

# Highway Safety Manual Analysis Utilizing Michigan Tools

Tracie Leix, P.E.  
Engineer-Manager  
MDOT Safety Programs Unit

The Cliff-Cliff-Cliff Notes Version

# Objectives

---

- Background
- Types of Safety
- Crash Data
- Language of the HSM
- **EXAMPLES – EXAMPLES – EXAMPLES**
- Systemic Safety

# What is the Highway Safety Manual?

A method to quantify safety!!



# Why do HSM Analysis?

---



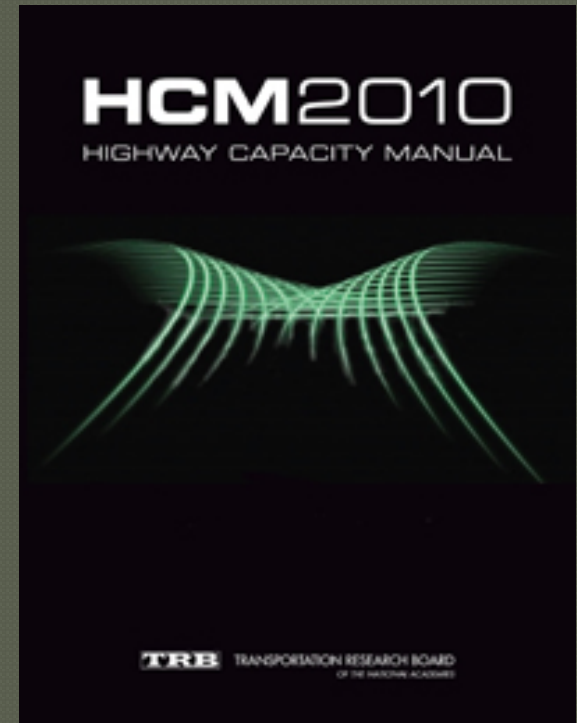
Why do capacity analysis?

# HSM Vision

---

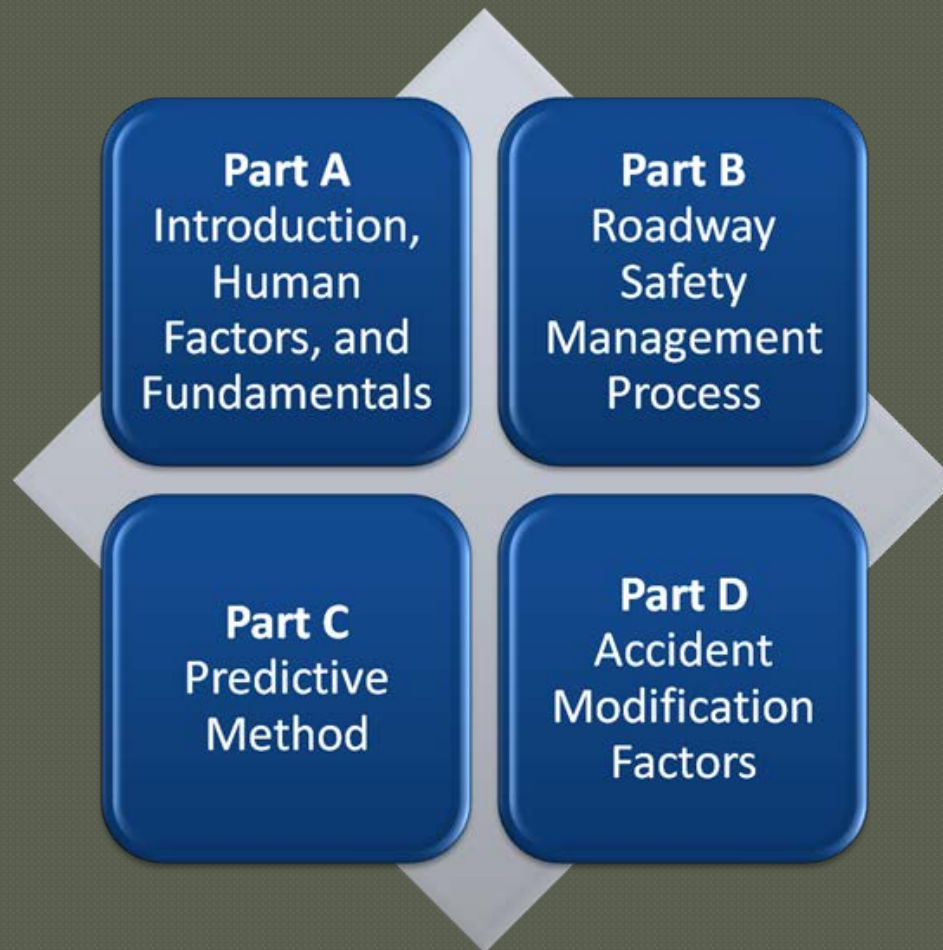
Document akin to Highway Capacity Manual

