Safety and Operational Effects of Geometric Design Features for Multilane Highways Workshop
Safety and Operational Effects of Highway Design Features for Multilane Highways

Day 1 Agenda

REGISTRATION (7:45am – 8:00 a.m.)

8:00 a.m. PREDICTING HIGHWAY SAFETY FOR MULTILANE RURAL HIGHWAY SEGMENTS– 50 minutes - Workshop Participants are requested to bring calculators capable of scientific notation calculations.

Overview of course purpose and content, introduction to instructors and participants. Introduction to the concept of nominal versus substantive safety, including the application of the “Science of Safety” of the Highway Safety Manual to geometric design, design standards, and substantive safety performance.

Proven methodology is now available to predict safety performance in a like manner to that of predicting capacity and level of service based upon large scale definitive research. The substantive safety philosophy is presented and discussed.

8:50 a.m. BREAK – 10 minutes

9:00 a.m. PREDICTING HIGHWAY SAFETY FOR MULTILANE RURAL HIGHWAY SEGMENTS– 60 minutes

The crash prediction models for total crashes based upon lane width, shoulder width, roadside hazard, traffic volume (exposure) and other characteristics are presented. Examples of safety performance prediction are presented for highway segments.

Discussion of research on the safety effects of lane and shoulder widths, hazard rating, and access density (driveways) and application as Accident Modification Factors. Draft Models from Highway Safety Manual for predicting crashes on Multilane Highways are presented from FHWA and NCHRP research projects. The interactive effects of lane width with other variables (roadside, alignment) are presented.

10:00 a.m. BREAK – 10 minutes

10:10 a.m. Exercise I – Predicting Safety Performance of a Multilane Highway + Student Worksheet – 20 minutes

Application of Highway Safety Manual predictive equations to an improvement project to improve a 4-lane undivided state highway with aggregate shoulders to a 6-lane with median and paved outside shoulders design. Participants will compute predicted annual crashes for lane and shoulder width, for median width and other geometric design features and compare to substantive safety performance (crash summary).

10:30 a.m. Exercise I - Discussion and Summary – 10 minutes
Summary and discussion of the Highway Safety Manual predictive methodology to design designs in the improvement of the 4-lane undivided state highway to a 6-lane highway with median, paved shoulders, and access improvement.

10:40 a.m.   Break – 10 minutes

10:50 a.m. PREDICTING HIGHWAY SAFETY FOR MULTILANE URBAN HIGHWAYS – 55 minutes

11:45 a.m. LUNCH

12:45 noon. Exercise II – Predicting Safety Performance of a Multilane Urban Highway + Student Worksheet – 30 minutes

Application of Highway Safety Manual predictive equations to an improvement project to improve a 4-lane undivided state highway with aggregate shoulders to a 6-lane with median and paved outside shoulders design. Participants will compute predicted annual crashes for lane and shoulder width, for median width and other geometric design features and compare to substantive safety performance (crash summary).

1:15 p.m. Exercise II - Discussion and Summary – 5 minutes

Summary and discussion of the Highway Safety Manual predictive methodology to design designs in the improvement of the 4-lane undivided state highway to a 6-lane highway with median, paved shoulders, and access improvement.

1:20 p.m. PREDICTING SAFETY PERFORMANCE FOR MULTI-LANE HIGHWAY CURVES – 20 Minutes

Proven methodology is now available to predict safety performance of highway curves in a like manner to that of predicting safety of highway segments based upon large scale definitive research. The crash prediction models for total crashes and Crash Modification Factors and 85th Percentile Speeds based upon Degree of Curve, curve length, spiral transistion, lane width, shoulder width, roadside hazard, traffic volume (exposure) and other characteristics are presented. Examples of safety performance prediction are presented for curves.

1:40 p.m. Exercise III – Predicting Safety Performance of a Multilane Curve + Student Worksheet – 15 minutes

Application of Highway Safety Manual predictive equations to a multilane curve. Participants will compute predicted annual crashes for the curve and compare to substantive safety performance (crash summary).

1:55 p.m. Exercise III - Discussion and Summary – 5 minutes

Summary and discussion of the Highway Safety Manual predictive methodology to design designs in the improvement of the 4-lane undivided state highway to a 6-lane highway with median, paved shoulders, and access improvement.

2:00 p.m. Break – 10 minutes
2:10 p.m.  Multilane Intersections – 60 minutes

Discussion of the safety characteristics of multilane intersections. Presentation of predictive equations for crash frequency as a function of number of approaches, type of traffic control, and volume of intersecting roadways. Safety effects of design and traffic operational treatments are described.

3:10 p.m.  Break – 10 minutes

3:20 p.m.  Exercise IV – Predicting Safety Performance of a Multilane Intersections + Student Worksheet – 20 minutes

Application of Highway Safety Manual predictive equations for intersections to quantify safety performance of the “before” geometric and operational features and comparison to substantive safety performance. Participants will quantify the safety effects of both “before” and “after” geometric and operational features and compare to the substantive safety performance.

3:40 p.m.  Exercise IV - Discussion and Summary – 10 minutes

Summary and discussion of the Highway Safety Manual predictive methodology to multilane intersections.

3:50 p.m.  Break – 10 minutes

4:00 p.m.  Exercise V – Discussion and Summary - CASE STUDY – IL 64 North Avenue – 30 minutes

Application of the Highway Safety Manual predictive equations to a mile section of a multilane suburban highway in Northeast Illinois (DuPage County).

4:30 p.m.  Exercise IV - Discussion and Summary – 10 minutes

Summary and discussion of the Highway Safety Manual predictive methodology to the Case Study for IL 64 North Avenue in DuPage County Illinois.

4:40 p.m.  Workshop Closure – 10 minutes

4:50 p.m.  End of Workshop
NHI Course No. 380070B
Safety Effects of Geometric Design Features for Multilane Highways Workshop

Pre Test

Name: ________________________________   Date: ____________________

Directions: Please circle and/or fill in the answer for each question.

1. Substantive Safety is?
   (A) One of the crash statistical values
   (B) A subset of nominal safety
   (C) The total Accident Experience
   (D) The actual crash frequency and severity for a highway or roadway

2. Rural multilane highways are defined as?
   (A) Places outside of cities of populations greater than 50,000
   (B) Places located more than 5.0 miles away from the incorporated boundary
       of any city or town
   (C) Places outside the boundaries of urban places where the population is less
       than 5000 inhabitants
   (D) Places that are suburban as well as rural

3. Countermeasures with AMF values less than 1.00 indicates which of the following:
   (A) Lowers the crash frequency with application of the countermeasure
   (B) Raises the crash frequency with application of the countermeasure
   (C) Evidence of regression to the mean
   (D) Imply that an incorrect correlation factor was applied.

4. List at least four geometric features that have specific AMF values or equations to
   compute AMF values for rural multilane highways:

   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
   ________________________________________________________________
5. For urban/suburban highways and streets, the term Multilane means:
   (A) Facilities with more than two through lanes
   (B) Facilities with three, or more, through lanes
   (C) Facilities with four, or more, through lanes
   (D) Facilities with six, or more, through lanes

6. For urban/suburban highways and streets, the total predicted number of crashes consists of:
   (A) Predicted Crash Frequency of the Baseline Model multiplied by the Correction Factor
   (B) Predicted Crash Frequency for the entire arterial street/roadway plus the predicted number of total intersection related crashes
   (C) Predicted segment crashes multiplied by the AMF’s
   (D) The sum of the predicted crashes for undivided and divided roadways

7. List at least four geometric features that have specific AMF values or equations to compute AMF values for urban/suburban multilane streets:

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

8. The greatest predictor of crash risk at an intersection is?
   (A) the number of stop signs
   (B) the number of signal indications
   (C) traffic volume
   (D) the approach speeds

9. For urban/suburban multilane street intersections, the predicted number of total intersection crashes is?
   (A) \[ N = e^a \times \text{AADT}_{\text{major}} \times \text{AADT}_{\text{minor}} \]
   (B) the predicted number of multivehicle crashes plus the predicted number of single vehicle crashes plus the predicted number of pedestrian and bicycle crashes
   (C) based on the model for traffic signal control only
   (D) based on the approach speeds

10. The AMF for Converting a Signalized Intersection to a Modern Roundabout for total crashes in “All Settings with one or two lanes” is: (see Exhibit 14-8)
    (A) 0.99
    (B) 1.10
    (C) 0.33
    (D) 0.52
Safety and Operational Effects of Geometric Design Features for Multilane Rural Highways Workshop

Introduction and Background

- Session #1

Logistics

- Health and safety (emergency exits, procedures for evacuation, etc.)
- Please turn off cell phones/Pagers
- Breaks (when, restrooms, telephones)
- Lunch arrangements
- Other site-specific issues
- Completing NHI Forms
Course Instructors

- Jeff Shaw, P.E., P.T.O.E.
  Jeffery.shaw@fhwa.dot.gov

- Fred Ranck, P.E., P.T.O.E.
  Fred.ranck@fhwa.dot.gov

Self Introductions

- Who you are
- Who you work for and what you do
- What issue of a multi-lane highway project would you like to know more about?
This is a workshop! Expect to do some work!

- Ask your questions as you have them.
- “Parking Lot” for Questions to be addressed later in workshop
- Work problems and exercises (based on actual case studies)
- Facilitated questioning and discussions

Introduction and Background

Outcomes:

- Describe the Safety Performance of Multilane Highways and Streets

- Define Substantive Safety beyond Nominal Safety
The View by AASHTO: Highway Fatalities in 2005 Highest Since 1990; Numbers have gone down but rates have plateau

Future Safety Vision

* NHTSA FARS of 8/2007

Rate = 1.45 (70,000)
Rate = 1.0 (48,000)
Rate = .41 (20,000)

2030
Demographics and Travel:

- 140 Million more Americans by 2055 (South & Southwest get 88% of growth)
- More Elderly Drivers by 2030: 70 million, 65 or older vs. 35 million today
- Population more ethnically diverse
- Overall travel growth 2% per year
- Truck Travel: 114% growth from 2004-2035

High Safety Payoff/ Problem Areas:

- Alcohol – 40% of Fatals
- Speed – 30 % of Fatals
- Belts – 50% of Fatals unbelted
- Motorcycles – 10% of Fatals; double digit growth
- Large Truck involved – 12% of Fatals
- Highway Intersections – 21% of Fatals
- Highway Lane Departure – 60% of Fatals
## Key Countermeasures:

<table>
<thead>
<tr>
<th>Issue</th>
<th>Roadway</th>
<th>Vehicle Technology</th>
<th>Laws &amp; Enforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Speed</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Seat Belts</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Motorcycles</td>
<td></td>
<td>●</td>
<td>X</td>
</tr>
<tr>
<td>Large Trucks</td>
<td>X</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Intersections</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Lane Departures</td>
<td>X</td>
<td>X</td>
<td>●</td>
</tr>
</tbody>
</table>

X = Primary  ● = Secondary

## Multilane Highways:

- 3,995,644 miles – US Public Roads
- 976,477 miles - US Federal Aid Mileage
- 165,783 miles - Multilane Highways 17%
- 44,673 miles – Multilane Undivided 27%
- 121,100 miles – Multilane Divided 73%
Introduction

Substantive Safety Varies Significantly by Type of Road, Location and Other Factors

<table>
<thead>
<tr>
<th></th>
<th>Fatal Accidents</th>
<th>Injury Accidents</th>
<th>Total Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number per MVM</td>
<td>Number per MVM</td>
<td>Number per MVM</td>
</tr>
<tr>
<td><strong>RURAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Lanes</td>
<td>0.07</td>
<td>0.94</td>
<td>2.39</td>
</tr>
<tr>
<td>4 or more lanes, divided subtotal</td>
<td>0.063</td>
<td>0.77</td>
<td>2.09</td>
</tr>
<tr>
<td>Freeway</td>
<td>0.025</td>
<td>0.27</td>
<td>0.79</td>
</tr>
<tr>
<td><strong>URBAN</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Lanes</td>
<td>0.045</td>
<td>1.51</td>
<td>4.94</td>
</tr>
<tr>
<td>4 or more lanes, undivided</td>
<td>0.04</td>
<td>2.12</td>
<td>6.65</td>
</tr>
<tr>
<td>4 or more lanes, divided</td>
<td>0.027</td>
<td>1.65</td>
<td>4.86</td>
</tr>
<tr>
<td>Freeway</td>
<td>0.012</td>
<td>0.4</td>
<td>1.43</td>
</tr>
</tbody>
</table>

US Intersection Crash Data

- Over 30% of all rural crashes occur at intersections
- Over 50% of all urban crashes occur at intersections
### 2006 U.S. National Total Crash Characteristics

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Total Crashes</th>
<th>Fatalities + Injury Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Non-Intersection</td>
<td>2,826,900</td>
<td>47%</td>
</tr>
<tr>
<td>Stop and No Control Intersection</td>
<td>1,955,467</td>
<td>33%</td>
</tr>
<tr>
<td>Signalized Intersection</td>
<td>1,181,848</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>5,964,000</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Key Safety Principles and Design

Knowledge is imprecise, judgment is essential

- Meeting standard does not necessarily make highway safe
- Some important features of highways not determined by standards
  - e.g., Spacing of interchanges and intersections;
  - Spiral transitions to horizontal curves

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**Session 1 – Introduction and Background**
Nominal Safety: “But Captain, it met all design standards”

What Constitutes “Safe” Design?
**Approaches for Considering Safety**

`nominal safety’ refers to adherence to applicable design criteria and standards

Substantive and Nominal Safety

- **Nominal Safety** is examined in reference to compliance with standards, warrants, guidelines and sanctioned design procedures

- **Substantive Safety** is the actual crash frequency and severity for a highway or roadway
Substantive Safety is a Continuum

Transportation Engineering

Safety – an absolute

“Safer” - a relative term
Nominal Safety

1st Step

Complies?

Yes  No

- Based on research and operational experience
- Provides consistent level of quality
- Reflective of general cost-effectiveness
- Protection from claims of legal liability - ???

Substantive and Nominal Safety

Example:

1st Step

Nominal Safety – 12 foot lane + 8 foot gravel shoulder (AMF = 1.00 x 0.87 x 1.00 x 0.79 = 0.887)

2nd Step

Substantive Safety
Paved 8 foot Shoulder + Shoulder Longitudinal Rumble Strip ((AMF = 1.00 x 0.87 x 1.00 x 0.79 for ROR Crashes) = 0.687 or 31% fewer crashes
Substantive Safety

The “Science” Associated with Safety Improvements to Achieve Substantive Safety

AASHTO Strategic Safety Plan Guidebooks:

Website for NCHRP Report 500 Guidebooks is:

http://trb.org/news/search_news.asp?subjectradio=0&id=2&id.name=NCHRP+Reports&q_sw=500&subject=
The Highway Safety Manual of 2009

- Methodology is the same as for assessing and assuring the adequacy of Capacity
- HSM allows the transportation professional to understand and quantify highway safety performance for informed and balanced decision making

Consideration of Safety in the Design Process – Jan 7, 2005

It is the policy of FHWA that Safety must be fully considered in every aspect of:

- Planning
- Programming
- Environmental Analysis
- Project Design
- Construction
- Maintenance
- Operations
Balancing safety with many other factors is critical to good design decision-making in the planning and preliminary design phases...and it is a Requirement

Role of Road Design in Crash Prevention

- Design can reduce:
  - Incidence of human error
  - Chance of human error resulting in crash
  - Severity of the consequences of crashes

- How a particular segment of highway or an intersection is built (Engineering) and how it is operated impacts both the number and severity of crashes
Introduction and Background

Outcomes:

- Described the Safety Performance of Multilane Highways and Streets
- Defined Substantive Safety beyond Nominal Safety

Questions and Discussion:
Predicting Highway Safety for Rural Multilane Highway Segments

Outcomes:

- Describe the Highway Safety Model base equation for prediction of Crash Performance for Rural Multilane Highways
- Describe AMFs and demonstrate their Quantitative safety effects on Rural Multilane Highways
Defining Rural Multilane Highways

- Methodology applies to **four-lane undivided and divided rural highways**.
- **“Rural”:**
  - Places outside the boundaries of urban places where the population is less than 5,000 inhabitants.
- Any highway located outside the city limits of an urban agglomeration above 5,000 inhabitants is considered rural.
- The boundary delimitating rural and urban areas can at times be difficult to determine, especially since most multilane rural highways are located on the outskirts of urban agglomerations.

Defining Multilane Highways

- **Multilane Facilities:**
  - Have four through lanes.
  - May be divided with a rigid or flexible barrier, paved or landscaped median
  - Should **not** have access and egress limited by grade-separated interchanges (i.e., not freeways).
  - May have occasional grade-separated interchanges, but these should not be the primary form of access and egress
Limitations of Methodology

- Methodology incorporates the effects on safety of many *but not all* geometric and traffic control features.

- Only includes geometric design elements:
  - whose relationship to safety are well understood
  - Associated data is available for

- The Statistical Model:
  - treats the effects of individual geometric design element and traffic control features as independent of each other
  - Ignores any potential interactions between them.
Baseline Models

- Baseline models are used for predicting the total accident frequency of each roadway segment or intersection on a four-lane divided or undivided highway.

- Baseline models predict annual crash frequencies for roadway segments or intersections as a function of traffic volumes for a specified set of nominal baseline conditions.

- Nominal baseline conditions include geometric design and traffic control elements, such as roads with 12-ft lane widths and 8-ft shoulder widths.

- Baseline estimates are adjusted by AMFs, which represent the safety effects of individual geometric design and traffic control elements that differ from the baseline conditions.

Rural Multilane Highway Safety Prediction Methodology

1. Select a roadway segment or intersection
2. Apply Baseline Model
3. Apply calibration factors
4. Apply AMFs for specific baseline conditions or average conditions, as appropriate
5. Determine predicted crash frequency, crash severity distribution, and crash type distribution
6. Calculate variance and confidence intervals, if information is available
7. Present final predicted values (with associated uncertainty, if available) to user

Note: Optional
Accident Modification Factors (AMFs)

- AMFs are multiplicative factors used to adjust the baseline accident frequency to account for the effect of differences in individual geometric design characteristics and traffic control features that depart from the baseline conditions (assumed and specified in the baseline model).

- AMF for the nominal or baseline value of each geometric design traffic control feature in the baseline model has a value of 1.0.

