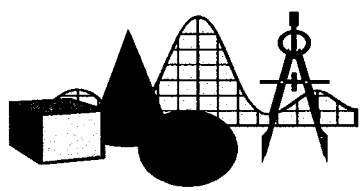
Texas Department of Transportation

Texas Transportation Institute

Roadway Safety Design

An Engineer's Guide to Evaluating the Safety of Design Alternatives



Course Notes

Product 0-4703-P8

SAFETY BY DESIGN

Multilane Highways and Freeways Workshop

Published: December 2008

INCORPORATING SAFETY INTO THE HIGHWAY DESIGN PROCESS:

MULTILANE HIGHWAYS AND FREEWAYS WORKSHOP

Date: ______________
Location: ______________
Contact: Jim Bonneson, (979) 845-9906, j-bonneson@tamu.edu

Agenda

9:30	Introduction
9:45	Session 1: Review of Highway Safety Issues
10:00	Session 2: Overview of Safety Evaluation
10:25	Break
10:40	Session 2: Overview of Safety Evaluation
11:00	Session 3: Procedure for Multilane Highway Segments
11:55	Lunch Break
1:10	Session 4: Procedure for Freeway Segments
1:40	Session 5: Procedure for Interchange Ramps
2:05	Break
2:20	Session 6: Multilane Highway Section Evaluation
2:55	Session 7: Alternatives Analysis
4:05	Wrap-Up, Complete Course Review Form
4:15	Adjourn

Course Materials: Course Workbook
Interim Roadway Safety Design Workbook
Texas Roadway Safety Design (TRSD) software
Web Site: http://tcd.tamu.edu/documents/rsd.htm

Incorporating Safety into the Highway Design Process

Part I. Introduction to Workshop Series

Texas Department of Transportation

Published: December 2008

Welcome

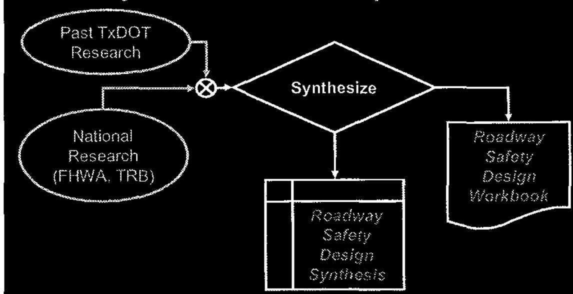
- Introductory Session
  - *Objectives, outcomes, scope, main points*
  - *Background*
  - *Agenda*
- Instructor
  - *Jim Bonneson*
    - Researcher with TTI
    - College Station

Objectives & Outcomes

- Objectives
  - *To inform participants about:*
    - Safety impacts of design alternatives
    - Availability of tools for evaluating safety impact
  - *To demonstrate how to apply these tools*
- Outcomes
  - *Participants should be able to:*
    - Apply the evaluation tools to typical designs
    - Evaluate the safety associated with a design

Background

- Safety Information Development Process



More Information

- Safety Resources from Project 0-4703
  - *Roadway Safety Design Synthesis*
  - *Procedures Guide*
  - *Texas Roadway Safety Design software*
- Web Address
  - *http:// tcd.tamu.edu/documents/rsd.htm*
  - *Also link from DES-PD site CROSSROADS*
  - *Check periodically for updates*

Agenda

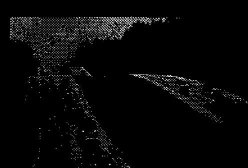
- Session 1:
  - *Review of highway safety issues*
- Session 2:
  - *Overview of safety evaluation*
- Session 3:
  - *Procedure for multilane highway segments*
- Lunch Break

1. Highway Safety Issues

- Key Highway Design Elements
- Safety-Conscious Design
- Crash Data Variability

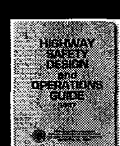
Key Design Elements

- Design Elements that Influence Safety
  - *Design speed*
  - *Lane width*
  - *Shoulder width*
  - *Bridge width*
  - *Structural capacity*
  - *Horizontal alignment*
  - *Vertical curvature*
  - *Grade*
  - *Stopping sight distance*
  - *Cross slope*
  - *Superelevation*
  - *Vertical clearance*



Safety-Conscious Design

- AASHTO Guidance
  - *"Consistent adherence to minimum [design criteria] values is not advisable"*
  - *"Minimum design criteria may not ensure adequate levels of safety in all situations"*
  - *"The challenge to the designer is to achieve the highest level of safety within the physical and financial constraints of a project"*
    - Highway Safety Design and Operations Guide, 1997



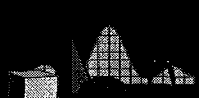
Overcoming Variability

- Summary
  - *Large variability makes it difficult to observe a change in crash frequency due to change in geometry at one site*
  - *Large variability in crash data may frustrate attempts to confirm expected change*
  - *Large databases needed to overcome large variability in crash data*
  - *Statistics must be used to accurately quantify effect*

Questions – Comments?

