>Paved</td>
<td>Shoulder Type</td>
<td>Gravel</td>
</tr>
</tbody>
</table>

\[ N_{predicted} = 1.07 \text{ crashes/year} \times 1.17^a \times 1.18^a = 1.48 \text{ crashes/year} \]

\^a – Each of these CMF’s were adjusted to reflect total crashes

This is potentially a 41% increase in total crashes for the existing cross section. Over a 10 year period that is potentially 4 more crashes with one of those crashes likely being a fatal or injury crash.
Some Insights from Review of CMFs for Lane Width and Shoulders for Rural Two-Lane Roads

- Not much difference between 11- and 12-ft lanes
- Lane width is less important for very low volume roads
- Incremental width for shoulders is much more sensitive than for lanes
- Shoulder width effectiveness increases significantly as volume increases
Applying the HSM for an Intersection Project

Integrating Safety into Decision Processes

“It would cost my agency about $50,000 to construct turn lanes at this two-lane rural road intersection – how can I quantify the expected safety benefits in order to convince my leadership that this is a wise public investment?”

Table 10-13. Crash Modification Factors (CMF₂) for Installation of Left-Turn Lanes on Intersection Approaches

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Intersection Traffic Control</th>
<th>One Approach</th>
<th>Two Approaches</th>
<th>Three Approaches</th>
<th>Four Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-leg Intersection</td>
<td>Minor road stop control b</td>
<td>0.56</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Four-leg Intersection</td>
<td>Minor road stop control b</td>
<td>0.72</td>
<td>0.52</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.82</td>
<td>0.67</td>
<td>0.55</td>
<td>0.45</td>
</tr>
</tbody>
</table>

*Stop-controlled approaches are not considered in determining the number of approaches with left-turn lanes
*Stop signs present on minor road approaches only.
Chapter 12 Urban and Suburban Road Segments and Intersections
Crash Frequency Prediction Models for Urban/Suburban Roadway Segments

Base Models and Adjustment Factors addresses five types of Roadway Segments:

- (2U) Two-lane undivided arterials
- (3T) Three-lane arterials including a center two-way Left Turn Lane
- (4U) Four-lane undivided arterials
- (4D) Four-lane divided arterials (including a raised or depressed median)
- (5T) Five-lane arterials including a center TWLTL
## Chapter 12 Base Conditions for Urban/Suburban Roadways

<table>
<thead>
<tr>
<th>Base Condition</th>
<th>Measurement</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Street Parking</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Roadside Fixed Objects</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Median Width</td>
<td>15 ft</td>
<td>1.00</td>
</tr>
<tr>
<td>Lighting</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Automated Speed Enforcement</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Left Turn Lanes</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Left Turn Signal Phasing</td>
<td>Permissive</td>
<td>1.00</td>
</tr>
<tr>
<td>Right Turn Lanes</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Right Turn on Red</td>
<td>Permitted</td>
<td>1.00</td>
</tr>
<tr>
<td>Lighting</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Red Light Cameras</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Bus Stops</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Schools</td>
<td>None</td>
<td>1.00</td>
</tr>
<tr>
<td>Alcohol Sales Establishment</td>
<td>None</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Predicting Crash Frequency of Suburban/Urban Multilane Streets

\[ N_{\text{predicted rs}} = (N_{\text{br}} + N_{\text{pedr}} + N_{\text{biker}}) \times C_r \]

Where:

- \( N_{\text{predicted rs}} \) = Predicted number of total roadway segment crashes per year
- \( N_{\text{br}} \) = Predicted number of total roadway segment crashes per year with CMFs applied
- \( N_{\text{pedr}} \) = Predicted number of vehicle-pedestrian collisions per year
- \( N_{\text{biker}} \) = Predicted number of vehicle-bicycle collisions per year
- \( C_r \) = calibration factor for a particular geographical area
\[ N_{br} = N_{spf\ rs} \times (CMF_{1r} \times CMF_{2r} \times \ldots \times CMF_{nr}) \]

Where:

- \( N_{br} \) = Predicted number of total roadway segment crashes per year with CMFs applied (excluding ped and bike collisions)
- \( N_{spf\ rs} \) = Predicted number of total roadway segment crashes per year for base conditions
- \( CMF_{1r}, CMF_{2r}, \ldots, CMF_{nr} \) = Crash Modification Factors for roadway segments
Predicting Crash Frequency of Suburban/Urban Multilane Streets

\[ N_{spf \, rs} = N_{brmv} + N_{brsv} + N_{brdwy} \]