Accident Modification Factors (AMFs)

- Account for difference between base and actual geometry
- Estimate effects of individual geometry elements on safety
- Can be greater or less than 1:
  - < 1.0 -- lower crash frequency
  - > 1.0 -- increased crash frequency
- 1.0 – AMF = CRF or Crash Reduction Factor

For an AMF of 0.88, the CRF would be 12%
Accident Modification Factors (AMFs)

- For those elements for which the baseline condition is assumed as the average value of the variable, the AMF, where available, needs to be related to the average value of the variable, rather than to a specified baseline value.

- For example, if the average shoulder width is 4 ft. and accident prediction is being made for a segment with a 6 ft shoulder width, the applicable AMF is one for an increase in shoulder width from 4 to 6 ft.

Definition of Segments and Intersections

- **Segments:**
  - Portions of the facility delimited by:
    - major intersections or
    - significant changes in the roadway cross-section or
    - geometric characteristics of the facility or
    - surrounding land uses.
  - Roadway segments can be either undivided or divided.

- **Major intersections:**
  - Where the segment being analyzed intersects with:
    - major and minor arterials
    - major collectors
  - And where traffic volumes (ADT) are available on all approaches.
    - application of the intersection procedures requires ADT on all intersection approaches.

- **Minor Intersections:**
  - Intersections between the facility being analyzed and minor collectors, local roads, access driveways
  - or any intersection for which traffic volumes (ADT) are not available on approaches intersecting the facility being analyzed (it is assumed that ADT is available for the facility being analyzed).
Definition of Segments and Intersections

Crashes are assigned to either a major or minor intersection or a segment.

Crashes occurring within or near the intersection are assigned to the intersection, and all other crashes are assigned to the respective segment.

Use the following two criteria to define intersection and intersection-related crashes:

1. Crashes that have already been defined as intersection or intersection-related in the accident report and that occurred within 250 ft (76 m) of the intersection center are assigned to the intersection.
2. For cases where no such definitions are available, all crashes occurring within 250 ft from the middle of the intersection are assigned to that intersection.
Subdividing Roadway Segments

- Before applying the safety prediction methodology to an existing or proposed rural segment facility, the roadway must be divided into analysis units consisting of individual homogeneous roadway segments and intersections.
- A new analysis section begins at each location where the value of one of the following variables changes (alternatively a section is defined as homogenous if none of these variables changes within the section):
  - Average daily traffic (ADT) volume (veh/day)
  - Lane width (ft)
  - Shoulder width (ft)
  - Presence of a median
  - Major intersections

SAFETY EFFECTS of Cross-Section Design on Rural Multilane Highways

- Fatality rates on rural Federal-aid primary highways are significantly higher than urban and rural Interstate freeways
- More than 65,357 miles of arterial highways in the US are multilane rural highways

Source: HWA HSIS Study 97-207 (Jun Wang, Warren Hughes and Richard Stewart)
Cross Sectional Elements

Lane Width

Roadside Hazard

Side Slope

Shoulder Width

What should you expect would be the safety and operational influence of cross sectional elements?

<table>
<thead>
<tr>
<th></th>
<th>Crashes</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Width</td>
<td>Head-on</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td>Wider is “better”</td>
<td>Wider means “faster”</td>
</tr>
<tr>
<td>Shoulder Width</td>
<td>Run-off-Road</td>
<td>Capacity</td>
</tr>
<tr>
<td></td>
<td>Wider is “better”</td>
<td>Functionality (peds, bikes, emergency stops, capacity, maintenance)</td>
</tr>
<tr>
<td>Sideslope</td>
<td>Run-off-road (severity)</td>
<td>Maintenance</td>
</tr>
<tr>
<td></td>
<td>Flatter is better</td>
<td>Flatter is better</td>
</tr>
<tr>
<td>Clear Zone</td>
<td>Run-off-road (frequency and severity)</td>
<td>Horizontal sight distance</td>
</tr>
</tbody>
</table>
Functions of shoulders in a rural environment

- Clear zone (recovery)
- Protection for turns off the roadway
- Highway Capacity
- Provide pavement support
- Clear zone (horizontal sight distance)
- Store snow
- Store vehicles in emergency
- Provide space for maintenance activities
- Pedestrians, bicyclists
- Enforcement activities

Predicting Safety Performance
- Analysis Sections

Separate Prediction Models for:

- Homogeneous highway segments
  (including effect of Grade)

- Curves
  Weighted Average of AMF by Length of Curves

- Intersections
  Sum of Individual Intersection Calculations
Safety Predictions for an Entire Rural Multilane Segment

\[ N_t = \text{Sum } N_{rs} + \text{Sum } N_{int} \]

Three-step process:
1) Predict number of total roadway segment crashes per year \( (N_{rs}) \)
2) Predict number of total intersection-related crashes per year \( (N_{int}) \)
3) Combine predicted roadway segment and intersection related crashes to obtain the total \( (N_t) \)
Base Models for Rural Multilane Roadway Segments

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

1) Undivided Multilane Roads
2) Divided Multilane Roads

- Base models are the same for divided and undivided highways
- Regression Coefficients differ

Predicting Safety Performance for Rural Multilane Roadway Segments

Procedure for safety prediction for a divided or undivided roadway segment: Apply Base Models, AMFs, and calibration factor

\[ N_{rs} = N_{brbase} \times (AMF_{1r} \times AMF_{2r} \times \ldots \times AMF_{ir})C_r \]

\[ N_{brbase} = e^{(a + b(\ln(ADT)) + \ln (L))} \]
Highway Segment Model

\[ N_{rs} = N_{brbase} \times (AMF_1 \times \ldots \times AMF_n) \times C_r \]

Where:
- **N_{rs}** = expected number of total crashes per year on a segment
- **N_{brbase}** = expected number of total crashes per year for base conditions
- **AMF_1 ... AMF_n** for individual geometry elements
- **C_r** = calibration factor

Predicting Safety Performance of Multilane Rural Highways

Baseline model for Rural Segments:

\[ N_{brbase} = e^{(a + b \ln ADT + \ln L)} \]

Where:
- **N_{brbase}** = Baseline Total Crashes per year for segment
- **L** = Length of roadway segment (miles)
- **ADT** = Average Daily Traffic (vehicles/day)
- **a & b** = regression coefficients
Rural Multilane Undivided Roadway Segments

Predicting Safety Performance for Rural Multilane Undivided Roadway Segments

Procedure for safety prediction for an undivided roadway segment: Apply Base Models, AMFs, and calibration factor

- \( N_{rs} = N_{br base} (AMF_{1ru} \times AMF_{2ru} \times \ldots \times AMF_{nr u})C_r \)
- \( N_{br base} = e^{(a + b(\ln(ADT)) + \ln(L))} \)
Predicting Safety Performance of Multilane Rural Undivided Highways

Baseline model: \( N_{rbase} = e^{(a + b \ln ADT + \ln L)} \)

Exhibit 11-4: Base Models for Total and KAB Injury Accidents on Undivided Roadway Segments (Based on Equations 11-4 and 11-5)

<table>
<thead>
<tr>
<th>Segment</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>Base conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four-lane Total</td>
<td>-11.6546</td>
<td>1.3124</td>
<td>2.0634</td>
<td>11-12 ft lanes; 7-8 ft shoulders; no horizontal curves; 1:7 side slope</td>
</tr>
<tr>
<td>Four-lane Injury</td>
<td>-10.3052</td>
<td>1.0545</td>
<td>12.2379*</td>
<td></td>
</tr>
</tbody>
</table>

*This value implies that the regression model tends toward a Poisson model.

Base Conditions for Multilane Rural Undivided Highway Segments

Baseline Geometric Conditions:

- 12-foot lanes
- 6-foot shoulders
- No Horizontal Curves
- 1:7 Side Slopes
Predicting Total Crashes for Multilane Rural Undivided Highways – Example Calculation

Where:

- $ADT = 16,000$
- $Length = 8.0$ miles
- $Lane width = 11.0$ feet
- $Outside Shoulder Width = 4$ feet aggregate
- $Side Slope = 1:6$

$$N_{brbase} = e^{(a + b \ln ADT + \ln L)}$$

$$= e^{(-11.6546 + 1.3124 \times \ln 16,000 + \ln 8.0)}$$

$$= e^{3.1293}$$

$$= 22.86$$ crashes per year
Predicting Total Crashes for Multilane Rural Undivided Highways – Exercise Calculation

Where:

- ADT = 18,000
- Length = 8.0 miles
- Lane width = 11.0 ft
- Outside Shoulder Width = 8 ft paved
- Side Slope = 1:6

\[ N_{\text{brbase}} = e^{(a + b \ln \text{ADT} + \ln L)} \]
\[ = e^{(-11.6546 + 1.3124 \times \ln 18,000 + \ln 8.0)} \]
\[ = e^{(3.284)} \]
\[ = ? \]
Crash Modification Factors

\[ N_{rs} = N_{brbase} \times (AMF_1 \times AMF_2 \times \ldots \times AMF_n) \]

- \( N_{rs} = \) predicted number of crashes after treatment/improvement
- \( N_{brbase} = \) base or existing number of crashes before treatment/improvement
- \( AMF = \) accident (crash) modification factor

Undivided Segments: AMFs for Lane Width ADT \( \geq 2,000 \text{ vpd} \)

\[ AMF_{1ru} \]

Exhibit 11-7: AMF for Lane Width on Undivided Segments with Traffic Volumes Equal to or Greater than 2,000 Vehicles per Day and the Percentage of Related Crashes Equal to 35%

<table>
<thead>
<tr>
<th>Lane Width (ft)</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.13</td>
<td>1.08</td>
<td>1.02</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Base condition is 12’ wide lane
Undivided Segments: AMF for Paved Shoulder Width AADT $\geq$ 2,000 vpd

\[ \text{AMF}_{\text{wra}} \]

<table>
<thead>
<tr>
<th>Shoulder Width (ft)</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.18</td>
<td>1.11</td>
<td>1.05</td>
<td>1.00</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Base condition is 6’ wide paved shoulder

AMFs for Shoulder Width AADT $<$ 2,000 vpd or Shoulder is not paved or related crashes are not 35%

\[ \text{AMF}_{2ru} = (\text{AMF}_{WRA} \cdot \text{AMF}_{TRA} - 1.0) \cdot \text{P}_{RA} + 1.0 \]

Where:

- \( \text{AMF}_{2ru} \) = AMF for total crashes related to shoulder width
- \( \text{AMF}_{WRA} \) = AMF for related crashes base on shoulder width from Exhibit 11-10
- \( \text{AMF}_{TRA} \) = AMF for related crashes based on shoulder type from Exhibit 11-11
- \( \text{P}_{RA} \) = proportion of total crashes constituted by related crashes (default value is 0.35)
**Undivided Segments: AMF for Shoulder Width AADT < 2,000 vpd or Shoulder is not Paved**

<table>
<thead>
<tr>
<th>Shoulder Width (ft)</th>
<th>Average Daily Traffic (ADT)</th>
<th>0 &lt; 400</th>
<th>400 to 2000</th>
<th>&gt; 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.10</td>
<td>1.10</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1.07</td>
<td>1.07</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.02</td>
<td>1.02</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.98</td>
<td>0.98</td>
<td>0.87</td>
<td></td>
</tr>
</tbody>
</table>

**Example Calculation**

\[
AMF_{2ru} = (AMF_{WRA} AMF_{TRA} - 1.0) 0.35 + 1.0
\]

Four-lane undivided rural highway, 4-ft aggregate shoulder, 18,000 ADT:

1. From Exhibit 11-10: \(AMF_{WRA} = 1.15\)
2. From Exhibit 11-11: \(AMF_{TRA} = 1.01\)

\[
AMF_{2ru} = ((1.15)(1.01) - 1.0) 0.35 + 1.0
\]

\[
= (0.1615)(0.35) + 1.0
\]

\[
= 1.057
\]
Undivided Segments: AMFs for Shoulder Width and Type, AADT < 2,000 vpd and Shoulder is not paved—Example Calculation:

\[ AMF_{2ru} = (AMF_{WRA} AMF_{TRA} - 1.0) 0.35 + 1.0 \]

Four-lane undivided rural highway, 4-ft aggregate shoulder, 350 ADT:

- From Exhibit 11-10: \( AMF_{WRA} = 1.02 \)
- From Exhibit 11-11: \( AMF_{TRA} = 1.01 \)

\[
AMF_{2ru} = ((1.02)(1.01) - 1.0) 0.35 + 1.0
\]
\[
= (0.030)(0.35) + 1.0
\]
\[
= 1.011
\]

Undivided Segments: AMF for Side Slope

<table>
<thead>
<tr>
<th>Exhibit 11-12: AMF for Side Slope on Undivided Roadway Segments (AMF_{3ru})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:2 or Steeper</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>1.18</td>
</tr>
</tbody>
</table>

Base condition is 1:7 or Flatter
### Undivided Segments: AMF for number of Horizontal Curves

**Exhibit 11-13:** AMF for the Number of Horizontal Curves per Mile on an Undivided Roadway Segment ($AMF_{ru}$)

<table>
<thead>
<tr>
<th>Number of Horizontal Curves per Mile</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undivided</td>
<td>1.00</td>
<td>1.07</td>
<td>1.14</td>
<td>1.22</td>
<td>1.31</td>
<td>1.40</td>
</tr>
</tbody>
</table>

Base condition is no horizontal curves present on the segment.

### Undivided Segments: AMF for Lighting

**AMF_{ru} = 1 - [(1 - 0.36P_{ftr} - 0.72P_{inr} - 0.83P_{pnr})P_{nr}]**

**Exhibit 11-14:** Nighttime Accident Proportions for Unlighted Roadway Segments

<table>
<thead>
<tr>
<th>Roadway Type</th>
<th>Proportion of total nighttime accidents by severity level</th>
<th>Proportion of accidents that occur at night</th>
</tr>
</thead>
<tbody>
<tr>
<td>2U</td>
<td>Fatal $p_{ftr}$</td>
<td>Injury $p_{inr}$</td>
</tr>
</tbody>
</table>

**PLACEHOLDER: VALUES ARE FORTHCOMING**

Base condition is no lighting present on the segment.
### AMF for Lane Width + Shoulder Width – Example:

For Undivided highway, 16,000 ADT, Length = 8.0 miles, 11 foot lanes, 4 ft gravel shoulders with 1:6 side slope, 2 curves/mi:

\[
N = N_{brbase} \times AMF_{1ru} \times AMF_{2ru} \times AMF_{3ru} \times AMF_{4ru}
\]

ADT is not less than 2,000, so AMF\(_{1ru}\) is directly from Exhibit 11-7, AMF\(_{ra}\) = 1.02

But shoulder is gravel so AMF\(_{2ru}\) is from Exhibit 11-10, AMF\(_{wra}\) = 1.15 and from Exhibit 11-11, AMF\(_{tra}\) = 1.01

\[
AMF_{2ru} = (AMF_{WRA} \times AMF_{TRA} - 1.0) \times 0.35 + 1.0
\]

\[
= (1.15 \times 1.01 - 1.0) \times 0.35 + 1.0 = 1.057
\]

---

### AMF for Lane Width + Shoulder Width – Example:

For Undivided highway, 16,000 ADT, 11 foot lanes and 4 ft aggregate shoulders with 1:6 side slope, 2 curves/mi:

\[
N = N_{brbase} \times AMF_{1ru} \times AMF_{2ru} \times AMF_{3ru} \times AMF_{4ru}
\]

AMF\(_{3ru}\) from Exhibit 11-12

\[
= 1.06
\]

AMF\(_{4ru}\) from Exhibit 11-13,

\[
= 1.14
\]
AMF for Lane Width + Shoulder Width – Example:

For Undivided highway, 16,000 ADT, 11 foot lanes and 4 ft aggregate shoulders with 1:6 side slope, 2 curves/mi:

\[
\begin{align*}
\text{AMF}_{1ru} &= 1.013 \\
\text{AMF}_{3ru} &= 1.06 \\
\text{AMF}_{2ru} &= 1.057 \\
\text{AMF}_{4ru} &= 1.14
\end{align*}
\]

\[
N = N_{\text{brbase}} \times \text{AMF}_{1ru} \times \text{AMF}_{2ru} \times \text{AMF}_{3ru} \times \text{AMF}_{4ru}
\]

\[
= 22.86 \times 1.013 \times 1.057 \times 1.06 \times 1.14
\]

\[
= 29.57 \text{ crashes per year}
\]

Predicting Safety Performance for Rural Undivided Highways – Exercise:

4-lane UnDivided Rural Highway:
- ADT = 18,000
- Length = 8.0 miles with 1 Curve/mi
- Lane width = 11.0 feet
- Side slope = 1:6
- Outside shoulder width = 8 feet gravel

\[
N_{\text{brbase}} = 26.68
\]

\[
\begin{align*}
\text{AMF}_{\text{ra}} &= ? \\
\text{AMF}_{\text{wra}} &= ? \\
\text{AMF}_{\text{tra}} &= ? \\
\text{AMF}_{3ru} &= ? \\
\text{AMF}_{4ru} &= ?
\end{align*}
\]

\[
N_{rs} = N_{\text{brbase}} \times \text{AMF}_{1ru} \times \text{AMF}_{2ru} \times \text{AMF}_{3ru} \times \text{AMF}_{4ru}
\]

\[
= \text{?} \text{ crashes per year}
\]
AMF for Lane Width + Shoulder Width – Exercise:

For Undivided highway, 18,000 ADT, Length = 8.0 miles, 11 foot lanes, 8 ft gravel shoulders with 1:6 side slope, 1 curves/mi:

\[ N = N_{brbase} \times AMF_{1ru} \times AMF_{2ru} \times AMF_{3ru} \times AMF_{4ru} \]

AMF\(_{1ru}\) directly from Exhibit 11-7 as ADT not less than 2,000, AMF\(_{ra}\) = AMF\(_{1ru}\) = 1.02

AMF\(_{2ru}\) from Exhibit 11-10 and 11-11,
AMF\(_{wra}\) = 0.87 and AMF\(_{tra}\) = 1.01,
AMF\(_{2ru}\) = (AMF\(_{wra}\) x AMF\(_{tra}\) – 1.0) 0.35 + 1.0
= 0.02 x 0.35 + 1 = 0.958