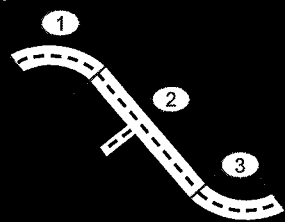
2. Safety Evaluation

- Safety Prediction Model
- Analysis Procedures
- Texas Roadway Safety Design Software



Analysis Procedures

- Safety Prediction Procedure
- Segmentation Process



Safety Prediction Procedure

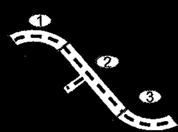
- Overview
  - *Six steps*
  - *Use base model and AMFs in Workbook*
  - *Evaluate a specific roadway segment or intersection (i.e., facility component)*
- Output
  - *Estimate of crash frequency for segment or intersection*

Step 1

- Identify Roadway Section
  - *Define limits of roadway section of interest*
    - Limits of design project
    - Portion of highway with safety issue or concern
  - *May include one or more components*

Segmentation Process

- Overview
  - *Use to identify homogenous roadway segments*
  - *Intersections and interchange ramps are not segments*



Homogeneous Segment

- Definition
  - *A homogeneous segment has the same basic character for its full length*
    - Lane width
    - Shoulder width
    - Number of lanes
    - Curvature
    - Median type
    - Median width

Segmentation Process

- Define Initial Segments
  - *Begin new segment when:*
    - ADT changes by 5% or more
    - Number of lanes changes
    - Horizontal curvature begins or ends
    - Two-way left-turn lane begins or ends
    - Median begins or ends
  - *Intersections or ramp terminals are* ***not*** *necessarily segment end points*
  - *Curve length includes spirals, if present*

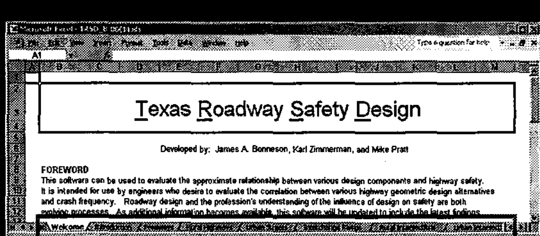
Questions – Comments?

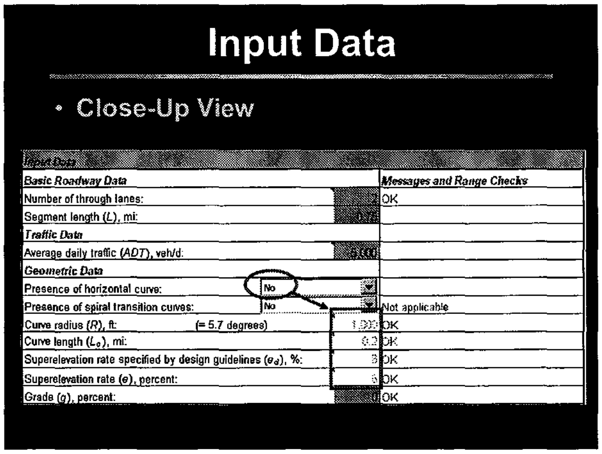
TRSD Worksheet

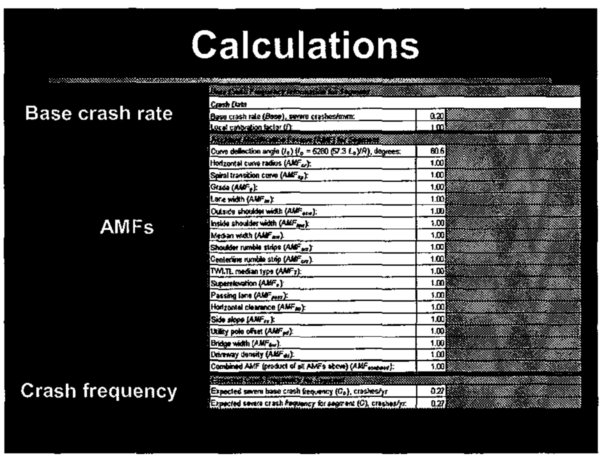
- Texas Roadway Safety Design Worksheet
  - Overview
  - Navigation
  - Input
  - Output

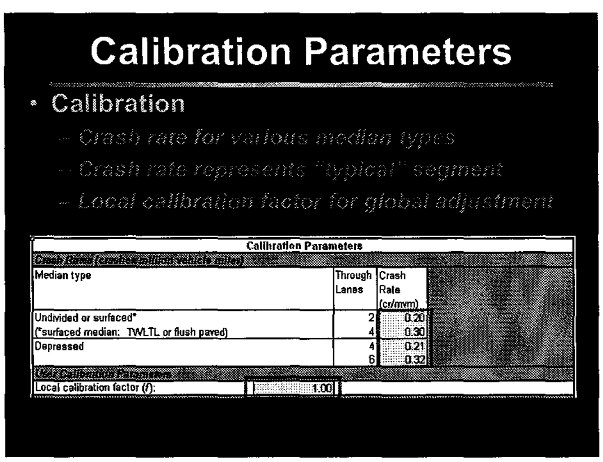
TRSD Worksheet

- Welcome Screen
  - Tab for Introduction (User's Guide)
  - Tabs for selecting specific worksheets