Where:

- \( N_{spf \, rs} = \) Predicted number of total roadway segment crashes per year for base conditions
- \( N_{brmv} = \) Predicted number of multiple-vehicle non-driveway crashes per year for base conditions
- \( N_{brsv} = \) Predicted number of single-vehicle collision and non-driveway crashes per year for base conditions
- \( N_{brdwy} = \) Predicted number of multiple-vehicle driveway related crashes per year
CMFs

- Roadway segments (Ch. 13)
- Intersections (Ch. 14)
- Interchanges (Ch. 15)
- Special facilities and geometric situations (Ch. 16)
Some Part D CMFs are included in Part C and for use with specific Safety Performance Functions (SPFs).

Other Part D CMFs are not presented in Part C but can be used in the methods to estimate change in crash frequency.

Part D presents information regarding the effects of various safety treatments (i.e., countermeasures).

Standard error in Part D is important because more accurate and precise CMFs lead to more cost effective decisions.
CMF Standard Error

Expressed as:

\[ \text{CMF} \pm \text{SE} \]

SE = standard error

Used to determine low (SE), medium (2 × SE) and high (3 × SE) confidence interval for CMF
The most reliable (i.e., valid) CMFs have a standard error of **0.1 or less**, and are indicated with **bold** font.

Reliability indicates that the CMF is unlikely to change substantially with new research.

Less reliable CMFs have standard errors of **0.2 or 0.3** and are indicated with *italic* font.

All quantitative standard errors presented with CMFs in Part D are less than or equal to 0.3.
Confidence Intervals (CI) for CMFs

\[
\text{CI (x\%) = CMF} \pm (SE \times \text{MSE})
\]

where:

\[
\text{SE} = \text{Standard Error for the particular CMF}
\]

<table>
<thead>
<tr>
<th>Desired Level of Confidence</th>
<th>Confidence Interval</th>
<th>Multiple of Standard Error (MSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>65% - 70%</td>
<td>1</td>
</tr>
<tr>
<td>Medium</td>
<td>95%</td>
<td>2</td>
</tr>
<tr>
<td>High</td>
<td>99.9%</td>
<td>3</td>
</tr>
</tbody>
</table>
### Table 14-28. Potential Crash Effects of Installing Red-Light Cameras at Intersections (23,30)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install red-light cameras</td>
<td>Urban (Unspecified)</td>
<td>Unspecified</td>
<td>Right-angle and left-turn opposite direction</td>
<td>0.74_+</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(All severities) (23,30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Right-angle and left-turn opposite direction</td>
<td>0.84_?</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Injury) (23)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rear-end</td>
<td>1.18_+</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(All severities) (23,30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rear-end</td>
<td>1.24_?</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Injury) (23)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: A signalized intersection without red-light cameras.

**NOTE:** **Bold** text is used for the most reliable CMFs. These CMFs have a standard error of 0.1 or less.

vpd = vehicles per day

+ Combined CMF, see Part D—Introduction and Applications Guidance.

? Treatment results in a decrease in right-angle crashes and an increase in rear-end crashes. See Chapter 3.
Table 13-27. Potential Crash Effects of Improving Superelevation Variance (SV) of Horizontal Curves on Rural Two-Lane Roads (16,35)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Road Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve SV &lt; 0.01</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Improve 0.01 ≤ SV &lt; 0.02</td>
<td>Rural (Two-lane)</td>
<td>Unspecified</td>
<td>All types (All severities)</td>
<td>= 1.00 + 6 (SV – 0.01)</td>
</tr>
<tr>
<td>Improve SV &gt; 0.02</td>
<td></td>
<td></td>
<td></td>
<td>= 1.06 + 3 (SV – 0.02)</td>
</tr>
</tbody>
</table>

Base Condition: Superelevation variance < 0.01.