AMF\(_{3ru}\) from Exhibit 11-12
= 1.06

AMF\(_{4ru}\) from Exhibit 11-13,
= 1.07
Predicting Safety Performance for Rural Undivided Highways – Exercise:

4-lane UnDivided Rural Highway:
- ADT = 18,000
- Length = 8.0 miles with 1 Curve/mi
- Lane width = 11.0 feet
- Side slope = 1:6
- Outside shoulder width = 8 feet gravel

\[ N_{br\text{base}} = 26.68 \]

\[ \text{AMF}_{1ru} = ? \quad \text{AMF}_{2ru} = ? \quad \text{AMF}_{ss} = ? \quad \text{AMF}_{4ru} = ? \]

\[ N_{rs} = 26.68 \times ? \times ? \times ? \times ? \]

= ____?____ crashes per year

Undivided Segments: AMFs for Lane Width AADT < 2,000 vpd and related crashes are not 35%

\[ \text{AMF}_{1ru} = f \left( \text{AMF}_{RA} - 1.0 \right) \text{P}_{RA} + 1.0 \]

Where:
- \( \text{AMF}_{1ru} = \text{AMF} \) for total crashes related to lane width
- \( f = \text{factor for roadway type (0.75 for undivided rural multilane)} \)
- \( \text{AMF}_{RA} = \text{AMF} \) for related crashes (run-off road, head-on, and sideswipe) from Exhibit 11-8
- \( \text{P}_{RA} = \text{proportion of total crashes constituted by related crashes (default value is 0.35)} \)
### Crash Modification Factors - Lane Width Adjustment for Related Crashes

- Adjustment from crashes related to lane width (Run off Road + Head-on + Sideswipes) to total crashes

\[
AMF_{1ru} = f (AMF_{RA} - 1.0) P_{RA} + 1.0
\]

- \( p_{ra} = 0.35 \)

#### Undivided Segments: AMFs for Lane Width AADT < 2,000 vpd and related crashes is not 35%

\[
AMF_{1ru} = 0.75 (AMF_{RA} - 1.0) P_{ra} + 1.0
\]

#### Exhibit 11-8: AMF<sub>RA</sub>

<table>
<thead>
<tr>
<th>Lane Width</th>
<th>Average Daily Traffic (ADT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 400</td>
</tr>
<tr>
<td>9 ft</td>
<td>1.05</td>
</tr>
<tr>
<td>10 ft</td>
<td>1.02</td>
</tr>
<tr>
<td>11 ft</td>
<td>1.01</td>
</tr>
<tr>
<td>12 ft</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Undivided Segments: AMFs for Lane Width
AADT < 2,000 vpd – Example Calculation:

\[
AMF_{1ru} = 0.75 \times (AMF_{RA} - 1.0)^{0.35} + 1.0
\]

Four-lane undivided rural highway, 10-ft lanes, 350 ADT:

- From Exhibit 11-8: \(AMF_{RA} = 1.02\)

\[
AMF_{1ru} = 0.75 \times (1.02 - 1.0) \times 0.35 + 1.0
\]

\[
= (0.75)(0.02)(0.35) + 1.0
\]

\[
= 0.00525 + 1.0
\]

\[
= 1.005
\]

Predicting Safety Performance for Rural Undivided Segments

Additional AMF’s on Safety Effects:
- Lane Width Conversion (e.g., 12 ft to 11 ft)
- Shoulder Width Conversion (e.g., 6 ft to 8 ft)
- Providing a Median
- Changing to a Less Rigid Roadside Barrier
- Use of Crash Cushions at Fixed Objects
- Use of Horizontal Alignment + Advisory Speed Signs
- Installing Edgeline and Centerline Markings
### Safety Effect of Lane Width Conversion for Undivided Rural Multilane Highways

**Exhibit 13-5: Safety Effects of Lane Width for Undivided Segments**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 to 11 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Equal to or Greater than 2,000 Vehicles per day and the Percentage of Related Crashes Equal to 35%</td>
<td>All types</td>
<td>1.02</td>
<td>N/A</td>
</tr>
<tr>
<td>12 to 10 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Equal to or Greater than 2,000 Vehicles per day and the Percentage of Related Crashes Equal to 35%</td>
<td>All types</td>
<td>1.08</td>
<td>N/A</td>
</tr>
<tr>
<td>12 to 9 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Equal to or Greater than 2,000 Vehicles per day and the Percentage of Related Crashes Equal to 35%</td>
<td>All types</td>
<td>1.13</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Base Condition: 12 foot lanes

### Safety Effect of Shoulder Width Conversion for Undivided Rural Multilane Highways

**Exhibit 13-10: Safety Effects of Paved Shoulder Width on Undivided Segments**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 to 8 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>0.95</td>
<td>N/A</td>
</tr>
<tr>
<td>6 to 4 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>1.05</td>
<td>N/A</td>
</tr>
<tr>
<td>6 to 2 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>1.11</td>
<td>N/A</td>
</tr>
<tr>
<td>6 to 0 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>1.18</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Base Condition: 6 foot shoulder width.
### Safety Effect of Providing a Median on Rural Multilane Highways

**Exhibit 13-14: Safety Effects of Providing a Median on Multi-Lane Roads**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a median</td>
<td>Urban Arterial Multi-lane&lt;sup&gt;(a)&lt;/sup&gt;</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td>0.78&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Rural Multi-lane&lt;sup&gt;(a)&lt;/sup&gt;</td>
<td></td>
<td>All types Non-injury</td>
<td>1.09&lt;sup&gt;+&lt;/sup&gt;</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Injury</td>
<td>0.88</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-injury</td>
<td>0.82</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Base Condition: Absence of raised median.

### Safety Effect of Changing Roadside Barrier to Less Rigid Type

**Exhibit 13-22: Safety Effects of Changing Roadside Barrier to Less Rigid Type**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change barrier along embankment to less rigid type</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>Run-off-road Injury</td>
<td>0.68</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Run-off-road Fatal</td>
<td>0.59</td>
<td>0.2&lt;sup&gt;+&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Base Condition: Rigid barrier.

AMF is applicable to injury and fatal crashes only.
### Safety Effect of Crash Cushions at Fixed Roadside Features on Multilane Highways

**Exhibit 13-24: Safety Effects of Installing Crash Cushions at Fixed Roadside Features**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install crash cushions at fixed roadside features</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>Fixed object Fatal</td>
<td>0.31</td>
<td>0.3&lt;sup&gt;#&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed object Injury</td>
<td>0.31</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed object Non-Injury</td>
<td>0.54</td>
<td>0.3&lt;sup&gt;#&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Base Condition: Absence of crash cushions.

### Safety Effect of Installing Horizontal Alignment/Advisory Speed Signs

**Exhibit 13-41: Safety Effects of Installing Combination Horizontal Alignment/Advisory Speed Signs (W1-1a, W1-2a)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install combination horizontal alignment/ advisory speed signs</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td>0.87</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-Injury</td>
<td>0.71</td>
<td>0.2&lt;sup&gt;#&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Base Condition: Absence of any signage.

Notes: Based on US studies; McCannent 1959; Hammer 1969 and international study; Rutley 1972
# Observed variability suggests less confidence than AMF values in bold. See Part D Introduction and Applications Guide.
Safety Effect of Placing Edgeline and Centerline Markings on Undivided Multilane Highways

Exhibit 13-50: Safety Effects of Placing Edgeline and Centerline Markings

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMI</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place edgeline and centerline markings</td>
<td>Rural Two Lane/</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td>0.76</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Multilane undivided</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Absence of markings.

Rural Multilane Divided Roadway Segments
Predicting Safety Performance for Rural Multilane Divided Roadway Segments

Procedure for safety prediction for a divided roadway segment: Apply Base Models, AMFs, and calibration factor

- $N_{rs} = N_{brbase} (AMF_{1ru} \times AMF_{2ru} \times \ldots \times AMF_{nru}) C_r$
- $N_{brbase} = e^{(a + b(\ln(ADT)) + \ln(L))}$

Predicting Safety Performance of Multilane Rural Divided Highways

Baseline model for Divided Rural Segments:

$N_{brbase} = e^{(a + (b \ln ADT) + \ln L)}$

Where:
- $N_{br base} = \text{Baseline Total Crashes per year for segment}$
- $L = \text{Length of roadway segment (miles)}$
- $ADT = \text{Average Daily Traffic (vehicles/day)}$
- $a & b = \text{regression coefficients}$
Predicting Safety Performance of Multilane Rural Divided Highways

Baseline model: \[ N_{\text{brbase}} = e^{(a + b \ln \text{ADT} + \ln L)} \]

Exhibit 11-15: Base Models for Total and KAB Injury Accidents on Divided Roadway Segments (Based on Equations 11-9 and 11-10)

<table>
<thead>
<tr>
<th>Roadway Segment</th>
<th>A</th>
<th>b</th>
<th>c</th>
<th>Base conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-lane Total</td>
<td>-9.266</td>
<td>1.0492</td>
<td>1.5493</td>
<td>median width = 30 ft;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>average right shoulder width = 8 ft;</td>
</tr>
<tr>
<td>4-lane Injury</td>
<td>-8.746</td>
<td>0.8736</td>
<td>1.7297</td>
<td>12-ft lanes</td>
</tr>
</tbody>
</table>

Base Conditions for Multilane Rural Divided Highway Segments

Baseline Geometric Conditions:

- **12 ft Lanes**
- **8 ft Right Shoulder**
- **30 ft Median Width**
Predicting Safety Performance for Rural Divided Highways – Example:

4-lane Divided Rural Highway:
- ADT = 16,000  
- Length = 8.0 miles  
- Lane width = 11.0 feet  
- Side Slope = 1:6  
- Outside shoulder width = 8 feet aggregate  
- Inside shoulder width = 4 feet paved  
- Median width = 24 feet – no barrier  

\[ N_{brbase} = e^{(a + (b \ln ADT) + \ln L)} \]
\[ = e^{-9.266 + (1.0492 \ln 16,000) + \ln 8.0} \]
\[ = e^{2.970} \]
\[ = 19.49 \text{ crashes per year} \]

Predicting Safety Performance for Rural Divided Highways – Exercise:

4-lane Divided Rural Highway:
- ADT = 18,000  
- Side Slope=1:6  
- Length = 8.0 miles  
- Lane width = 11.0 feet  
- Outside shoulder width = 8 feet aggregate  
- Inside shoulder width = 4 feet paved  
- Median width = 24 feet – no barrier  

\[ N_{brbase} = e^{(a + (b \ln ADT) + \ln L)} \]
\[ = e^{-9.266 + (1.0492 \ln 18,000) + \ln 8.0} \]
\[ = e^{3.094} \]
\[ = ? \]
Crash Modification Factors

\[
N_{rs} = N_{brbase} \times (AMF_1 \times AMF_2 \times \ldots AMF_n)
\]

- \(N_{rs}\) = predicted number of crashes after treatment/improvement
- \(N_{brbase}\) = base or existing number of crashes before treatment/improvement
- \(AMF\) = accident (crash) modification factor

Rural Divided Multilane Segments: AMFs for Lane Width AADT \(\geq 2,000\) vpd

\(AMF_{1ru}\)

<table>
<thead>
<tr>
<th>Lane Width (ft)</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.09</td>
<td>1.05</td>
<td>1.01</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Base condition is 12’ wide lane
AMF for Shoulder Width - Rural Divided Multilane Highways

**AMF**

**Exhibit 11-19: AMF for Paved Right Shoulder Width on Divided Roadway Segments**

<table>
<thead>
<tr>
<th>Average Shoulder Width (ft)</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.18</td>
<td>1.13</td>
<td>1.09</td>
<td>1.04</td>
<td>1.00</td>
<td></td>
</tr>
</tbody>
</table>

Base condition is 8’ wide shoulder

---

AMF for Shoulder Type – Multiple Lane Highways

**Exhibit 11-11: AMF_{\text{typ}}**

<table>
<thead>
<tr>
<th>Shoulder Type</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paved</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Gravel</td>
<td>1.00</td>
<td>1.00</td>
<td>1.01</td>
<td>1.01</td>
<td>1.01</td>
<td>1.02</td>
<td>1.02</td>
<td>1.03</td>
</tr>
<tr>
<td>Composite</td>
<td>1.00</td>
<td>1.01</td>
<td>1.02</td>
<td>1.02</td>
<td>1.03</td>
<td>1.04</td>
<td>1.05</td>
<td>1.07</td>
</tr>
<tr>
<td>Turf</td>
<td>1.00</td>
<td>1.01</td>
<td>1.03</td>
<td>1.04</td>
<td>1.05</td>
<td>1.08</td>
<td>1.11</td>
<td>1.14</td>
</tr>
</tbody>
</table>

• **HSM-2nd Draft** does not provide AMF’s for Shoulder type – will be added in final HSM
• use AMF’s from undivided rural multilane for time being
### AMF for Median Width for Medians without Barrier

<table>
<thead>
<tr>
<th>Median width (ft)</th>
<th>AMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.010</td>
</tr>
<tr>
<td>20</td>
<td>1.006</td>
</tr>
<tr>
<td>25</td>
<td>1.003</td>
</tr>
<tr>
<td>30</td>
<td>1.000</td>
</tr>
<tr>
<td>35</td>
<td>0.997</td>
</tr>
<tr>
<td>40</td>
<td>0.994</td>
</tr>
<tr>
<td>45</td>
<td>0.991</td>
</tr>
<tr>
<td>50</td>
<td>0.988</td>
</tr>
<tr>
<td>55</td>
<td>0.985</td>
</tr>
<tr>
<td>60</td>
<td>0.983</td>
</tr>
<tr>
<td>65</td>
<td>0.980</td>
</tr>
<tr>
<td>70</td>
<td>0.978</td>
</tr>
<tr>
<td>75</td>
<td>0.975</td>
</tr>
<tr>
<td>80</td>
<td>0.973</td>
</tr>
<tr>
<td>85</td>
<td>0.970</td>
</tr>
<tr>
<td>90</td>
<td>0.968</td>
</tr>
<tr>
<td>95</td>
<td>0.966</td>
</tr>
<tr>
<td>100</td>
<td>0.963</td>
</tr>
</tbody>
</table>

- Baseline: 30 ft median width
- Accounts for total crashes on segment
- Median width mainly affects median related crashes (20% of all crashes and cross-median crashes = 2% of all crashes)

### AMF for Median Width for Medians with Barrier

<table>
<thead>
<tr>
<th>Median width (ft)</th>
<th>AMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.019</td>
</tr>
<tr>
<td>20</td>
<td>1.012</td>
</tr>
<tr>
<td>25</td>
<td>1.006</td>
</tr>
<tr>
<td>30</td>
<td>1.000</td>
</tr>
<tr>
<td>35</td>
<td>0.994</td>
</tr>
<tr>
<td>40</td>
<td>0.988</td>
</tr>
<tr>
<td>45</td>
<td>0.983</td>
</tr>
<tr>
<td>50</td>
<td>0.977</td>
</tr>
<tr>
<td>55</td>
<td>0.972</td>
</tr>
<tr>
<td>60</td>
<td>0.967</td>
</tr>
<tr>
<td>65</td>
<td>0.962</td>
</tr>
<tr>
<td>70</td>
<td>0.953</td>
</tr>
<tr>
<td>75</td>
<td>0.948</td>
</tr>
<tr>
<td>80</td>
<td>0.944</td>
</tr>
<tr>
<td>85</td>
<td>0.940</td>
</tr>
<tr>
<td>90</td>
<td>0.935</td>
</tr>
<tr>
<td>95</td>
<td>0.931</td>
</tr>
<tr>
<td>100</td>
<td>0.957</td>
</tr>
</tbody>
</table>
Divided Segments: AMF for Lighting

\[
AMF_{5ru} = 1 - [(1- 0.36P_{fnr} - 0.72P_{inr} - 0.83P_{pnr})P_{nr}]
\]

<table>
<thead>
<tr>
<th>Roadway Type</th>
<th>Proportion of total nighttime accidents by severity level</th>
<th>Proportion of accidents that occur at night</th>
</tr>
</thead>
<tbody>
<tr>
<td>2U</td>
<td>Fatal $p_{fnr}$</td>
<td>Injured $p_{inr}$</td>
</tr>
</tbody>
</table>

PLACEHOLDER: VALUES ARE FORTHCOMING

Base condition is no lighting present on the segment

Predicting Safety Performance for Rural Divided Highways – Example:

4-lane Divided Rural Highway:

- ADT = 16,000
- Length = 8.0 miles
- Lane width = 11.0 feet
- Side Slope = 1:6
- Outside shoulder width = 8 aggregate
- Inside shoulder width = 4 feet paved
- Median width = 25 feet – no barrier

\[
AMF_{ra} = ? \quad AMF_{wra} = ? \quad AMF_{tra} = ? \quad AMF_{5rd} = ?
\]

ADT is not less than 2,000, but shoulder is gravel

\[
N_{rs} = N_{brbase} \times AMF_{1ru} \times AMF_{2ru} \times AMF_{3rd} \times AMF_{5rd}
\]

\[
= 19.49 \times ? \times ( ? ) \times ? \times ? \times ?
\]

\[
= ? \text{ crashes per year}
\]
Divided Segments: AMFs for Lane Width AADT < 2,000 vpd

\[ \text{AMF}_{1\text{rd}} = f \left( \text{AMF}_{RA} - 1.0 \right) P_{RA} + 1.0 \]

Where:
- \( \text{AMF}_{1\text{rd}} \) = AMF for total crashes related to lane width
- \( f \) = factor for roadway type (0.50 for divided rural multilane)
- \( \text{AMF}_{RA} \) = AMF for related crashes (run-off road, head-on, and sideswipe) from Exhibit 11-18
- \( P_{RA} \) = proportion of total crashes constituted by related crashes (default value is 0.35)
Divided Segments: AMFs for Lane Width
AADT < 2,000 vpd – Example Calculation:

\[
\text{AMF}_{1\text{rd}} = 0.50 \left( \text{AMF}_{RA} - 1.0 \right)^{0.35} + 1.0
\]

Four-lane divided rural highway, 11-ft lanes, 350 ADT:

- From Exhibit 11-18: \( \text{AMF}_{RA} = 1.01 \)

\[
\text{AMF}_{1\text{ru}} = 0.50 \left( 1.01 - 1.0 \right) 0.35 + 1.0
\]

\[
= (0.50)(0.01)(0.35) + 1.0
\]

\[
= 0.00175 + 1.0
\]

\[
= 1.002
\]