Input Data
Close-Up View
Basic Roadway Data
Messages and Range Checks
Number of through lanes:
OK
Segment length (L), mi:
Traffic Data
Average daily traffic (ADT), veh/d:
Geometric Data
Presence of horizontal curve:
No
Presence of spiral transition curves:
No
Not applicable
Curve radius (R), ft:
(= 5.7 degrees)
OK
Curve length (Lc), mi:
OK
Superelevation rate specified by design guidelines (ed), %:
OK
Superelevation rate (e), percent:
OK
Grade (g), percent:
0
OK


Calculations
Base crash rate
AMFs
Crash frequency
Crash Data
Base crash rate (Base), severe crashes/mvm:
0.20
Local calibration factor (f):
1.00
Curve deflection angle (Ic) (Ic = 6280 (57.3 Lc)/R), degrees:
60.6
Horizontal curve radius (AMFcr):
1.00
Spiral transition curve (AMFsp):
1.00
Grade (AMFg):
1.00
Lane width (AMFlw):
1.00
Outside shoulder width (AMFosw):
1.00
Inside shoulder width (AMFisw):
1.00
Median width (AMFmw):
1.00
Shoulder rumble strips (AMFsrs):
1.00
Centerline rumble strip (AMFcrs):
1.00
TWLTL median type (AMFT):
1.00
Superelevation (AMFe):
1.00
Passing lane (AMFpass):
1.00
Horizontal clearance (AMFhc):
1.00
Side slope (AMFss):
1.00
Utility pole offset (AMFpd):
1.00
Bridge width (AMFbw):
1.00
Driveway density (AMFdd):
1.00
Combined AMF (product of all AMFs above) (AMFcombined):
1.00
Expected severe base crash frequency (Cb), crashes/yr
0.27
Expected severe crash frequency for segment (C), crashes/yr:
0.27


Calibration Parameters
Calibration
Crash rate for various median types
Crash rate represents "typical" segment
Local calibration factor for global adjustment
Calibration Parameters
Median type
Through Lanes
Crash Rate (cr/mvm)
Undivided or surfaced*
(*surfaced median: TWLTL or flush paved)
2
0.20
4
0.30
Depressed
4
0.21
6
0.32
Local calibration factor (f):
1.00

3. Highway Segments

- Overview
  - *Safety prediction model*
  - *Accident modification factors*
  - *Exercises*

Safety Prediction Model

- Components
  - *Base model*
    - C_b = base crash rate × volume × length
  - *Accident modification factors*
- Relationship

$$C = C_b \times AMF_{lw} \times AMF_{dd} \cdots \qquad (3\text{-}3)$$

where:
C = expected severe crash frequency, crashes/yr;
C_b = expected severe base crash frequency, crashes/yr;
AMF_{lw} = lane width accident modification factor; and
AMF_{dd} = driveway density accident modification factor.

Base Model

- Base Model
  - *Rates in Workbook*
    - Based on typical conditions
    - Injury (plus fatal) crashes
    - All crash types

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$$C_b = 0.000365\ Base\ ADT\ L\ f \qquad (3\text{-}1)$$

where:
C_b = expected severe base crash frequency, crashes/yr;
$Base$ = severe crash rate (see Table 3-1), crashes/mvm;
ADT = average daily traffic volume, veh/d;
L = highway segment length, mi; and
f = local calibration factor.

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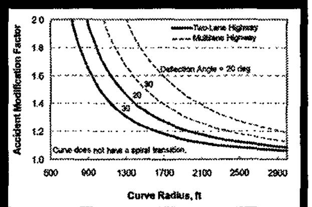
Median Type	Attributes	Base Crash Rate, severe crashes/mvm [1]		
	Through Lanes:	2	4	6
Undivided or Surfaced [2]		0.20	0.30	data not available
Depressed		data not available	0.21	0.32

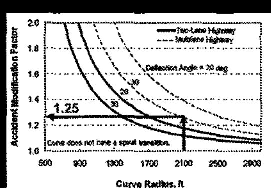
Curve Radius

- Base Condition
  - *No curvature*
- Limits
  - *Radius ≥ 500 ft*
- Notes
  - *If spirals present, include their length in curve length*
  - *If no spirals, measure PC to PT*



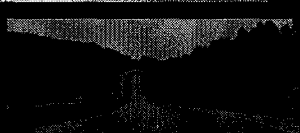
Example

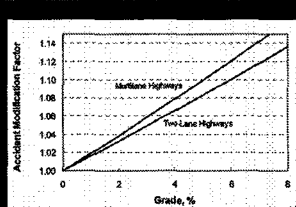
- Questions
  - *What is the AMF for a 2100-ft radius curve?*
    - Multilane highway
    - Deflection angle = 30°