- ◎ State-of-the-art info
- ◎ Widely accepted
- ◎ Science-based

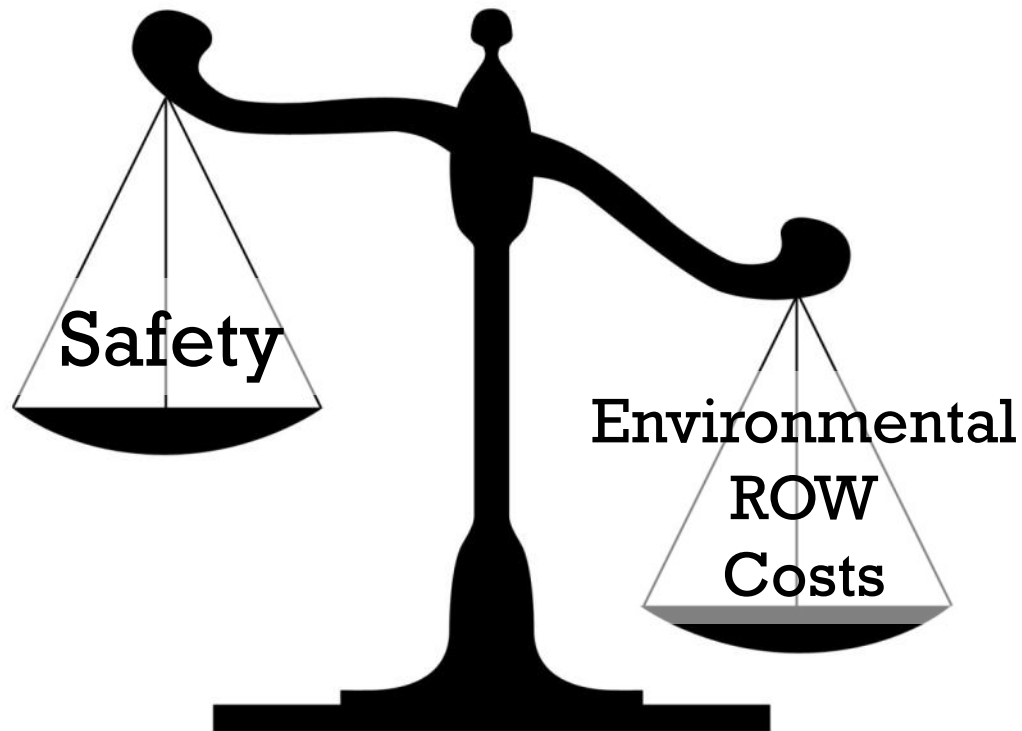


# Outline of the HSM

---



# Balancing Safety





# Where can HSM be applied?

---

## ◎ Project Development

- Planning, Project Scoping, Design, Road Safety Audits, Design Exceptions

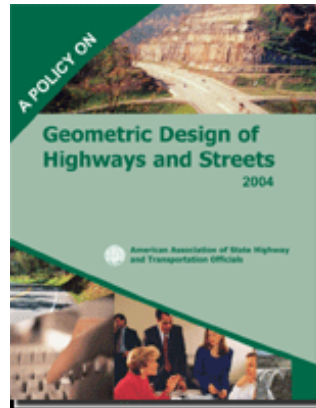
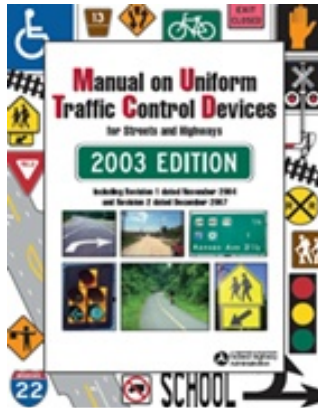
## ◎ System Management

- Network Screening, Road Safety Audits, Operations

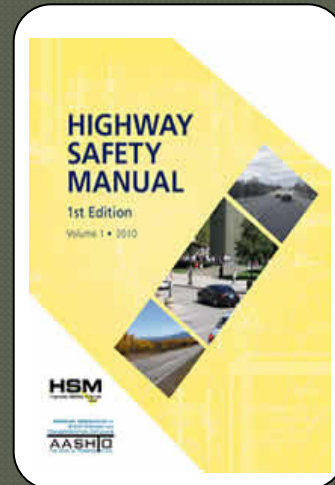


# What the HSM is NOT

- ◉ Does NOT set requirements or mandates
- ◉ Is NOT a best practice document
- ◉ Does NOT contain warrants or standards



VS





# Important!

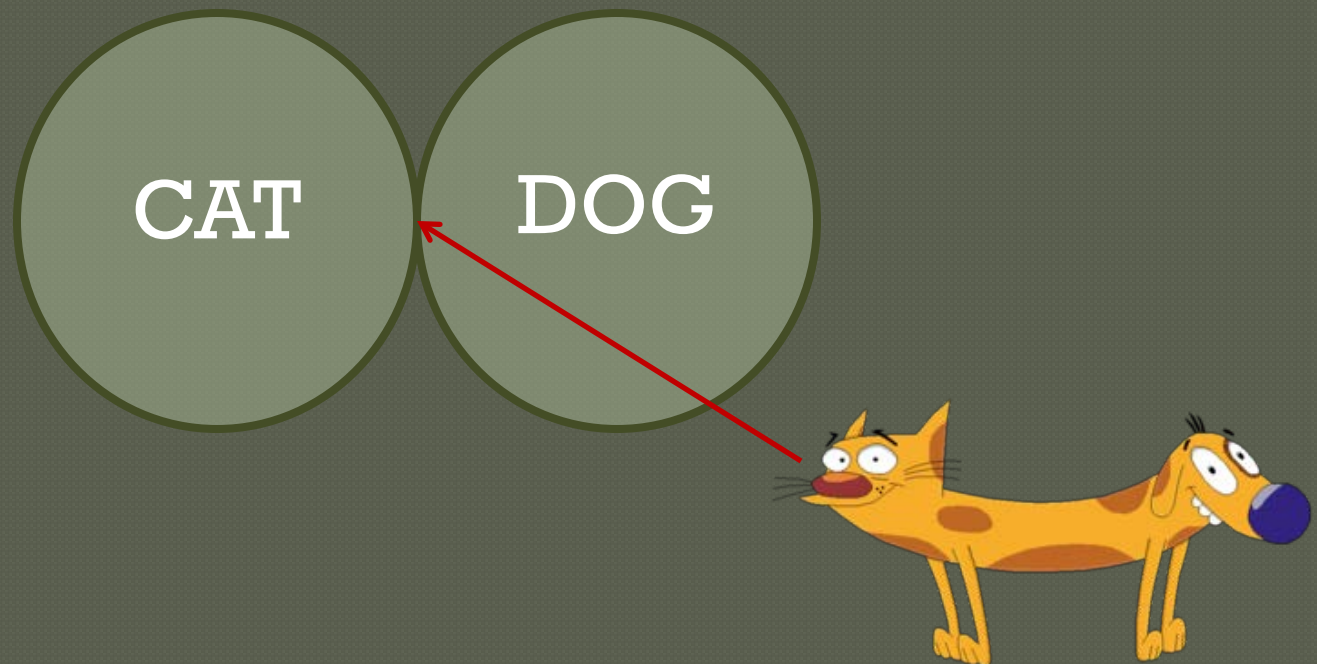
---

The HSM does NOT establish a legal standard of care nor does it create a duty to the public.

# Nominal Safety

---

- ◉ Nominal safety = Compliance with a design standard or warrant



It met all the design standards...

---























# Substantive Safety

---

- ◉ Going beyond those minimums
- ◉ Previous example?
  - Curve warning, chevrons, target arrow, rumble stripEs, horizontal signing
  - Vegetation, lighting

# Substantive Safety Can Vary When Nominal Safety Does Not



Existing  
23.6 Crsh/Mi



Alternative 1  
17.2 Crsh/Mi



Alternative 2  
8.6 Crsh/Mi



Alternative 3  
4.2 Crsh/Mi

# Crash Data

---

# Crash Reporting

MSF LD-10 (Rev. 02/2015)  
Authority: 1949 PA 323, Sec. 257(2)3  
Compliance Required  
Penalty: \$100 and/or 60 days

Revised August 9, 2013

### State of Michigan Traffic Crash Report

LD-10 SERIAL NUMBER

Department Name: \_\_\_\_\_ Investigator(s): \_\_\_\_\_ Badge #: \_\_\_\_\_

Crash Date: \_\_\_\_\_ Crash Time: \_\_\_\_\_ No. of Units: \_\_\_\_\_

Crash Type:  Single Motor Vehicle  Head-On  Head-On/Left Turn  Angle  Backing  Rear End

Special Circumstances:  None  Hit and Run  School Bus  Special Needs  Fire  Off-Road Copy  Weather  Light  Road Surface Condition  Total Loss

Special Circumstances:  None  Hit and Run  School Bus  Special Needs  Fire  Off-Road Copy  Weather  Light  Road Surface Condition  Total Loss

County: \_\_\_\_\_ City/Town: \_\_\_\_\_ Area: \_\_\_\_\_ Traffic Control: \_\_\_\_\_ Relation to Roadway: \_\_\_\_\_ Work Zone-Active: \_\_\_\_\_ Work Zone-Workers Present: \_\_\_\_\_ Work Zone-Activity: \_\_\_\_\_ Work Zone-Location: \_\_\_\_\_ Contributing Circumstances: \_\_\_\_\_

Primary Road Name: \_\_\_\_\_ Road Type: \_\_\_\_\_ UNIDG Roadway: \_\_\_\_\_

Intersecting Road Name: \_\_\_\_\_ Road Type: \_\_\_\_\_ UNIDG Roadway: \_\_\_\_\_

