Highway Safety Manual Lite

Woodside, DE

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U.S. Department of Transportation
Federal Highway Administration

Federal Highway Administration
RESOURCE CENTER

Safe Roads for a Safer Future
Investment in roadway safety saves lives

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.

Safety Problem (or Opportunity) Areas

Fatal Crash Statistics (2009 Preliminary)

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

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

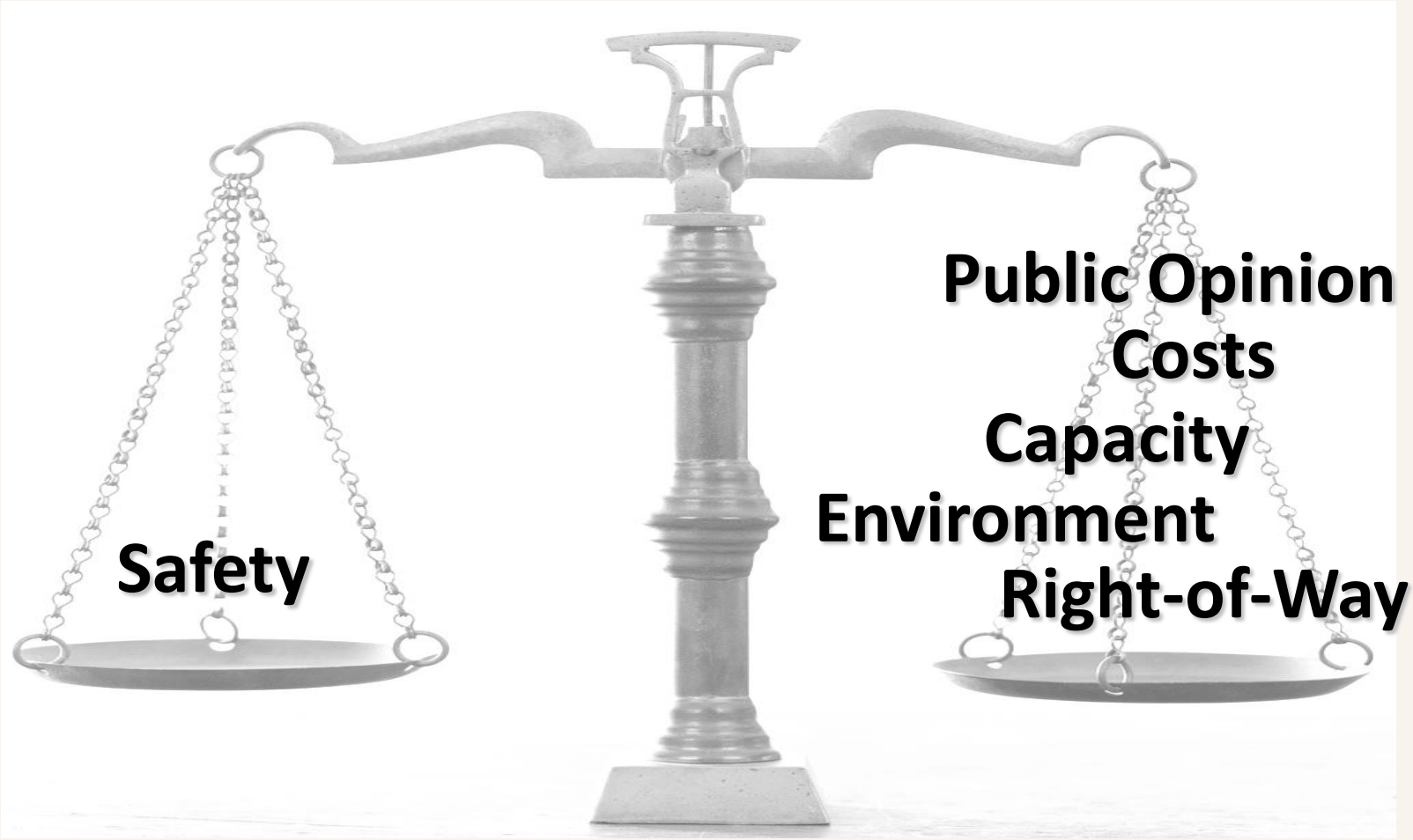
Formidable Safety Challenges

- 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?

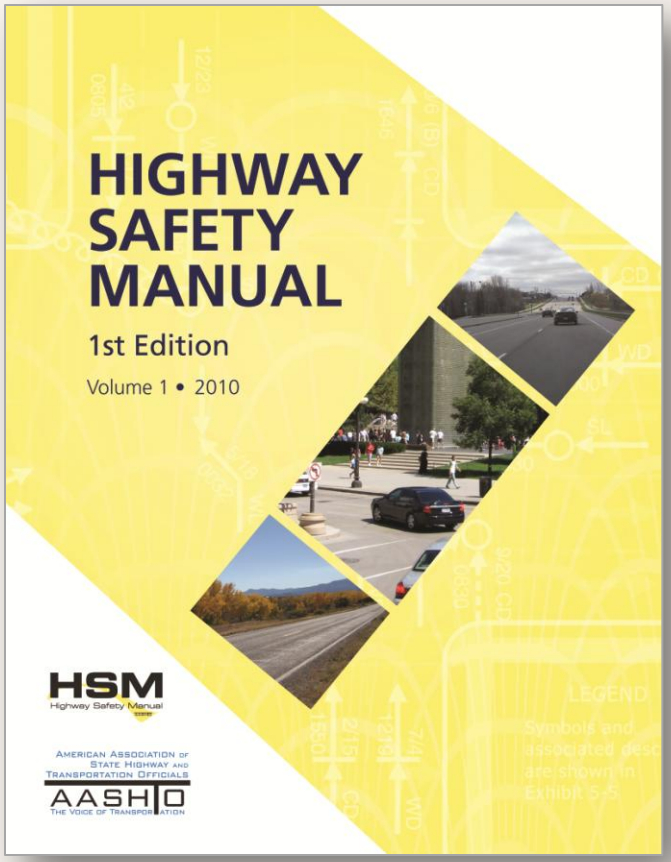


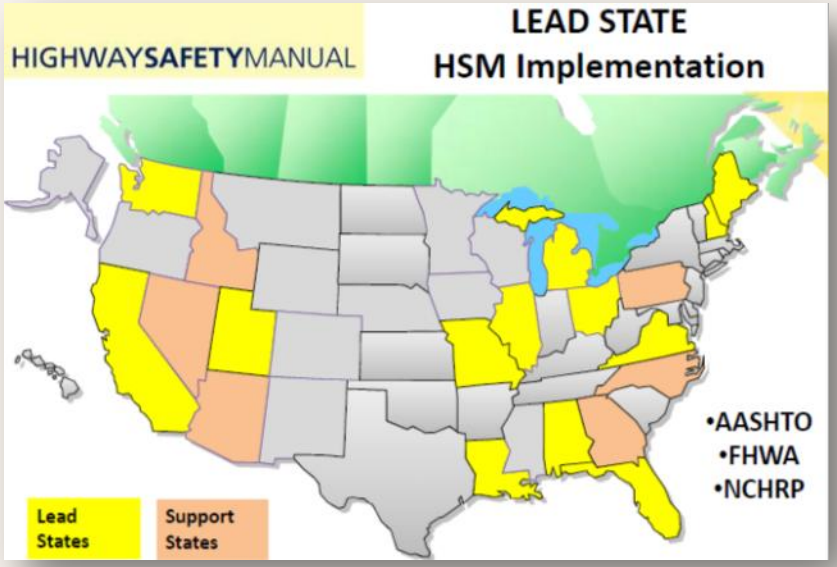
What Do You Do?

Roadway Safety

"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



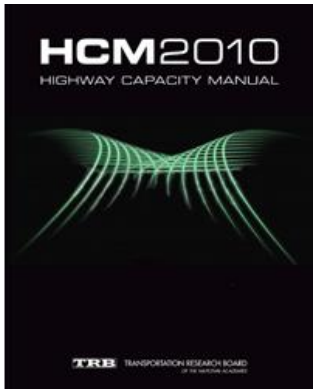


The Highway Safety Manual…

- 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

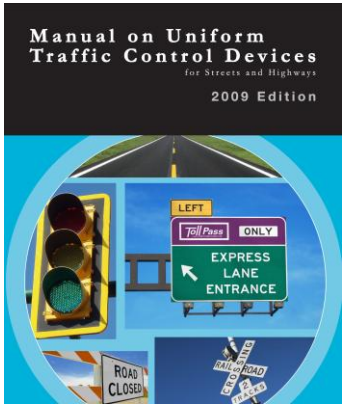
The Highway Safety Manual is a Tool

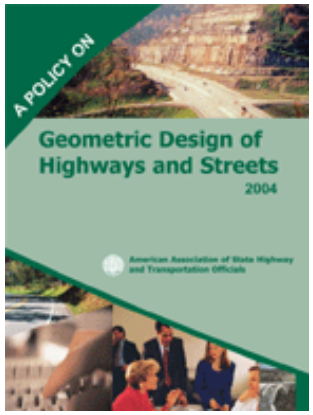
HSM is like the Highway Capacity Manual



- 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

HSM is ***not*** Like the MUTCD & Green Book





- 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.

Legal Context

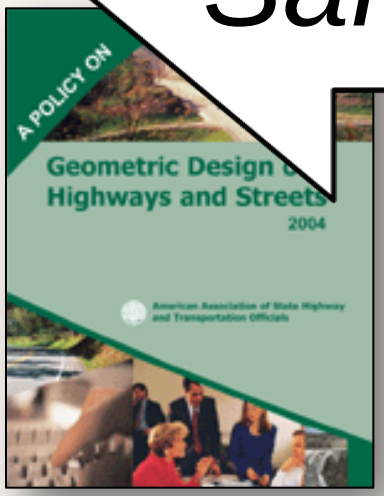
Use is Protected Under Federal Law 23 USC Section 409: Discovery and admission as evidence of certain reports and surveys

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

Substantive Safety

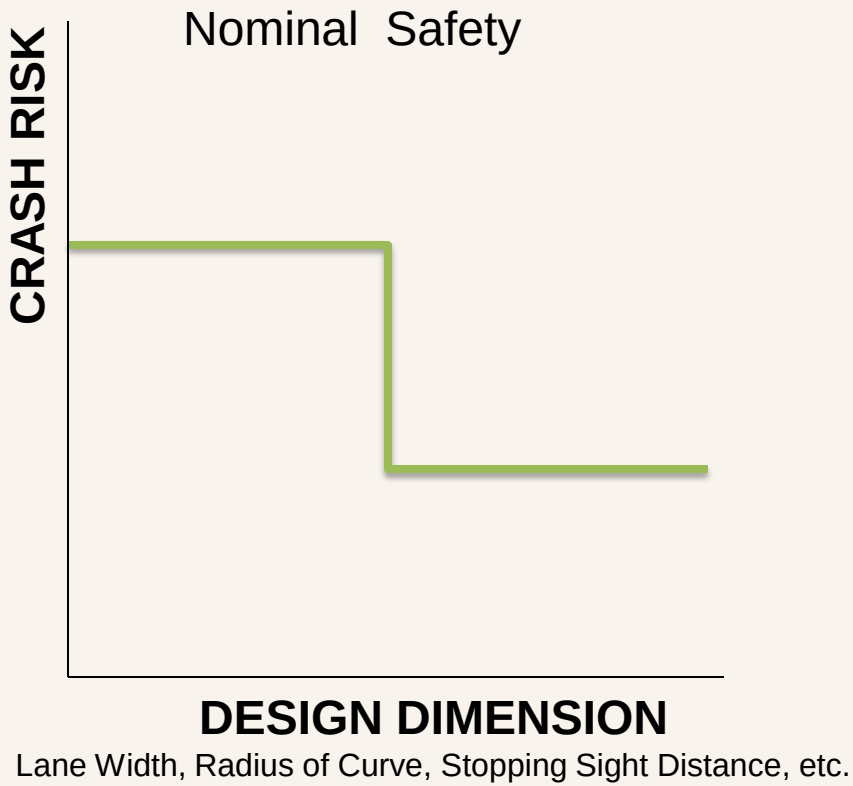


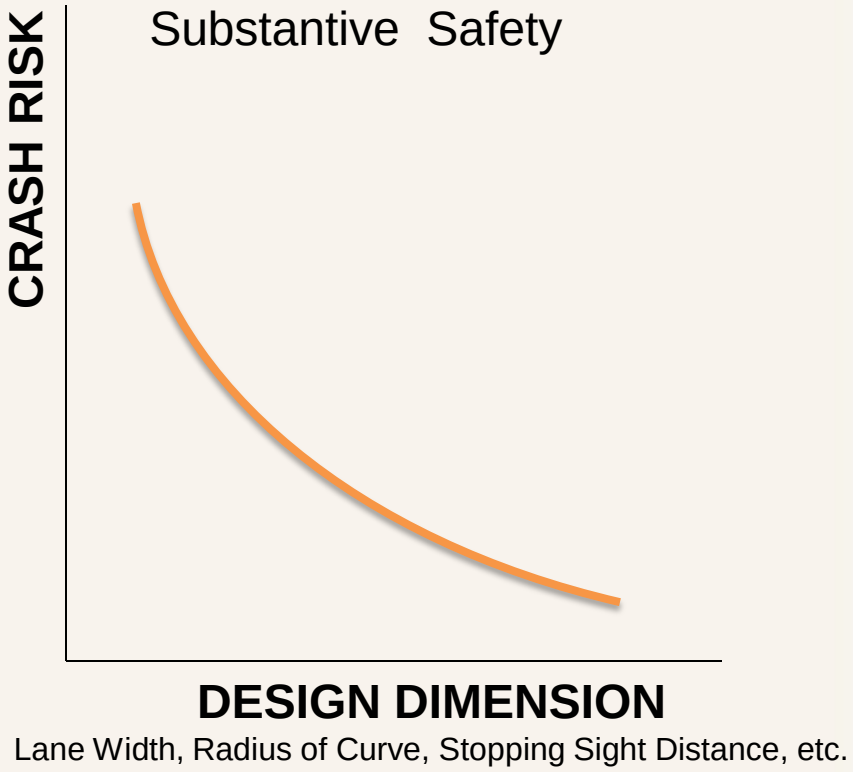
Standards Compliance

HSM
Highway Safety Manual
AASHTO

Expected or Actual Crash Frequency and Severity

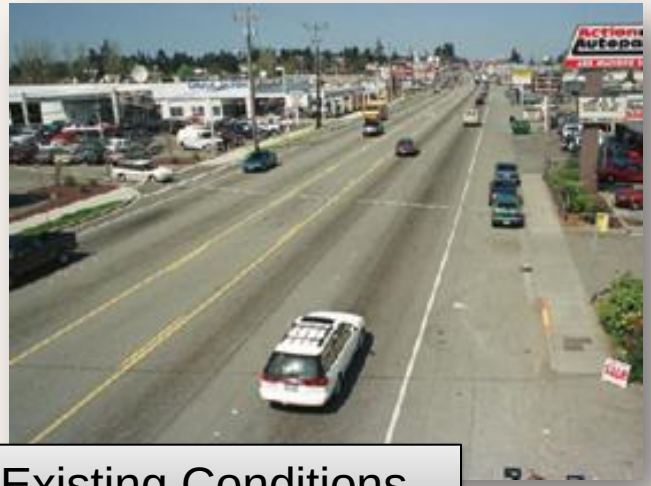
Unlike Nominal Safety, Substantive Safety is a Continuum