Grade

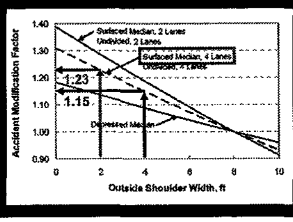
- Base Condition
  - *No grade*
- Limits
  - *Grade ≤ 8%*
- Notes
  - *"Upgrade" and "Downgrade" have same effect on safety*





Example

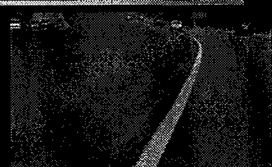
- Question
  - *If a multilane rural highway's outside shoulders are widened from 2 to 4 ft, what would be the expected crash reduction?*
    - Surfaced median, 4 lanes

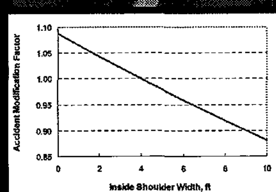


2 ft shoulder: AMF = 1.23
4 ft shoulder: AMF = 1.15
Crash reduction:
100 × (1 - 1.15/1.23) = 6.5 %

Inside Shoulder Width

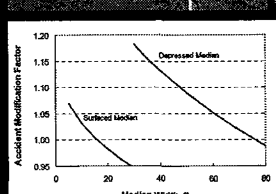
- Base Condition
  - *4-ft inside shoulder*
- Limits
  - *Shoulder widths between 0 and 10 ft*
- Notes
  - *If width > 10 ft, use AMF for 10 ft*





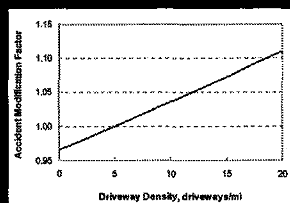
Median Width

- Base Condition
  - *16 ft (surfaced)*
  - *76 ft (depressed)*
- Limits
  - *Surfaced medians between 4 and 30 ft*
  - *Depressed medians between 30 and 80 ft*
- Notes
  - *Not for highways that have a TWLTL*



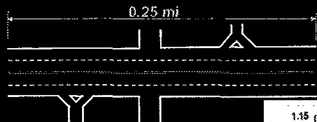
Driveway Density

- Base Condition
  - *5 drives/mi*
- Notes
  - *Count drives on both sides of roadway*
  - *Full-access drives (all mvmts) count as 1.0 toward total*
  - *Partial-access drives count as 0.5 toward total*

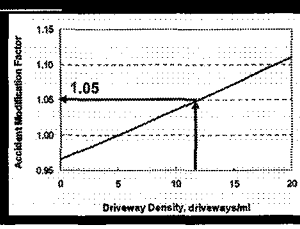


Example

- Question
  - *What is the AMF for the 0.25 mi road?*



- Answer
  - *Density = (0.5 + 2.0 + 0.5)/0.25 = 12 drives/mi*



Exercise 1: Rural Highway

- Given
  - *Rural multilane highway segment*
    - Lanes: 4
    - Length: 2 mi
    - Volume: 22,000 veh/d
    - No curvature
    - No grade
    - Lane width: 11 ft
    - Shoulder width: 8 ft
    - 10-ft flush-paved median
    - No rumble strips
    - 3 driveways/mi
    - Horiz. clearance: 30 ft
    - Side slope: 1:6
    - 25 poles/mi at 20 ft off
    - No bridges
- Question
  - *What is the expected crash frequency?*

Exercise 1: Rural Highway

- Additional Questions
  - *What does the combined AMF say about this segment, relative to the typical segment?*
  - *Which attribute(s) tend to increase the crash rate of this segment, relative to the typical segment?*
- Now it's your turn. . .

Exercise 2: Rural Highway

- Given
  - *Rural multilane highway segment*
    - Lanes: 4
    - Length: 2 mi
    - Volume: 17,000 veh/d
    - No curvature
    - 1 percent grade
    - Lane width: 12 ft
    - Shoulder width: 6 ft outside, 2 ft inside
    - 30-ft depressed median
    - No rumble strips
    - 2 driveways/mi
    - Horiz. clearance: 30 ft
    - Side slope: 1:6
    - 25 poles/mi at 30 ft off
    - No bridges
- Question
  - *What is the expected crash frequency?*

Exercise 2

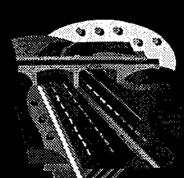
- Answer

Agenda

- Session 4:
  - Procedure for freeway segments
- Session 5:
  - Procedure for interchange ramps
- Session 6:
  - Multilane highway section evaluation
- Session 7:
  - Alternatives analysis

4. Freeway Segments

- Overview
  - Safety prediction model
  - Accident modification factors
  - Exercises



Safety Prediction Model

- Components
  - Base model
    - C_b = base crash rate × volume × length
  - Accident modification factors
- Relationship

Page 2-8

$$C = C_b \times AMF_{lw} \times AMF_{mw} \cdots \qquad \textbf{(2-3)}$$

where:

C = expected severe crash frequency, crashes/yr;
C_b = expected severe base crash frequency, crashes/yr;
AMF_{lw} = lane width accident modification factor; and
AMF_{mw} = median width accident modification factor.