Predicting Safety Performance for Rural Divided Segments

Additional AMF’s on Safety Effects:
- Lane Width Conversion (e.g., 12 ft to 11 ft)
- Shoulder Width Conversion (e.g., 6 ft to 8 ft)
- Median Width Conversion w and w/o Barrier
- Providing a Median Barrier
- Changing to a Less Rigid Roadside Barrier
- Use of Crash Cushions at Fixed Objects
- Use of Horizontal Alignment + Advisory Speed Signs
- Providing Rumble Strips
- Horizontal Clearance
- Access Control
## Safety Effect of Lane Width Conversion for Divided Rural Multilane Highways

### Exhibit 13-6: Safety Effects of Lane Width for Divided Roadway Segments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 to 11 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Equal to or Greater than 2,000 Vehicles per day and the Percentage of Related Crashes Equal to 35%</td>
<td>All types</td>
<td>1.01</td>
<td>N/A</td>
</tr>
<tr>
<td>12 to 10 foot conversion</td>
<td>Rural Multilane Highways</td>
<td></td>
<td>All types</td>
<td>1.05</td>
<td>N/A</td>
</tr>
<tr>
<td>12 to 9 foot conversion</td>
<td>Rural Multilane Highways</td>
<td></td>
<td>All types</td>
<td>1.19</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Base Condition: 12 foot lanes

## Safety Effect of Shoulder Width Conversion for Divided Rural Multilane Highways

### Exhibit 13-11: Safety Effects of Paved Right Shoulder Width on Divided Segments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 to 6 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>1.04</td>
<td>N/A</td>
</tr>
<tr>
<td>8 to 4 foot conversion</td>
<td>Rural Multilane Highways</td>
<td></td>
<td>All types</td>
<td>1.09</td>
<td>N/A</td>
</tr>
<tr>
<td>8 to 2 foot conversion</td>
<td>Rural Multilane Highways</td>
<td></td>
<td>All types</td>
<td>1.13</td>
<td>N/A</td>
</tr>
<tr>
<td>8 to 0 foot conversion</td>
<td>Rural Multilane Highways</td>
<td></td>
<td>All types</td>
<td>1.18</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Base Condition: 8 foot shoulder width.
### AMFs for Median Width Conversion for Divided Rural Multilane Highways w/o Barrier

**Exhibit 13-15: Safety Effects of Median Width on Divided Segments Without a Barrier**

<table>
<thead>
<tr>
<th>Median width (ft)</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 15 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>1.010</td>
</tr>
<tr>
<td>30 to 20 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>1.006</td>
</tr>
<tr>
<td>30 to 25 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>1.003</td>
</tr>
<tr>
<td>30 to 30 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>30 to 35 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.997</td>
</tr>
<tr>
<td>30 to 40 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.994</td>
</tr>
<tr>
<td>30 to 45 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.991</td>
</tr>
<tr>
<td>30 to 50 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.988</td>
</tr>
<tr>
<td>30 to 55 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.985</td>
</tr>
<tr>
<td>30 to 60 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.983</td>
</tr>
<tr>
<td>30 to 65 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.980</td>
</tr>
<tr>
<td>30 to 70 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.978</td>
</tr>
<tr>
<td>30 to 75 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.975</td>
</tr>
<tr>
<td>30 to 80 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.973</td>
</tr>
<tr>
<td>30 to 85 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.970</td>
</tr>
<tr>
<td>30 to 90 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.968</td>
</tr>
<tr>
<td>30 to 95 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.966</td>
</tr>
<tr>
<td>30 to 100 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.963</td>
</tr>
</tbody>
</table>

Base Condition: 30 foot median width.

### AMFs for Median Width Conversion for Divided Rural Multilane Highways with Barrier

**Exhibit 13-16: Safety Effects of Median Width on Divided Segments With a Barrier**

<table>
<thead>
<tr>
<th>Median width (ft)</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 15 foot conversion</td>
<td>Rural Multilane Highways</td>
<td>Unspecified</td>
<td>All types</td>
<td>1.019</td>
</tr>
<tr>
<td>30 to 20 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>1.012</td>
</tr>
<tr>
<td>30 to 25 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>1.006</td>
</tr>
<tr>
<td>30 to 30 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
<tr>
<td>30 to 35 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.994</td>
</tr>
<tr>
<td>30 to 40 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.988</td>
</tr>
<tr>
<td>30 to 45 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.983</td>
</tr>
<tr>
<td>30 to 50 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.977</td>
</tr>
<tr>
<td>30 to 55 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.972</td>
</tr>
<tr>
<td>30 to 60 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.967</td>
</tr>
<tr>
<td>30 to 65 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.962</td>
</tr>
<tr>
<td>30 to 70 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.953</td>
</tr>
<tr>
<td>30 to 75 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.948</td>
</tr>
<tr>
<td>30 to 80 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.944</td>
</tr>
<tr>
<td>30 to 85 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.940</td>
</tr>
<tr>
<td>30 to 90 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.935</td>
</tr>
<tr>
<td>30 to 95 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.931</td>
</tr>
<tr>
<td>30 to 100 foot conversion</td>
<td></td>
<td></td>
<td></td>
<td>0.957</td>
</tr>
</tbody>
</table>

Base Condition: 30 foot median width.
### Safety Effect of Installing a Median Barrier
#### Multilane Divided Highways

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road Type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install any type of median barrier</td>
<td>Unspecified Multi-lane divided highways</td>
<td>20,000 to 60,000 veh/day</td>
<td>All types Fatal</td>
<td>0.57&quot;</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Injury</td>
<td>0.70&quot;</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types All severities</td>
<td>1.24&quot;</td>
<td>0.03</td>
</tr>
<tr>
<td>Install steel median barrier</td>
<td></td>
<td></td>
<td>All types Injury</td>
<td>0.65</td>
<td>0.08</td>
</tr>
<tr>
<td>Install cable median barrier</td>
<td></td>
<td></td>
<td>All types</td>
<td>0.71</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Base Condition: Absence of a median barrier.

### Safety Effect of Changing Roadside Barrier to Less Rigid Type

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road Type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change barrier along embankment to less rigid type</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>Run-off-road Injury</td>
<td>0.68</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Run-off-road Fatal</td>
<td>0.59</td>
<td>0.2&quot;</td>
</tr>
</tbody>
</table>

Base Condition: Rigid barrier.

AMF is applicable to injury and fatal crashes only.
Safety Effect of Crash Cushions at Fixed Roadside Feature Multilane Highways

Exhibit 13-24: Safety Effects of Installing Crash Cushions at Fixed Roadside Features

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install crash cushions at fixed roadside features</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>Fixed object Fatal</td>
<td>0.31</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed object Injury</td>
<td><strong>0.31</strong></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed object Non-Injury</td>
<td>0.54</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Base Condition: Absence of crash cushions.

Safety Effect of Installing Horizontal Alignment/Advisory Speed Signs

Exhibit 13-41: Safety Effects of Installing Combination Horizontal Alignment/Advisory Speed Signs (W1-1a, W1-2a) *(a)*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install combination horizontal alignment/ advisory speed signs</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td><strong>0.87</strong></td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-Injury</td>
<td>0.71</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Base Condition: Absence of any signage.

Notes: Based on US studies: McCammon 1959; Hammer 1969 and international study; Rutley 1972
* Observed variability suggests less confidence than AMF values in bold. See Part D Introduction and Applications Guide.
Safety Effect of Installing Continuous Shoulder Rumble Strips on Multilane Highways

Exhibit 13-55: Safety Effects of Installing Continuous Shoulder Rumble Strips on Multilane Highways

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type</th>
<th>Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install continuous milled-in shoulder rumble strips</td>
<td>Rural Multi-lane divided</td>
<td>2,000 to 50,000 veh/day</td>
<td>All types</td>
<td>0.84</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td>0.83</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Injury</td>
<td>0.90*</td>
<td>0.3*</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SV ROR All severities</td>
<td>0.78</td>
<td>0.3*</td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Absence of shoulder rumble strips.

AMF for Horizontal Clearance

$AMF_{hc} = (e^b * (Whc-30) -1.0) P_s + 1.0$

Where:

$Whc =$ Horizontal Clearance (avg for segment), ft

From TTI synthesis

<table>
<thead>
<tr>
<th>Model Source</th>
<th>Roadway Type</th>
<th>Crash Severity</th>
<th>Subset of Influenced Crash Types</th>
<th>Subset Proportion, $P_s$</th>
<th>Coefficient $b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed (18)</td>
<td>Rural, 2-lane undivided</td>
<td>All</td>
<td>Single-vehicle run-off-road</td>
<td>unreported</td>
<td>-0.037</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Medium Type</th>
<th>Crash Type Subet</th>
<th>Through Lane</th>
<th>Subset Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressed</td>
<td>Single-vehicle run-off-road, right side</td>
<td>4</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0.15</td>
</tr>
<tr>
<td>Undivided, TWTL, or flush paved</td>
<td>Single-vehicle run-off-road, either side</td>
<td>2</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.27</td>
</tr>
</tbody>
</table>
**AMF for Horizontal Clearance: Example**

For 10 feet Horizontal Clearance on 4-lane Undivided Hwy:

\[
AMF_{hc} = (e^b \times (W_{hc}-30) -1.0) P_s + 1.0
\]

**AMF for Access Control for 4-Ln Divided Highways**

\[
AMF_{dd} = (e^b \times (D_d - D_{base}) -1.0) P_s + 1.0
\]

Where:

- \( D_d \) = Driveway Density (Driveways per mile)
- \( D_{base} \) = Base driveway density of 5 per mile
- \( b \) = coefficient
- \( P_s \) = subset proportion

---

**Table 3-18. Coefficient Values for Horizontal Clearance on Rural Highways.**

<table>
<thead>
<tr>
<th>Model Source</th>
<th>Roadway Type</th>
<th>Crash Severity</th>
<th>Subset of Influenced Crash Types</th>
<th>Subset Proportion, ( P_s )</th>
<th>Coefficient ( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Missouri (16)</td>
<td>Rural, 2-lane undivided</td>
<td>All</td>
<td>Single-vehicle run-offroad</td>
<td>unreported</td>
<td>-0.0137</td>
</tr>
</tbody>
</table>

**Table 3-19. Crash Distribution for Rural Highway Horizontal Clearance Width AMF.**

<table>
<thead>
<tr>
<th>Median Type</th>
<th>Crash Type Subset</th>
<th>Through Lanes</th>
<th>Subset Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depressed</td>
<td>Single-vehicle run-offroad, right side</td>
<td>4</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>0.15</td>
</tr>
<tr>
<td>Undivided, TW/TL, or flush paved</td>
<td>Single-vehicle run-offroad, either side</td>
<td>2</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>0.27</td>
</tr>
</tbody>
</table>

**Table 3-26. Coefficient Values for Driveway Density for Rural Highways.**

<table>
<thead>
<tr>
<th>Model Source</th>
<th>Roadway Type</th>
<th>Crash Severity</th>
<th>Subset of Influenced Crash Types</th>
<th>Subset Proportion, ( P_s )</th>
<th>Coefficient ( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wang et al. (4)</td>
<td>Rural, 4-lane, divided</td>
<td>All</td>
<td>All</td>
<td>3.0</td>
<td>0.034</td>
</tr>
</tbody>
</table>

* From TTI synthesis
AMF for Access Control for 4-Ln Divided Highways: Example

For 4-Ln Divided, 32 driveways in 1.8 miles

\[ AMF_{dd} = (e^{b(Dd - D_{base})} - 1.0) P_s + 1.0 \]

\[ AMF_{dd} = (e^{0.034(17.8 - 5)} - 1.0) \times 1.0 + 1.0 \]

\[ = 1.544 \]

Predicting Safety Performance for Rural Divided Highways – Question:

4-lane Divided Rural Highway:
- ADT = 26,000
- Length = 1.8 miles
- Lane width = 12.0 feet
- Driveways = 20

\[ AMF_{dd} = ? \]

a) 1.23
b) 1.023
c) 1.46
d) 1.046
4-lane Divided Rural Highway:
- ADT = 26,000
- Length = 1.8 miles
- Lane width = 12.0 feet
- Driveways = 20

AMF_{dd} = (e^{b(Dd - Dbase) - 1.0}) P_s + 1.0

AMF_{dd} = (e^{0.034(11.1 - 5) - 1.0}) x 1.0 + 1.0

= ?

Predicting Highway Safety for Multilane Rural Highway Segments

Outcomes:
- Describe the Highway Safety Model base equation for prediction of Crash Performance for Rural Multilane Highways
- Describe AMFs and demonstrate their Quantitative safety effects on Rural Multilane Highways
Questions and Discussion
Safety and Operational Effects of Geometric Design Features for Multilane Highways Workshop

Exercise I – Prediction of Safety Performance for Rural Multilane Highway and Comparison to Substantive Safety Performance
  - Session #3

Exercise I – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:

- Calculate Severity Rate
- Apply Rural Multilane Crash Prediction model
- Compare predicted safety performance to actual safety performance
Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

**IL 64, DuPage County, Illinois:**
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.
Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Geometric Information:

Cross-Section:
- Four 12-foot wide lanes with double yellow centerline dividing the opposing directions of travel (Undivided)
- 8 foot wide aggregate shoulders
- 12 foot wide left turn lanes at all major intersections

No left turn lanes at minor street intersections nor at commercial driveways

No highway illumination other than some minor intersection lighting by local municipalities and the County Highway Department

Study Section:

Length of Section = 0.97 miles
ADT = 37,000 AADT
No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi; side slope = 1:6

Driveways:
- Residential driveways 7
- Minor commercial driveways (< 50 parking spaces) 7
- Major commercial driveways (> 50 parking spaces) 11

Total # of Driveways 25
### Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

#### Study Section:

- Number of Unsignalized Intersections with left turn lanes: 0
- Number of Unsignalized Intersections without turn lanes: 9
- Trees and Power poles: 18.0 feet from edge of pavement

#### Signalized Intersections:

- Bloomingdale Road: 16,100 AADT
- Shopping Center (north and south): 2,400 AADT
- Main Street-Glen Ellyn: 16,700 AADT

---

### Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

#### Study Section:


<table>
<thead>
<tr>
<th></th>
<th>Total Crashes</th>
<th>Injury Crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rdwy Segment</td>
<td>200</td>
<td>62</td>
<td>136</td>
<td>64</td>
</tr>
<tr>
<td>Intersections:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloomingdale Rd</td>
<td>170</td>
<td>68</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Main St-Glen Ellyn</td>
<td>146</td>
<td>45</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td>Totals:</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>
Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

From the crash information, perform the following:
1. Compute the Severity Index (SI) for the segment and for the 3 signalized intersections
   \[
   SI_{\text{segment}} = \frac{\text{Fatal} + \text{Injury Crashes}}{\text{Total Crashes}}
   \]
   \[
   SI_{\text{intersections}} = \frac{\text{Fatal} + \text{Injury Crashes}}{\text{Total Crashes}}
   \]

Is the Severity Index higher or lower than normal?

Severity Index

Severity index (SI) is the ratio of crashes involving an injury or fatality to total crashes

<table>
<thead>
<tr>
<th>Accident severity level</th>
<th>Proportion of total accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roadway segments</td>
</tr>
<tr>
<td>Fatal and Injury</td>
<td>0.321</td>
</tr>
<tr>
<td>Property damage only</td>
<td>0.079</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

2. Predict the Crash Performance for the segment using the Rural Undivided Multilane model for the following:
   a. Base Model for the Roadway Segment
   b. AMFs for; Lane Width, Shoulder Width and type, Horizontal Clearance and Driveway Density
   c. Total Predicted Crashes for Segment (with AMF’s applied)

Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

From the Crash Prediction analysis, perform the following:

3. Is the actual Safety Performance of the geometrics for IL 64 (Lane Width, Shoulder Width and Type, Horizontal Clearance and Driveway Density) safer than predicted value?

Actual Safety Performance = ? crashes per year
Predicted Segment Crashes = ? crashes per year
Severity Index

Severity index (SI) is the ratio of crashes involving an injury or fatality to total crashes.

<table>
<thead>
<tr>
<th>Accident severity level</th>
<th>Proportion of total accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roadway segments</td>
</tr>
<tr>
<td>Fatal and injury</td>
<td>0.321</td>
</tr>
<tr>
<td>Property damage only</td>
<td>0.679</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Exercise I – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:

- Calculated Severity Rate
- Applied Rural Multilane Crash Prediction model
- Compared predicted safety performance to actual safety performance
Questions and Discussion
GROUP EXERCISE “I”

IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.