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

HSM Vol 1 (Part A) Introduction, Human Factors, and Fundamentals

Part A

Part B

Part C

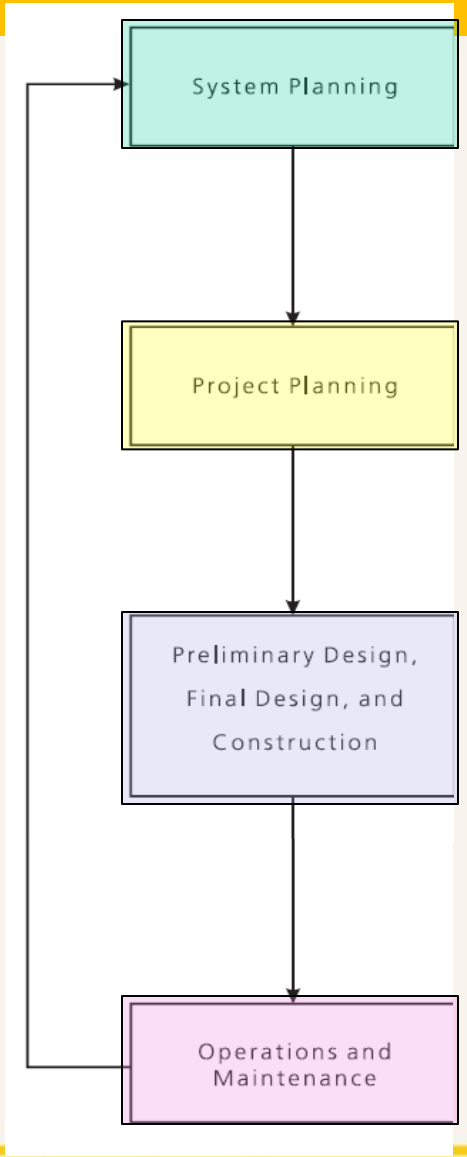
Part D

- **Introduction and Overview (Ch. 1)**
- **Human Factors (Ch. 2)**
- **Fundamentals (Ch. 3)**

Knowledge Building

- Internal staff, consultants, and FLMA partners
- Safety partners (law enforcement, medical)
- External stakeholders
- General public
- Elected officials

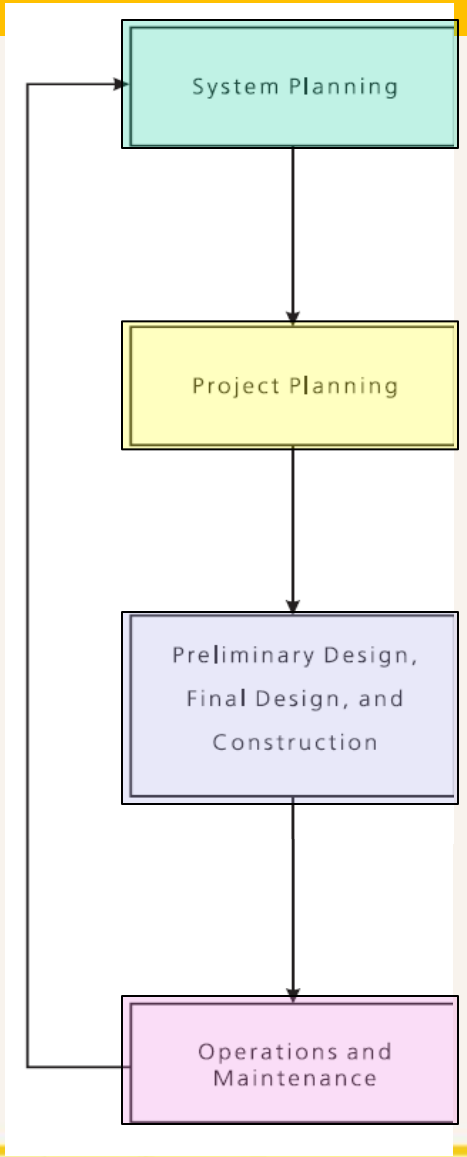
Chapter 1 – Relating the HSM to the Project Development Process



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.

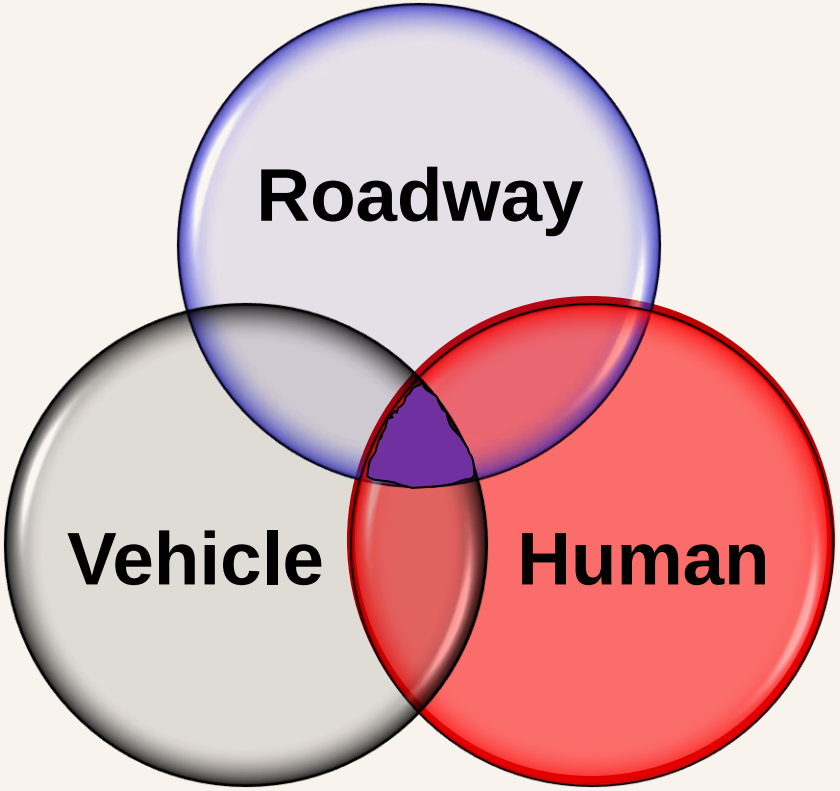
Chapter 9 (Part B) can be used to evaluate the effect of the countermeasures on crash frequency and severity and can contribute to the implementation of safety policy for future system planning.

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



Chapter 2 - Human Factors Common to all Road Users: Information Processing

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

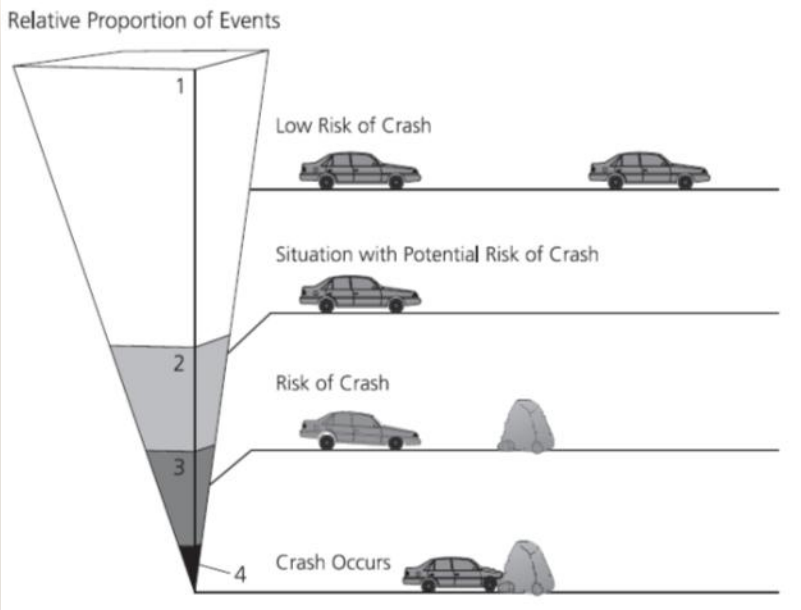
- Say the same thing in different ways

Clarify & Simplify

Clarify and Simplify Examples

Chapter 3 - Fundamentals

- Introduces basic concepts for understanding
  - Roadway Safety Management Techniques
  - Crash estimation methods



Chapter 3 – Definition of Terms

- **'Crash Frequency'** (not rate)
- **KABCO** (Crash severity scale)
- **'Safety Performance Functions'**
- **'Crash Modification Factors'**
- **'Standard Error'**
- **'Regression to the Mean'**
- **'Empirical Bayes (EB)'** Procedures

Crash Frequency = Crashes/Year

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)

Chapter 4 - Network Screening

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

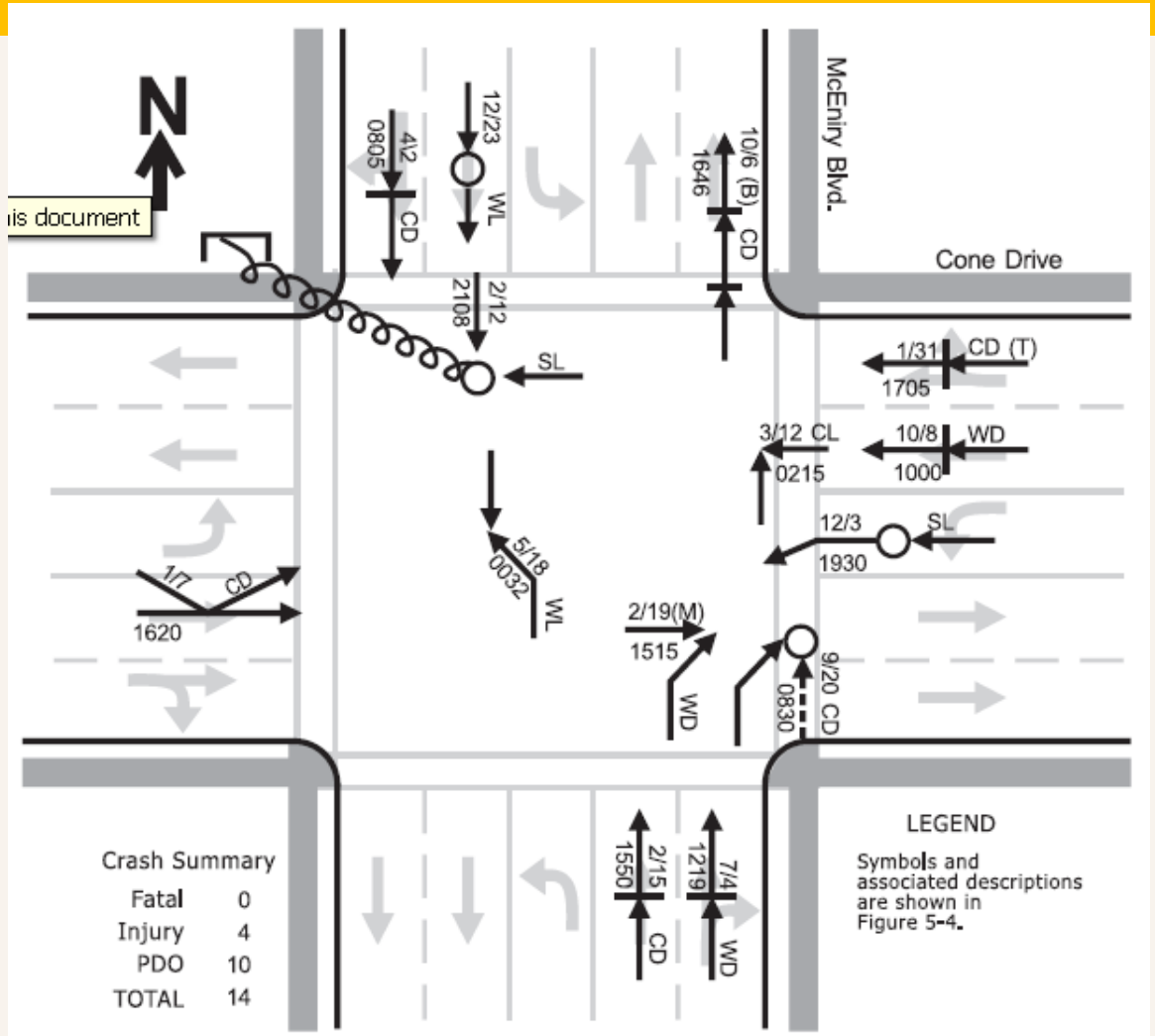
Evaluating crash data and field conditions to identify crash patterns using:

- Crash data
- Historic site data
- Field conditions
- Other information

Chapter 5 - Diagnosis

- 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?