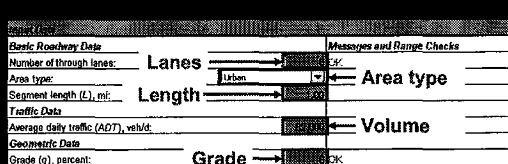
Accident Modification Factors

- Freeway
  - *Grade*
  - *Lane width*
  - *Outside shoulder width*
  - *Inside shoulder width*
  - *Median width*
  - *Shoulder rumble strips*
  - *Utility pole offset*

Exercise 3: Freeway

- Given
  - *Freeway segment*
    - Lanes: 6
    - Area type: Urban
    - Length: 1 mi
    - Volume: 82,000 veh/d
    - No grade
    - Lane width: 11 ft
    - Shoulder width: 6 ft outside, 4 ft inside
    - No HOV lanes
    - Depressed median
    - Median width: 50 ft
    - Rumble strips on outside and inside shoulders
    - 25 poles/mi at 15 ft off
- Question
  - *What is the expected crash frequency?*

Exercise 3: Freeway



Exercise 4: Freeway

- Given
  - *Freeway segment*
    - Lanes: 4
    - Area type: Rural
    - Length: 5 mi
    - Volume: 27,000 veh/d
    - Grade: 2 percent
    - Lane width: 12 ft
    - Shoulder width: 10 ft outside, 4 ft inside
    - No HOV lanes
    - Depressed median
    - Median width: 40 ft
    - No rumble strips
    - 25 poles/mi at 15 ft off
- Question
  - *What is the expected crash frequency?*

Exercise 4: Freeway

- Answer

Exercise 4: Freeway

- Question
  - *What is the expected crash frequency if the poles are relocated?*
    - 20 poles/mi at 30 ft offset
- Answer

Ramp Types

- Non-Frontage Road Ramps

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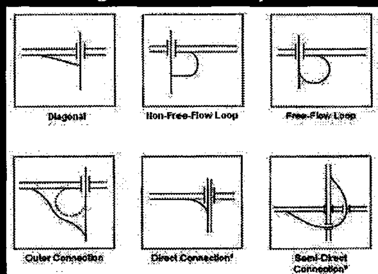

a – when used in directional interchanges

Ramp Types

- Frontage Road Ramps

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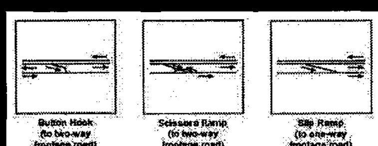

Base Model

- Ramp Proper
  - Base crash rate
    - Ramp type
    - Ramp configuration
  - Crash definition
    - Injury (plus fatal) crashes
    - All crash types
  - Observations
    - Higher rates for exit ramps
    - Free-flow loops have low rates

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Interchange Setting	Ramp Type	Ramp Configuration	Base Crash Rate, cr/mv[1]
Non-Frontage Road	Exit	Diagonal	0.28
		Non-free-flow loop	0.51
		Free-flow loop	0.20
		Outer connection	0.33
		Semi-direct conn.	0.25
		Direct connection	0.21
	Entrance	Diagonal	0.17
		Non-free-flow loop	0.31
		Free-flow loop	0.12
		Outer connection	0.20
		Semi-direct conn.	0.16
		Direct connection	0.13
Frontage Road	Exit	Button hook	0.57
		Scissor	0.48
		Slip	0.36
	Entrance	Button hook	0.28
		Scissor	0.21
		Slip	0.23

Note:
1 - cr/mv: severe crashes per million vehicles.

Exercise 5: Ramp

Output Summary	
Expected severe crash frequency for ramp and speed-change lanes (*Base* + C_b), crashes/yr:	0.38
Base Crash Frequency Information for Interchange Ramp	
Crash Data	
Base crash rate (*Base*), severe crashes/mv:	0.23
Ramp local calibration factor (f_{ramp}):	1.00
Expected Crash Frequency for Interchange Ramp	
Expected severe base crash frequency (C_b), crashes/yr:	0.21
Base Crash Frequency Information for Speed-Change Lane	
Crash Data	
Base crash rate (*Base*), severe crashes/mv:	0.011
Acceleration lane local calibration factor (f):	1.00
Expected Crash Frequency for Speed-Change Lane	
Expected severe base crash frequency for acceleration lane (Cb), crashes/yr:	0.17

Output (all crashes)

Ramp crashes

Speed-change lane crashes

Exercise 5: Ramp

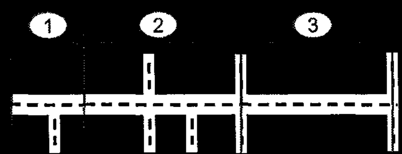
- Additional Question
  - *What is the crash frequency for an exit ramp with similar conditions?*
    - Ramp type: Exit
    - All other data are unchanged
- Now it's your turn. . .