NOTE: Standard error of CMF is unknown.
Based on a horizontal curve radius of 842.5 ft.
SV = Superelevation variance. Difference between recommended design value for superelevation and existing superelevation on a horizontal curve, where existing superelevation is less than recommended.
To determine the CMF for changing superelevation, divide the “new” condition CMF by the “existing” condition CMF.
<table>
<thead>
<tr>
<th>HSM Part</th>
<th>Supporting Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><a href="http://www.safetyanalyst.org">www.safetyanalyst.org</a></td>
</tr>
<tr>
<td>Part C: Predictive Methods</td>
<td>IHSDM</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.ihsdm.org">www.ihsdm.org</a></td>
</tr>
<tr>
<td>Part D: Crash Modification Factors</td>
<td>FHWA CRF/CMF Clearinghouse</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.cmfclearinghouse.com">www.cmfclearinghouse.com</a></td>
</tr>
</tbody>
</table>
A crash modification factor (CMF) is a multiplicative factor used to compute the expected number of crashes after implementing a given countermeasure at a specific site. The Crash Modification Factors Clearinghouse houses a Web-based database of CMFs along with supporting documentation to help transportation engineers identify the most appropriate countermeasure for their safety needs. Using this site, you can search to find CMFs or submit your own CMFs to be included in the clearinghouse.

**Recently Added CMFs**

- **Four to five lane conversion**
  - CMF: 1.1
  - CRF: -10
  - Crash type: All
  - Crash severity: All

- **Prohibit on-street parking**
  - CMF: 0.65
  - CRF: 35
  - Crash type: All
  - Crash severity: Serious injury, Minor injury

- **Reduce driveways from 26-48 to 10-24 per mile**
  - CMF: 0.69
  - CRF: 31
  - Crash type: All
  - Crash severity: Serious injury, Minor injury
### Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections

#### General Information
- **Analyst:** HNI
- **Agency or Company:** FHWA
- **Date Performed:** 03/29/10
- **Roadway Analysis Year:** 2010
- **Jurisdiction Intersection:** STH 70
- **Location Information:** Crescent Road, Rhinelander, WI

#### Input Data

<table>
<thead>
<tr>
<th>Intersection type (3ST, 3SG, 4ST, 4SG)</th>
<th>Base Conditions</th>
<th>Site Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>AADT</em> <em>max</em> (veh/day)</td>
<td>--</td>
<td>3ST</td>
</tr>
<tr>
<td>45,700 (veh/day)</td>
<td>--</td>
<td>14,000</td>
</tr>
<tr>
<td><em>AADT</em>_ <em>min</em> (veh/day)</td>
<td>9,300</td>
<td>4,000</td>
</tr>
</tbody>
</table>

#### Other Data

- **Intersection lighting (present/not present):** Not Present
- **Calibration factor, C<sub>i</sub>:** 1.00
- **Data for unsignalized intersections only:** --
- **Data for signalized intersections only:** --
- **Number of major-road approaches with left-turn lanes:** 0
- **Number of major-road approaches with right-turn lanes:** 0
- **Number of approaches with left-turn lanes:** 0
- **Number of approaches with right-turn lanes:** 0
- **Number of approaches with left-turn signal phasing:** 0
- **Type of left-turn signal phasing for Leg #1:** Permissive
- **Type of left-turn signal phasing for Leg #2:** Not Applicable
- **Type of left-turn signal phasing for Leg #3:** Not Applicable
- **Type of left-turn signal phasing for Leg #4:** Not Applicable
- **Number of approaches with right-turn-on-red prohibited:** 0
- **Intersection red light cameras:** Not Present
- **Sum of all pedestrian crossing volumes (PedVol):** 10
- **Maximum number of lanes crossed by a pedestrian:** 0
- **Number of bus stops within 300 m (1,000 ft) of the intersection:** 0
- **Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection:** Not Present
- **Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection:** 0
BREAK
Applying the HSM

Low Cost Safety Improvements

FHWA Proven Safety Countermeasures

Crash Modification Factors

Clarify and Simplify
How can I use the HSM if I have limited traffic volume and/or crash data?

- Knowing where crashes are most likely to occur on your roadway (i.e. horizontal curves, intersections, undivided facilities)
- Understanding the effect of various geometric and roadway features can be used to design safer roadways (i.e. turn lanes, driveway density, shoulder width, fixed objects, etc.)
- Becoming familiar with countermeasures that potentially reduce crashes and their CMF’s (i.e. roundabouts, lighting, rumble strips) and implementing.
2008 FHWA 9 Proven Safety Countermeasures

- Safety Edge
- Road Safety Audits (RSAs)
- Rumble Strips and Rumble Stripes
- Median Barriers
- Roundabouts
- Left-and Right-Turn Lanes
- Yellow Change Intervals
- Median and Pedestrian Refuge Areas
- Walkways
The **NEW** Proven Safety Countermeasures Web site is now available!