Vehicle Registration: \_\_\_\_\_ State: \_\_\_\_\_ Insurance Company: \_\_\_\_\_ Policy Number: \_\_\_\_\_

Vehicle Type: \_\_\_\_\_ Location of Greatest Damage: \_\_\_\_\_ Impact: \_\_\_\_\_ Extent of Damage: \_\_\_\_\_ Vehicle Direction: \_\_\_\_\_ Private Trailer Type: \_\_\_\_\_ Vehicle Defect: \_\_\_\_\_

Passengers: \_\_\_\_\_ Ejected: \_\_\_\_\_

Driver Information: \_\_\_\_\_

Witness Information: \_\_\_\_\_

Reported Date: \_\_\_\_\_ Reported Time: \_\_\_\_\_ Damaged Property: \_\_\_\_\_

- Quality & Accuracy
- Reporting
- Thresholds
- Jurisdictional Differences
- Randomness & Change

**New UD-10 Form  
January 1, 2016**

# Observed Crash Rates

Before

After

Year	No. Crashes	AADT	Rate	Year	No. Crashes	AADT	Rate
1988	13	2,900	2.11	1992	30	10,618	1.33
1989	11	2,900	1.79	1993	30	13,200	1.07
1990	13	3,050	2.01	1994	36	14,300	1.19
1991	23	3,400	3.19	1995	40	13,900	1.36
Average Rate = 2.28				Average Rate = 1.24			