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

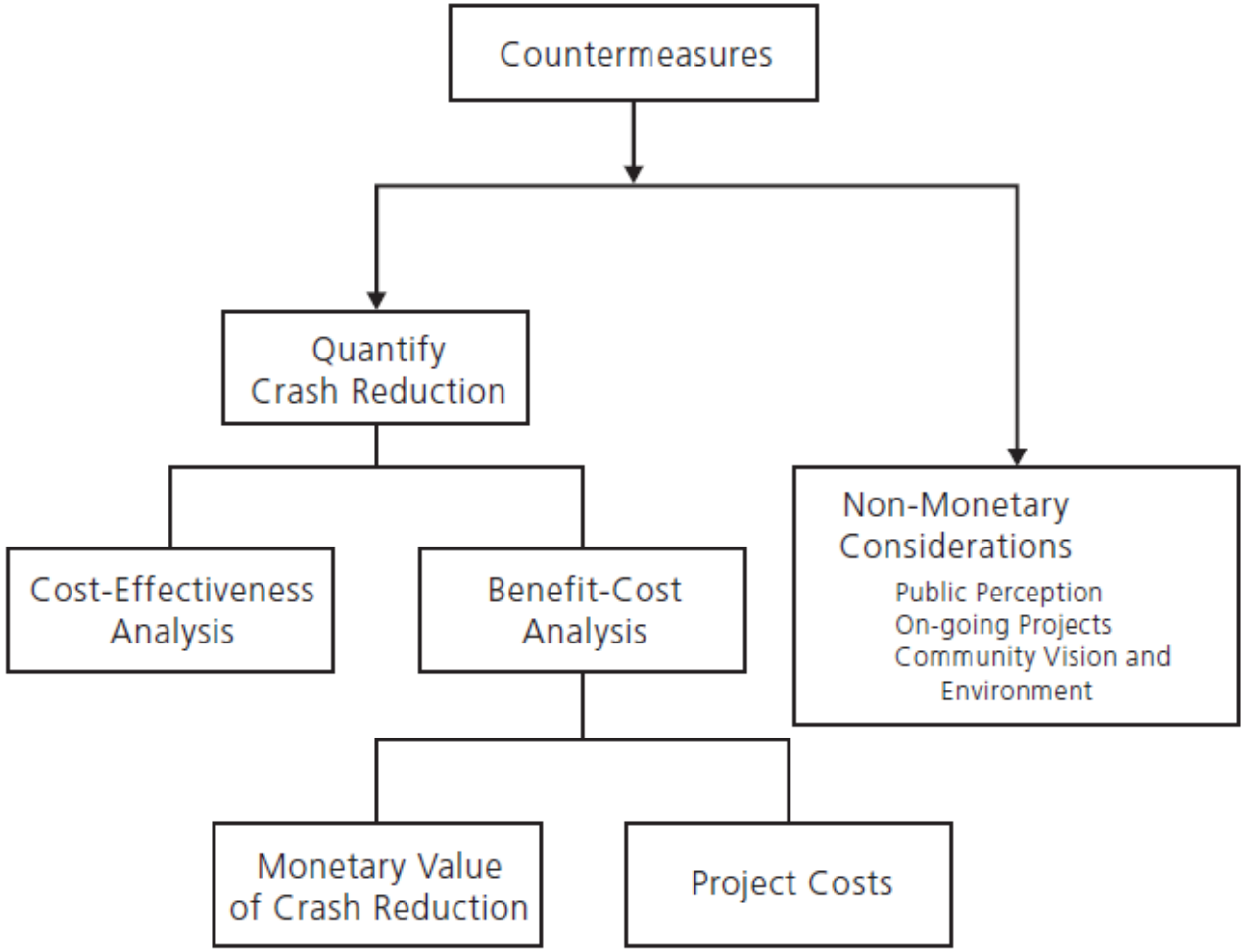
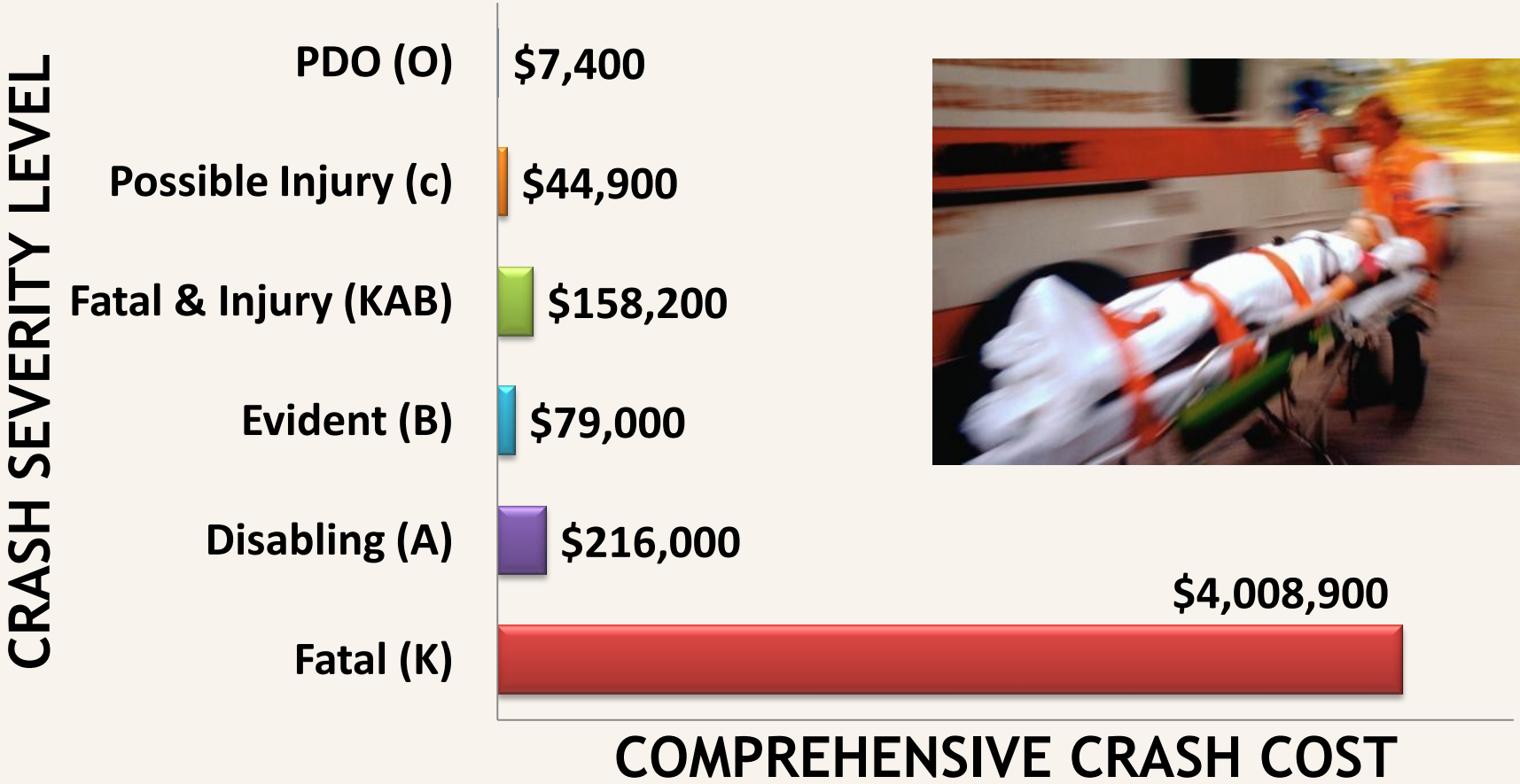


Figure 7-2. Economic Appraisal Process

Chapter 7 - Societal Crash Cost Estimates by Crash Severity



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

Intersections	Traffic Control	Number of Approaches	Major AADT	Minor AADT	Urban/ Rural	Crash Data: Total Year 1	Crash Data: Total Year 2	Crash Data: Total Year 3
2	TWSC	4	22,100	1,650	U	9	11	15
7	TWSC	4	40,500	1,200	U	11	9	14
11	Signal	4	42,000	1,950	U	12	15	11
12	Signal	4	46,000	18,500	U	10	14	8

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

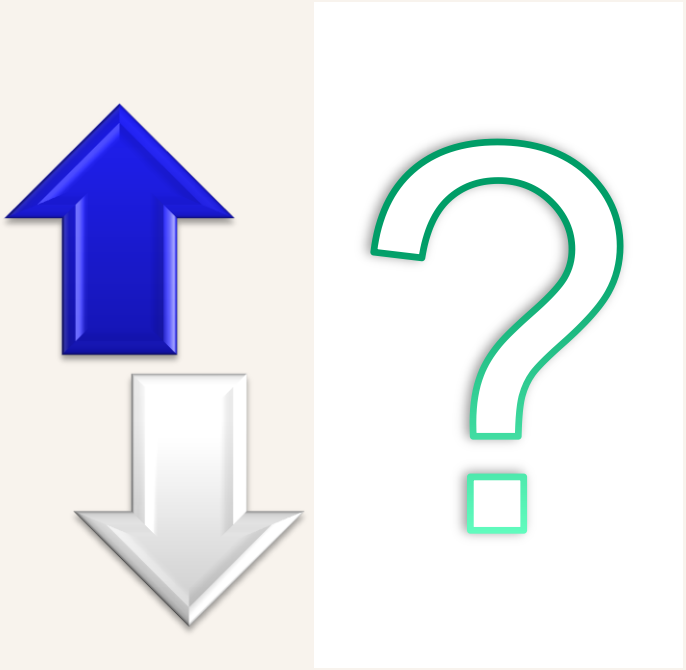
Intersection	Countermeasure	Present Value of Crash Reduction	Cost Estimate
2	Single-Lane Roundabout	$33,437,850	$695,000
7	Add Right-Turn Lane	$1,200,000	$200,000
11	Add Protected Left-Turn Lane	$1,400,000	$230,000
12	Install Red Light Cameras	$1,800,000	$100,000

Table 8-5. Cost-Effectiveness Evaluation

Project	Total	Cost	Cost Effectiveness (Cost/Crash Reduced)
Intersection 2	47	$695,000	$14,800
Intersection 7	6	$200,000	$33,300
Intersection 11	7	$230,000	$32,900
Intersection 12	9	$100,000	$11,100

Chapter 9 - Safety Effectiveness

- Evaluating effectiveness of a countermeasure at one or more sites
- Crash reduction
  - Frequency
  - Severity



Chapter 9 - Safety Effectiveness Evaluation

- 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.

HSM Vol 2 (Part C) Predictive Methods

Part A

Part B

Part C

Part D

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

Part B

Part C

Part D

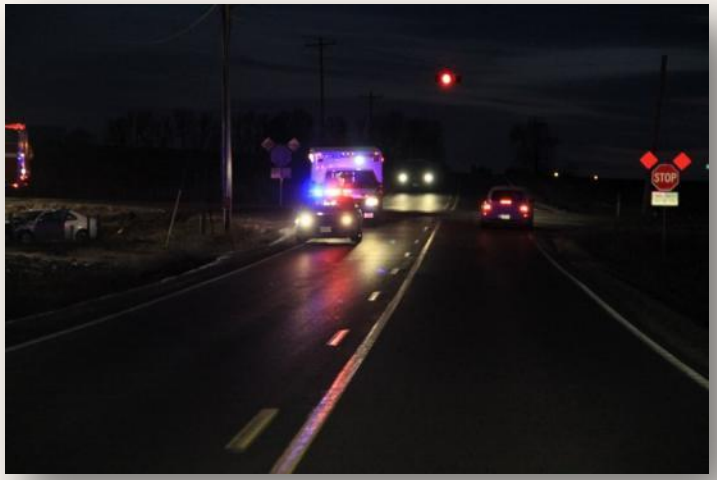
- **Rural Two-lane Roads (Ch. 10)**

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

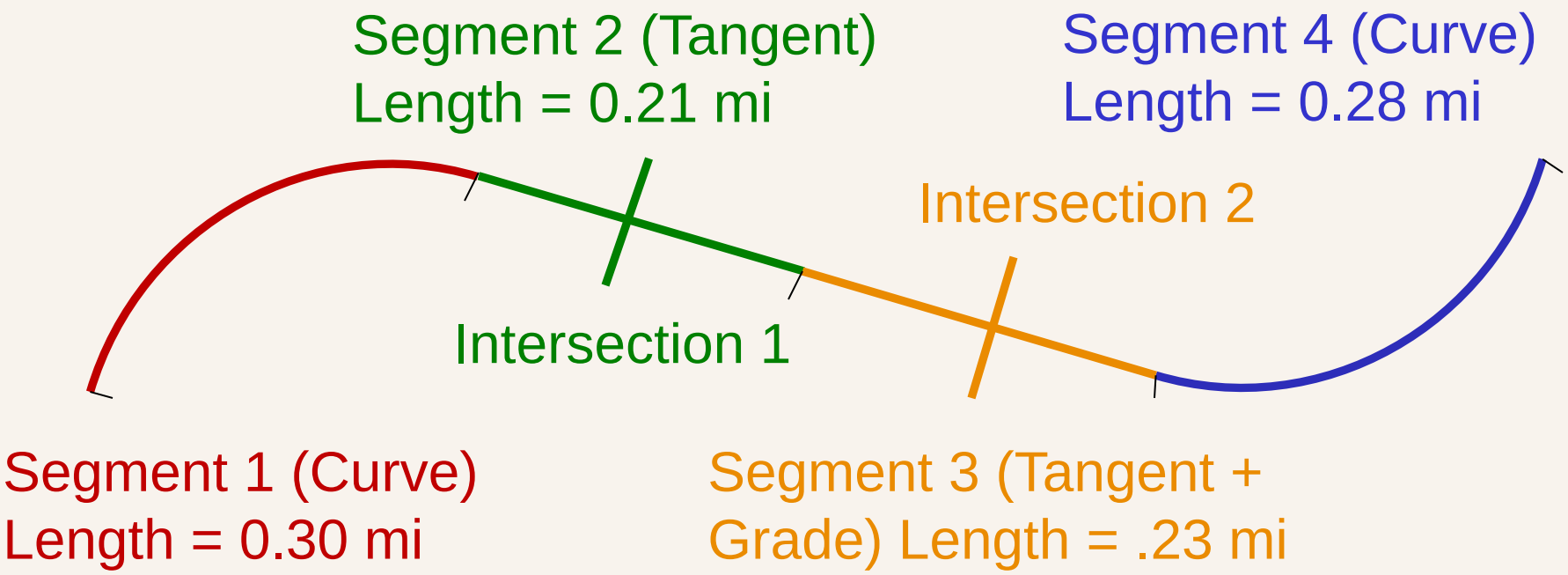
- **Urban Suburban Arterials (Ch. 12)**

Key Components to Applying the Predictive Methods

- Traffic volumes (AADT)
- Roadway characteristics
- Crash data



Divide Road Into Homogeneous Segments



Predicted Crash Frequency (Crash Prediction Model)

$$N_{predicted} = \mathbf{SPF} \times (CMF_1 \times CMF_2 \times \ldots.) \times C$$

where:

Npredicted = crashes per year

SPF = Safety Performance Function

CMF = Crash Modification Factors

C = Local Calibration Factor

Predictive Methods – Safety Performance Functions

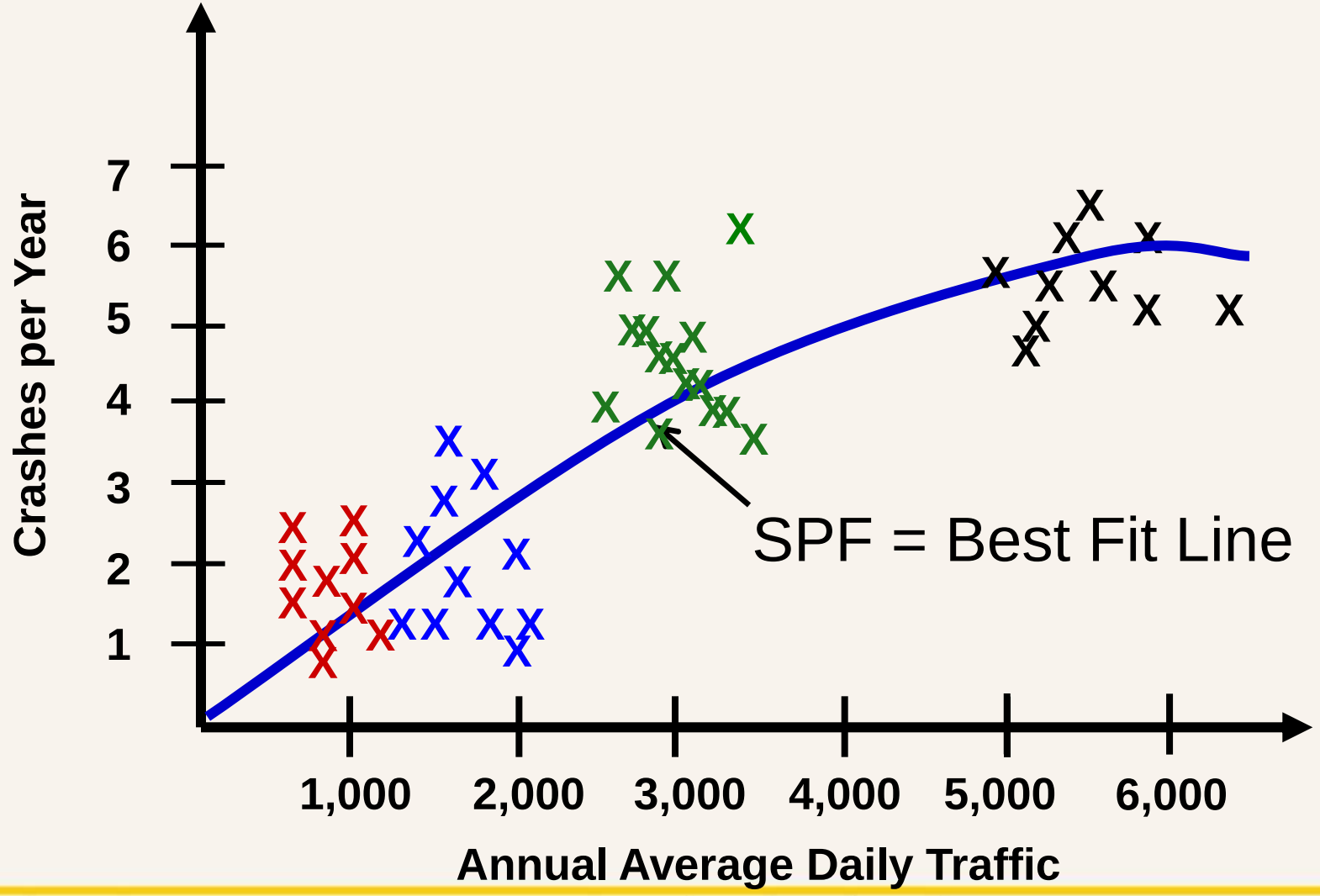
What are *Safety Performance Functions* (SPF)?

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)



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:

$$N_{SPF\ int} = e^{[a + b \ln(AADTmaj) + c \ln(AADTmin)]}$$

Where a, b and c vary for intersection type and traffic control and are given in the HSM

Predictive Methods – Crash Modification Factors

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 or C_i)

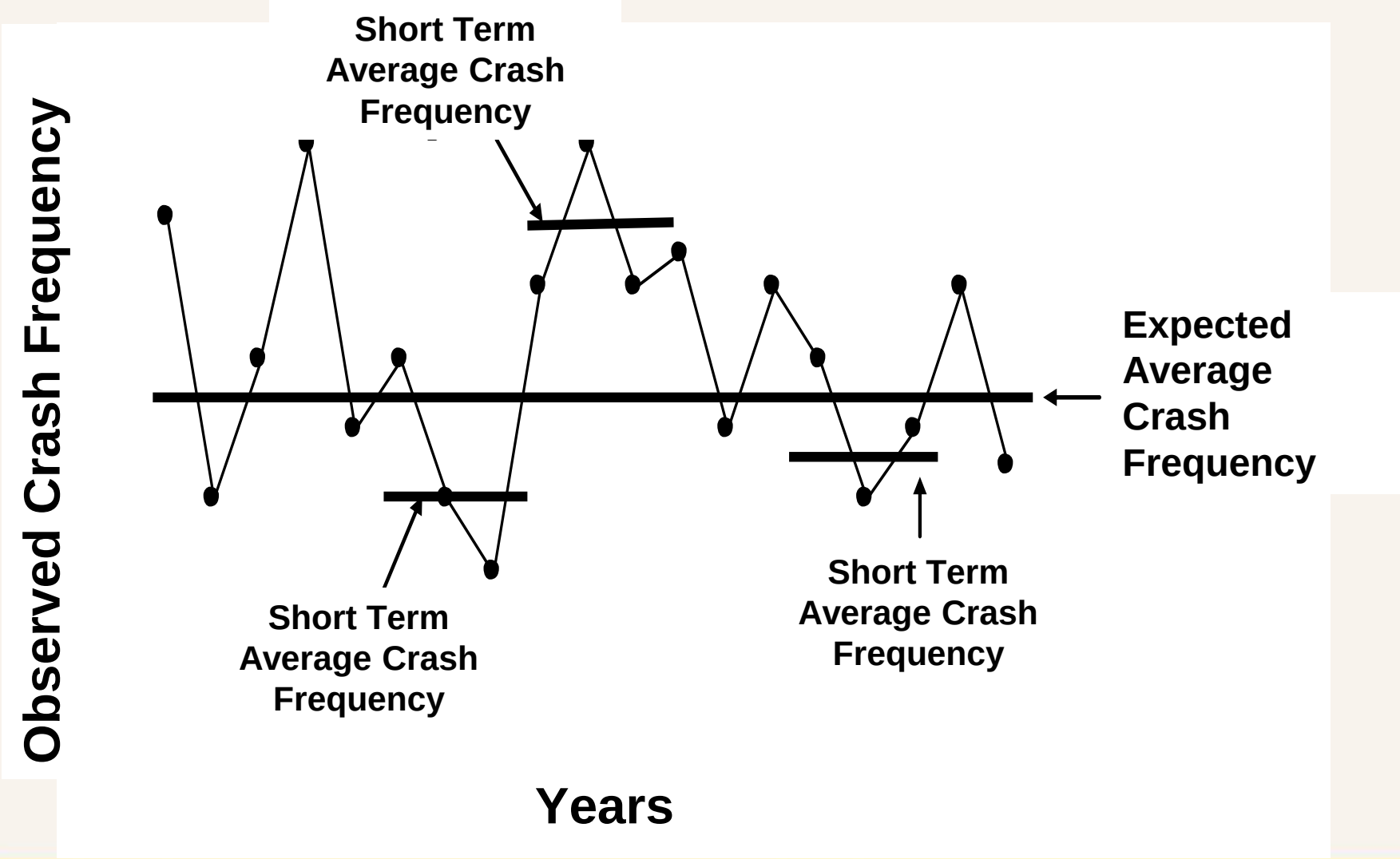
- Adjust HSM SPF-derived crash estimates to reflect local conditions
- Provide method to address for local variations such as:
  - Climate,
  - Driver populations,
  - Animal populations,
  - Crash Reporting Thresholds, and
  - Crash Reporting System Procedures

Appendix A – Specialized Procedures

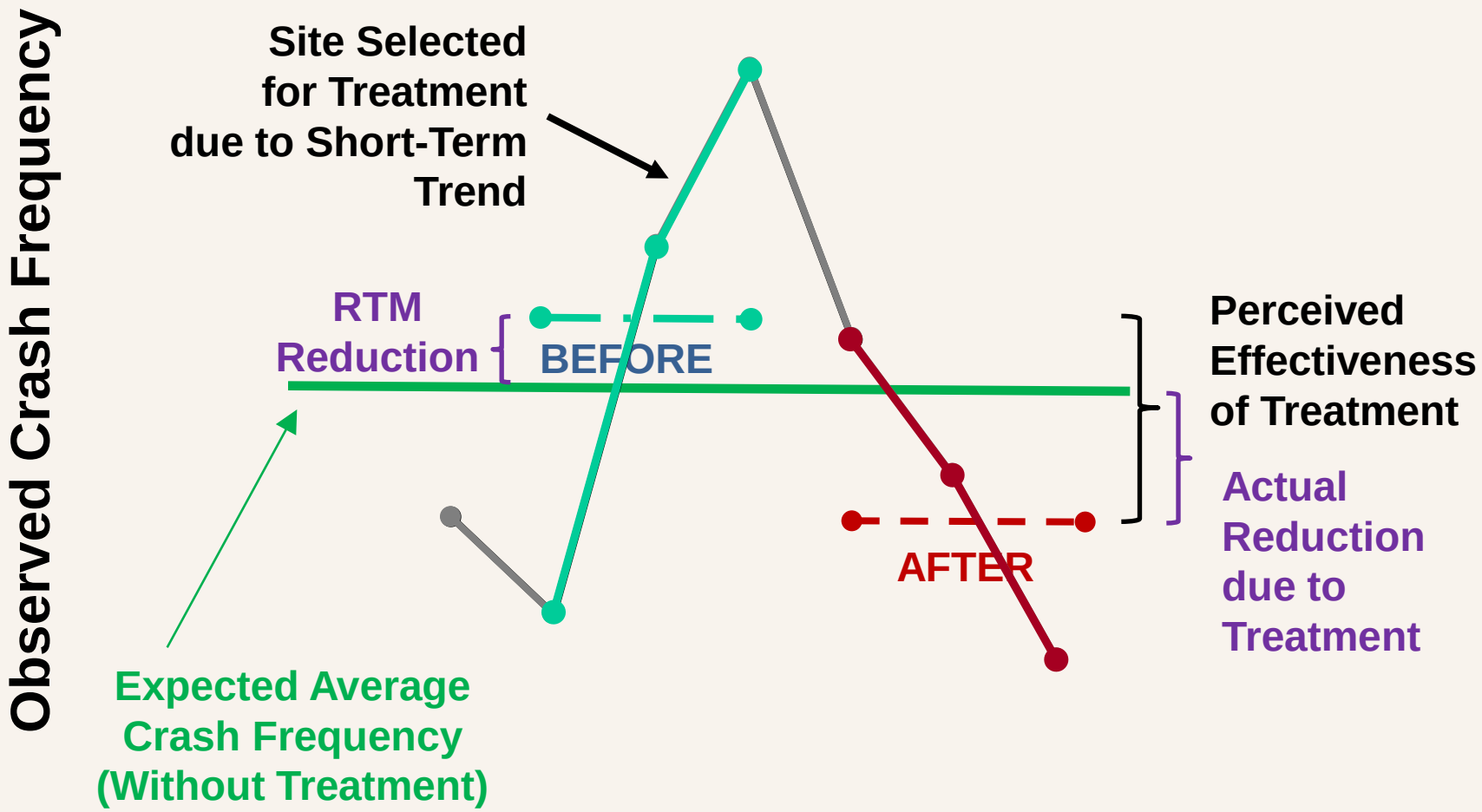
Empirical Bayes (EB) Methodology - method used to combine observed crash frequency data for a given site with predicted crash frequency data from many similar sites to estimate its expected crash frequency.