This Web site will be your one-stop shop for information on the **latest** FHWA-recommended set of research-proven safety countermeasures and FHWA guidance on countermeasure considerations. The updated list of proven countermeasures was developed based on recent safety research to address **intersection**, **roadway departure**, and **pedestrian** issues wherever they may occur.

Many of these countermeasures are low-cost solutions, and FHWA encourages its partners to consider implementing these countermeasures broadly, as appropriate, to reap the benefits of using solutions that are known to save lives.

**UPDATED! FHWA-Recommended and Proven Countermeasures:**

- Roundabouts
- “Road Diet” (Roadway Reconfiguration)
- Pedestrian Hybrid Beacon
- Medians and Pedestrian Crossing Islands in Urban and Suburban Areas
- Corridor Access Management
- Backplates with Retroreflective Borders
- Longitudinal Rumble Strips and Stripes on Two-Lane Roads
- Safety Edge™
- Enhanced Delineation and Friction for Horizontal Curves

**LEARN MORE TODAY!**

Low Cost Safety Enhancements for Stop-Controlled and Signalized Intersections

- Signing and Pavement Marking
- J-Turns on multi-lane facilities
- Lighting
- High Friction Surfaces
- Speed Reduction

http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/
Low-Cost Treatments for Horizontal Curves

- Enhanced signing
- Shoulder widening
- Lighting

Example Case Study for a Rural Two-Lane Road: Application of Crash Modification Factors (CMFs) on a 10-mile segment of US HSM ROUTE

Traffic Volume and Geometric Information:

AADT: 10,000 vpd
Length: 10 miles
Lane Width: 12 feet
Shoulders: None
Hazard Rating: 3 (HSM base condition)
Driveway Density per mile = 5 (HSM base condition)
Grades +/- 3%

The US HSM Route is a two-lane rural highway with a section length of 10 miles and AADT of 10,000 vehicles per day. The pavement width is 24 feet and the terrain is rolling. The jurisdiction that is responsible for US HSM Route has no funds available to make any substantial upgrades to the roadway; however they believe that this site operates at an unacceptable level of risk with a substantially higher crash rate than the national and regional average. Currently the roadway is striped with 2-12 feet lanes and the edge line markings are striped every 2 years.
Case Study

Q. Can we influence safety on this roadway without any funds to do so?
A. Yes, with the HSM we can examine different lane/shoulder width combination to determine the best design with respect to safety performance?

In investigating this project, is striping this section of roadway with 2 lanes of 12-feet widths more effective than striping with 2 lanes of 11-feet lane widths and 1 foot shoulders? The HSM allows us to perform such analyses. Let scenario 1 be the existing condition which involves striping the roadway with 12 feet lane widths and no shoulders and scenario 2 has 11 feet lane widths and 1 foot shoulders. Below are the CMFs for these 2 scenarios.

Scenario #1 CMFs for Existing Conditions:
12 ft lane width, CMF = 1.00
No shoulders, CMF = 1.29
Combined CMFs = 1.00 x 1.29 = 1.29

CMFs for Scenario #2:
11 ft lane width, CMF = 1.03
1 ft shoulder width, CMF = 1.22
Combined CMFs = 1.03 x 1.22 = 1.26

Using the SPF for 2 lane rural highways for a 10 mile segment with 10,000 vpd we would estimate a base number of crashes to be 26.72 crashes per year. Scenario 1 conditions yield an expected 26.72 x 1.29 = 34.47 crashes per year or 344.7 crashes in 10 years. Scenario 2 conditions yield an expected 26.72 x 1.26 = 33.66 crashes per year or 336.6 crashes in 10 years. A difference of 344.7 – 336.6 = 8.1 crashes saved in 10 years.
Case Study