**Gambling Introduced in 1992**

*Example Provided by Jake Kononov, Ph.D., P.E., Colorado DOT (retired)*



# Crash Rate Example

---

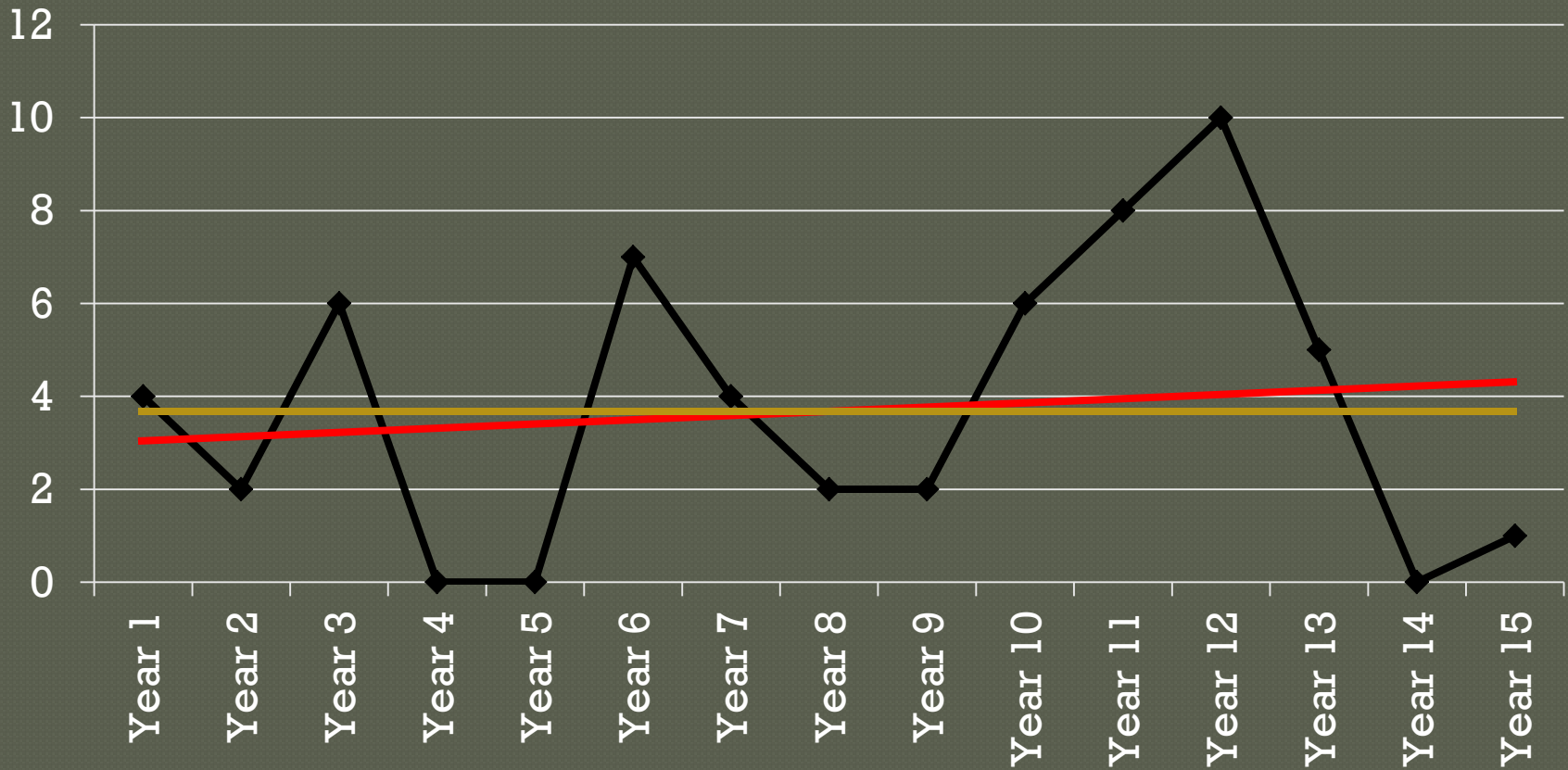
Alcohol involved +500%

Drinking + Driving + Gambling = Safe Roads



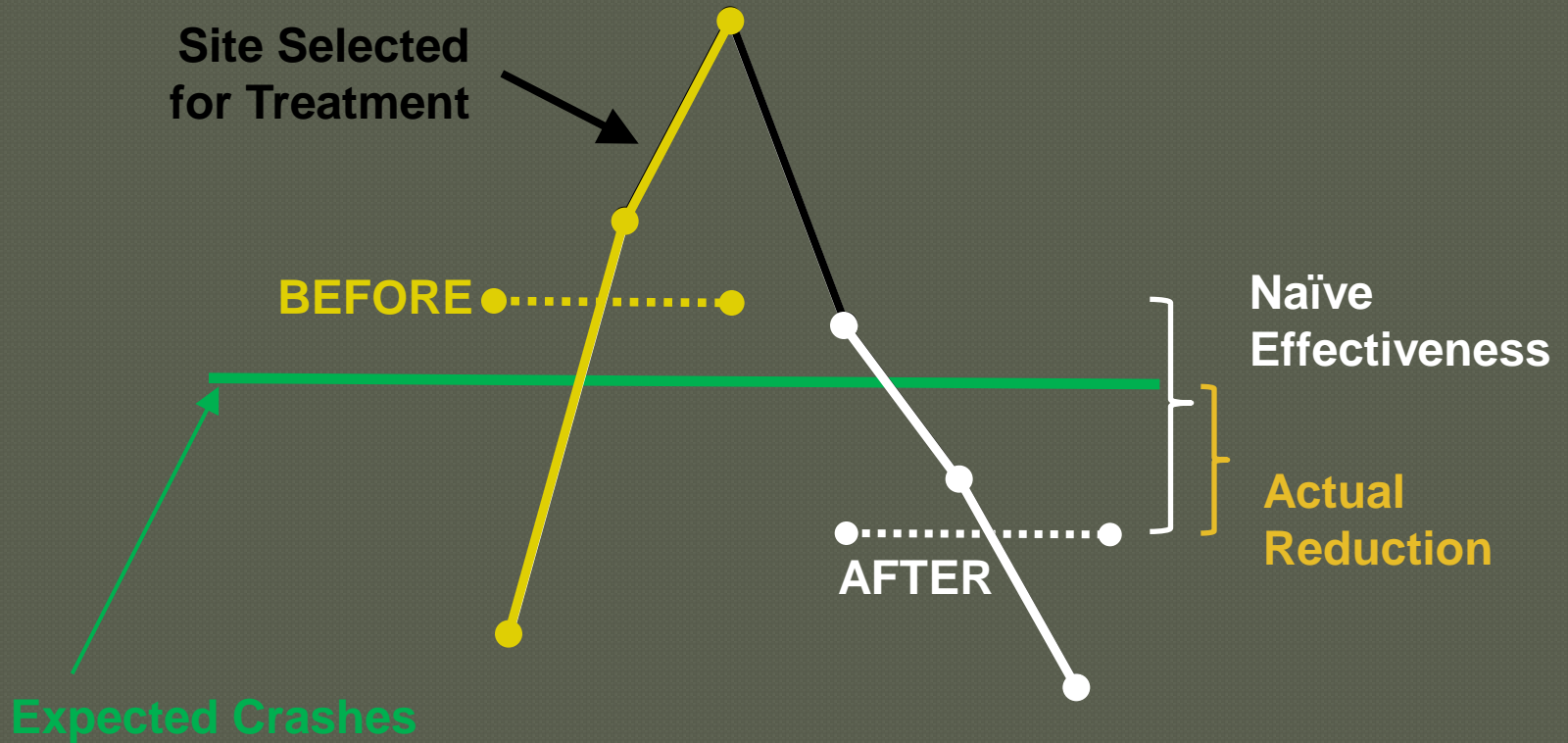
# Regression to the Mean

## RTM Example



# RTM Project Example

Observed Crash Frequency





# The Language of the HSM

---

# HSM Lingo

---

## ◎ **Observed** Crashes

- What is happening right now

## ◎ **Predicted** Crashes

- What a Safety Performance Function (SPF) says will happen

## ◎ **Expected** Crashes

- What will happen once you apply known info to a SPF

# Empirical Bayes

---

A statistical method of analysis  
to combat  
Regression to the Mean.

Product of EB = EXPECTED Crashes

# Excess Crashes

---

**Excess = Observed – Expected**

How much opportunity  
we have to improve safety!



# Elements of Predicting Crashes

---

- ◎ **Safety Performance Functions**
  - Predict crashes for base conditions
- ◎ **Crash Modification Factors**
  - Alter the SPF to match existing or proposed
- ◎ **Calibration Factors**
  - Account for local conditions
  - Already included in MI spreadsheet tool

# Base Conditions

- Conditions a SPF was developed around
  - Site Types



# CMFs vs CRFs

---

## Crash Modification Factors

- ◉ CMFs related to base conditions
- ◉ CMFs applied during calculations

$$1 - (\text{CRF}/100) = \text{CMF}$$

$$10\% \text{ CRF} = 0.90 \text{ CMF}$$

# CMF Clearinghouse



[Skip to main content](#) | [Site Map](#) | [Notice](#) | [Sign Up for our e-Newsletter](#) | [Home](#)

[About CMFs](#) | [Submit CMFs](#) | [Resources](#) | [Contact](#)

Search for:

in

Countermeasure Name

[Need Help?](#)

[Search CMFs](#)

## CMFs in Practice

Learn how CMFs are being used in situations such as safety management, road safety audits,

## Search Results

There were 84 CMFs returned for your search on "**chevrons**". [\[modify your search\]](#).

Having trouble deciding between similar CMFs? [Check out our FAQs.](#)

Overwhelmed by too many results? See our [Search Tips.](#)

### ▶ Star Quality Rating

- 1 (0)
- 2 (17)
- 3 (56)
- 4 (11)
- 5 (0)

### ▶ Crash Type

**Results Control:** [Collapse All](#) | [Expand All](#)

*Click on the links below to expand individual categories.*

▶ Category: Signs (83)

▶ Category: Speed management (1)



# When Selecting CMFs

---

- ◉ Know Background Conditions
- ◉ Same Setting and Road Type
- ◉ With Volume Range
- ◉ Crash Type/Severity