- 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

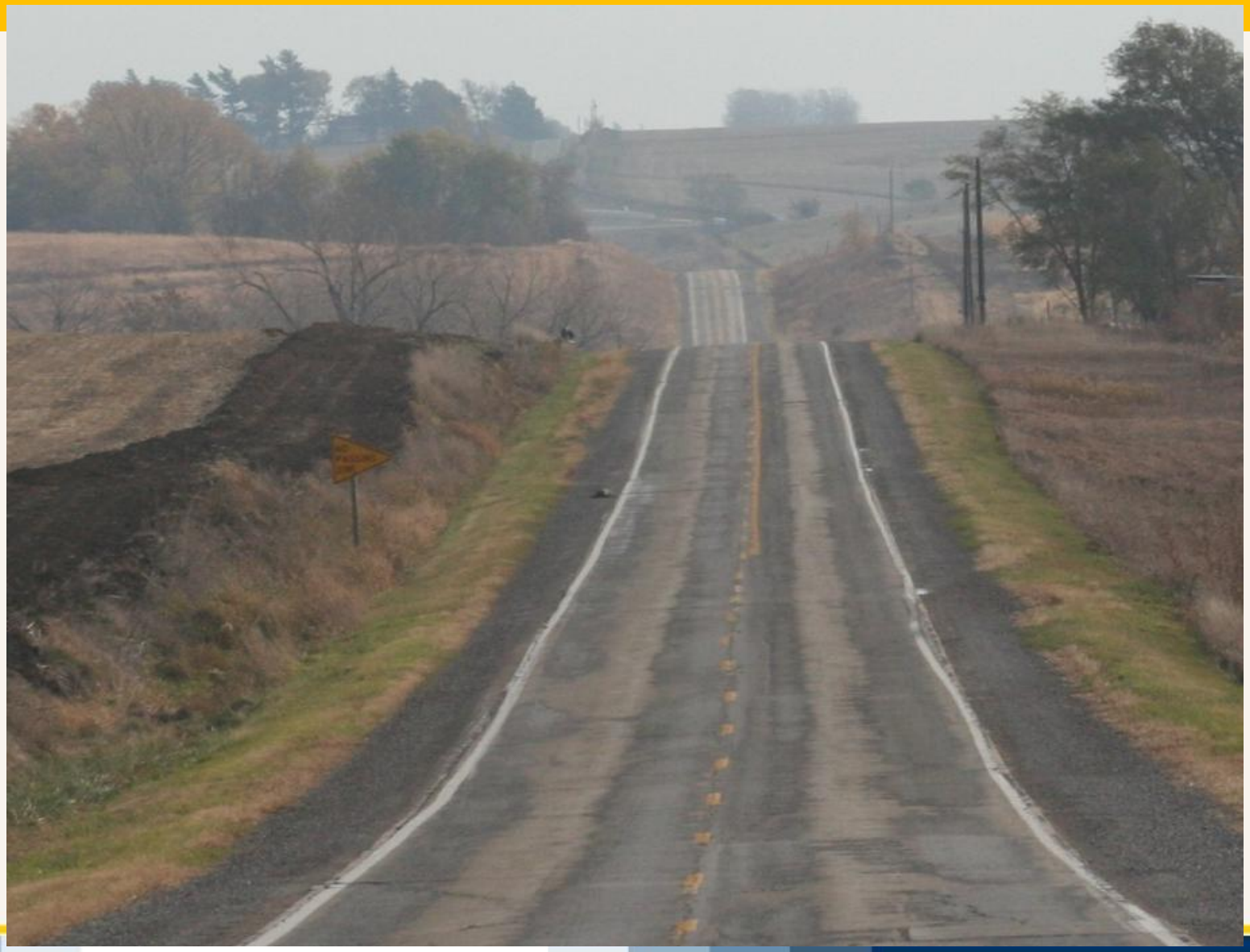
Natural Variability in Crash Frequency



Regression to the Mean – Example



Chapter 10 Rural Two-Lane Road Segments and Intersections



Chapter 10 Base Conditions for Rural Two-Lane Segments

Base Condition	Measurement	CMF
Lane Width (LW)	12 ft	1.00
Shoulder Width (SW)	6 ft	1.00
Shoulder Type	paved	1.00
Roadside Hazard Rating (1-7)	3	1.00
Driveway Density (DD)	5 per mile	1.00
Horizontal Curves	None	1.00
Vertical Curves	None	1.00
Passing Lane	None	1.00
Centerline Rumble Strips	None	1.00
Grade	None	1.00
TWLTL	None	1.00
Lighting	None	1.00
Automated Speed Enforcement	None	1.00

Chapter 10 Base Conditions for Rural Two-Lane Road Intersections

Base Condition	Measurement	CMF
Skew Angle	none	1.00
Presence of Left Turn Lane	none	1.00
Presence of Right Turn Lane	none	1.00
Lighting	none	1.00

Applying the HSM

Step 1 Calculate SPF:

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

AADT = Annual Average Daily Traffic

L = Length of Segment

AADT range from zero to 17,800 vehicles per day

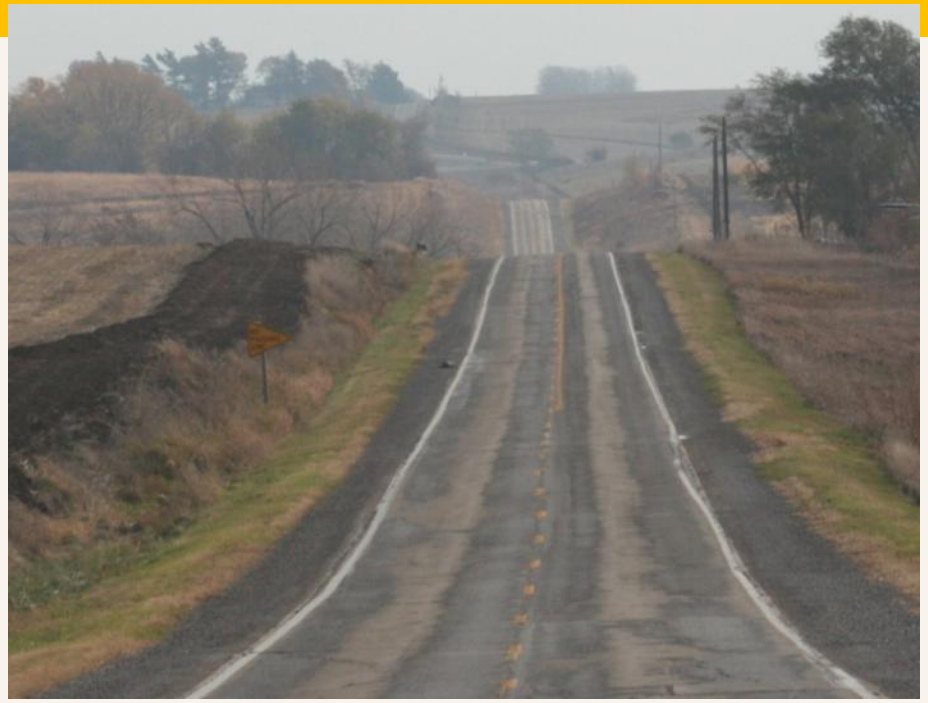
AADT = 2,000

Length of Segment = 2 miles

$N_{spf\ rs} = 2{,}000 \times 2 \times 365 \times 10^{-6} \times e^{-0.312}$

= 1.07 crashes/year or ~ 1 crash every year

Applying the HSM



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

Base Condition		Existing Roadway
12 ft	Lane Width	10 ft
6 ft	Shoulder Width	4 ft
Paved	Shoulder Type	Gravel

CMF for Lane Width on Roadway Segments (CMF_{ra})

Table 10-8. CMF for Lane Width on Roadway Segments (CMF_{ra})

	AADT (vehicles per day)		
Lane Width	**< 400**	**400 to 2000**	**> 2000**
9 ft or less	1.05	$1.05 + 2.81 \times 10^{-4}(AADT - 400)$	1.50
10 ft	1.02	$1.02 + 1.75 \times 10^{-4}(AADT - 400)$	1.30
11 ft	1.01	$1.01 + 2.5 \times 10^{-5}(AADT - 400)$	1.05
12 ft or more	1.00	1.00	1.00

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.

CMF for Shoulder Width on Roadway Segments

Table 10-9. CMF for Shoulder Width on Roadway Segments (CMF_{wra})

	AADT (vehicles per day)		
Shoulder Width	**< 400**	**400 to 2000**	**> 2000**
0 ft	1.10	$1.10 + 2.5 \times 10^{-4}$ (AADT − 400)	1.50
2 ft	1.07	$1.07 + 1.43 \times 10^{-4}$ (AADT − 400)	1.30
4 ft	1.02	$1.02 + 8.125 \times 10^{-5}$ (AADT − 400)	1.15
6 ft	1.00	1.00	1.00
8 ft or more	0.98	$0.98 + 6.875 \times 10^{-5}$ (AADT − 400)	0.87

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

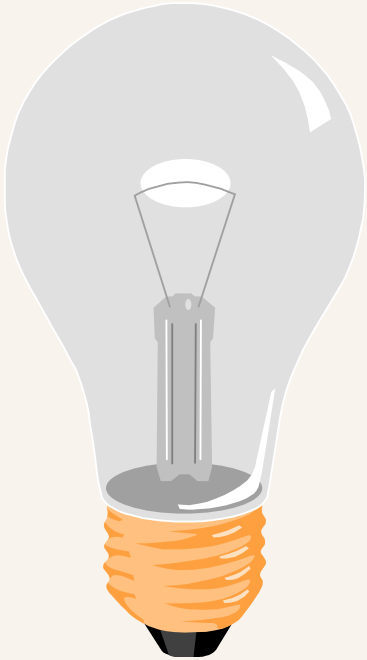
Base Condition		Existing Roadway	
12 ft	Lane Width	10 ft	CMF = 1.30
6 ft	Shoulder Width	2 ft	CMF = 1.30
Paved	Shoulder Type	Gravel	CMF = 1.01

$N_{predicted}$ = 1.07 crashes/year x 1.17[a] x 1.18[a] = 1.48 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 (CMF_{2i}) for Installation of Left-Turn Lanes on Intersection Approaches

		Number of Approaches with Left-Turn Lanes[a]			
Intersection Type	**Intersection Traffic Control**	**One Approach**	**Two Approaches**	**Three Approaches**	**Four Approaches**
Three-leg Intersection	Minor road stop control[b]	0.56		—	—
Four-leg Intersection	Minor road stop control[b]	0.72	0.52	—	—
	Traffic signal	0.82	0.67	0.55	0.45

[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.

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

	Base Condition	Measurement	CMF
Roadway Segments	On Street Parking	None	1.00
	Roadside Fixed Objects	None	1.00
	Median Width	15 ft	1.00
	Lighting	None	1.00
	Automated Speed Enforcement	None	1.00
Multiple Vehicle and Single Vehicle Crashes at Intersections	Left Turn Lanes	None	1.00
	Left Turn Signal Phasing	Permissive	1.00
	Right Turn Lanes	None	1.00
	Right Turn on Red	Permitted	1.00
	Lighting	None	1.00
	Red Light Cameras	None	1.00
Vehicle-Ped Crashes at Signalized Intersections	Bus Stops	None	1.00
	Schools	None	1.00
	Alcohol Sales Establishment	None	1.00

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{predicted\ rs} = (N_{br} + N_{pedr} + N_{biker}) \times C_r$$

Where:

$N_{predicted\ rs}$ = Predicted number of total roadway segment crashes per year

N_{br} = Predicted number of total roadway segment crashes per year with CMFs applied

N_{pedr} = Predicted number of vehicle-pedestrian collisions per year

N_{biker} = Predicted number of vehicle-bicycle collisions per year

C_r = calibration factor for a particular geograhical area

Predicting Crash Frequency of Suburban/Urban Multilane Streets

$$N_{br} = N_{spf\ rs} \times (CMF_{1r} \times CMF_{2r} \times .. CMF_{nr})$$

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}, .. 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)**

PART D - Crash Modification Factors

Part A

Part B

Part C

Part D

- 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:

$$\boxed{CMF \pm SE}$$

SE = standard error

Used to determine low (SE), medium (2 × SE) and high (3 × SE) confidence interval for CMF

Standard Error

- 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

CI (x%) = CMF ± (SE × MSE)

where:

SE = Standard Error for the particular CMF

Desired Level of Confidence	Confidence Interval	Multiple of Standard Error (MSE)
Low	**65% - 70%**	**1**
Medium	**95%**	**2**
High	**99.9%**	**3**

CMF for Red Light Running Automated Enforcement

Table 14-28. Potential Crash Effects of Installing Red-Light Cameras at Intersections (23,30)

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

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)

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF
Improve SV < 0.01	Rural (Two-lane)	Unspecified	All types (All severities)	1.00
Improve 0.01 ≤ SV < 0.02				= 1.00 + 6 (SV – 0.01)
Improve SV > 0.02				= 1.06 + 3 (SV – 0.02)
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.

HSM Companion Software

HSM Part	Supporting Tool
Part B: Roadway Safety Management Process	**SafetyAnalyst** www.safetyanalyst.org
Part C: Predictive Methods	**IHSDM** www.ihsdm.org
Part D: Crash Modification Factors	**FHWA CRF/CMF Clearinghouse** www.cmfclearinghouse.com

CMF
CRASH MODIFICATION FACTORS CLEARINGHOUSE

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Quick Search

rumble

- narrow by countermeasure category
- narrow by crash type -
- narrow by crash severity -
- narrow by roadway type -

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Search CMFs

Read the latest issue of our e-newsletter CMF Update

Read and subscribe to CMF Update, the quarterly e-newsletter of the CMF Clearinghouse.