RESULTS:
The combined CMFs for scenario #1 (existing conditions) and scenario #2 (proposed conditions) are 1.29 and 1.26 respectively, which represents a 2.3% reduction in crashes. After 10 years assuming constant AADT data provided for this 10 mile section of roadway if we change the striping to reflect scenario #2 conditions, approximately 8.1 say 8 total crashes would be reduced. Of these 8 crashes (using severity split of 2/3 PDO and 1/3 F+I for segment) we would expect 5.3 of the crashes are expected to be PDO and 2.7 Fatal/Injury crashes. Assuming the average cost of a fatal/injury crash is $100,000 and the average cost of a PDO crash of $1,000, we would expect a benefit of $275,300. The cost associated with this change is the time it took to conduct this analysis. The additional construction costs for this project are $0, yielding an infinite benefit-cost ratio!
Examples Using the HSM with Limited Data

- Intersections
- Geometrics/Roadside
- Curves
### Table 10-13. Crash Modification Factors (CMF$_{3i}$) for Installation of Left-Turn Lanes on Intersection Approaches

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Intersection Traffic Control</th>
<th>One Approach</th>
<th>Two Approaches</th>
<th>Three Approaches</th>
<th>Four Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-leg Intersection</td>
<td>Minor road stop control$^b$</td>
<td>0.56</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Four-leg Intersection</td>
<td>Minor road stop control$^b$</td>
<td>0.72</td>
<td>0.52</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.82</td>
<td>0.67</td>
<td>0.55</td>
<td>0.45</td>
</tr>
</tbody>
</table>

$^a$ Stop-controlled approaches are not considered in determining the number of approaches with left-turn lanes.  
$^b$ Stop signs present on minor road approaches only.

### Table 10-14. Crash Modification Factors (CMF$_{3i}$) for Right-Turn Lanes on Approaches to an Intersection on Rural Two-Lane, Two-Way Highways

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Intersection Traffic Control</th>
<th>One Approach</th>
<th>Two Approaches</th>
<th>Three Approaches</th>
<th>Four Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-Leg Intersection</td>
<td>Minor road stop control$^b$</td>
<td>0.86</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Four-Leg Intersection</td>
<td>Minor road stop control$^b$</td>
<td>0.86</td>
<td>0.74</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.96</td>
<td>0.92</td>
<td>0.88</td>
<td>0.85</td>
</tr>
</tbody>
</table>

$^a$ Stop-controlled approaches are not considered in determining the number of approaches with right-turn lanes.  
$^b$ Stop signs present on minor road approaches only.
Intersection Conflict Points

32

Crossing (0)
Diverging (4)
Converging (4)
Roundabouts are Alternatives to Conventional Intersections

- Number of conflicts is reduced
- Severe conflicts (angle) are eliminated
- Large speed differentials are reduced
CMF’s for Conversion of 2-Way Stop Intersection to a Roundabout

<table>
<thead>
<tr>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>All settings (One or two lanes)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.56</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td><strong>0.18</strong></td>
<td>0.04</td>
</tr>
<tr>
<td>Rural (One lane)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.29</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td><strong>0.13</strong></td>
<td>0.04</td>
</tr>
</tbody>
</table>
### CMF’s for Converting a Signalized Intersection to a Modern Roundabout

#### Table 14-3. Potential Crash Effects of Converting a Signalized Intersection into a Modern Roundabout (29)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert signalized intersection to modern roundabout</td>
<td>Urban (One or two lanes)</td>
<td>Traffic Volume</td>
<td>All types (All severities)</td>
<td>0.99*</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Convert signalized intersection to modern roundabout</td>
<td>Suburban (Two lanes)</td>
<td>All types (Injury)</td>
<td>0.40</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All settings (One or two lanes)</td>
<td>Unspecified</td>
<td>All types (All severities)</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>All settings (One or two lanes)</td>
<td>Unspecified</td>
<td>All types (Injury)</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>All settings (One or two lanes)</td>
<td>Unspecified</td>
<td>All types (Injury)</td>
<td>0.22</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Base Condition:** Signalized intersection.

**NOTE:** Bold text is used for the most reliable CMFs. These CMFs have a standard error of 0.1 or less.

*Observed variability suggests that this treatment could result in an increase, decrease, or no change in crashes. See Part D—Introduction and Applications Guidance.