Cross-Section:
- 4 12-foot wide lanes with double yellow centerline dividing the opposing directions of travel
- 8 foot wide aggregate shoulders
- 12 foot wide left turn lanes at all major intersections
- No left turn lanes at minor street intersections nor at commercial driveways
- No highway illumination other than some minor intersection lighting by local municipalities and the County Highway Department

Study Section: Bloomingdale Road to Main Street-Glen Ellyn
- Length of Section = 0.97 miles
- ADT = 37,000 AADT
- No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi

Driveways:
- Residential driveways 7
- Minor commercial driveways (less than 50 parking spaces) 7
- Major commercial driveways (more than 50 parking spaces) 10
- Total # of Driveways 24

Total number of Unsignalized Intersections with left turn lanes 0

Total number of Unsignalized Intersections without turn lanes 9
- Mildred Av
- Virginia Av
- Bernice Av
- Western Ave
- Pearl Ave
- Diane Av
- Evergreen Av
- Amy Av
- Newton Ave

Side slope = 1:6
Trees and Power poles 18.0 feet from edge of pavement; Hazard Rating of 5.0

Signalized Intersections:
- Bloomingdale Road 16,100 AADT
- Shopping Center (north and south) 2,400 AADT
- Main Street-Glen Ellyn 16,700 AADT
**Substantive Safety Performance:** 3-years crash data 1986, 1987, 1988

<table>
<thead>
<tr>
<th>Segment</th>
<th>Total crashes</th>
<th>Injury crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segment</td>
<td>200</td>
<td>62</td>
<td>136</td>
<td>64</td>
</tr>
<tr>
<td>Bloomingdale Road</td>
<td>170</td>
<td>68</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Main Street-Glen Ellyn</td>
<td>146</td>
<td>45</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>

1. Compute the Severity Index

\[
\text{Severity Index} = \frac{\text{Number of Fatal + Injury Crashes}}{\text{Total Number of Crashes}}
\]

**Segment:**

\[
= \frac{62}{200} = \underline{_____} \%
\]

**Intersections:**

\[
= \frac{118}{334} = \underline{_____} \%
\]

Is the Severity Index higher or lower than normal?
(For comparison see slide 3-14)

2. Predict the Crash Performance for the following:

a. Rural Multilane Base Model for IL 64 (excluding curves and on-grade sections)

\[
N_{br} = e^{(a + b \ln ADT + \ln L)}
\]

\[
= e^{(\quad + \ln \quad + \ln \quad \quad \quad)}
\]

\[
= e^{(\quad + \quad + \quad \quad \quad)}
\]

\[
= e^{(\quad \quad)}
\]

\[
= \underline{_____} \text{ crashes per year}
\]
b. AMF for Lane Width (12 ft)

\[ AMF_{1ru} = \]

AMF for Shoulder Width (8 ft)

\[ AMF_{wra} = \]

AMF for Shoulder Type (aggregate)

\[ AMF_{tra} = \]

\[ AMF_{2ru} = \left( \frac{12}{8} \times -1.0 \right) \times 0.35 + 1 \]

= \]

AMF for Side Slope (1:6)

\[ AMF_{ss} = \]

AMF for Horizontal Curves: none

\[ AMF_{curve} = \]

AMF for Horizontal Clearance

\[ AMF_{hc} = \left( e^{b \times (Whc-30) -1.0} \right) Ps + 1.0 \]

\[ = e^{(-0.0137 \times \left( \frac{-30}{-1.0} \right)) \times 0.27 + 1} \]

\[ = e^{(-0.0137 \times \left( -30 \right)) -1.0 \times 0.27 + 1} \]
Exercise I – Prediction of Crashes for IL 64-North Avenue as a Rural Multilane Highway

\[ = e^{(Dd - D_{base}) - 1.0} \times 0.27 + 1 \]

AMF for Driveway Density (Access Control)

\[ AMF_{dd} = (e^{b(Dd - D_{base}) - 1.0}) Ps + 1.0 \]

\[ = e^{( - 5) - 1.0} \times 1 + 1 \]

\[ = e^{-1.0} \times 1 + 1 \]

\[ = 1 + 1 \]

c. Rural Multilane Base Model with AMF’s for Lane Width, Shoulder Width, Side Slope, Horizontal Curves, Horizontal Clearance, Access Density

AMF for Lane Width = (see chart on Lane Widths)

Combined AMF for Shoulder = (AMF_{2ru})

AMF for Side Slope = (see exhibit)

AMF for Horizontal Curves = (see exhibit)

AMF for Horizontal Clearance = (calculate using AMF_{hc} equation)

AMF for Driveway Access = (calculate using AMF_{dd} equation)
\[ N = N_{br} \times AMF_{1ru} \times AMF_{2ru} \times AMF_{ss} \times AMF_{curve} \times \]
\[ \times AMF_{horclr} \times AMF_{dd} \]

\[ = \quad × \quad × \quad × \quad \]
\[ × \quad × \quad × \quad \]
\[ N_{seg} = \quad \text{crashes per year} \]

3. Is the Actual Safety Performance of the geometrics for IL 64 (Lane Width, Shoulder Width and Type, Horizontal Clearance and Driveway Density) safer than predicted value?

Actual Safety Performance = 200 crashes/ 3 years

\[ = \quad 66.67 \text{ crashes per year} \]

Predicted Segment Crashes per year =

Is the Actual Safety Performance of the 4-lane undivided geometrics for IL 64 North Avenue (Lane Width, Shoulder Width and Type, Horizontal Clearance and Driveway Density) safer than predicted value?

Yes or No
Predicting Highway Safety for Urban/Suburban Multilane Streets

Outcomes:

- Described human factors basis for design and operation of urban highways
- Described the Highway Safety Model base equation for prediction of Crash Performance
- Detailed the Quantitative safety effects of AMFs for various geometric conditions and their interaction with the base model
Three Assumptions to Describing Road User Needs

1. Integrated, systems view founded on human factors

<table>
<thead>
<tr>
<th>Roadway</th>
<th>Driver</th>
<th>Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>34%</td>
<td>93%</td>
<td>12%</td>
</tr>
<tr>
<td>3%</td>
<td>57%</td>
<td>2%</td>
</tr>
<tr>
<td>3%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td>2%</td>
<td></td>
</tr>
</tbody>
</table>

Urban Street Users

2. Users of all modes are accommodated - motorist, bicyclist, pedestrian, trucks, ADA needs
Three Assumptions to Describing Road User Needs

3. Need to understand and quantify multilane highway operations and safety performance in pursuit of informed and balanced decision making

Human Factors Analysis encompasses:

1. Ensuring road users are presented with tasks that are within their capabilities
2. Designing facilities that are accessible to and usable by all road users
3. Anticipating how road users may react to specific situations
Human Factors Analysis encompasses:

4. Designing and applying appropriate traffic control devices so that they are conspicuous, legible, comprehensible, credible, and provide sufficient time to respond in an appropriate manner.

5. Understand how geometric design properties of width, enclosure, slope, and deflection affect users and contribute to speeding, yielding, and gap acceptance.

Human Factors common to Drivers:

**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
Human Factors common to all Road Users:

- **Information Processing**
  - Road Users perform best under moderate levels of demand
  - Overload or underload tends to degrade performance

Human Factors common to all Road Users:

- **User Error**

  Risk of user error is greater when needed information is:
  - Missing or incomplete
  - Difficult to locate, read or interpret
  - Lacks credibility
  - Leads to false expectations
  - Provides insufficient time for decision and to take appropriate action
**Human Factors common to all Road Users:**

- **Driver Distraction**

  38% of the actual Intersection crashes were related to driver distraction.

**NHTSA 100 Car Study**

- **Almost 80 percent of all crashes** and **65 percent of all near-crashes** involved the driver looking away from the forward roadway just prior to the onset of the conflict.

**NHTSA 100-Car Naturalistic Driving Study**
Two Overall Principles for Urban Multilane Highways:

- Clarify
- Simplify

Applying Human Factors:

To Minimize driver error at intersections:

- All Road Users must first recognize the intersection
- Must have clear presentation of the intersection on the approach
- Must have adequate visibility and Illumination
Applying Human Factors:

>To Achieve error-free road user performance at signalized intersections:

- Must have adequate advance Navigational info to allow adequate time for lane change
- Signal indications must be visible
- Phasing and Change Intervals of signals must be Adequate
- Geometric aspects must be clear to user

Defining Urban Multilane Highways

- Methodology applies to arterial four-lane undivided and divided urban and suburban highways.
- Urban and Suburban areas are defined as areas within the urban and urbanized area boundaries established by FHWA. These include all areas with populations of 5,000 or more.
- Some areas beyond the FHWA boundaries may be treated as urban or suburban if the boundaries have not been adjusted to include recent development.
- The boundary dividing rural and urban areas can at times be difficult to determine, especially since most multilane rural highways are located on the outskirts of urban agglomerations.
- These procedures may be used for any multilane road in which the general design features and land use setting are urban or suburban in nature rather than rural.
Defining Multilane Highways

- **Multilane Facilities:**
  - Have four through lanes.
  - May be divided with a rigid or flexible barrier, paved or landscaped median.
  - Should **not** have access and egress limited by grade-separated interchanges (i.e., not freeways).
  - May have occasional grade-separated interchanges, but these should not be the primary form of access and egress.

Limitations of Methodology

- Methodology incorporates the effects on safety of many, but **not all**, geometric and traffic control features.
- Only includes those geometric design elements:
  - whose relationship to safety are well understood
  - Associated data is available
- Methodology treats the effects of individual geometric design element and traffic control features as independent of each other and ignores any potential interactions between them.
Baseline Models

- Baseline models are used for predicting the total accident frequency of each roadway segment or intersection on a four-lane divided or undivided highway.
- Baseline models predict annual crash frequencies for roadway segments or intersections as a function of traffic volumes for a specified set of nominal baseline conditions.
- Nominal baseline conditions include geometric design and traffic control elements, such as roads with 12-ft lane widths and 8-ft shoulder widths.
- Baseline estimates are adjusted by AMFs, which represent the safety effects of individual geometric design and traffic control elements that differ from the baseline conditions.
Accident Modification Factors (AMFs)

- AMFs are multiplicative factors used to adjust the baseline accident frequency to account for the effect of differences in individual geometric design characteristics and traffic control features that depart from the baseline conditions (assumed and specified in the baseline model).

- AMF for the nominal or baseline value of each geometric design traffic control feature in the baseline model has a value of 1.0.

Accident Modification Factors (AMFs)

- Account for difference between base and actual geometry
- Estimate effects of individual geometry elements on safety
- Can be greater or less than 1:
  - < 1.0 -- lower crash frequency
  - >1.0 -- increased crash frequency
Definition of Segments and Intersections

- **Segments:** Portions of the facility delimited by:
  - major intersections or significant changes in the roadway cross-section or geometric characteristics of the facility or surrounding land uses.
  - Roadway segments can be either undivided or divided.

- **Major intersections:**
  - Where the segment being analyzed intersects with:
    - major and minor arterials
    - major collectors
  - And where traffic volumes (ADT) are available on all approaches.
    - Application of the intersection procedures requires ADT on all intersection approaches.

- **Minor Intersections:**
  - Intersections between the facility being analyzed and minor collectors, local roads, access driveways
  - Or any intersection for which traffic volumes (ADT) are not available on approaches intersecting the facility being analyzed (it is assumed that ADT is available for the facility being analyzed).

Exhibit 12-3: Definition of Roadway Segments and Intersections

- **Segment Length**
- 250’

- **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 the characteristics of the crash.
- **C** All crashes that occur within this region are classified as roadway segment crashes.
Definition of Segments and Intersections

- Crashes are assigned to either a major or minor intersection or a segment.
- Crashes occurring within or near the intersection are assigned to the intersection, and all other crashes are assigned to the respective segment.
- Use the following two criteria to define intersection and intersection-related crashes:
  1. Crashes that have already been defined as intersection or intersection-related in the accident report and that occurred within 250 ft (76 m) of the intersection center are assigned to the intersection.
  2. For cases where no such definitions are available, all crashes occurring within 250 ft from the middle of the intersection are assigned to that intersection.

Subdividing Roadway Segments

- Before applying the safety prediction methodology to an existing or proposed rural segment facility, the roadway must be divided into analysis units consisting of individual homogeneous roadway segments and intersections.
- A new analysis section begins at each location where the value of one of the following variables changes (alternatively a section is defined as homogenous if none of these variables changes within the section):
  - Average daily traffic (ADT) volume (veh/day)
  - Lane width (ft)
  - Shoulder width (ft)
  - Presence of a median
  - Major intersections
Predicting Safety Performance
- Analysis Sections

Separate Prediction Models for:

- Homogeneous highway segments
  *(including effect of Grade)*

- Curves
  Weighted Average of AMF by Length of Curves

- Intersections
  Sum of Individual Intersection Calculations

Predicting Safety Performance for Urban/Suburban Roadway Segments

Procedure for safety prediction for a roadway segment: Combine base models, AMFs, and calibration factor

\[ N_{rs} = \left( N_{br} + N_{pedr} + N_{biker} \right) C_r \]

\[ N_{br} = N_{brbase} \left( AMF_{1r} \times AMF_{2r} \times \ldots \times AMF_{ir} \right) \]

\[ N_{brbase} = N_{brmv} + N_{brsv} + N_{brdwy} \]
Predicting Safety Performance for Urban/Suburban Roadway Segments

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

Where:
- \(N_{rs}\) = Predicted number of total roadway segment crashes per year
- \(N_{br}\) = Predicted number of total roadway segment crashes per year for base conditions
- \(N_{pedr}\) = 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 geographical area

Predicting Safety Performance for Urban/Suburban Roadway Segments

\[
N_{br} = N_{brbase}(AMF_{1r} \times AMF_{2r} \times \ldots AMF_{ir})
\]

Where:
- \(N_{br}\) = Predicted number of total roadway segment crashes per year with AMFs applied
- \(N_{brbase}\) = Predicted number of total roadway segment crashes per year for base conditions
- \(AMF_{1r}, AMF_{2r}, \ldots, AMF_{ir}\) = Accident (Crash) modification factors for roadway segments
Predicting Safety Performance for Urban/Suburban Roadway Segments

\[ N_{\text{brbase}} = N_{\text{brmv}} + N_{\text{brsv}} + N_{\text{brdwy}} \]

Where:

- \( N_{\text{brmv}} = \) Predicted number of multiple-vehicle non-driveway crashes per year for base conditions
- \( N_{\text{brsv}} = \) Predicted number of single-vehicle collision and non-collision crashes per year for base conditions
- \( N_{\text{brdwy}} = \) Predicted number of multiple-vehicle driveway related crashes per year

Combining Safety Predictions for an Entire Arterial Street

\[ N_t = \text{Sum } N_{\text{rs}} + \text{Sum } N_{\text{int}} \]

Where:

- \( N_t = \) Predicted crash frequency for the entire arterial street
- \( N_{\text{rs}} = \) Predicted number of total roadway segment crashes
- \( N_{\text{int}} = \) Predicted number of total intersection-related crashes
### Base Models for Urban/Suburban Roadway Segments

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

1. Two-lane undivided arterials (2U)
2. Three-lane arterials including a center two-way Left Turn Lane (3T)
3. Four-lane undivided arterials (4U)
4. Four-lane divided arterials (including a raised or depressed median) (4D)
5. Five-lane arterials including a center TWLTL (5T)

### Base Models for Urban/Suburban Roadway Segments

**Five types of Collisions are considered:**

1. Multiple-vehicle nondriveway crashes
2. Single-vehicle crashes
3. Multiple-vehicle driveway related crashes
4. Vehicle-pedestrian crashes
5. Vehicle-bicycle collisions
Base Models for Urban/Suburban Roadway Segments

No procedure has been developed for application to six-lane undivided (6U) nor for six-lane divided (6D) arterials. Until such procedures are developed:

- The procedures for 4U arterials may be applied to 6U arterials and for 4D arterials to 6D arterials.
- These procedures should be applied cautiously to 6U and 6D arterials because this application is not based on data for 6U and 6D arterials.

Predicting Safety Performance for Urban/Suburban Multilane Highways

Multiple-Vehicle NonDriveway Crashes

\[ N_{brmv} = \exp(a + b \ln(ADT) + \ln(L)) \]

Where:
- ADT = Average Daily Traffic (veh/day)
- L = Length of roadway segment (mi)
- a & b = regression coefficients (Exhibit 12-3)
### Multiple-Vehicle NonDriveway Crashes

\[ N_{brmv} = \exp(a + b \ln(ADT) + \ln(L)) \]

#### Exhibit 12-3: Base Models for Multiple-Vehicle Nondriveway Collisions on Roadway Segments

<table>
<thead>
<tr>
<th>Road type</th>
<th>Coefficients used in Equation 12-8</th>
<th>Overdispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>ADT (b)</td>
</tr>
<tr>
<td>Total accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2U</td>
<td>-14.75</td>
<td>1.68</td>
</tr>
<tr>
<td>3T</td>
<td>-11.92</td>
<td>1.41</td>
</tr>
<tr>
<td>4U</td>
<td>-11.53</td>
<td>1.33</td>
</tr>
<tr>
<td>4D</td>
<td>-11.88</td>
<td>1.36</td>
</tr>
<tr>
<td>5T</td>
<td>-0.93</td>
<td>1.17</td>
</tr>
</tbody>
</table>

---

#### Exhibit 12-3: Base Models for Multiple-Vehicle Nondriveway Collisions on Roadway Segments

<table>
<thead>
<tr>
<th>Road type</th>
<th>Coefficients used in Equation 12-8</th>
<th>Overdispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>ADT (b)</td>
</tr>
<tr>
<td>Total accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2U</td>
<td>-15.75</td>
<td>1.66</td>
</tr>
<tr>
<td>3T</td>
<td>-15.97</td>
<td>1.69</td>
</tr>
<tr>
<td>4U</td>
<td>-11.98</td>
<td>1.25</td>
</tr>
<tr>
<td>4D</td>
<td>-12.30</td>
<td>1.28</td>
</tr>
<tr>
<td>5T</td>
<td>-10.70</td>
<td>1.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road type</th>
<th>Coefficients used in Equation 12-8</th>
<th>Overdispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>ADT (b)</td>
</tr>
<tr>
<td>Fatal-and-injury accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2U</td>
<td>-15.15</td>
<td>1.69</td>
</tr>
<tr>
<td>3T</td>
<td>-11.47</td>
<td>1.33</td>
</tr>
<tr>
<td>4U</td>
<td>-12.43</td>
<td>1.38</td>
</tr>
<tr>
<td>4D</td>
<td>-12.35</td>
<td>1.38</td>
</tr>
<tr>
<td>5T</td>
<td>-10.20</td>
<td>1.17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Road type</th>
<th>Coefficients used in Equation 12-8</th>
<th>Overdispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>ADT (b)</td>
</tr>
<tr>
<td>Property-damage-only accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2U</td>
<td>-15.15</td>
<td>1.69</td>
</tr>
<tr>
<td>3T</td>
<td>-11.47</td>
<td>1.33</td>
</tr>
<tr>
<td>4U</td>
<td>-12.43</td>
<td>1.38</td>
</tr>
<tr>
<td>4D</td>
<td>-12.35</td>
<td>1.38</td>
</tr>
<tr>
<td>5T</td>
<td>-10.20</td>
<td>1.17</td>
</tr>
</tbody>
</table>
Predicting Safety Performance for Suburban Highways – Example:

**4-lane Undivided commercial Suburban Street:**
- ADT = 24,000
- Length = 3.6 miles

Base Crash Rate – Multiple-Vehicle NonDriveway Crashes - use 4U

\[ N_{brmv} = \exp(a + b \ln(ADT) + \ln(L)) \]
\[ = \exp(-11.53 + 1.33 \ln(24,000) + \ln(3.6)) \]
\[ = \exp(3.165) \]
\[ = 23.7 \text{ crashes/yr} \]