# Applying CMFs

## ◎ Quality

- Study Design
- Sample
- Standard Error
- Bias
- Data Source

CMF	CRF (%)	Quality
0.96	4	★★★★☆

## ◎ Can be used outside predictive process

- Countermeasure selection

# Safety Performance Functions

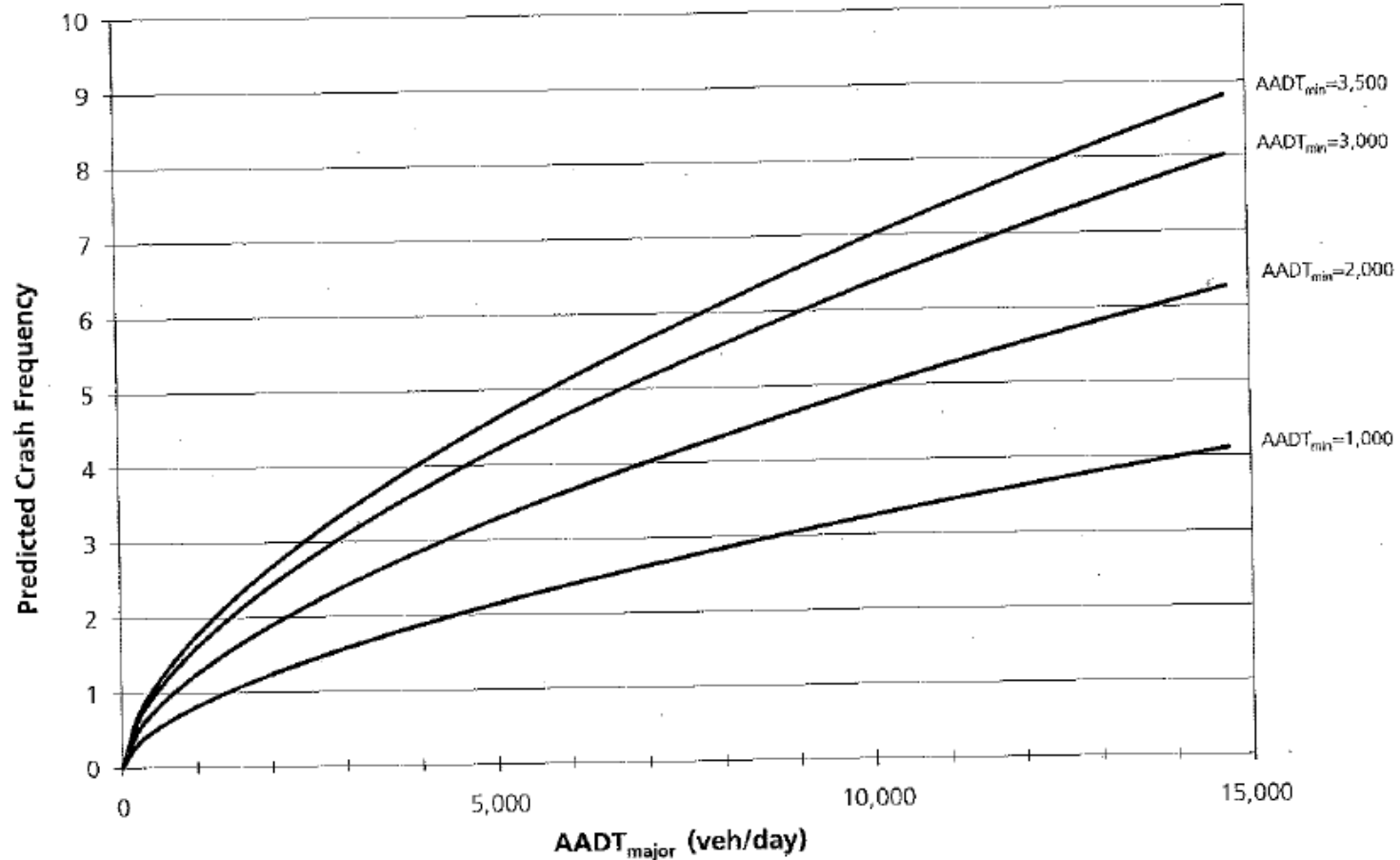


Figure 10-5. Graphical Representation of the SPF for Four-leg, Stop-controlled (4ST) Intersections (Equation 10-9)

# Where CAN we Predict?

---



**Two-Lane  
Rural Roads**



**Urban/ Suburban  
Arterial Highways**



**Rural Multilane  
Highways**

**Freeways**



# Where CAN'T we Predict?

---

- ◉ Gravel Roads
- ◉ Ultra Low Volume
- ◉ One Way Roads
- ◉ Tee Intersections can be tricky

**HSM 1<sup>st</sup> Edition!**

# **Safety Projects on the Local System**

---

# LAP Safety Funding Targets

FY 2015 Safety Program Financial Goals:

<b>Project Type</b>	<b>Total Program</b>
Road Safety Audits (RSA)	\$50,000
Non-motorized facility/Pedestrian improvements	\$100,000
Traffic signal optimization (all red phase)	\$150,000
Centerline and Shoulder Rumble Strip	\$200,000
Guardrail Upgrades and Clear Zone Improvements	\$1,500,000
Projects with scopes that directly correct areas with a concentration of Types "A" and "K" crashes	\$9,500,000
Safety Funds per MDOT Region	\$350,000

# TOR vs HSM Analysis

---

## ◎ CRFs may be DIFFERENT


- Rumble Strips:
- TOR – 20% reduction (targeted crashes)
- HSM – 16% reduction (all crashes)

## ◎ Years of analysis may be DIFFERENT

- TOR – 2009-2013
- HSM – 2006-2010 (can use TOR crash data)



# Where is the MI Spreadsheet?



Michigan.gov Home | MDOT Home | Site Map | Contact MDOT | FAQ | State Web Sites

[print friendly](#) [email this page](#) [Like](#)

## Doing Business

- Forms
- Contractor Services
- Vendor/Consultant Services

## Local Agency Program

- Urban Road Program
- Rural Road Program
- Bridge Program
- Enhancement Program
- Safety Program

## Passenger Transportation

## Roads and Travel

## Rail and Public Transit

## Bridges, Borders and Ferries

## Contacts

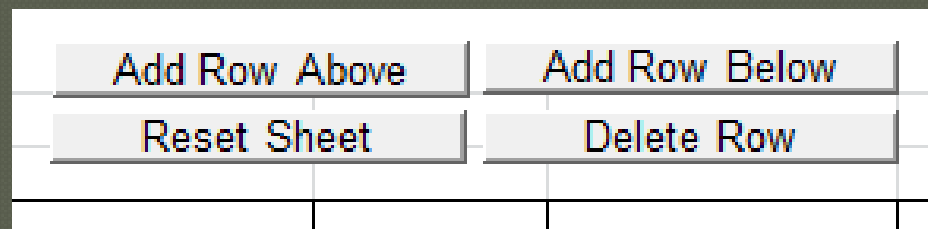
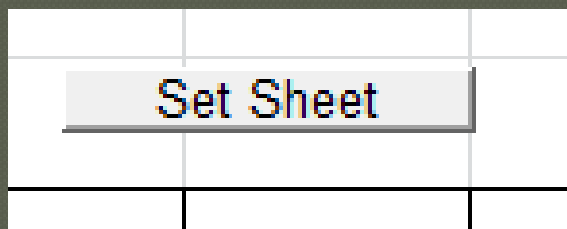
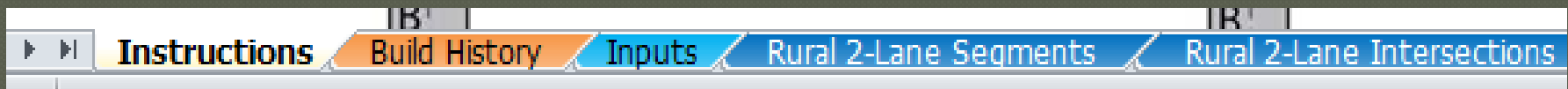
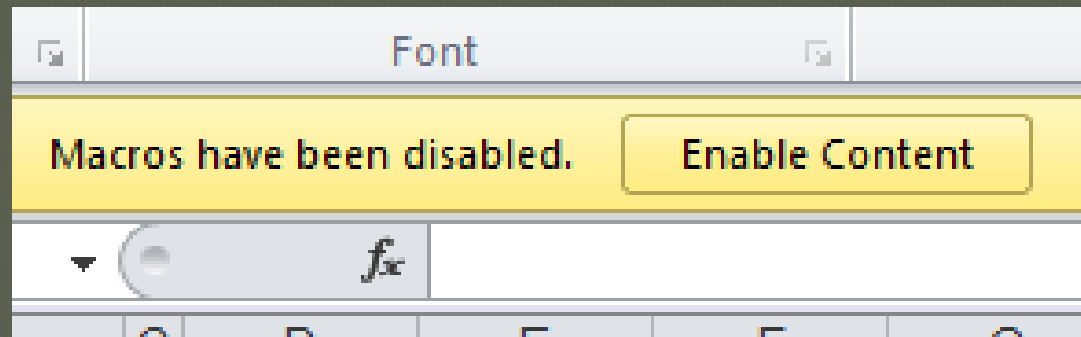
- Mark Harbison, P.E., Supervisor, 517-335-2744
- Gonzalo Puente, P.E., Project Development Engineer, 517-335-0878
- Lynnette Firman, P.E., Safety Engineer, 517-335-2224

## Application Process

- [Call for Projects \(Safety\) FY 2015](#) **PDF**  
Due:10/04/2013
- [Call for Projects \(HRRR\) FY 2014](#) **PDF**  
Due:08/13/2012
- [Safety Project Submittal, MDOT Form 1627](#) **PDF**
- [Time of Return \(TOR\) Calculation Spreadsheet](#) **XLS**
- [Roundabout Time of Return \(TOR\) Calculation Spreadsheet](#) **XLS**
- [Highway Safety Manual \(HSM\) Analysis Spreadsheet](#) **XLS**
- [MDOT Highway Safety Website](#)
- [FHWA Good Practices](#) **PDF**
- [Traffic Crash Maps](#)