The study from which this information was obtained does not contain information related to the posted or observed speeds at or on approach to the intersections that were converted to a modern roundabout.
NCHRP 650: Before and After studies of crashes identified up to a 100% reduction in left turn crashes; one study found an increase in rear-end crashes; typical crash reduction in left turn crashes is 70%.
Positive Offset Left Turn Lanes

Angled positive offset

Florida DOT – very wide offsets

Parallel positive offset

Ohio DOT
### Table 14-27. Potential Crash Effects of Modifying Change Plus Clearance Interval (28)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unspecified (Four-leg signalized)</td>
<td>Unspecified</td>
<td>All types (All severities)</td>
<td>0.92*</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.88</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Multiple-vehicle (All severities)</td>
<td>0.95*</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Multiple-vehicle (Injury)</td>
<td>0.91*</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rear-end (All severities)</td>
<td>1.12</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rear-end (Injury)</td>
<td>1.08*</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Right angle (All severities)</td>
<td>0.96*</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Right angle (Injury)</td>
<td>1.06</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pedestrian and Bicyclist (All severities)</td>
<td>0.63</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pedestrian and Bicyclist (Injury)</td>
<td>0.63</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Base Condition: Unspecified.
Signal Backplates

Enhance Traffic Signal Visibility – Add Backplates:
CRF 2% to 24% (All Crashes)  CRF 32% (Angle Crashes)
CRF 50% (Red Light Running Frequency)
Enhance Traffic Signal Visibility – Retroreflectorized Border:
CRF 24% (All Crashes)  CRF 16% (Injury/Fatal Crashes)
Retroreflectorized Border

Enhance Traffic Signal Visibility
Modification of Left Turn Phase at Urban Signal

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume AADT (veh/day)</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change to protected phasing (8,15)</td>
<td>Urban (Four- and three-leg signalized)</td>
<td>Unspecified</td>
<td>Left-turn crashes on treated approach (All severities)</td>
<td>$0.01^+$</td>
<td>0.01</td>
</tr>
<tr>
<td>Change from permissive to protected/permisive or permisive/protected phasing (15,22)</td>
<td>Urban (Four-leg signalized)</td>
<td>Major road 3,000 to 77,000 and minor road 1 to 45,500</td>
<td>Left-turn (Injury)</td>
<td>0.84</td>
<td>0.02</td>
</tr>
<tr>
<td>Change from permissive to protected/permisive or permisive/protected phasing (15)</td>
<td>Urban (Four-leg signalized)</td>
<td>Unspecified</td>
<td>All types (All severities)</td>
<td>0.99</td>
<td>N/A^+</td>
</tr>
</tbody>
</table>

Base Condition: For changing to protected phasing, the base condition is permissive, permissive/protected, or protected/permisive phasing. For changing to permissive/protected or protected/permisive phasing, the base condition is permitted phasing.

NOTE: Bold text is used for the most reliable CMFs. These CMFs have a standard error of 0.1 or less.
* Observed variability suggests that this treatment could result in an increase, decrease, or no change in crashes. See Part D—Introduction and Applications Guidance.
* Standard error of CMF is unknown.
+ Combined CMF, see Part D—Introduction and Applications Guidance.
Table 14-22. Potential Crash Effects of Providing Flashing Beacons at Stop-Controlled, Four-Leg Intersections on Two-Lane Roads (31)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume AADT (veh/day)</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>All settings (Stop-controlled)</td>
<td></td>
<td></td>
<td>All types (All severities)</td>
<td>0.95*</td>
<td>0.04</td>
</tr>
<tr>
<td>All settings (Stop-controlled)</td>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.90*</td>
<td>0.06</td>
</tr>
<tr>
<td>All settings (Stop-controlled)</td>
<td>Rural (Stop-controlled)</td>
<td></td>
<td>Rear-end (All severities)</td>
<td>0.92*</td>
<td>0.1</td>
</tr>
<tr>
<td>All settings (Stop-controlled)</td>
<td>Suburban (Stop-controlled)</td>
<td>Major road volume 250 to 42,520, minor road volume 90 to 13,270</td>
<td>Angle (All severities)</td>
<td>0.87</td>
<td>0.06</td>
</tr>
<tr>
<td>All settings (Stop-controlled)</td>
<td>Urban (Stop-controlled)</td>
<td></td>
<td>Angle (All severities)</td>
<td>0.84</td>
<td>0.06</td>
</tr>
<tr>
<td>All settings (Minor-road stop-controlled)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>0.88</td>
<td>0.1</td>
</tr>
<tr>
<td>All settings (All-way stop-controlled)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>1.12</td>
<td>0.3</td>
</tr>
<tr>
<td>All settings (Standard overhead beacons)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>0.87</td>
<td>0.06</td>
</tr>
<tr>
<td>All settings (Standard stop-mounted beacons)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>0.72</td>
<td>0.2</td>
</tr>
<tr>
<td>All settings (Standard overhead and stop-mounted beacons)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>0.88</td>
<td>0.06</td>
</tr>
<tr>
<td>All settings (Actuated beacons)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>0.42</td>
<td>0.2</td>
</tr>
<tr>
<td>All settings (Actuated beacons)</td>
<td></td>
<td></td>
<td>Angle (All severities)</td>
<td>0.87</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Base condition: Stop-controlled, four-leg intersection on a two-lane road without flashing beacons.