Predicting Safety Performance for Suburban Highways – Exercise:

**4-lane Divided Suburban Street:**
- ADT = 24,000
- Length = 3.6 miles
- Base Crash Rate for Multilane NonDriveway crashes
  - Use 4D

\[ N_{brmv} = \exp(a + b \ln(ADT) + \ln(L)) \]
\[ = \exp(-11.88 + 1.36 \ln(24,000) + \ln(3.6)) \]
\[ = \text{? \text{ crashes per year}} \]
Predicting Safety Performance for Urban/Suburban Multilane Highways

Single Vehicle Crashes:

\[ N_{brmv} = \exp(a + b \ln(ADT) + \ln(L)) \]

Where:
- ADT = Average Daily Traffic (veh/day)
- \( L \) = Length of roadway segment (mi)
- \( a \) & \( b \) = regression coefficients (Exhibit 12-5)

Single Vehicle Crashes

\[ N_{brsv} = \exp(a + b \ln(ADT) + \ln(L)) \]

Exhibit 12-5: Base Models for Single-Vehicle Accidents on Roadway Segments

<table>
<thead>
<tr>
<th>Road type</th>
<th>Coefficients used in Equation 12-11</th>
<th>Overdispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>ADT (b)</td>
</tr>
<tr>
<td>Total accidents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2U</td>
<td>−5.00</td>
<td>0.56</td>
</tr>
<tr>
<td>3T</td>
<td>−5.26</td>
<td>0.54</td>
</tr>
<tr>
<td>4U</td>
<td>−7.89</td>
<td>0.81</td>
</tr>
<tr>
<td>4D</td>
<td>−4.59</td>
<td>0.47</td>
</tr>
<tr>
<td>5T</td>
<td>−5.05</td>
<td>0.54</td>
</tr>
</tbody>
</table>
Predicting Safety Performance for Suburban Highways – Example:

4-lane Undivided commercial Suburban Street:
- ADT = 24,000
- Length = 3.6 miles

Base Total Crash Rate – Single-Vehicle NonDriveway Crashes - use 4U

\[ N_{brsv} = \exp(a + b \ln(ADT) + \ln(L)) \]
\[ = \exp(-7.89 + 0.81 \ln(24,000) + \ln(3.6)) \]
\[ = \exp(1.56) \]
\[ = 4.8 \text{ crashes/yr} \]
Predicting Safety Performance for Suburban Highways – Exercise:

4-lane Divided Suburban Street:
- ADT = 24,000
- Length = 3.6 miles
- Base Crash Rate for Single-Vehicle Non-Driveway crashes – Use 4D

\[ N_{brsv} = \exp(a + b \ln(ADT) + \ln(L)) \]

\[ N_{brsv} = ? \]

- a) 2.1 crashes per year
- b) 4.2 crashes per year
- c) 8.4 crashes per year
- d) 12.6 crashes per year

Driveway Related Crashes

- 75% of driveway related crashes involve a left turning vehicle – either into the driveway or out of the driveway

NCHRP 500, Objective 17.1A – Improve Management of Access Near Unsignalized Intersections
Predicting Safety Performance for Urban/Suburban Multilane Highways

Multiple-Vehicle Driveway Related Crashes

- Major driveways are those that serve 50 or more parking spaces
- Minor driveways serve sites with less than 50 parking spaces
- Major residential driveways have ADT greater than 900 vpd
- Minor residential driveways have ADT less than 900 vpd

\[
N_{brdwy} = \text{SUM} \left( n_j N_j \left( \frac{\text{ADT}}{15,000} \right)^t \right)
\]

Where:
- \( n_j \) = number of driveways within roadway segment of driveway type \( j \)
- \( N_j \) = Number of crashes per year for an individual driveway of driveway type \( j \) from Exhibit 12-7
- \( t \) = coefficient for traffic volume adjustment
- \( \text{ADT} \) = Average Daily Traffic (veh/day)
Multiple-Vehicle Driveway Crashes

\[ N_{\text{brdwy}} = \sum (n_j N_j (\text{ADT}/15,000)^t) \]

**Exhibit 12-7: Driveway Factors for Roadway Segments**

<table>
<thead>
<tr>
<th>Driveway type</th>
<th>Coefficients for specific roadway types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2U</td>
</tr>
<tr>
<td>Number of driveway-related collisions per driveway per year (N)</td>
<td></td>
</tr>
<tr>
<td>Major commercial</td>
<td>0.252</td>
</tr>
<tr>
<td>Minor commercial</td>
<td>0.050</td>
</tr>
<tr>
<td>Major industrial/institutional</td>
<td>0.274</td>
</tr>
<tr>
<td>Minor industrial/institutional</td>
<td>0.026</td>
</tr>
<tr>
<td>Major residential</td>
<td>0.132</td>
</tr>
<tr>
<td>Minor residential</td>
<td>0.025</td>
</tr>
<tr>
<td>Other</td>
<td>0.040</td>
</tr>
<tr>
<td>All driveways</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Predicting Safety Performance for Suburban Highways – Example:

**4-lane Undivided commercial Suburban Street:**
- ADT = 24,000
- Length = 3.6 miles
- 3 major commercial driveways
- 42 minor commercial driveways
- 2 major industrial/institutional driveways
- 5 major residential driveways
- 2 minor residential driveways
- 7 other
- 61 total driveways

\[ N_{\text{brdwy}} = \sum (n_j N_j (\text{ADT}/15,000)^t) \]
Predicting Safety Performance for Suburban Highways – Example:

4-lane Undivided commercial Suburban Street:

\[ N_{\text{brdwy}} = \sum (n_j N_j (ADT/15,000)^t) \]

\[ = 3 \times 0.202 \times (24,000/15,000)^{1.172} \]
\[ + 42 \times 0.064 \times (24,000/15,000)^{1.172} \]
\[ + 2 \times 0.220 \times (24,000/15,000)^{1.172} \]
\[ + 0 \times 0.029 \times (24,000/15,000)^{1.172} \]
\[ + 5 \times 0.106 \times (24,000/15,000)^{1.172} \]
\[ + 2 \times 0.020 \times (24,000/15,000)^{1.172} \]
\[ + 7 \times 0.032 \times (24,000/15,000)^{1.172} \]

\[ = 7.9 \]

Predicting Safety Performance for Suburban Highways – Exercise:

4-lane Divided (Commercial) Suburban Street:

- ADT = 24,000
- Length = 3.6 miles
- same driveways as in the example just provided
- Use 4D

\[ N_{\text{brdwy}} = \sum (n_j N_j (ADT/15,000)^t) \]

\[ = ? \]

a) 28.8 crashes per year
b) 36.3 crashes per year
c) 2.07 crashes per year
d) 3.63 crashes per year
Predicting Safety Performance for Suburban Highways – Answer:

4-lane Divided (Commercial) Suburban Street:
- ADT = 24,000
- Length = 3.6 miles
- same driveways as in the example just provided

\[ N_{brdwy} = \text{SUM} \left( n_j N_j \left( \text{ADT/15,000} \right)^t \right) \]

\[ = 2.07 \]

- Use 4D

a) 28.8 crashes per year
b) 36.3 crashes per year
c) 2.07 crashes per year
d) 3.63 crashes per year

Predicting Safety Performance for Urban/Suburban Roadway Segments

\[ N_{brbase} = N_{brmv} + N_{brsv} + N_{brdwy} \]

Where:
- \( N_{brbase} \) = Predicted number of total roadway segment crashes per year for base conditions for suburban 4-Lane Undivided (4U) of 24,000 ADT for 3.6 miles
- \( N_{brmv} \) = 23.7
- \( N_{brsv} \) = 4.8
- \( N_{brdwy} \) = 7.9

\[ N_{brbase} = 23.7 + 4.8 + 7.9 \]
\[ = 36.4 \text{ crashes per year} \]
Highway Segment Model using AMFs

\[ N_{br} = N_{brbase}(AMF_{1r} \times AMF_{2r} \times \ldots AMF_{nr}) \]

Where:
- \( N_{br} \) = Predicted number of total roadway segment crashes per year with AMFs applied
- \( N_{brbase} \) = Predicted number of total roadway segment crashes per year for base conditions
- \( AMF_{1r}, AMF_{2r}, \ldots, AMF_{nr} \) = Accident (Crash) modification factors for roadway segments

AMF for Curb Parking on Urban Streets

\[ AMF_{1r} = 1 + P_{pk} \times (f_{pk} - 1.0) \]

Exhibit 12-10: Values of \( f_{pk} \) Used in Determining the Accident Modification Factor for On-street Parking

<table>
<thead>
<tr>
<th>Type of parking and land use</th>
<th>Parallel parking</th>
<th>Angle parking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road type</td>
<td>Residential/other</td>
<td>Commercial or industrial/institutional</td>
</tr>
<tr>
<td>2U</td>
<td>1.465</td>
<td>2.074</td>
</tr>
<tr>
<td>3T</td>
<td>1.465</td>
<td>2.074</td>
</tr>
<tr>
<td>4U</td>
<td>1.100</td>
<td>1.709</td>
</tr>
<tr>
<td>4D</td>
<td>1.100</td>
<td>1.709</td>
</tr>
<tr>
<td>5T</td>
<td>1.100</td>
<td>1.709</td>
</tr>
</tbody>
</table>

Where:
- \( P_{pk} \) = Proportion of curb length with parking, = \((0.5L_{pk}/L)\)
- \( L_{pk} \) = curb length with on-street parking, both sides (mi)
- \( f_{pk} \) = factor from Exhibit 12-10
AMF for Curb Parking Urban Streets

Example: For 4-Ln Urban commercial street (4U), angle parking one side 3.12 miles of 3.6 mile length, commercial area:

\[ \text{AMF}_{1r} = 1 + P_{pk} (f_{pk} - 1.0) \]

\[ \text{AMF}_{1r} = 1 + (0.50 \left( \frac{L_{pk}}{L} \right)^1) \times (f_{pk}-1) \]

\[ = 1 + (0.50 \left( \frac{3.12}{3.6} \right)^1) \times (3.999-1) \]

\[ = 2.30 \]

AMF for Curb Parking Urban Streets: Exercise

For 4-Ln Urban commercial street (4U), parallel parking both sides 3.12 miles of 3.6 mile length, commercial area:

\[ \text{AMF}_{1r} = 1 + P_{pk} (f_{pk} - 1.0) \]

\[ \text{AMF}_{1r} = 1 + (0.50 \left( \frac{3.12}{3.6} \right)^2) \times (f_{pk} - 1.0) \]

\[ = 1 + (0.50 \left( \frac{3.12}{3.6} \right)^2) \times (1.709-1) \]

\[ = 1 + (0.50 \left( \frac{3.12}{3.6} \right)^2) \times 0.709 \]

\[ = ? \]
AMF for Roadside Fixed Objects

\[
AMF_{2r} = f_{\text{offset}} \cdot D_{fo} \cdot p_{fo} + (1 - p_{fo})
\]

Where:
- \( f_{\text{offset}} \) = fixed object offset factor from Exh 12-11
- \( D_{fo} \) = fixed object density (fixed objects/mi)
- \( p_{fo} \) = fixed-object collisions as a proportion of total crashes, Exhibit 12-12

- Only point objects that are 4 inches or more in diameter and do not have breakaway design are considered.
- Point objects that are within 70 feet of each other longitudinally are considered as a single object

**AMF for Roadside Fixed Objects**

**Exhibit 12-11: Fixed-Object Offset Factor**

<table>
<thead>
<tr>
<th>Offset to fixed objects (ft)</th>
<th>Fixed-object offset factor (f_{\text{offset}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.232</td>
</tr>
<tr>
<td>5</td>
<td>0.133</td>
</tr>
<tr>
<td>10</td>
<td>0.087</td>
</tr>
<tr>
<td>15</td>
<td>0.069</td>
</tr>
<tr>
<td>20</td>
<td>0.057</td>
</tr>
<tr>
<td>25</td>
<td>0.049</td>
</tr>
<tr>
<td>30</td>
<td>0.044</td>
</tr>
</tbody>
</table>

EX: For 4-Ln Urban undivided street (4U) with power poles at 2 ft offset

- \( f_{\text{offset}} = 0.232 \)
- \( p_{fo} = 0.037 \)

**Exhibit 12-12: Proportion of Fixed-Object Collisions**

<table>
<thead>
<tr>
<th>Road type</th>
<th>Proportion of fixed-object collisions (p_{fo})</th>
</tr>
</thead>
<tbody>
<tr>
<td>2U</td>
<td>0.059</td>
</tr>
<tr>
<td>3T</td>
<td>0.034</td>
</tr>
<tr>
<td>4U</td>
<td>0.037</td>
</tr>
<tr>
<td>4D</td>
<td>0.036</td>
</tr>
<tr>
<td>5T</td>
<td>0.016</td>
</tr>
</tbody>
</table>
AMF for Roadside Fixed Objects: Example

For one mile of 4-Ln Urban undivided commercial curbed street (4U) with power poles on one side on 150 foot spacing 2 feet back of curb:

\[
\text{AMF}_{2r} = f_{\text{offset}} \times D_{\text{fo}} \times p_{\text{fo}} + (1 - p_{\text{fo}})
\]

\[
\begin{align*}
&= 0.232 \times \frac{5280}{150} \times (1)(0.037) + (1 - 0.037) \\
&= 0.232 \times 35.2 \times 0.037 + (0.963) \\
&= 0.302 + 0.963 \\
&= 1.265
\end{align*}
\]

AMF for Roadside Fixed Objects: Example

For one mile of 4-Ln Urban undivided commercial curbed street (4U) with power poles on both sides on 150 foot spacing 2 feet back of curb:

\[
\text{AMF}_{2r} = f_{\text{offset}} \times D_{\text{fo}} \times p_{\text{fo}} + (1 - p_{\text{fo}})
\]

\[
\begin{align*}
&= 0.232 \times \frac{5280}{150} \times (2)(0.037) + (1 - 0.037) \\
&= 0.232 \times 70.4 \times 0.037 + (0.963) \\
&= 1.567
\end{align*}
\]
AMF for Roadside Fixed Objects: Exercise

For one mile of 4-Ln Urban undivided commercial curbed street (4U) with trees (12” dia) on one side spaced 80 feet apart 5 feet back of curb:

\[
AMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1 - p_{fo})
\]

\[
AMF_{2r} = 0.133 \times \frac{5280}{80} \times (1)(0.037) + (1 - 0.037)
\]

\[
= 0.133 \times 66 \times 0.037 + (0.963)
\]

\[
= 1.288
\]

AMF for Lighting

\[
AMF_{3r} = 1 - ((1 - 0.36 P_{fnr} - 0.72 p_{inr} - 0.83 p_{pnr}) \times p_{nr})
\]

Where:

- \( P_{fnr} \) = proportion of total nighttime crashes for unlighted roadway segments that involve a fatality
- \( p_{inr} \) = proportion of total nighttime crashes for unlighted roadway segments that involve a nonfatal injury
- \( p_{pnr} \) = proportion of total nighttime crashes for unlighted roadway segments that involve PDO crashes only
- \( p_{nr} \) = proportion of total crashes for unlighted roadway segments that occur at night
### AMF for Lighting

**AMF_{3r} = 1 - [(1 - 0.36 P_{fnr} - 0.72 p_{inr} - 0.83 p_{pnr}) p_{nr}]**

**Exhibit 12-13: Nighttime Accident Proportions for Unlit Roadway Segments**

<table>
<thead>
<tr>
<th>Road type</th>
<th>Proportion of total nighttime accidents by severity level</th>
<th>Proportion of accidents that occur at night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal p_{fnr}</td>
<td>Injury p_{inr}</td>
</tr>
<tr>
<td>2U</td>
<td>0.005</td>
<td>0.239</td>
</tr>
<tr>
<td>3T</td>
<td>0.004</td>
<td>0.238</td>
</tr>
<tr>
<td>4U</td>
<td>0.006</td>
<td>0.300</td>
</tr>
<tr>
<td>4D</td>
<td>0.004</td>
<td>0.281</td>
</tr>
<tr>
<td>5T</td>
<td>0.011</td>
<td>0.270</td>
</tr>
</tbody>
</table>

- These are default values for nighttime crash proportions; replace with local information.
- If light installation increases the density of roadside fixed objects, adjust AMF_{2r}.