# Demo Spreadsheet

- Instructions
- Input
- Models

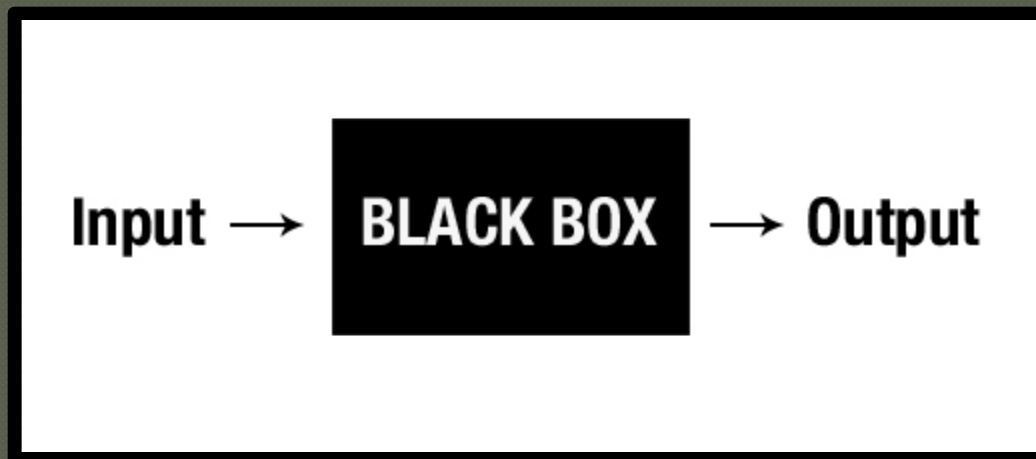


# Caution Using MI Spreadsheets

---

- ◎ HSM 1<sup>st</sup> Edition

- ◎ Engineering Judgment



# **Good Safety Projects**

---

# Lane Departure Projects

---

Shoulder Paving  
Rumble Strips  
Curve Signing



# Shoulder Paving

---

- ⦿ Input existing conditions
- ⦿ Input shoulder paving info
- ⦿ Existing: Expected Ave Crash Freq = 1.79
- ⦿ Pave Sh: Exp Ave Crash Freq = 1.77

**UNITS: Crashes/Mile/Year**

# Rumble Strips

---

- ◉ Apply CMF for shoulder rumble strips
- ◉ Rumbles: Exp Ave Crash Freq = 1.52
- ◉ NOTE: 2 ways to reflect countermeasures
  - Change input information for feature
  - Apply CMF from dropdown or type in

# Intersection Projects

---

Sign/Marking Upgrades  
Transverse Rumble Strips  
Flashing Beacons/Box Span  
Signal Backplates

# Sign/Marking Upgrades

---

- ◎ Upgrade signing at stop control
  - Clearinghouse – Targeted Crash Types
  - TOR – Targeted Crash Types
  - ENGINEERING JUDGMENT
    - 5% reduction in total crashes (0.95)
- ◎ Existing: Exp Ave Crash Freq = 3.89
- ◎ Signing: Exp Ave Crash Freq = 3.78

# Signal Backplates

---

- Add traffic signal backplates
- Existing: Exp Ave Crash Freq = 1.948
- Backplates: Exp Ave Crash Freq = 1.725



# Network Screening

---

Intersections

Segments

Curves

Other?

# Network Screening Example

---



# **Project Level Analysis**

---

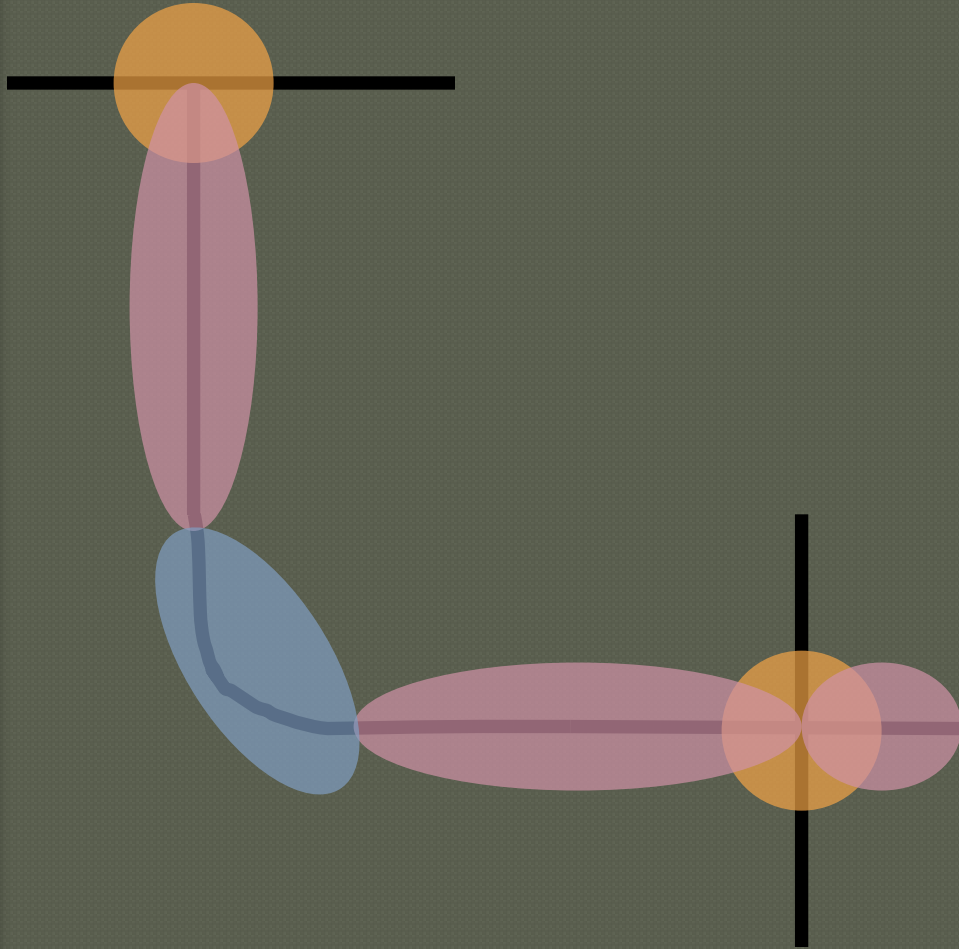
# Project Analysis Basic Method

---

- Collect Data
- Divide Project into Segments & Intersections
- Fill out Spreadsheets
- Calculate Predicted Crashes:
  - Without Treatment
  - With Treatment
- Compare to Observed Crashes