1 2 3 4

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

www.cmfclearinghouse.org

HSM prediction urban and suburban arterials_120210.xls [Compatibility Mode] - Microsoft Excel

K7 | 2010

Worksheet 2A -- General Information and Input Data for Urban and Suburban Arterial Intersections

General Information		Location Information	
Analyst	HNI	Roadway	STH 70
Agency or Company	FHWA	Intersection	Crescent Road
Date Performed	03/25/10	Jurisdiction	Rhinelander, WI
		Analysis Year	2010

Input Data		Base Conditions	Site Conditions
Intersection type (3ST, 3SG, 4ST, 4SG)		--	3ST
AADT $_{major}$ (veh/day)	$AADT_{MAX}$ = 45,700 (veh/day)	--	14,000
AADT $_{minor}$ (veh/day)	$AADT_{MAX}$ = 9,300 (veh/day)	--	4,000
Intersection lighting (present/not present)		Not Present	Not Present
Calibration factor, C_i		1.00	1.00
Data for unsignalized intersections only:		--	--
Number of major-road approaches with left-turn lanes (0,1,2)		0	1
Number of major-road approaches with right-turn lanes (0,1,2)		0	0
Data for signalized intersections only:		--	--
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	0
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		0	0
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		--	0
Type of left-turn signal phasing for Leg #1		Permissive	Not Applicable
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 (if applicable)		--	Not Applicable
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3		0	0
Intersection red light cameras (present/not present)		Not Present	Not Present
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only			10
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		--	0
Number of bus stops within 300 m (1,000 ft) of the intersection		0	0
Schools within 300 m (1,000 ft) of the intersection (present/not present)		Not Present	Not Present
Number of alcohol sales establishments within 300 m (1,000 ft) of the intersection		0	0

Instructions | Segment1 | Segment2 | Segment Tables | Intersection1 | Intersection2 | Intersection Tables | Urban

Ready

BREAK

Applying the HSM

Low Cost Safety Improvements

FHWA Proven Safety Countermeasures

Clarify and Simplify

Crash Modification Factors

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

2012 FHWA Proven Safety Countermeasures

Proven Safety Countermeasures Web Site

Scan the code at right to go directly to the Web site!

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$_{SM}$
- Enhanced Delineation and Friction for Horizontal Curves

LEARN MORE TODAY!

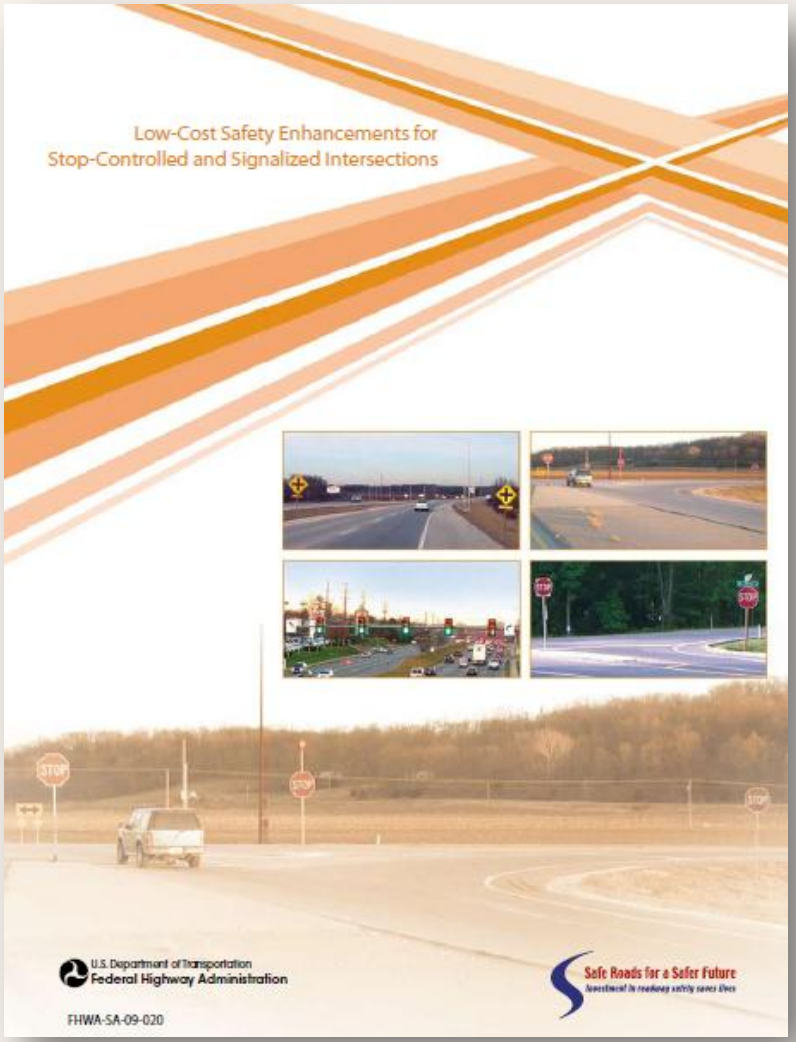
http://safety.fhwa.dot.gov/provencountermeasures

U.S. Department of Transportation
Federal Highway Administration

Safe Roads for a Safer Future
Investment in roadway safety saves lives

Low Cost Safety Enhancements for Stop-Controlled and Signalized Intersections

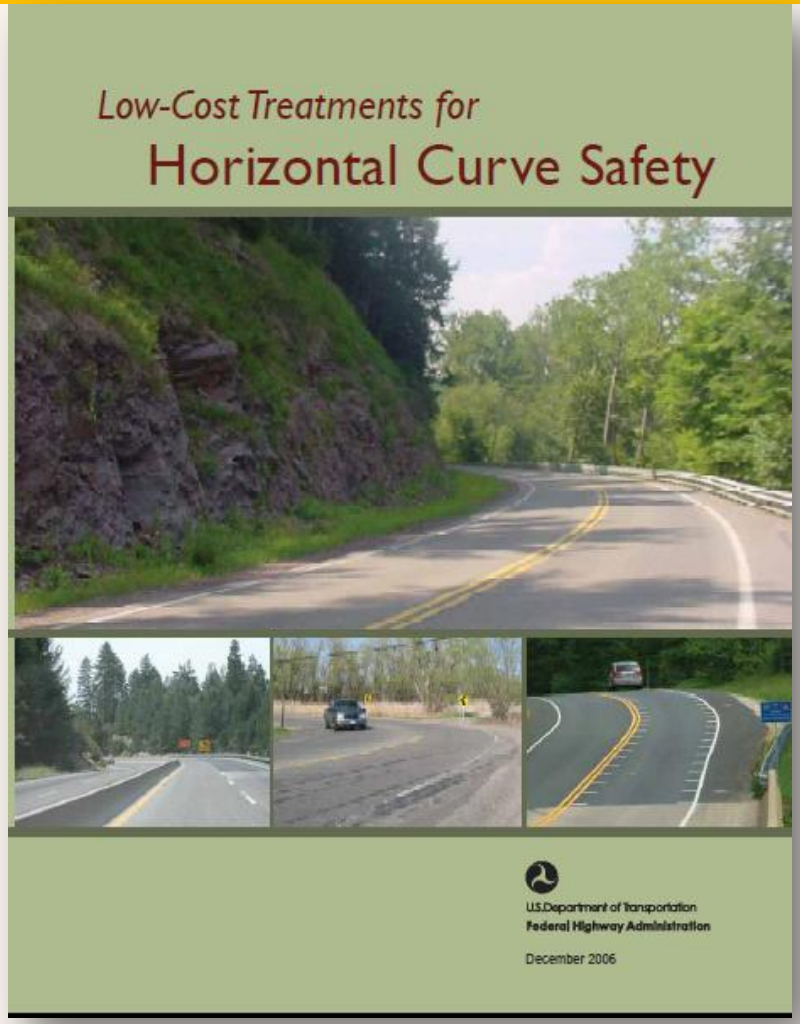
- Signing and Pavement Marking
- J-Turns on multi-lane facilities
- Lighting
- High Friction Surfaces
- Speed Reduction



http://safety.fhwa.dot.gov/intersection/resources/fhwasa09020/

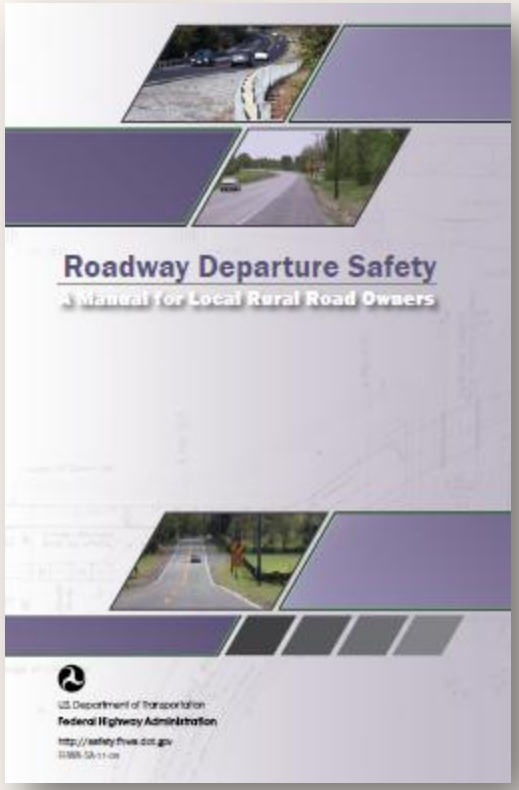
Low-Cost Treatments for Horizontal Curves

- Enhanced signing
- Shoulder widening
- Lighting

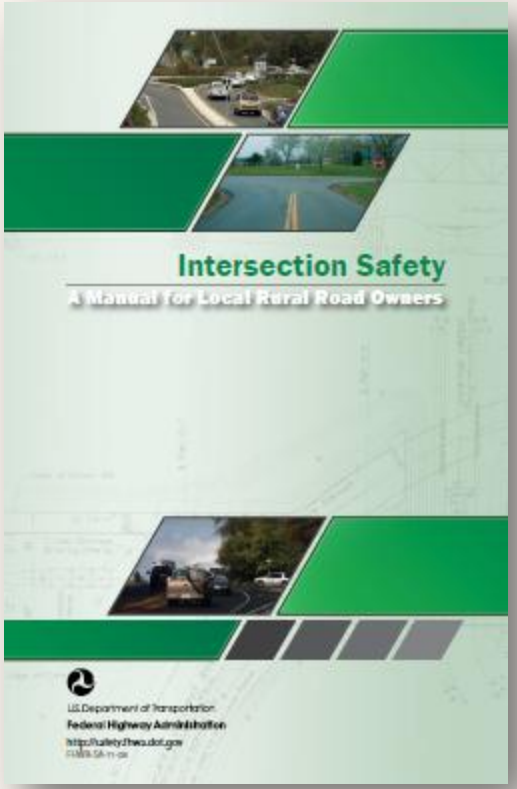


http://safety.fhwa.dot.gov/roadway_dept/horicurves/fhwasa07002/fhwasa07002.pdf

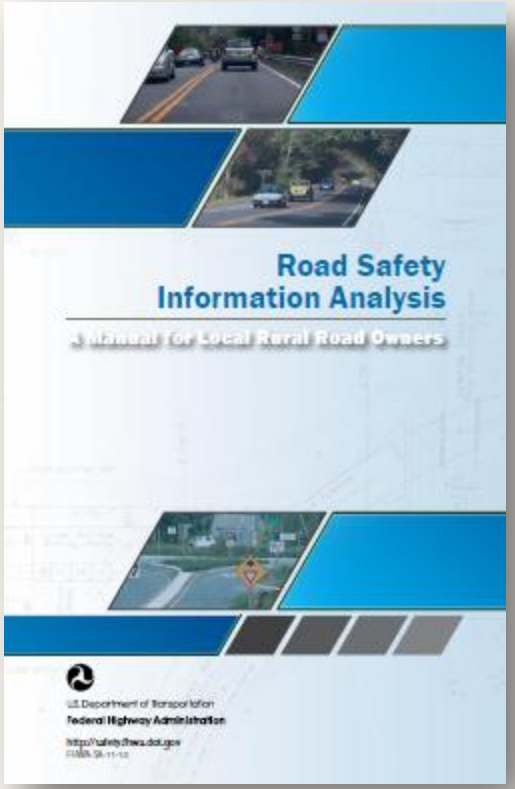
Manuals for Local Rural Road Owners



Roadway Departure



Intersections



Safety Analysis

Case Study

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.

<u>Scenario # 1CMFs for Existing Conditions:</u>
12 ft lane width, CMF= 1.00
No shoulders, CMF = 1.29
Combined CMFs = 1.00x1.29x=<u>1.29</u>

<u>CMFs for Scenario #2:</u>
11 ft lane width, CMF = 1.03
1 ft shoulder width, CMF = 1.22
Combined CMFs = 1.03x1.22=<u>1.26</u>

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 * 1.29 = 34.47 crashes per year or 344.7 crashes in 10 years. Scenario 2 conditions yield an expected 26.72 * 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

Turn Lanes

Table 10-13. Crash Modification Factors (CMF_{2i}) for Installation of Left-Turn Lanes on Intersection Approaches

Intersection Type	Intersection Traffic Control	Number of Approaches with Left-Turn Lanes[a]			
		One Approach	Two Approaches	Three Approaches	Four Approaches
Three-leg Intersection	Minor road stop control[b]	0.56	—	—	—
Four-leg Intersection	Minor road stop control[b]	0.72	0.52	—	—
	Traffic signal	0.82	0.67	0.55	0.45

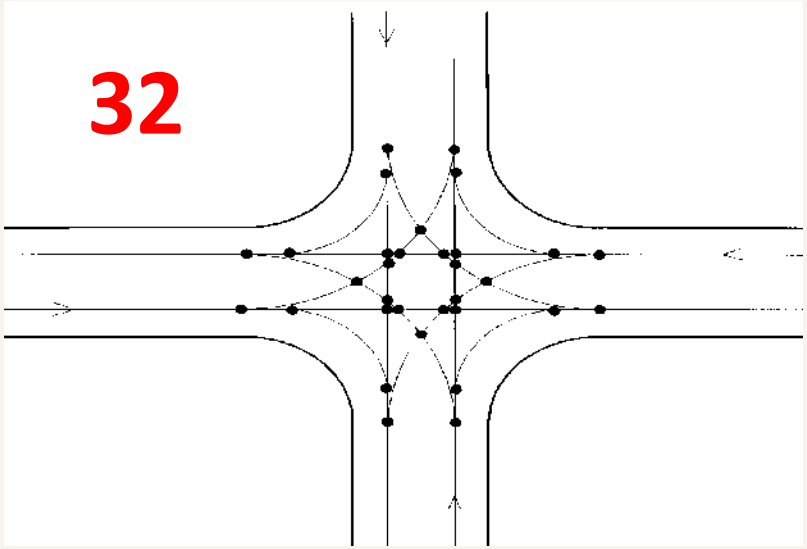
[a] Stop-controlled approaches are not considered in determining the number of approaches with left-turn lanes
[b] Stop signs present on minor road approaches only.