Exercise 6: Ramp

- Given
  - *Highway ramp*
    - Area type: Rural
    - Ramp volume: 2500 veh/d
    - Adjacent mainline volume: 8500 veh/d
    - Ramp type: Exit
    - Ramp configuration: Diagonal
- Question
  - *What is the expected crash frequency?*

6. Section Evaluation

- Review Safety Prediction Procedure
- Road Section Evaluation
- Project Evaluation

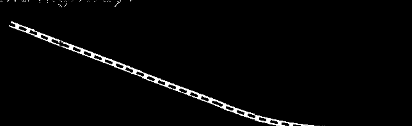


Safety Prediction Procedure

- Six Steps
  1. *Identify roadway section*
  2. *Divide section into facility components*
  3. *Gather data for subject component*
  4. *Compute expected crash frequency*
  5. *Repeat steps 3 and 4 for each additional component*
  6. *Add up results for roadway section*

Exercise 7: Section Evaluation

- Given
  - *Rural highway*
  - *Input data to follow*
- Question
  - *What is the expected crash frequency for the highway?*



Exercise 7: Section Evaluation

- Given

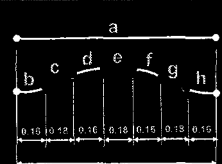
  - *Highway segment "c"*
    - Lanes: 4
    - Length: 0.18 mi
    - Volume: 4000 veh/d
    - No curvature
    - No grade
    - Lane width: 12 ft
    - Shoulder width: 8 ft
    - TWLTL median
    - No rumble strips
    - 11 driveways/mi
    - Horiz. clearance: 30 ft
    - Side slope: 1:4
    - 25 poles/mi at 20 ft off
- Question
  - *What is the expected crash frequency?*

Exercise 7: Section Evaluation

- Answers
  - *Segment "a"*
  - *Segment "b"*
  - *Segment "c"*
  - *Entire highway section*

Exercise 7: Section Evaluation

- Observations



Exercise 8: Project Evaluation

- Answers
  - *North/south road (Ex. 2-a)*
  - *East/west road (Ex. 7 "a")*
  - *Intersection (given)*
  - *Entire facility*

Exercise 8: Project Evaluation

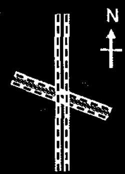
- Additional Questions
  - *What is the best measure of safety benefit?*
  - *Which facility component(s) may yield the most benefit through design change?*
- Answers
  - *Expected number of* ***crashes reduced*** *is the best measure of safety benefit*
  - *Segments or intersections with many crashes have more potential for a large safety benefit through a design change, so. . .*

Exercise 8: Project Evaluation

- Additional Questions
  - *What does the combined AMF tell us?*
  - *What does it mean when the combined AMF is greater than 1.0?*
- Answers
  - *The combined AMF tells us about "relative risk"*
  - *Values larger than 1.0 indicate the component is potentially less safe than the "typical" one*
  - *So. . .*

Exercise 9: Alternatives Analysis

- Current Design
  - *Two intersecting rural highways*
    - North/south highway
      - 4-lane depressed median
    - East/west highway
      - 4-lane TWLTL
    - Intersection
      - Stop-controlled
      - 25-degree skew angle
  - *From Exercise 8*
    - Crash frequency = 6.63 crashes/yr

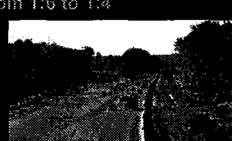


Exercise 9: Alternatives Analysis

- Analysis Process
  1) *Identify components that have a combined AMF > 1.0*
     - North/south road (Ex. 2-a): 1.27
     - Intersection (Ex-8): 1.19
     - East/west road (Ex. 7 "a"): 1.01
  2) *Rank them in order of crash frequency*
     - North/south road: 3.32 crashes/yr
     - Intersection: 2.79 crashes/yr
     - East/west road: 0.52 crashes/yr
  3) *Identify potential design changes of those components with a larger crash frequency*

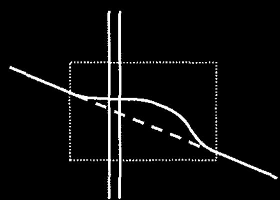
Exercise 9a: Alternatives Analysis

- Alternative A
  - *Treatment*
    - Increase shoulder width for north/south road
  - *Repeat the analysis for Exercise 2, but:*
    - Outside shoulder: Increase from 6 to 10 ft
    - Inside shoulder: Increase from 2 to 6 ft
    - Side slope: Decrease from 1:6 to 1:4



Exercise 9b: Alternatives Analysis

- Alternative B
  - *Treatment*
    - Realign east/west road to eliminate skew
    - Requires addition of two curves
    - Crash estimates from Exercises 2 and 7