### AMF for Lighting: Example

For 4-Ln Urban undivided commercial curbed street (4U) with power poles on 150 foot spacing 2 feet back of curb - Add Lighting

**AMF_{3r} = 1 - [(1 - 0.36 P_{fnr} - 0.72 p_{inr} - 0.83 p_{pnr}) p_{nr}]**

= 1 - [(1 - 0.36 0.006 - 0.72 0.300 - 0.83 x 0.694 0.209)]

= 0.957

- Lighting adds light poles at 160 foot spacing set back 2 feet from back of curb
  - Recompute AMF_{2r}
AMF for Roadside Fixed Objects – combined effect of trees and luminaire supports

Exercise: For one mile of 4-Ln Urban undivided commercial curbed street with trees (12” dia) spaced 80 feet apart 5 feet back of curb both sides + Street lighting (non-breakaway) at 160 foot spacing at 5 feet back of curb both sides:

\[ \text{AMF}_{2r} = f_{\text{offset}} \times D_{\text{fo}} \times p_{\text{fo}} + (1 - p_{\text{fo}}) \]

\[ = 0.133 \times ((5280/80)(2)+(5280/160)(2)) \times 0.037 + (1 - 0.037) \]

\[ = 0.133(132 + 66)(0.037) + (0.963) \]

\[ = 1.937 \]

AMF for Roadside Fixed Objects – combined effect of trees and luminaire (breakaway)

Exercise: For one mile of 4-Ln Urban undivided commercial curbed street with trees (12” dia) spaced 80 feet apart 5 feet back of curb both sides + Street lighting (breakaway) at 160 foot spacing at 5 feet back of curb both sides:

\[ \text{AMF}_{2r} = f_{\text{offset}} \times D_{\text{fo}} \times p_{\text{fo}} + (1 - p_{\text{fo}}) \]

\[ = 0.133 \times ((5280/80)(2)+(5280/160)(2)) \times 0.037 + (1 - 0.037) \]

\[ = 0.133(132 + 0)(0.037) + (0.963) \]

\[ = 1.613 \]
Predicting Safety Performance for Urban/Suburban Roadway Segments

\[ N_{br} = N_{br\text{base}} (\text{AMF}_1 \times \text{AMF}_2 \times \ldots \times \text{AMF}_n) \]

Where:
- \( N_{br} \) = Predicted number of total roadway segment crashes per year with effects of commercial on-street parallel parking both sides + Roadside Fixed Objects (trees@80' and non-breakaway light poles@160' both sides) + Lighting
- \( N_{br} = N_{br\text{base}} (\text{AMF}_1 \times \text{AMF}_2 \times \ldots \times \text{AMF}_n) \)
- \( N_{br} = 36.4 \times (1.614 \times 1.937 \times 0.957) \)
- \( N_{br} = 108.9 \) crashes per year

Predicting Safety Performance for Urban/Suburban Roadway Segments

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

Where:
- \( N_{rs} \) = Predicted number of total roadway segment accidents per year
- \( N_{sr} \) = Predicted number of total roadway segment crashes per year for base conditions
- \( N_{\text{pedr}} \) = Predicted number of vehicle-pedestrian collisions per year
- \( N_{\text{biker}} \) = Predicted number of vehicle-bicycle collisions per year
- \( C_r \) = calibration factor
Predicting Pedestrian Safety for Urban/Suburban Roadway Segments

\[ N_{\text{pedr}} = N_{\text{br}} \times f_{\text{pedr}} \]

**Exhibit 12-8: Pedestrian Safety Adjustment Factor for Roadway Segments**

<table>
<thead>
<tr>
<th>Road type</th>
<th>Pedestrian safety adjustment factor ( f_{\text{pedr}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low speed</td>
<td>Intermediate or high speed</td>
</tr>
<tr>
<td>2U</td>
<td>0.033</td>
</tr>
<tr>
<td>3T</td>
<td>0.034</td>
</tr>
<tr>
<td>4U</td>
<td>0.045</td>
</tr>
<tr>
<td>4D</td>
<td>0.019</td>
</tr>
<tr>
<td>5T</td>
<td>0.039</td>
</tr>
</tbody>
</table>

Note: These factors apply to the methodology for predicting total accidents (all severity levels combined). All pedestrian collisions resulting from this adjustment factor should be treated as fatal-and-injury accidents and none as property-damage-only accidents.

Low Speed = Posted or Operational Speeds < 30 mph

**Example:**

\[ N_{\text{pedr}} = N_{\text{br}} \times f_{\text{pedr}} = 108.9 \text{ crashes per year} \times 0.008 = 0.87 \text{ crashes per year} \]
Predicting Bicyclist Safety for Urban/Suburban Roadway Segments

\[ N_{\text{biker}} = N_{\text{br}} \times f_{\text{biker}} \]

### Exhibit 12-9: Bicycle Safety Adjustment Factors for Roadway Segments

<table>
<thead>
<tr>
<th>Road type</th>
<th>Bicycle safety adjustment factor (( f_{\text{biker}} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low speed</td>
</tr>
<tr>
<td>2U</td>
<td>0.013</td>
</tr>
<tr>
<td>3T</td>
<td>0.026</td>
</tr>
<tr>
<td>4U</td>
<td>0.029</td>
</tr>
<tr>
<td>4D</td>
<td>0.011</td>
</tr>
<tr>
<td>5T</td>
<td>0.023</td>
</tr>
</tbody>
</table>

Low Speed = Posted or Operational Speeds < 30 mph

Predicting Safety Performance for Urban/Suburban Roadway Segments

\[ N_{\text{biker}} = N_{\text{br}} \times f_{\text{biker}} \]

### Exhibit 12-9: Bicycle Safety Adjustment Factors for Roadway Segments

<table>
<thead>
<tr>
<th>Road type</th>
<th>Bicycle safety adjustment factor (( f_{\text{biker}} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low speed</td>
</tr>
<tr>
<td>2U</td>
<td>0.015</td>
</tr>
<tr>
<td>3T</td>
<td>0.026</td>
</tr>
<tr>
<td>4U</td>
<td>0.029</td>
</tr>
<tr>
<td>4D</td>
<td>0.011</td>
</tr>
<tr>
<td>5T</td>
<td>0.023</td>
</tr>
</tbody>
</table>

From continued Example:
- For 4-Ln Undivided
  - \( N_{\text{biker}} = 108.9 \) crashes per year \times 0.010
  - \( N_{\text{biker}} = 1.09 \) crashes per year
- For > 30 mph

---

Session 4 – Predicting Highway Safety Performance for Multilane Urban Streets
Predicting Safety Performance for Urban/Suburban Roadway Segments

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

\[ N_{rs} = 108.9 + 0.87 + 1.09 \]
\[ = 110.9 \text{ crashes per year} \]

Predicting Safety Performance for Urban/Suburban Roadway Segments

**Additional AMF’s on Safety Effects:**
- Four to Three Lane Conversion
- Providing a Median
- Changing to Less Rigid Roadside Barrier
- Use of Crash Cushions at Fixed Objects
- Increasing Degree of Horizontal Curves
- Installing signs in conformance with MUTCD
- Use of Horizontal Alignment + Advisory Speed Signs
- Installing Edgelines, Centerlines, and PMDs
- Parking
- Access Density
### Safety Effect of Four To Three Lane Conversion on Urban Arterials

**Exhibit 13-8: Safety Effects of Four to Three Lane Conversion or "Road Diet"**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Four to three lane conversion</td>
<td>Urban arterials</td>
<td>Unspecified</td>
<td>All types All severities</td>
<td>0.94*</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Base Condition: Four-lane geometry.

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

* Observed variability suggests that this treatment could result in a benefit, disbenefit, or no safety effect.

See Part D Introduction and Applications Guide.

### Safety Effect of Median on Two-Lane Urban Arterial

**Exhibit 13-11: Safety Effects of Providing a Median on Urban Two-Lane Roads**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide a raised median</td>
<td>Urban Two-lane</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td>0.61</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Base Condition: Absence of raised median.

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

Based on international studies: Leong 1970; Thorson and Mourtizan 1971; Muskau 1965; Blakstad and Glaever 1989.
Safety Effect of Median on Multilane Urban Arterial Street

AMF total = 0.78 (0.321) + 1.09(0.679) = 0.99

Safety Effect of Changing Roadside Barrier to Less Rigid Type

AMF is applicable to injury and fatal crashes only.
Safety Effect of Crash Cushions at Fixed Roadside Features on Urban/Suburban Streets

### Exhibit 13-24: Safety Effects of Installing Crash Cushions at Fixed Roadside Features

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install crash cushions at fixed roadside features</td>
<td>Unspecified</td>
<td>Unspecified</td>
<td>Fixed object</td>
<td>0.31</td>
<td>0.3&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fatal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed object</td>
<td>0.31</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fixed object</td>
<td>0.54</td>
<td>0.3&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-injury</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Absence of crash cushions.

\[
\text{AMF}_{\text{total}} = 0.31(0.321) + 0.54(0.679) = 0.47
\]

---

Safety Effect of Increasing Degree of Horizontal Curvature on Urban/Suburban Aterials

### Exhibit 13-35: Safety Effects of Increasing the Degree of Horizontal Curvature (15)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase horizontal curvature by one degree</td>
<td>Urban and suburban arterials</td>
<td>Unspecified</td>
<td>Off-the-road</td>
<td>1.06</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Off-the-road</td>
<td>1.04</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Off-the-road</td>
<td>1.05</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All seventies</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Unspecified.

Notes: Bold text is used for the most reliable AMFs. These AMFs have a standard error of 0.1 or less.

Degree of curvature approximately = 5730 / radius in ft or = 1747 / radius in m
### Safety Effect of Installing Signs that Conform to MUTCD on Urban/Local Streets

**Exhibit 13-40: Safety Effects of Installing Signs to Conform To MUTCD**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install signs to conform to MUTCD</td>
<td>Urban Local streets</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td>0.85</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-injury</td>
<td>0.93*</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Base Condition: Absence of signs that conform to the MUTCD.

Notes: Based on US study: Lyles, Lightizer, Drakeopoulos and Woods, 1986
The study does not indicate which sign conditions were corrected
* Observed variability suggests that this treatment could result in a benefit, disbenefit, or no safety effect.
See Part D Introduction and Applications Guide.

\[
AMF_{\text{total}} = 0.85(0.321) + 0.93(0.679) = 0.90
\]

### Safety Effect of Installing Combination Horizontal Alignment Warning + Advisory Speed Signs

**Exhibit 13-41: Safety Effects of Installing Combination Horizontal Alignment/ Advisory Speed Signs (W1-1a, W1-2a)**

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

Base Condition: Absence of any signage.

Notes: Based on US studies: McCormant 1999; Hammer 1969 and international study; Ratby 1972
* Observed variability suggests less confidence than AMF values in bold. See Part D Introduction and Applications Guide.

\[
AMF_{\text{total}} = 0.87(0.321) + 0.71(0.679) = 0.76
\]
### Safety Effect of Prohibiting Parking on Urban Arterial Street

**Exhibit 13-62: Safety Effects of Prohibiting On-Street Parking**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident Type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prohibit on-street parking</td>
<td>Urban Arterial</td>
<td>30,000 vehicles/day</td>
<td>All types</td>
<td>0.58</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>64 ft wide</td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prohibit on-street parking</td>
<td>Urban Arterial</td>
<td>30,000 to 40,000</td>
<td>All types</td>
<td>0.78</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>vehicles/day</td>
<td></td>
<td>Injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types</td>
<td>0.72</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-injury</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Base Condition:** Provision of on-street parking.

**Notes:**
- **(10)** Based on U.S. studies: Cressette and Allen 1969; Bonneson and McCoy 1997 and International studies: Macleod and Ford 1966; Good and Houwst 1979; Main 1983; Westman 1986; Blakstad and Gjolberg 1989
- **+** Combined AMF; See Part D: Introduction and Applications Guide.

### Safety Effect of Regulated Parking on Urban Arterial Streets

**Exhibit 13-63: Safety Effects of Converting From Free to Regulated On-Street Parking**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident Type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert free to regulated parking</td>
<td>Urban Arterial</td>
<td>Unspecified</td>
<td>All types</td>
<td>0.94</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types</td>
<td>1.19</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Non-injury</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Base Condition:** Provision of free parking.

**Exhibit 13-64: Safety Effects of Implementing Time-Limited On-Street Parking**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident Type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implement time-limited parking restrictions</td>
<td>Urban Arterial and Collector</td>
<td>Unspecified</td>
<td>All types</td>
<td>0.81</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Parking-related accidents All severities</td>
<td>0.21</td>
<td>0.09</td>
</tr>
</tbody>
</table>

**Base Condition:** Absence of time-limited parking.
Safety Effect of Reducing Access Points on Urban and Suburban Arterial Streets

Exhibit 13-73: Safety Effects of Reducing Access Point Density

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Road type</th>
<th>Traffic Volume</th>
<th>Accident Type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce driveways from 48 to 26-49 per mi</td>
<td>Urban and suburban</td>
<td>Unspecified</td>
<td>All types Injury</td>
<td>0.71</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Arterial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce driveways from 26-48 to 10-24 per mi</td>
<td></td>
<td></td>
<td></td>
<td>0.69</td>
<td>0.02</td>
</tr>
<tr>
<td>Reduce driveways from 10-24 to less than 10 per mi</td>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Base Condition: Specific driveway densities based on values in this table (48, 26-49, and 10-24 per mi).

Notes: Based on international studies: Jensen 1963; Grindegaard 1976; Huusleif 1977; Amundsen 1979; Grindegaard 1979; Hovd 1979; Muskaug 1985

Bold text is used for the most reliable AMFs. These AMFs have a standard error of 0.1 or less.

Predicting Highway Safety for Multilane Urban Streets

Outcomes:

➡ Described human factors basis for design and operation of urban highways
➡ Described the Highway Safety Model base equation for prediction of Crash Performance
➡ Detailed the Quantitative safety effects of AMFs for various geometric conditions and their interaction with the base model
Questions and Discussion
Safety and Operational Effects of Geometric Design Features for Multilane Highways Workshop


- Session #5

Exercise II – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:

➤ Apply Urban/Suburban Multilane Crash Prediction model
➤ Compare predicted safety performance to actual safety performance
Exercise II – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

**IL 64, DuPage County, Illinois:**
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St. Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.
Exercise II – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Geometric Information:

Cross-Section:
- Four 12-foot wide lanes with double yellow centerline dividing the opposing directions of travel (Undivided)
  - 8 foot wide aggregate shoulders
  - 12 foot wide left turn lanes at all major intersections
- No left turn lanes at minor street intersections nor at commercial driveways
- Parking prohibited
- No highway illumination other than some minor intersection lighting by local municipalities and the County Highway Department

Exercise I – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Study Section:

Length of Section = 0.97 miles
ADT = 37,000 AADT
No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi
Driveways:
- Minor Residential driveways 7
- Minor commercial driveways (< 50 parking spaces) 7
- Major commercial driveways (> 50 parking spaces) 11
Total # of Driveways 25
Exercise II – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Study Section:

Number of Unsignalized Intersections with left turn lanes 0
Number of Unsignalized Intersections without turn lanes 9

Trees and Power poles 18.0 feet from edge of pavement with spacing of 160 foot apart, one side

Signalized Intersections:
- Bloomingdale Road 16,100 AADT
- Shopping Center (north and south) 2,400 AADT
- Main Street-Glen Ellyn 16,700 AADT

Exercise II – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Study Section:

<table>
<thead>
<tr>
<th></th>
<th>Total Crashes</th>
<th>Injury Crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rdwy Segment</td>
<td>200</td>
<td>62</td>
<td>136</td>
<td>64</td>
</tr>
<tr>
<td>Intersections:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloomingdale Rd</td>
<td>170</td>
<td>68</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Main St-Glen Ellyn</td>
<td>146</td>
<td>45</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td>Totals:</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>
Exercise II – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

1. Predict the Crash Performance for the segment using the *Suburban Multilane Undivided* model (4U) for the following:
   a. Base Model Multiple Vehicle Non-Driveway
   b. Base Model Single Vehicle Non-Driveway
   c. Driveway Related Crashes
   d. AMF's for Parking, Roadside Objects, and Lighting
   e. Predicted Crashes with AMF’s Applied
   f. Pedestrian Crashes
   g. Bicycle Crashes
   h. Total Predicted Crashes for Segment

Exercise II – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

From the Crash Prediction analysis, perform the following:

2. Is the actual Safety performance for the geometrics for IL 64 safer than predicted value?

   Substantive Safety Performance = ?
   Predicted Safety Performance = ?
   Safer than Predicted YES/NO?
Exercise II – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:

- Calculated Severity Rate
- Applied Rural Multilane Crash Prediction model
- Compared predicted safety performance to actual safety performance

Questions and Discussion
GROUP EXERCISE “II”

IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.

Cross-Section:
4 12-foot wide lanes with double yellow centerline dividing the opposing directions of travel
8 foot wide aggregate shoulders
12 foot wide left turn lanes at all major intersections

Study Section: Bloomingdale Road to Main Street-Glen Ellyn
Length of Section = 0.97 miles
ADT = 37,000 AADT
No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi

Driveways:
Residential driveways 7
Minor commercial driveways (less than 50 parking spaces) 7
Major commercial driveways (more than 50 parking spaces) 11
Total # of Driveways 25

Total number of Unsignalized Intersections with left turn lanes 0
Total number of Unsignalized Intersections without turn lanes 9
Mildred Av Diane Av
Virginia Av Evergreen Av
Bernice Av Amy Av
Western Ave Newton Ave
Pearl Ave

No left turn lanes at minor street intersections nor at commercial driveways
No highway illumination other than some minor intersection lighting by local municipalities and the County Highway Department
Parking is prohibited
Trees and Power poles 18.0 feet from edge of pavement; Hazard Rating of 5.0

Signalized Intersections:
Bloomingdale Road 16,100 AADT
Shopping Center (north and south) 2,400 AADT
Main Street-Glen Ellyn 16,700 AADT
## Actual Safety Performance:

3-years crash data 1986, 1987, 1988

<table>
<thead>
<tr>
<th>Segment</th>
<th>Total crashes</th>
<th>Injury crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloomingdale Road</td>
<td>200</td>
<td>62</td>
<td>136</td>
<td>64</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>170</td>
<td>68</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Main Street-Glen Ellyn</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>

1. Predict the Crash Performance for the following:

a. **Suburban Multilane Base Model Multiple Vehicle Non-Driveway:**

   \[
   N_{brmv} = e^{(a + b \ln ADT + \ln L)}
   \]

   \[
   = e^{(\text{[insert formula here]} + \text{[insert formula here]} + \ln \text{[insert formula here]})}
   \]

   \[
   = e^{(\text{[insert formula here]})}
   \]

   \[
   = \text{[insert crashes per year]}
   \]

b. **Suburban Multilane Base Model Single Vehicle Non-Driveway:**

   \[
   N_{brsv} = e^{(a + b \ln ADT + \ln L)}
   \]

   \[
   = e^{(\text{[insert formula here]} + \text{[insert formula here]} + \ln \text{[insert formula here]})}
   \]

   \[
   = e^{(\text{[insert formula here]})}
   \]

   \[
   = \text{[insert crashes per year]}
   \]
c. Driveway Related Crashes:

\[ N_{brdwy} = \text{SUM} \left( n_j N_j \left( \frac{ADT}{15,000} \right)^4 \right) \]

\[ = 11 \times 0.202 \left( \frac{37,000}{15,000} \right)^{1.172} + 7 \times 0.064 \left( \frac{37,000}{15,000} \right)^{1.172} + 0 \times 0.220 \left( \frac{37,000}{15,000} \right)^{1.172} \\
+ 0 \times 0.029 \left( \frac{37,000}{15,000} \right)^{1.172} + 0 \times 0.106 \left( \frac{37,000}{15,000} \right)^{1.172} + 7 \times 0.020 \left( \frac{37,000}{15,000} \right)^{1.172} \\
+ 0 \times 0.032 \left( \frac{37,000}{15,000} \right)^{1.172} \]

\[ = \text{crashes per year} \]

\[ N_{brbase} = N_{brmv(\text{non-driveway})} + N_{brsv(\text{non-driveway})} + N_{brdwy} \]

\[ = \text{crashes per year} \]

d. AMF’s for Parking, Roadside Objects, and Lighting:

\[ AMF_{1r} = 1 + P_{pk} \times (f_{pk} - 1.0) \]

Where parking is prohibited, Ppk is zero

\[ = 1 + \text{zero} \times (f_{pk} - 1.0) \]

\[ = 1.00 \]
\[ \text{AMF}_{2r} = f_{\text{offset}} \times D_{\text{fo}} \times p_{\text{fo}} + (1 - p_{\text{fo}}) \]

For power poles at 160 foot spacing one side located 18 feet from travel lane, \( f_{\text{offset}} = 0.061 \quad p_{\text{fo}} = 0.037 \)

\[ = \boxed{} \times \left( \frac{5280}{\boxed{}} \right) \times \boxed{} + (1 - \boxed{}) \]

\[ = \boxed{} \]

\[ \text{AMF}_{3r} = 1 - ((1 - 0.36 \, P_{\text{fnr}} - 0.72 \, p_{\text{inr}} - 0.83 \, p_{\text{pn}}) \, p_{\text{nr}}) \]

Base condition is no lighting, hence, \( \text{AMF}_{3r} = 1.000 \)

\[ = 1.00 \]

e. Predicted Crashes with AMF’s Applied

\[ N_{br} = N_{\text{br base}} \times \text{AMF}_{1r} \times \text{AMF}_{2r} \times \text{AMF}_{3r} \]

\[ = \boxed{} \times \boxed{} \times \boxed{} \times \boxed{} \]

\[ = \boxed{} \text{ crashes per year} \]
f. Pedestrian Crashes

\[ N_{\text{pedr}} = N_{\text{br}} \times f_{\text{pedr}} \quad \text{for 4U, } f_{\text{pedr}} = 0.008 \]

\[ = \quad \times \quad \]

\[ = \quad \text{crashes per year} \]

g. Bicycle Crashes

\[ N_{\text{biker}} = N_{\text{br}} \times f_{\text{biker}} \quad \text{for 4U, } f_{\text{biker}} = 0.01 \]

\[ = \quad \times \quad \]

\[ = \quad \text{crashes per year} \]

h. Base Roadway Crashes for Segment (multilane Suburban 4U)

\[ N_{\text{br}} = N_{\text{br}} + N_{\text{pedr}} + N_{\text{biker}} \]

\[ = \quad + \quad + \quad \]

\[ = \quad \text{crashes per year} \]
Is the Actual Safety Performance for the geometrics for IL 64 (Driveway, Parking, and Lighting) safer than predicted value?