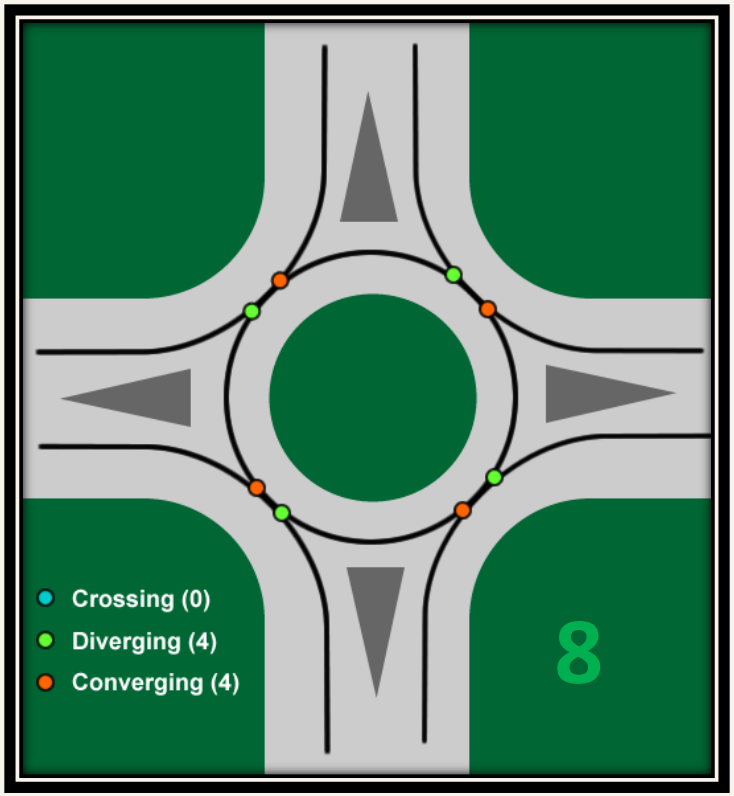
Table 10-14. Crash Modification Factors (CMF_{3i}) for Right-Turn Lanes on Approaches to an Intersection on Rural Two-Lane, Two-Way Highways

Intersection Type	Intersection Traffic Control	Number of Approaches with Right-Turn Lanes[a]			
		One Approach	Two Approaches	Three Approaches	Four Approaches
Three-Leg Intersection	Minor road stop control[b]	0.86	—	—	—
Four-Leg Intersection	Minor road stop control[b]	0.86	0.74	—	—
	Traffic signal	0.96	0.92	0.88	0.85

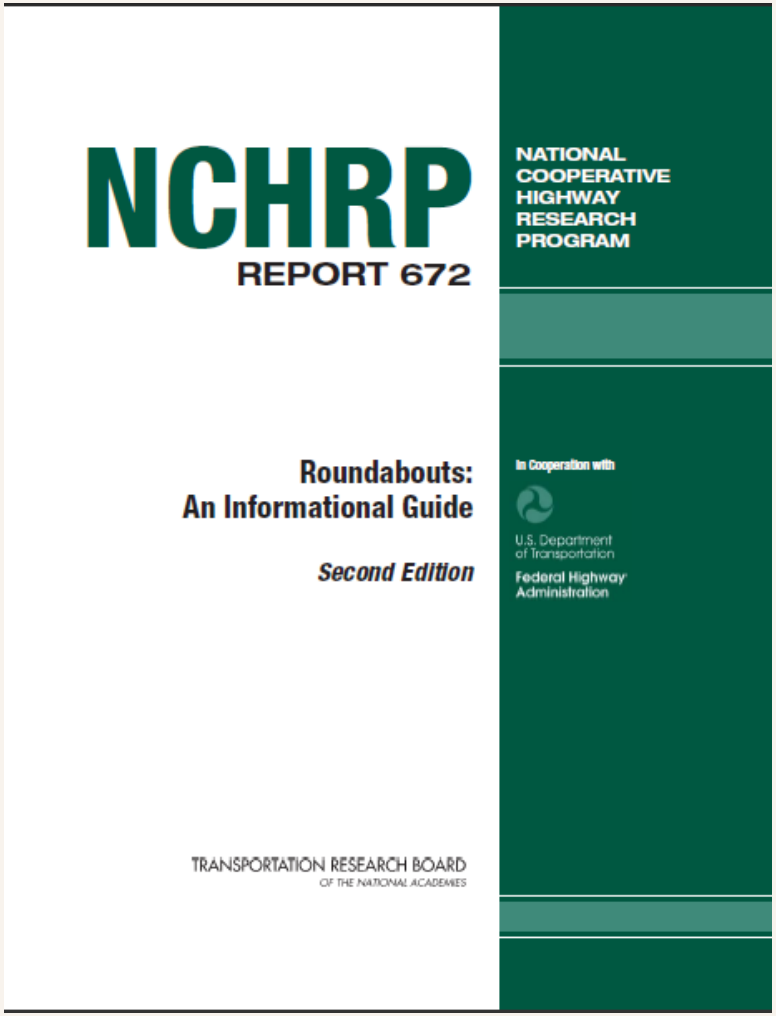
[a] Stop-controlled approaches are not considered in determining the number of approaches with right-turn lanes.
[b] Stop signs present on minor road approaches only.

Intersection Conflict Points

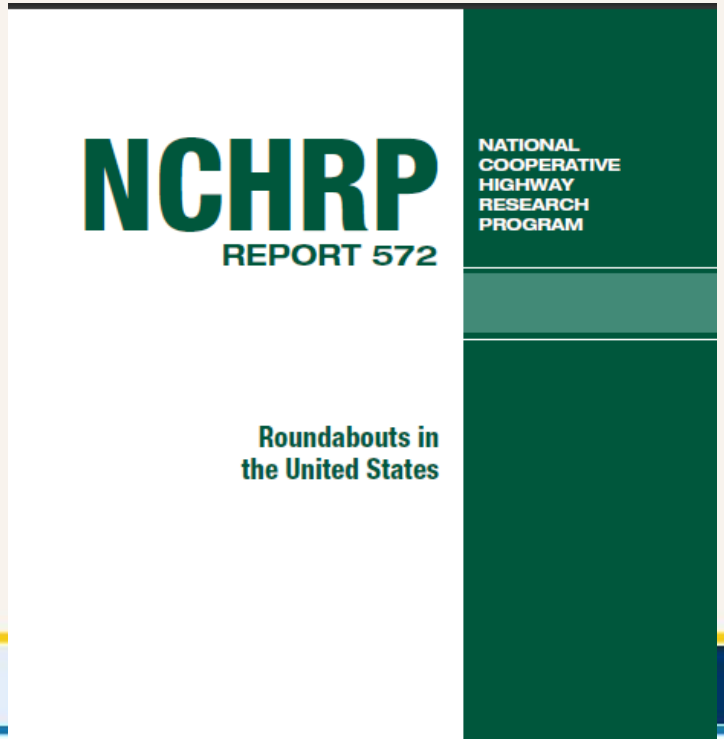




Roundabouts are Alternatives to Conventional Intersections



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

Setting (Intersection Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
All settings (One or two lanes)		All types (All severities)	0.56	0.05
		All types (Injury)	0.18	0.04
Rural (One lane)		All types (All severities)	0.29	0.04
		All types (Injury)	0.13	0.04

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)

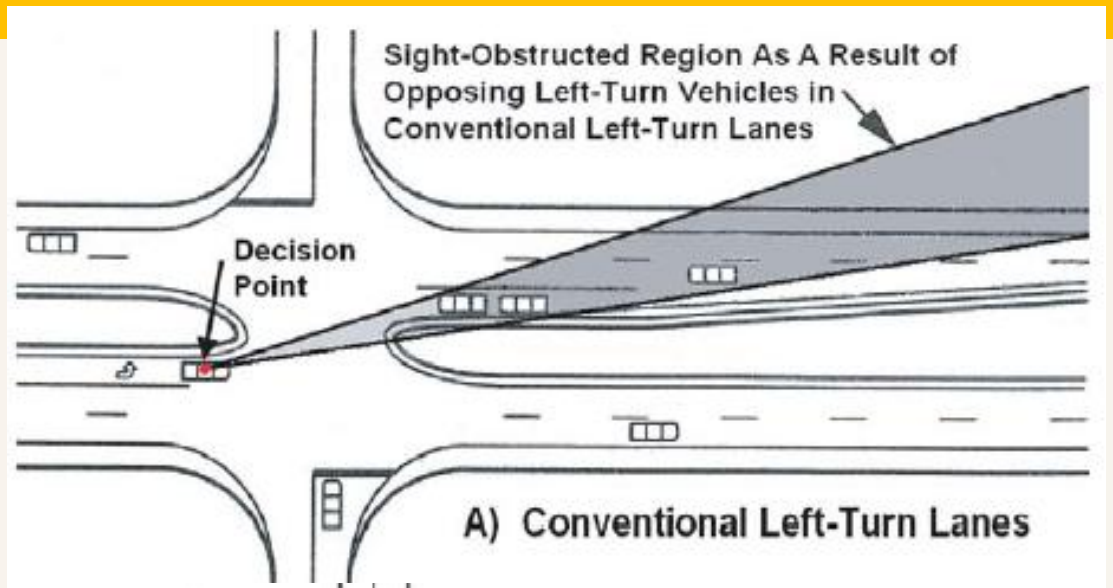
Treatment	Setting (Intersection Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
Convert signalized intersection to modern roundabout	Urban (One or two lanes)	Unspecified	All types (All severities)	**0.99***	**0.1**
			All types (Injury)	**0.40**	**0.1**
	Suburban (Two lanes)		All types (All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

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.

Rural Multilane Intersections – Positive Offset Left Turn Lanes

<u>NCHRP 650:</u> 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%.



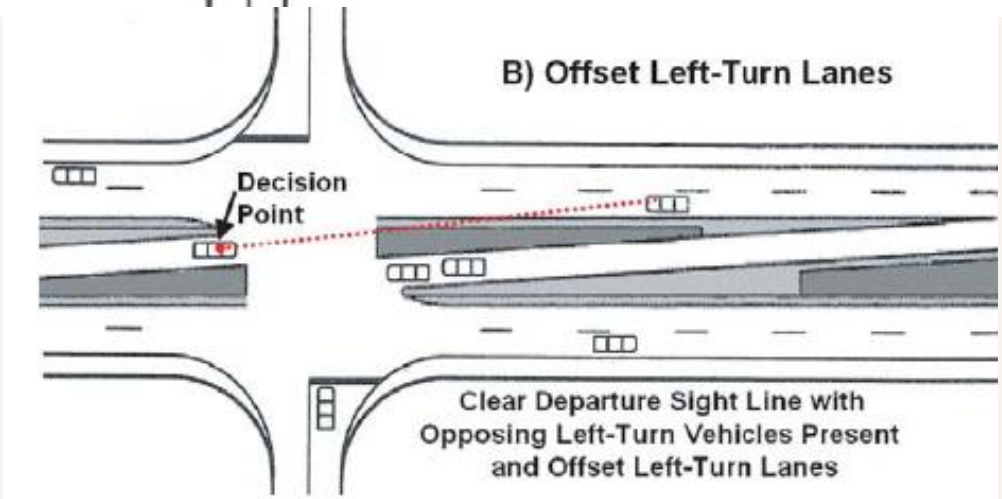


Figure 97. Offset left-turn lane design concept illustration.

Positive Offset Left Turn Lanes

Angled positive offset

Florida DOT –
very wide offsets

Parallel positive offset

Ohio DOT

Change Plus Clearance Interval

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

Treatment	Setting (Intersection Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
Modify change plus clearance interval to ITE 1985 Proposed Recommended Practice	Unspecified (Four-leg signalized)	Unspecified	All types (All severities)	**0.92***	**0.07**
			All types (Injury)	**0.88**	**0.08**
			Multiple-vehicle (All severities)	**0.95***	**0.07**
			Multiple-vehicle (Injury)	**0.91***	**0.09**
			Rear-end (All severities)	*1.12*[7]	*0.2*
			Rear-end (Injury)	*1.08**[7]	*0.2*
			Right angle (All severities)	*0.96**[7]	*0.2*
			Right angle (Injury)	*1.06*[7]	*0.2*
			Pedestrian and Bicyclist (All severities)	*0.63*	*0.3*
			Pedestrian and Bicyclist (Injury)	*0.63*	*0.3*

Base Condition: Unspecified.