# Divide Project

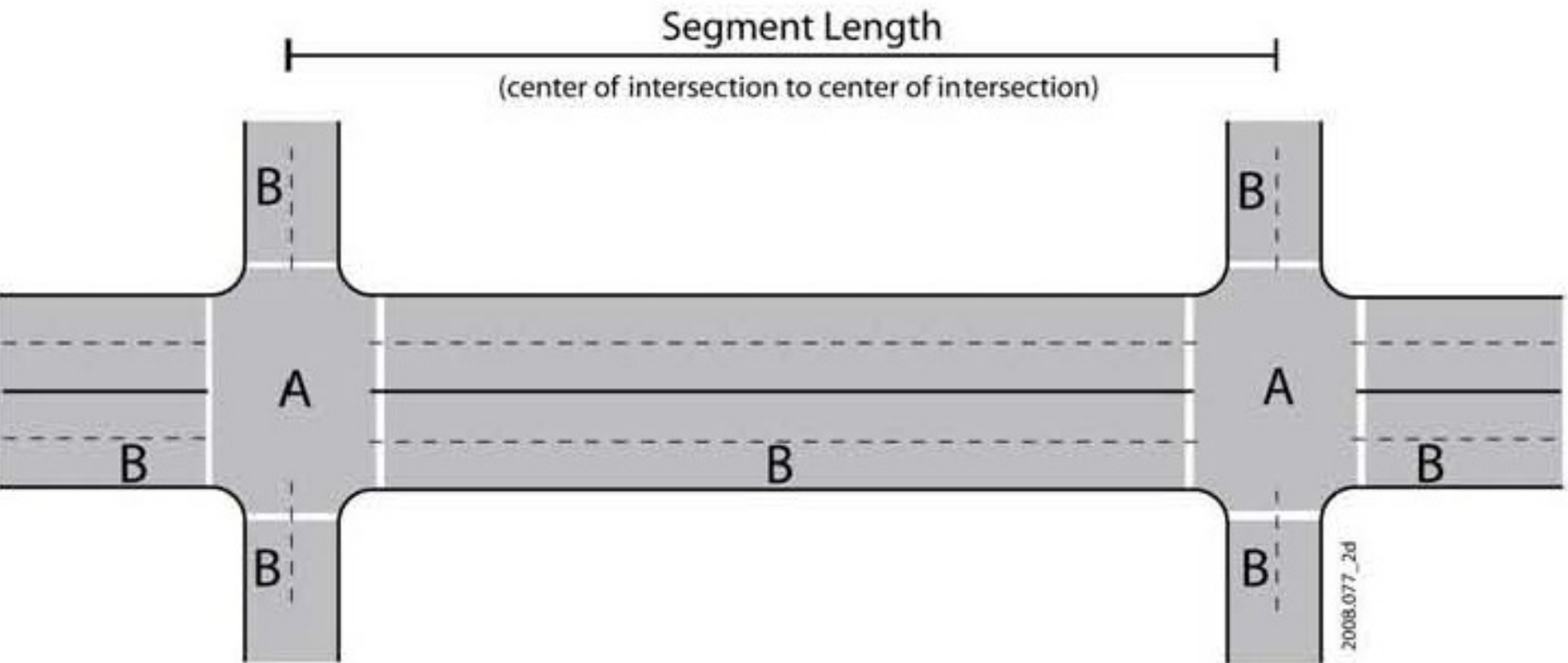
---



- ◉ Intersections
- ◉ Tangents
- ◉ Curves
- ◉ Cross Sections
- ◉ Roadside
- ◉ Volume
  
- ◉ Urban
- ◉ Rural



# Segment Length



- A** All crashes that occur within this region are classified as intersection crashes.
- B** Crashes in this region may be segment or intersection related, depending on on the characteristics of the crash.

# Compile Results

---

Calculate Expected Crashes  
For the Project

**ADD** them together!

$$\text{Exp}_a + \text{Exp}_b + \text{Exp}_c = \text{Exp}_{\text{project}}$$

# Crash Distribution in MI

Varies widely from other states!



# Michigan Distribution Tables



Department of Transportation



[Michigan.gov Home](#)

[T & S Home](#)

[MDOT Sitemap](#)

[Contact T & S](#)

[T & S FAQs](#)

• [Intro Page](#)

Categories ([Expand All](#))

Geometrics ▸

MMUTCD ▸

Microstation/CADD Files ▸

Miscellaneous ▸

Pavement Markings ▸

Pedestrian/Bicyclist ▸

Roadsoft Data ▸

Safety Programs ▾

Highway Safety Manual

Safety Guides

School ▸

Traffic Regulations/Speed/Stopping/Parking ▸

Traffic Signals ▸

Traffic Signing ▸

Traffic and Safety Notes ▸

Work Zones ▸

Keyword Search

Select a Keyword ▾

...type keyword,(s)...

Individual Files may be opened by clicking the on the links in the Title column for each Plan. You may also use the checkboxes to check the files you want to download and click the Download Checked Files button.

Download Checked Files

Check All

## Safety Programs - Highway Safety Manual (Click Column Header to change sort order)

PLAN

TITLE

Type(English/Metric) - DATE

MI - HSM - Analysis

HSM Analysis Spreadsheet

[English xlsx](#) - 1/23/2014 (1.5 MB)

MI - HSM - Calibration

Michigan HSM Calibration Values 1st Edition

[English pdf](#) - 5/21/2012 (170.0 KB)

MI - HSM - Distributions

Michigan HSM Distribution Values 1st Edition

[English pdf](#) - 5/21/2012 (183.7 KB)

## Safety Programs - Safety Guides (Click Column Header to change sort order)

PLAN

TITLE

Type(English/Metric) - DATE

Safety-High Risk Rural Roads Program

Implementing the High Risk Rural Roads Program

[English pdf](#) - 9/20/2011 (2.2 MB)

Safety-Information Analysis

Road Safety Information Analysis: A Manual for Local Rural Road Owners

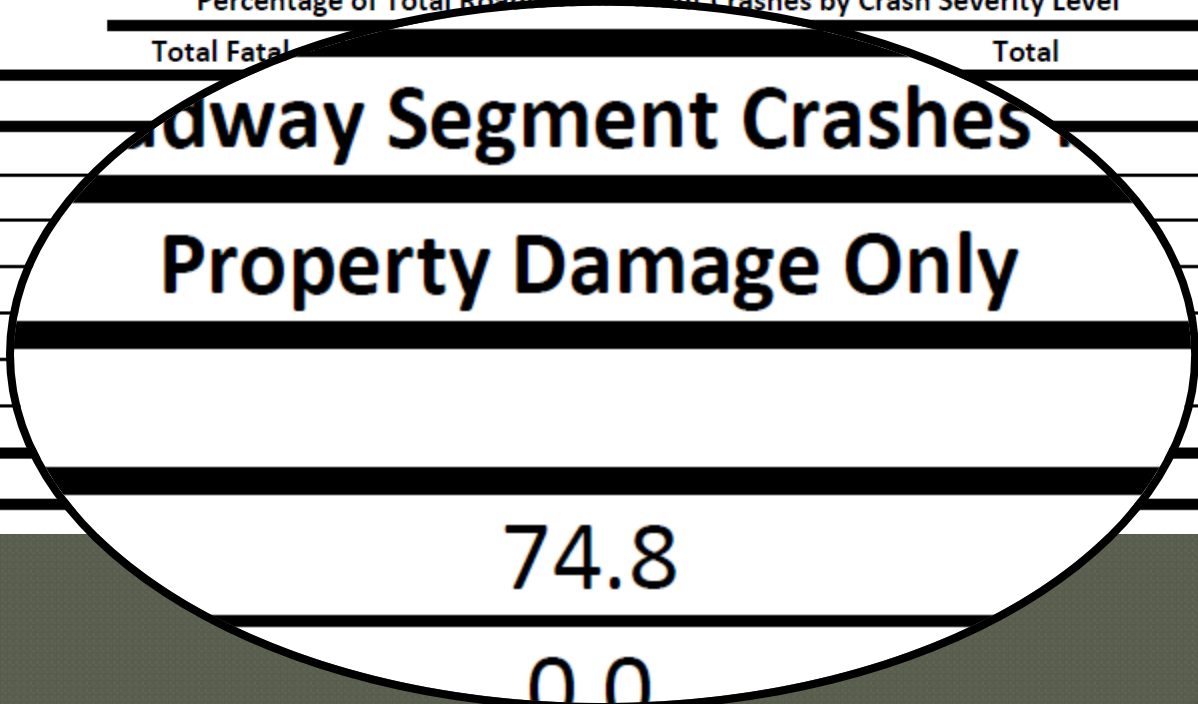


# Distribution Tables

## ○ Chapters 10 & 11 ONLY

**TABLE 10.4** Michigan Distribution by Collision Type for Specific Crash Severity Levels on Rural Two-Lane Two-Way Road Segments