Notes: **Bold** text is used for the most reliable CMFs. These CMFs have a standard error of 0.1 or less. *Italic* text is used for less reliable CMFs. These CMFs have standard errors between 0.2 to 0.3. *Observed variability suggests that this treatment could result in a increase, decrease, or no change in crashes. See Part D—Introduction and Applications Guidance.
Centerline Rumble Strips on Two-Lane Rural Roads:
CMF 0.85 (All Injury/Fatal Crashes)
CMF 0.75 (Head-On & Sideswipe Injury/Fatal Crashes)

1. “Crash Reduction Following Installation of Centerline Rumble Strips on Rural Two-Lane Roads”, Persaud, et al
Edgeline Rumble Strips

Night + Rain Conditions

NCHRP 500 Volume 6 “Guide for Addressing Run-Off-Road Collisions”
Safety Edge
Widened/Stabilized Lane or Shoulder on Inside of Curves
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Road Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide highway lighting</td>
<td>All settings (All types)</td>
<td>Unspecified</td>
<td>All types (Nighttime injury) (8)</td>
<td>0.72</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Nighttime non-injury) (8)</td>
<td>0.83</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Nighttime injury) (15)</td>
<td>0.71</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Nighttime all severities) (15)</td>
<td>0.80</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Base Condition: Absence of lighting.

NOTE: Based on U.S. studies: Harkey et al., 2008; and international studies: Elvik and Vaa 2004. **Bold** text is used for the most reliable CMFs. These CMFs have a standard error of 0.1 or less. N/A Standard error of the CMF is unknown.
# Safety Effects of Installing Combination Horizontal Alignment Warning + Advisory Speed Signs

## Table 13-30. Potential Crash Effects of Installing Combination Horizontal Alignment/Advisory Speed Signs (W1-1a, W1-2a) (8)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Road Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install combination horizontal alignment/advisory speed signs</td>
<td>Unspecified (Unspecified)</td>
<td>Unspecified</td>
<td>All types (Injury)</td>
<td>0.87</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Non-injury)</td>
<td>0.71</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Base Condition: Absence of any signage.
Chevrons

CMF = 0.65

*CMF Clearinghouse http://www.cmfclearinghouse.org
Overview of Good Alignment Design Practice
(suggested by safety research)

• Curves and grades are necessary features of alignment design (reflect the topography, terrain, and “context”)
• Pay particular attention to roadside design adjacent to curves
• Avoid long, sharp curves
• Adjust alignment design to reflect expected speeds on curves
• Minimize grades *within terrain context*
• Widen lanes and shoulders through curves
• Pay attention to access points related to horizontal and vertical curve locations
DE Route 52 @ DE
Route 82 Intersection Data

- Posted Speed Limit – 50mph
- High Profile Location
- 15,000 ADT
- Protected-permissive left-turn phasing (lead/lag operation) on the NB and SB 52 approaches and split phasing on the EB SR 82 and WB Kirk Road approaches.
SR 52/SR 82 - Crash Data

1999 – 2001 32 accidents
- 17 southbound rear end
- 7 northbound rear end
- 3 northbound/eastbound angle