Exercise 9b: Alternatives Analysis

- Question
  - *Is this alternative safer than the current configuration?*
- Answer
  - *Expected crash frequencies:*
    - North/south road (Ex. 2-a):
    - East/west road (Ex. 7 "b+...+h"):
    - Intersection:
    - Facility:

Exercise 9b: Alternatives Analysis

- Question
  - *Given*
    - $1,800,000 construction cost
    - 25-year life span
    - $100,000 benefit per crash prevented
  - *Is this alternative viable?*
- Answer

Exercise 9c: Alternatives Analysis

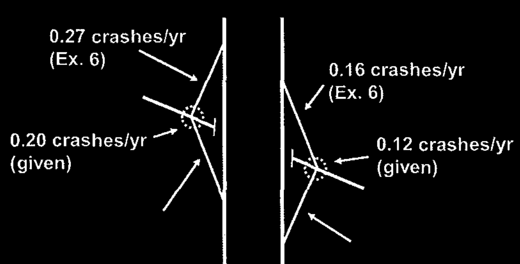
- Analysis
  - *Northbound exit ramp*
    - Area type: Rural
    - Ramp volume: 1000 veh/d
    - Adjacent mainline volume: 8500 veh/d
    - Ramp type: Exit
    - Ramp configuration: Diagonal
- Question
  - *What is the expected crash frequency?*
- Answer

Exercise 9c: Alternatives Analysis

- Analysis
  - *Southbound entrance ramp*
    - Area type: Rural
    - Ramp volume: 1000 veh/d
    - Adjacent mainline volume: 8500 veh/d
    - Ramp type: Entrance
    - Ramp configuration: Diagonal
- Question
  - *What is the expected crash frequency?*
- Answer

Exercise 9c: Alternatives Analysis

- Analysis



Exercise 9c: Alternatives Analysis

Finding	Current	Alt. A	Alt. B	Alt. C
Construction Cost, $1000				
Safety benefit, $1000/yr				
Capital cost, $1000/yr				
Benefit-cost ratio				
Net benefit, $1000/yr				

- Questions
  - *Which alternative is best based on safety benefit and cost?*
  - *What if the net benefit for Alt. B was $54,000 and its B/C ratio = 1.75?*

Exercise 9: Alternatives Analysis

- Alternative Selection Summary
  - *Establish a goal of reducing total crash frequency by some amount*
  - *Exclude projects that do not provide minimum benefit*
  - *Exclude projects that exceed available funds*
  - *If funds are earmarked for this project:*
    - Use net benefit to select project
  - *If unspent funds can be used for other projects:*
    - Use benefit-cost ratio to select projects

Exercise 9: Alternatives Analysis

- Observations
  - *Our computations reflect only safety impact*
    - Different conclusions may be reached if other impacts are considered
  - *Final decision must consider all impacts*
    - Safety
    - Environment
    - Traffic operations
    - Right-of-way
    - Construction costs

  - *Choose the most cost-effective alternative*

EXERCISE 1: RURAL MULTILANE HIGHWAY SEGMENT

INPUT DATA

Basic Roadway Data
- Number of through lanes: 4
- Segment length: 2 mi

Traffic Data
- Average daily traffic: 22,000 veh/d

Geometric Data
- Presence of horizontal curve: No
- Grade: 0 percent

Cross Section Data
- Lane width: 11 ft
- Outside shoulder width: 8 ft
- Median type: Flush paved
- Median width: 10 ft
- Presence of shoulder rumble strips: None

Access Control Data
- Driveway density: 3 driveways/mi

Roadside Data
- Horizontal clearance: 30 ft
- Side slope: 1:6
- Utility pole density: 25 poles/mi
- Utility pole offset: 20 ft

OUTPUT SUMMARY

What is the expected crash frequency?	
What is the combined AMF?	

What does the combined AMF say about this segment, relative to the typical segment? _______

____

Which attribute(s) tend to increase the crash rate of this segment, relative to the typical segment?

____

EXERCISE 3: FREEWAY SEGMENT

INPUT DATA

Basic Roadway Data
- Number of through lanes: 6
- Area type: Urban
- Segment length: 1 mi

Traffic Data
- Average daily traffic: 82,000 veh/d

Geometric Data
- Grade: 0 percent

Cross Section Data
- Lane width: 11 ft
- Outside shoulder width: 6 ft
- Inside shoulder width: 4 ft
- HOV lane presence: No HOV lane present
- Median type: Depressed
- Median width: 50 ft
- Presence of shoulder rumble strips: Both sides

Roadside Data
- Utility pole density: 25 poles/mi
- Utility pole offset: 15 ft

OUTPUT SUMMARY

What is the expected crash frequency? .... [ ]

What is the combined AMF? .... [ ]

If the cross section is changed to:
- Lane width: 12 ft
- Outside shoulder width: 10 ft
- Inside shoulder width: 6 ft
- Median width: 36 ft