Collision Type	Percentage of Total Roadway Segment Crashes by Crash Severity Level	
	Total Fatal	Total
<b>SINGLE-VEHICLE CRASHES</b>		
Collision with Animal		
Collision with Bicycle		
Collision with Pedestrian		
Overtaken		
Ran off Road		
Other Single Vehicle Crash		
Total Single Vehicle Crashes		
<b>MULTIPLE-VEHICLE CRASHES</b>		
Angle Collision		
		74.8
		0.0





# Applying Distribution Tables

---

- ◎ Stratify predicted crashes
  - Crash type
  - Injury type
- ◎ Already built into the spreadsheets
  - Hide calculations = N

# Systemic Safety

---

A deviation from HSM stuff

# Systemic Safety



**Police: Wrong-way teen causes crash**  
Police: A...  
under the influence  
WOOD) - A teenager who police say was...  
s and driving the wrong way caused a...  
8 p.m. Wednesday near the 87 mile...

**Five Killed in wrong-way crash on Michigan**  
Sun Oct 23, 2011 1:17pm EDT  
(Reuters) - A driver going the wrong way on a suburban Detroit freeway early Sunday slammed into another vehicle and both burst into flames... involved, Michigan state police

**3 Dead, 3 Critical In Wrong-Way Head-On Crash**  
A driver from Nebraska was traveling the wrong direction down I-96  
Posted: 3:27 PM May 29, 2011  
ZEELAND TOWNSHIP, Mich. (AP) - A wrong-way driver on a foggy day... into a car with five young people inside it early Sunday, lea...  
Michigan State Police said the two cars... about 15 miles northwest of Detroit.  
... accident between a car driven by... day on the M-10, a road common...  
... said they had not yet determin...  
... the time of day, alcohol is a pe...  
... re for more on this story from...

**Five Killed in Wrong-Way Car Accident Near Detroit**  
Published October 23, 2011 | NewsCore  
Five people died Sunday in a fiery accident when a car driving on the wrong side of a suburban Detroit freeway collided with another vehicle, the Detroit Free Press reported.

**WRONG-WAY DRIVER JAILED AFTER CRASH**  
09/11/2009 Kalamazoo Gazette  
GALESBURG -- A wrong-way driver who police say appeared to be under the influence of prescription medicine or narcotics was jailed Wednesday...  
Gazette Staff Reports

**E KILLED IN WRONG-WAY CRASH ON MICHIGAN**

**causes crash**  
driver was under the influence  
0 Sep 2009, 7:46 AM EDT  
10 Sep 2009, 7:44 AM EDT  
TOWNSHIP, Mich. (WOOD) - A teenager who police say was under the influence of prescription medicine or narcotics and driving the wrong way caused a head-on collision on I-94.

**ad, 3 Critical In Wrong-Way Head-On**  
A driver from Ne...  
The Lodge

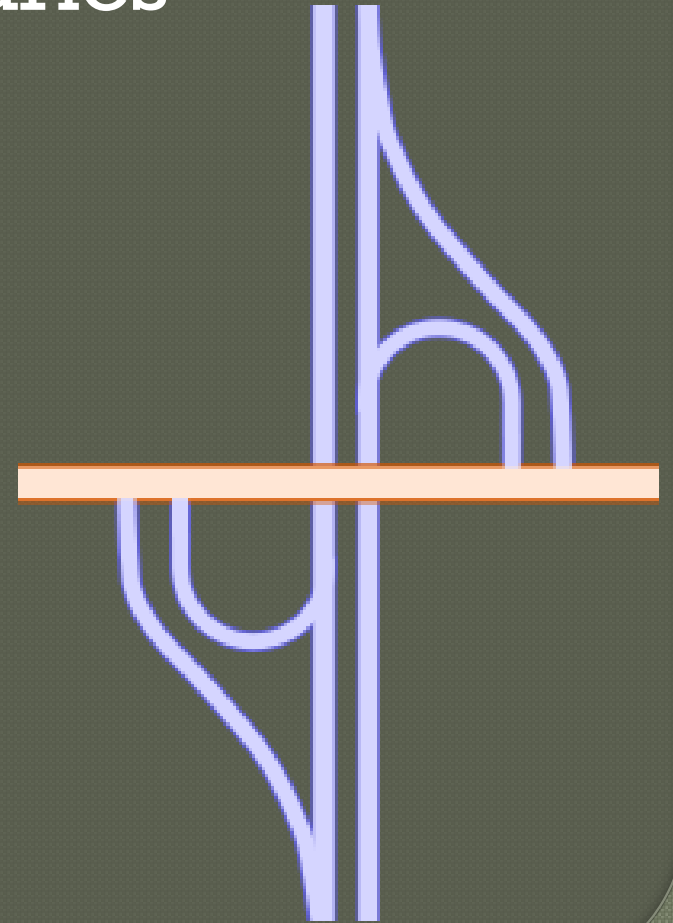
**GALESBURG -- A wrong-way driver who police say appeared to be under the influence of prescription medicine or narcotics was jailed Wednesday.**  
Gazette Staff Reports

**GALESBURG -- A wrong-way driver who police say appeared to be under the influence of prescription medicine or narcotics was jailed Wednesday.**  
Gazette Staff Reports

# The Problem

---

- ◎ 110 Crashes → 66 K/A Injuries
  - 35 Known Points of Entry
- ◎ 791 Interchanges
  - 161 are “Parclo”
  - 70% W-W crashes at “Parclo”



# Solutions

**Lower Bottom Height**



**Lollipops**



# Solutions

**Stop Bars**



**Off Ramp W-W Arrow**



# Solutions



**Pavement Marking Extensions  
Painted Gore Island  
W-W Delineation**



# Implementation

---

- ◉ When feasible
- ◉ Signing changes at all ramps
- ◉ Estimated Cost = \$1.16 M (materials)
- ◉ TOR = 3.51



# Systemic Safety for Local Agencies



Single Vehicle – 65%

- Curves – 25%

Angle – 60%



# What We Learned

---

- ◉ What the HSM is
- ◉ Types of Safety
- ◉ Crash Data
- ◉ Language of the HSM
- ◉ Crash Prediction
- ◉ Systemic Safety



# Questions?

“If you don’t like the government,  
why don’t you just leave?”



“No way. Why should I leave? They’re  
the ones who suck.”

# Thank you

---

Tracie Leix, P.E.  
Engineer-Manager  
MDOT Safety Programs Unit  
517-373-8950  
[LeixT@michigan.gov](mailto:LeixT@michigan.gov)