2006 – 2008 39 crashes
- 22 southbound rear end crashes (6 crashes resulted in injuries; 2 crashes involved a left-turning vehicle)
- 3 southbound left-turn crashes
- 2 northbound sideswipe crashes
- 2 eastbound right-turn rear end crashes
- 1 southbound/westbound angle crash (resulted in two fatalities)
- 1 southbound/eastbound angle crash
- 1 westbound left-turn crash
- 1 northbound rear end crash
- 1 northbound left-turn crash
- 1 northbound/eastbound angle crash
- 1 northbound/westbound angle crash
- 1 northbound motorists struck a fixed object just north of the intersection
- 1 eastbound rear end crash
- 1 eastbound vehicle struck a deer
Intersection Countermeasures

- Exclusive Left Turn Lane
- Protected Left Turn Phase
- Lighting (CMF – 0.89)
- Roundabout
## Countermeasure Crash Modification Factors

### Table 10-13. Crash Modification Factors (CMF<sub>3i</sub>) for Installation of Left-Turn Lanes on Intersection Approaches

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Intersection Traffic Control</th>
<th>One Approach</th>
<th>Two Approaches</th>
<th>Three Approaches</th>
<th>Four Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-leg Intersection</td>
<td>Minor road stop control&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.56</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Four-leg Intersection</td>
<td>Minor road stop control&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.72</td>
<td>0.52</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.82</td>
<td>0.67</td>
<td>0.55</td>
<td>0.45</td>
</tr>
</tbody>
</table>

<sup>a</sup> Stop-controlled approaches are not considered in determining the number of approaches with left-turn lanes.

<sup>b</sup> Stop signs present on minor road approaches only.

### Table 10-14. Crash Modification Factors (CMF<sub>3i</sub>) for Right-Turn Lanes on Approaches to an Intersection on Rural Two-Lane, Two-Way Highways

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Intersection Traffic Control</th>
<th>One Approach</th>
<th>Two Approaches</th>
<th>Three Approaches</th>
<th>Four Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-Leg Intersection</td>
<td>Minor road stop control&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.86</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Four-Leg Intersection</td>
<td>Minor road stop control&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.86</td>
<td>0.74</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.96</td>
<td>0.92</td>
<td>0.88</td>
<td>0.85</td>
</tr>
</tbody>
</table>

<sup>a</sup> Stop-controlled approaches are not considered in determining the number of approaches with right-turn lanes.

<sup>b</sup> Stop signs present on minor road approaches only.
### Table 14-3. Potential Crash Effects of Converting a Signalized Intersection into a Modern Roundabout (29)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert signalized intersection to modern roundabout</td>
<td>Urban (One or two lanes)</td>
<td>Unspecified</td>
<td>All types (All severities)</td>
<td>0.99*</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Suburban (Two lanes)</td>
<td></td>
<td>All types (Injury)</td>
<td>0.40</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All settings (One or two lanes)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>All types (Injury)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.22</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Base Condition: Signalized intersection.

### Table 14-4. Potential Crash Effects of Converting a Stop-Controlled Intersections into a Modern Roundabout (29)

<table>
<thead>
<tr>
<th>Setting (Intersection Type)</th>
<th>Traffic Volume</th>
<th>Crash Type (Severity)</th>
<th>CMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>All settings (One or two lanes)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.56</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.18</td>
<td>0.04</td>
</tr>
<tr>
<td>Rural (One lane)</td>
<td></td>
<td>All types (All severities)</td>
<td>0.29</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All types (Injury)</td>
<td>0.13</td>
<td>0.04</td>
</tr>
</tbody>
</table>
HSM Lite Summary
Achieving Safety is a Balance of Many Factors

We routinely balance safety in many decisions we make.

Tradeoffs we routinely make:

- Economics versus safety
- Stakeholder preferences
- Environmental impacts
- Capacity or speed versus safety
- Ease of maintenance versus safety
Safety Design Key Concepts

- Achieving appropriate balance requires information, evaluation, risk assessment, and a decision process.
- The level of evaluations should reflect the scope of the project, the extent of safety problems, and the potential opportunities to reduce crashes and their severity.
- Nominal safety and substantive safety have different, but related, goals.
Look for Opportunities...

• Look for opportunities to decrease number and severity of crashes
• Use available data
• “Cause” of crashes on crash reports?
  • Roadway and environment?
  • Driver error?
  • Vehicle?
• Look for opportunities to reduce driver errors
• Consider the proven safety countermeasures
Local Delaware Contacts

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