What is the expected crash frequency? .... [ ]

What is the combined AMF? .... [ ]

EXERCISE 5: INTERCHANGE RAMP

INPUT DATA

Basic Roadway Data
Area type: Urban

Traffic Data
Average daily traffic on ramp: 2500 veh/d
Average one-way daily traffic on the adjacent mainlanes: 41,000 veh/d

Geometric Data
Ramp type: Entrance
Ramp configuration: Slip

OUTPUT SUMMARY

What is the expected crash frequency? ……………………………………….. [ ]

For an exit ramp with similar conditions:
Ramp type: Exit
All other input data are unchanged

What is the expected crash frequency? ……………………………………….. [ ]

EXERCISE 7: SECTION EVALUATION

Location: Rural multilane highway segment "a"

INPUT DATA

Basic Roadway Data
Number of through lanes: 4
Segment length: 1.18 mi

Traffic Data
Average daily traffic: 4000 veh/d

Geometric Data
Presence of horizontal curve: No
Grade: 0 percent

Cross Section Data
Lane width: 12 ft
Outside shoulder width: 8 ft
Median type: TWLTL
Presence of shoulder rumble strips: None

Access Control Data
Driveway density: 4 driveways/mi

Roadside Data
Horizontal clearance: 30 ft
Side slope: 1:4
Utility pole density: 25 poles/mi
Utility pole offset: 20 ft

OUTPUT SUMMARY

Record your results in the table on the last page for Exercise 7.

EXERCISE 7: SECTION EVALUATION

Location: Rural multilane highway segment "c"

INPUT DATA

Basic Roadway Data
- Number of through lanes: 4
- Segment length: 0.18 mi

Traffic Data
- Average daily traffic: 4000 veh/d

Geometric Data
- Presence of horizontal curve: No
- Grade: 0 percent

Cross Section Data
- Lane width: 12 ft
- Outside shoulder width: 8 ft
- Median type: TWLTL
- Presence of shoulder rumble strips: None

Access Control Data
- Driveway density: 11 driveways/mi

Roadside Data
- Horizontal clearance: 30 ft
- Side slope: 1:4
- Utility pole density: 25 poles/mi
- Utility pole offset: 20 ft

OUTPUT SUMMARY

Record all results for segments "a," "b," and "c" into this table.

Facility Component	Expected Crash Frequency (crashes/yr)	Combined AMF
Segment "a"		
Segment "b"		
Segment "c"		
Total for roadway section		

What is the expected crash frequency for segments "b" through "h"?................ [ ]

EXERCISE 9a: ALTERNATIVE A

Description: Widen the inside and outside shoulders on the north-south road. To provide the increased width while remaining within the right-of-way, it is necessary to reduce the side slope.

Please complete the table and answer the questions below.

Facility Component	Exercise Number	Expected Crash Frequency (crashes/yr)	Combined AMF
North-south road	2-b (after change)		
East-west road	7 "a"		
Intersection	Given	2.48	1.19
Total for facility			

Is this alternative safer than the current configuration (see Exercise 8)? ____________________

How many crashes are reduced per year, relative to the current configuration? ______________

Given the following assumptions:

- $750,000 construction cost to widen the shoulders on the north-south road
- 25-year life span for the project
- $100,000 benefit per crash reduced

Benefit: [ ] crashes/yr reduced x $100,000/crash reduced = $[ ] / yr

Cost: $[ ] construction cost ÷ [ ] yr life span = $[ ] / yr

Is this alternative viable? ____

What is the net benefit for Alternative A, relative to the current configuration? ______________

EXERCISE 9c: ALTERNATIVE C

Description: Grade-separate the roads. Use a diamond interchange with four diagonal ramps.

INPUT DATA

Basic Roadway Data
Area type: Rural
Traffic Data
Average daily traffic on ramp: 1000 veh/d
Average one-way daily traffic on the adjacent mainlanes: 8500 veh/d
Geometric Data
Ramp type: Exit
Ramp configuration: Diagonal

OUTPUT SUMMARY

What is the expected crash frequency? .... [ ]

For an entrance ramp with similar conditions:
Ramp type: Entrance
All other input data are unchanged

What is the expected crash frequency? .... [ ]

INCORPORATING SAFETY INTO THE HIGHWAY DESIGN PROCESS:
MULTILANE HIGHWAYS AND FREEWAYS WORKSHOP

Date: ______________
Location: ______________

Your Agency:____

Your Position:____

Course Content (circle one)

	Yes				No
1. Did the course meet your expectations? Comments: ____________________________________ ____________________________________	1	2	3	4	5
2. Was the material presented at the correct level of difficulty? Comments: ____________________________________ ____________________________________	1	2	3	4	5
3. Was the topic of the course covered adequately (nothing left out, no one topic overemphasized)? Comments: ____________________________________ ____________________________________	1	2	3	4	5
4. Was the software easy to use? Comments: ____________________________________ ____________________________________	1	2	3	4	5