Signal Backplates

Enhance Traffic Signal Visibility – Add Backplates:

CRF 2% to 24% (All Crashes) CRF 32% (Angle Crashes)

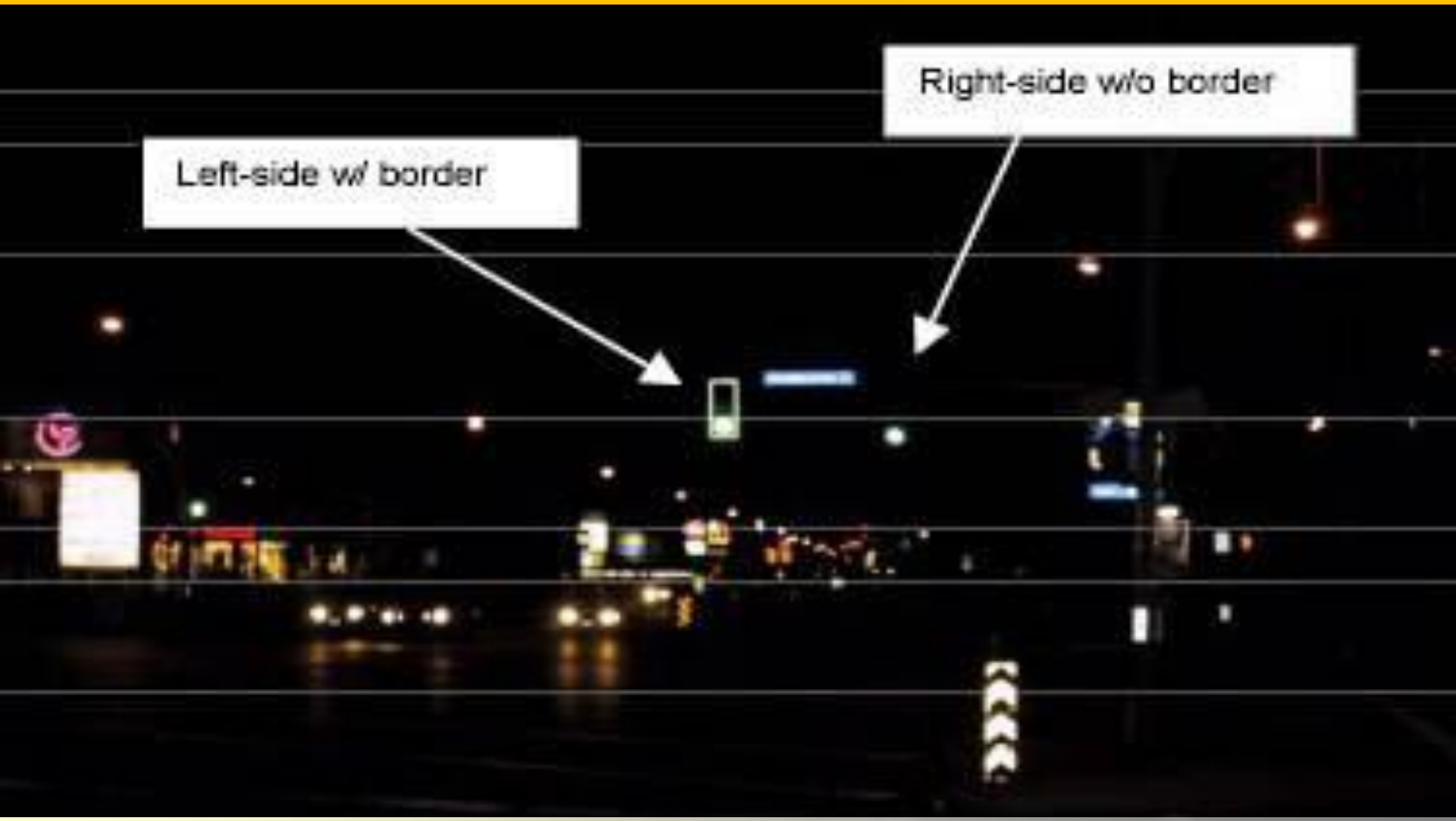
CRF 50% (Red Light Running Frequency)

Retroreflectorized Border

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 14-23. Potential Crash Effects of Modifying Left-Turn Phase at Urban Signalized Intersections (8,15,22)

Treatment	Setting (Intersection Type)	Traffic Volume AADT (veh/day)	Crash Type (Severity)	CMF	Std. Error
Change to protected phasing (8,15)	Urban (Four- and three-leg signalized)	Unspecified	Left-turn crashes on treated approach (All severities)	**0.01**+	**0.01**
			All types (All severities)	**0.94***+	**0.1**
Change from permissive to protected/permissive or permissive/protected phasing (15,22)	Urban (Four-leg signalized)	Major road 3,000 to 77,000 and minor road 1 to 45,500	Left-turn (Injury)	**0.84**	**0.02**
Change from permissive to protected/permissive or permissive/protected phasing (15)	Urban (Four-leg signalized)	Unspecified	All types (All severities)	0.99	N/A°

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

Flashing Beacons

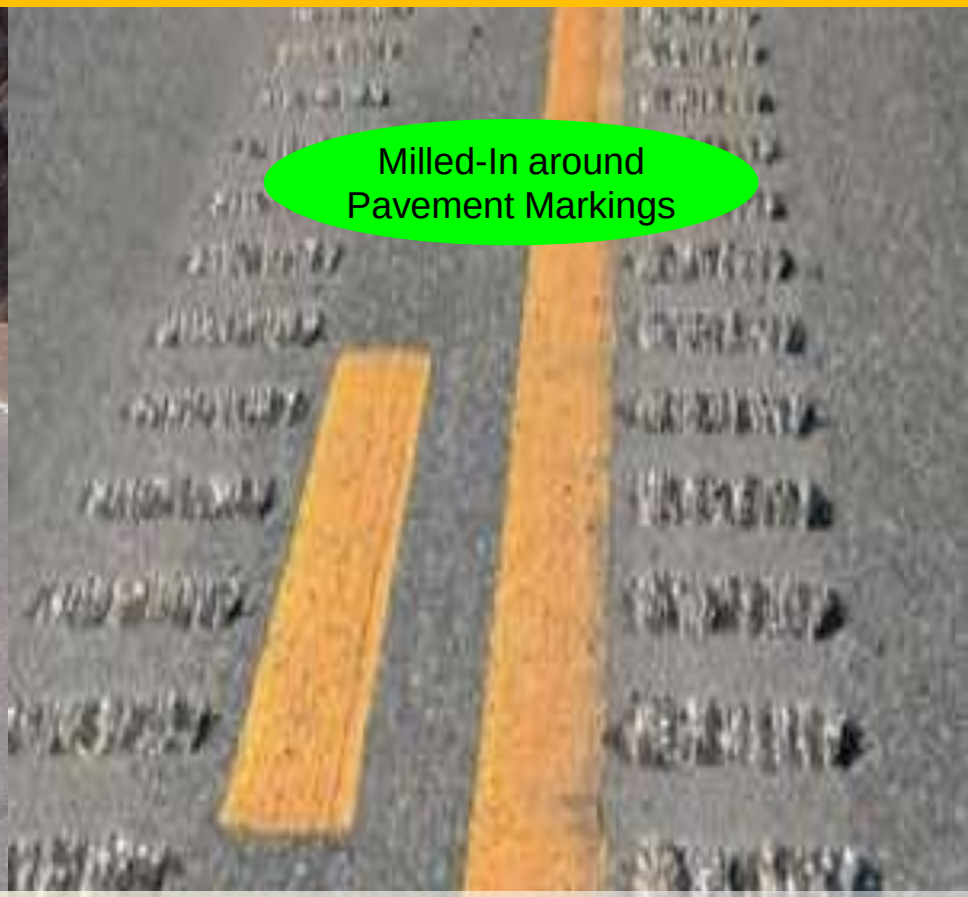
Table 14-22. Potential Crash Effects of Providing Flashing Beacons at Stop-Controlled, Four-Leg Intersections on Two-Lane Roads (31)

Treatment	Setting (Intersection Type)	Traffic Volume AADT (veh/day)	Crash Type (Severity)	CMF	Std. Error
Provide flashing beacons at stop-controlled intersections	All settings (Stop-controlled)	Major road volume 250 to 42,520, minor road volume 90 to 13,270	All types (All severities)	**0.95***	**0.04**
			All types (Injury)	**0.90***	**0.06**
			Rear-end (All severities)	**0.92***	**0.1**
			Angle (All severities)	**0.87**	**0.06**
	Rural (Stop-controlled)		Angle (All severities)	**0.84**	**0.06**
	Suburban (Stop-controlled)		Angle (All severities)	**0.88**	**0.1**
	Urban (Stop-controlled)		Angle (All severities)	*1.12*	*0.3*
	All settings (Minor-road stop-controlled)		Angle (All severities)	**0.87**	**0.06**
	All settings (All-way stop-controlled)		Angle (All severities)	*0.72*	*0.2*
	All settings (Standard overhead beacons)		Angle (All severities)	**0.88**	**0.06**
	All settings (Standard stop-mounted beacons)		Angle (All severities)	*0.42*	*0.2*
	All settings (Standard overhead and stop-mounted beacons)		Angle (All severities)	**0.87**	**0.06**
	All settings (Actuated beacons)		Angle (All severities)	**0.86**	**0.1**

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



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
2. "Evaluation of the Effects of Centerline Rumble Strips on Lateral Vehicle Placement and Speed", Porter, et al

Edgeline Rumble Strips

NCHRP 500 Volume 6 “Guide for Addressing Run-Off-Road Collisions”

Safety Edge

Widened/Stabilized Lane or Shoulder on Inside of Curves

NCHRP 500 Volume 7 "Guide for Collisions on Horizontal Curves"

Table 13-56. Potential Crash Effects of Providing Highway Lighting (7,8,12,27)

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
Provide highway lighting	All settings (All types)	Unspecified	All types (Nighttime injury) (8)	**0.72**	**0.06**
			All types (Nighttime non-injury) (8)	**0.83**	**0.07**
			All types (Nighttime injury) (15)	0.71	N/A
			All types (Nighttime all severities) (15)	0.80	N/A
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)

Treatment	Setting (Road Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
Install combination horizontal alignment/ advisory speed signs	Unspecified (Unspecified)	Unspecified	All types (Injury)	**0.87**	**0.09**
			All types (Non-injury)	*0.71*	*0.2*

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

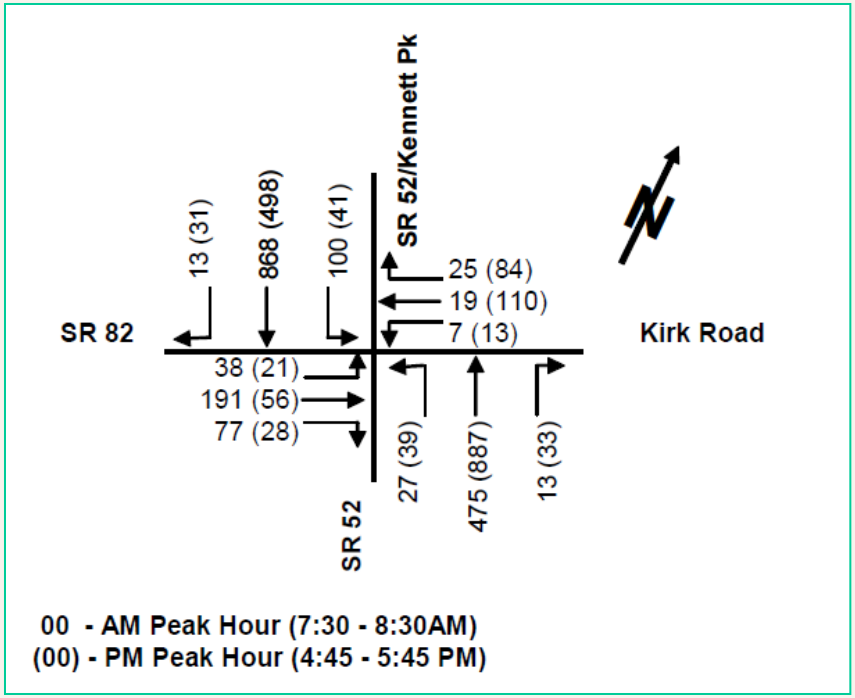
Overview of Good Alignment Design Practice (cont'd)

- Minimize grades *within terrain context*
- Widen lanes and shoulders through curves
- Pay attention to access points related to horizontal and vertical curve locations

LOCAL CASE STUDY
DE Route 52 @ DE Route 82

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*

o 17 southbound rear end

o 7 northbound rear end

o 3 northbound/eastbound angle

2006 – 2008 *39 crashes*

o 22 southbound rear end crashes
(6 crashes resulted in injuries;
2 crashes involved a left-turning vehicle)

o 3 southbound left-turn crashes

o 2 northbound sideswipe crashes

o 2 eastbound right-turn rear end crashes

o 1 southbound/westbound angle crash
(resulted in two fatalities)

o 1 southbound/eastbound angle crash

o 1 westbound left-turn crash

o 1 northbound rear end crash

o 1 northbound left-turn crash

o 1 northbound/eastbound angle crash

o 1 northbound/westbound angle crash

o 1 northbound motorists struck a fixed object just north of the intersection

o 1 eastbound rear end crash

o 1 eastbound vehicle struck a deer

Intersection Countermeasures

- o Exclusive Left Turn Lane
- o Protected Left Turn Phase
- o Lighting (CMF – 0.89)
- o Roundabout

Countermeasure Crash Modification Factors

Table 10-13. Crash Modification Factors (CMF_{2i}) for Installation of Left-Turn Lanes on Intersection Approaches

Intersection Type	Intersection Traffic Control	Number of Approaches with Left-Turn Lanes[a]			
		One Approach	Two Approaches	Three Approaches	Four Approaches
Three-leg Intersection	Minor road stop control[b]	0.56	—	—	—
Four-leg Intersection	Minor road stop control[b]	0.72	0.52	—	—
	Traffic signal	0.82	0.67	0.55	0.45

[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

Intersection Type	Intersection Traffic Control	Number of Approaches with Right-Turn Lanes[a]			
		One Approach	Two Approaches	Three Approaches	Four Approaches
Three-Leg Intersection	Minor road stop control[b]	0.86	—	—	—
Four-Leg Intersection	Minor road stop control[b]	0.86	0.74	—	—
	Traffic signal	0.96	0.92	0.88	0.85

[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.

Countermeasure Crash Modification Factors

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

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

Base Condition: Signalized intersection.

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

Setting (Intersection Type)	Traffic Volume	Crash Type (Severity)	CMF	Std. Error
All settings (One or two lanes)		All types (All severities)	0.56	0.05
		All types (Injury)	0.18	0.04
Rural (One lane)		All types (All severities)	0.29	0.04
		All types (Injury)	0.13	0.04

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

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FHWA HSM Information **http://safety.fhwa.dot.gov/hsm**	**Esther Strawder, FHWA** **esther.strawder@dot.gov 202-266-6836**
SafetyAnalyst Information **http://www.safetyanalyst.org**	**Vicki Schofield, AASHTO** **vschofield@aashto.org 202-366-3640**
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CMF Clearinghouse Information **http://www.cmfclearinghouse.org**	**Karen Yunk, FHWA** **Karen.yunk@dot.gov 609-637-4207**
Future HSM Development and Feedback **http://safetyperformance.org**	**Rick Pain, TRB Rpain@nas.edu** **202-334-2964**

Questions and Discussion

THE ~~END~~ Beginning

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