Actual Safety Performance = 200 crashes in 3 years

= 66.7 crashes per year

Predicted Segment Crashes per year =

Safer than predicted value? Yes or No?
Safety and Operational Effects of Geometric Design Features for Multilane Highways Workshop

Predicting Highway Safety for Intersections on Multilane Highways

- Session #6

Outcomes:

- Detail the Quantitative safety research on Intersections
- Describe the HSM Models for prediction of Intersection Crash Performance
U.S. Intersection Fatal Crashes

- 44% rural
- 56% urban
- 63% on arterials
- 19% on collectors
- 18% on local roads
- 43% at unsignalized intersections
- 16 - 20% due to red light running
- 57% at signalized intersections

2006 U.S. National Total Crash Characteristics

<table>
<thead>
<tr>
<th>Crash Type</th>
<th>Total Crashes</th>
<th>Fatalties + Injury Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Percent</td>
</tr>
<tr>
<td>Non-Intersection</td>
<td>2,826,900</td>
<td>47%</td>
</tr>
<tr>
<td>Stop and No Control Intersection</td>
<td>1,955,467</td>
<td>33%</td>
</tr>
<tr>
<td>Signalized Intersection</td>
<td>1,181,848</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>5,964,000</td>
<td>100%</td>
</tr>
</tbody>
</table>
### Yearly Average Number of FATAL Intersection Crashes By Rural/Urban and Traffic Control Type - (2002 - 2006)

<table>
<thead>
<tr>
<th>Type</th>
<th>Fatal crashes/Year</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalized Urban</td>
<td>2303</td>
<td>23.0%</td>
</tr>
<tr>
<td>Signalized Rural</td>
<td>380</td>
<td>3.8%</td>
</tr>
<tr>
<td>Unsignalized Urban</td>
<td>3580</td>
<td>35.7%</td>
</tr>
<tr>
<td>Unsignalized Rural</td>
<td>3585</td>
<td>35.8%</td>
</tr>
<tr>
<td>Other urban</td>
<td>92</td>
<td>0.9%</td>
</tr>
<tr>
<td>Other Rural</td>
<td>86</td>
<td>0.9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10026</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

### National Crash Characteristics

#### F/I YEARLY AVERAGE CRASHES RELATED TO JUNCTION BY TRAFFIC CONTROL (2002-2006)

<table>
<thead>
<tr>
<th>Type</th>
<th>Average</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signalized</td>
<td>427,115</td>
<td>41%</td>
</tr>
<tr>
<td>Unsignalized</td>
<td>577,657</td>
<td>55%</td>
</tr>
<tr>
<td>Other</td>
<td>46,758</td>
<td>4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,051,530</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Severity Index

Severity index (SI) is the ratio of crashes involving an injury or fatality to total crashes.

<table>
<thead>
<tr>
<th>Accident severity level</th>
<th>Proportion of total accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadway segments</td>
<td>Intersections</td>
</tr>
<tr>
<td>Fatal and injury</td>
<td>0.321</td>
</tr>
<tr>
<td>Property damage only</td>
<td>0.679</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.000</td>
</tr>
</tbody>
</table>
Definition of Segments and Intersections

- **Major intersections** are intersections between the highway segment being analyzed and other primary roads, such as major and minor arterials, or major collectors, and where traffic volumes (ADT) are available on all approaches. The latter requirement is extremely important, as the application of the intersection procedures requires ADT on all intersection approaches.

- All other intersections are then referred to as **minor intersections**, generally intersections between the facility being analyzed and minor collectors, local roads, access driveways, or any intersection for which traffic volumes (ADT) are not available on approaches intersecting the facility being analyzed (it is assumed that ADT is available for the facility being analyzed).

- **Segments** are defined as portions of the facility delimited by major intersections or significant changes in the roadway cross-section, geometric characteristics of the facility, or the surrounding land uses. Roadway segments can be either undivided or divided.
Definition of an Intersection

Exhibit 14-3: Elements of the functional area of an intersection

Three Basic Elements
1. Perception-reaction distance;
2. Maneuver distance; and,
3. Queue-storage distance.

Definition of Intersection Crashes

- Crashes are assigned to either a major/minor intersection or a segment.
- Use the following two criteria to define intersection and intersection-related crashes:
  1. All crashes that occur with the curb line limits if an intersection (Region A) are assigned to that intersection
  2. Crashes that occur on an intersection leg within 250 ft of an intersection (Region B) are assigned to either the roadway segment on which they occur or the intersection depending on their characteristics.
  3. Crashes that are classified on the crash report as intersection-related or have characteristics consistent with an intersection-related crash have been assigned to the intersection (such as rear-end crashes related to queues on an intersection approach).
Safety Predictions for Rural Multilane Intersections

Intersection Crash Frequency Equations (Models)

- From research on the largest crash data bases of the states
- Uses:
  - Provide basis for identifying “high crash” sites (calibration to local conditions)
  - Assess quantitative safety benefits of intersection improvements
  - Develop crash Modification Factors for intersection improvements
Combining Safety Predictions for an Entire Rural Multilane Segment

\[ N_t = \text{Sum } N_{\text{rs}} + \text{Sum } N_{\text{int}} \]

Where:

\( N_t \) = Predicted crash frequency for the entire rural facility
\( N_{\text{rs}} \) = Predicted number of total roadway segment crashes per year after application AMFs
\( N_{\text{int}} \) = Predicted number of total intersection-related crashes per year after application of the AMFs

Predicting Safety Performance for Rural Multilane At-Grade Intersections

Procedure for safety prediction for At-Grade Intersections: Combine base models, AMFs, and calibration factor

\[ N_{\text{int}} = N_{\text{bibase}} (\text{AMF}_{\text{i1}} \times \text{AMF}_{\text{i2}} \times \cdots \times \text{AMF}_{\text{ni}})C_i \]

\[ N_{\text{bibase}} = \exp(a + b \ln(\text{ADT}_{\text{maj}}) + c \ln(\text{ADT}_{\text{min}})) \]
Predicting Safety Performance for Rural Multilane At-Grade Intersections

Base Models and Adjustment Factors addresses three types of Intersections:
1) Three-leg intersections with STOP control on the minor road approach (3ST)
2) Four-leg intersections with STOP control on the minor-road approaches (4ST)
3) Four-leg signalized intersection (4SG)

- Used for both divided and undivided rural four-lane highways

Geometric Features Related to Substantive Safety at Intersections

- Configuration - Number of Legs
- Access near Intersections
- Median Openings for U-Turns and Left-Turns
- Left and Right Turn Lanes
- Shoulder Widening
- Intersection Sight Distance
- Angle of Intersection (Skew)
- Lighting
- Intersection Designs - Roundabouts
**Predicting Safety Performance for Rural Multilane At-Grade Intersections**

**Base Model for Rural Multilane Intersections:**

\[ N_{bibase} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

Where:
- \( N_{bibase} \) = expected number of intersection-related crashes per year for base conditions
- \( ADT_{maj} \) = average daily traffic volume for the major road (vpd)
- \( ADT_{min} \) = average daily traffic volume for the minor road (vpd)
- \( a, b, \) and \( c \) = regression coefficients from Exhibit 11-23

---

**Predicting Safety Performance for Rural Multilane Stop-Controlled Intersections**

\[ N_{bibase} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

**Exhibit 11-23: Base Models for Three- and Four-leg Intersections with Minor-Road Stop Control for Total and KAB Injury Incidents (Based on Equation 11-13a)**

<table>
<thead>
<tr>
<th>Intersection type/severity level</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>Overdispersion parameter (fixed ( K ))</th>
<th>Base conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>4ST Total</td>
<td>-10.714</td>
<td>0.848</td>
<td>0.448</td>
<td>0.494</td>
<td>No turn lanes; no illumination; median on major road; adequate sight distance; angle between -5° and +5°</td>
</tr>
<tr>
<td>4ST Injury</td>
<td>-11.440</td>
<td>0.828</td>
<td>0.412</td>
<td>0.655</td>
<td></td>
</tr>
<tr>
<td>3ST Total</td>
<td>-13.098</td>
<td>1.204</td>
<td>0.230</td>
<td>0.460</td>
<td></td>
</tr>
<tr>
<td>3ST Injury</td>
<td>-12.681</td>
<td>1.043</td>
<td>0.228</td>
<td>0.566</td>
<td></td>
</tr>
</tbody>
</table>

a. The models above could also be used for rural multilane highways without median (undivided) after proper calibration.
Predicting Safety Performance for Rural Multilane Signalized Intersections

\[ N_{\text{bibase}} = \exp(a + b \ln(ADT_{\text{maj}}) + c \ln(ADT_{\text{min}})) \]

Exhibit 11–24: Base Models for Four-leg Signalized Intersections for Total and KAB Injury Accidents (Based on Equations 11-13a and 11-13b)

<table>
<thead>
<tr>
<th>Intersection type/severity level</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>Overdispersion parameter (fixed ( k ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4SG Total</td>
<td>-7.423</td>
<td>0.722</td>
<td>0.332</td>
<td>0.277</td>
<td></td>
</tr>
<tr>
<td>4SG Injury</td>
<td>-12.252</td>
<td></td>
<td>1.279</td>
<td>0.566</td>
<td></td>
</tr>
</tbody>
</table>

Safety Prediction for a Rural Multilane Intersection: EXAMPLE

Four-Leg Stop-Controlled Intersection:

- 10,000 ADT and 2,500 ADT

\[ N_{\text{bibase}} = \exp(a + b \ln(ADT_{\text{maj}}) + c \ln(ADT_{\text{min}})) \]

\[ N = \exp(-10.714 + 0.848 \ln(10,000)) + 0.448 \ln(2,500) \]

\[ = \exp(-10.714 + 7.810 + 3.505) \]

\[ = \exp(0.6015) \]

\[ = 1.825 \text{ crashes per year} \]
Session 6 – Predicting Highway Safety Performance for Intersections

Safety Prediction for a Rural Multilane Intersection: EXERCISE

Four-Leg Signalized Intersection:
- 10,000 ADT and 2,500 ADT

\[
N_{bibase} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min}))
\]

\[
N = \exp(-7.423 + 0.722 \ln(10,000)) + 0.337 \ln(2,500)
= \exp(-7.423 + 6.650 + 2.637)
= \exp(1.864)
= ?
\]

Effect of Angle or Skew

- Some studies (McCoy, for example) show adverse effect of skew
- Skews increase exposure time to crashes; increase difficulty of driver view at stopped approach
**Rural Multilane Intersection**

**AMF for Intersection Skew Angle**

3- legged Intersections (Stop-Control) on Minor Approach:

\[
AMF_{1i} = 1 + \frac{(0.016 \text{Skew})}{(0.98 + 0.16 \text{Skew})}
\]

4- legged Intersections (Stop –Control) on Minor Approach:

\[
AMF_{1i} = 1 + \frac{(0.053 \text{Skew})}{(1.43 + 0.53 \text{Skew})}
\]

- AMF1i = AMF for the effect of intersection skew on total crashes
- SKEW = Intersection Angle (degrees) as difference (absolute value) between 90 degrees and actual intersection angle

---

**Solutions to Skewed Intersections**

*NCHRP 500, Strategy 17.1 B16 – Realign Intersection Approaches*
Solutions to Skewed Intersections

- Locate Intersection at Mid-Point of Curve

*NCHRP 500, Strategy 17.1 B16 – Realign Intersection Approaches

Safety Prediction for Intersection Skew Angle at a Rural Multilane Intersection: EXAMPLE

3-Leg Stop-Controlled Intersection:

- Skew Angle = 35 degrees

\[
AMF_{1i} = 1 + \left[\frac{0.016}{0.98 + 0.16 \times 35}\right]
\]

\[
AMF_{1i} = 1 + \left[\frac{0.016}{0.98 + 0.16 \times 35}\right] = 1 + 0.0851 = 1.085
\]
Safety Prediction for Intersection Skew Angle for a Rural Multilane Intersection: EXERCISE

4-Leg Stop-controlled Intersection:

- Skew Angle = 35 degrees

\[
AMF_{ii} = 1 + \left[\frac{0.053\text{Skew}}{1.43 + 0.16\text{Skew}}\right]
\]

\[
AMF_{ii} = 1 + \left[\frac{(0.053)(35)}{1.43 + (0.53)(35)}\right]
\]

\[
= 1 + \left(\frac{1.86}{19.98}\right)
\]

\[
= 1 + 0.0928
\]

\[
= ?
\]

Predicting Safety Performance for Rural Intersections

Additional AMF’s on Safety Effects:

- Providing Left-Turn Lanes
- Providing Right-Turn Lanes
- Converting Two-Way Stop to All-Way Stop Control
- Converting Conventional Intersection to Modern Roundabout
- Providing Access Control
Left Turn Lanes for Multilane Highways

- Left turn lanes remove stopped traffic from through lanes
  - mitigate rear-end conflict
  - enable selection of safe gap

- “Capacity” is generally not the issue

*NCHRP 500, Strategy 17.1 B1 – Provide Left-Turn Lanes

AMFs for Presence of Left-Turn Lanes at Rural Multilane Intersections:

Exhibit 11-29: Accident Modification Factors (AMFs) for Installation of Left-Turn Lanes on Intersection Approaches.

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Intersection traffic control</th>
<th>Number of approaches with left-turn lanes a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One approach</td>
</tr>
<tr>
<td>Three-leg</td>
<td>Minor-road STOP control b</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.85</td>
</tr>
<tr>
<td>Four-leg</td>
<td>Minor-road STOP control b</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.82</td>
</tr>
</tbody>
</table>

* 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.
Offset Left-Turn Lane Geometry

*NCHRP 500, Strategy 17.2 B1 – Provide Positive Offset for Left-Turn Lanes

Florida DOT – very wide offsets

Ohio DOT
AMFs for Presence of Right-Turn Lanes at Rural Multilane Intersections:

**Exhibit 11-31: Accident Modification Factors (AMFs) for Installation of Right-Turn Lanes on Intersections Approaches.**

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Intersection traffic control</th>
<th>Number of approaches with right-turn lanes a</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One approach</td>
</tr>
<tr>
<td>Three-leg intersection</td>
<td>Minor-road STOP control b</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.96</td>
</tr>
<tr>
<td>Four-leg intersection</td>
<td>Minor-road STOP control b</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.96</td>
</tr>
</tbody>
</table>

* STOP-controlled approaches are not considered in determining the number of approaches with right-turn lanes.

b STOP sign present on minor-road approaches only.

AMFs for Lighting at Rural Multilane Intersections:

\[
AMF_{4i} = 1 - 0.38P_{ni}
\]

Where:

\[
AMF_{4i} = \text{AMF for the effect of lighting on total crashes}
\]

\[
P_{ni} = \text{proportion of total crashes for unlighted intersections that occur at night}
\]

[Note: Values for this table will be provided in Draft 3]
AMFs for Providing Intersection Lighting:

**AMFs for Providing Intersection Lighting:**

**Exhibit 14-25:** Safety Effects of Providing Highway Illumination

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide intersection illumination</td>
<td>All settings All types</td>
<td>Unspecified</td>
<td>All types Nighttime Injury excluding Fatal</td>
<td>0.62</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*Base Condition: An intersection without lighting*

**NOTE:**

Bold text is used for the most reliable AMFs. These AMFs have a standard error of 0.1 or less.

**AMF applies to injury crashes only**

AMFs for Converting Minor - Road Stop Control to All-Way Stop Control:

**Exhibit 14-10:** Safety Effects of Converting Minor-Road Stop-Control to All-way Stop-Control

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert minor-road stop control to all-way stop control</td>
<td>Rural MUTCD warrants are not</td>
<td>All types All severities</td>
<td>0.52</td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

*Base Condition: Intersection with minor-road stop control meeting MUTCD warrants for an all-way stop controlled intersection.*
### AMFs for Converting Signalized Intersection to Modern Roundabout:

#### Exhibit 14-8: Safety Effects of Converting Signalized Intersections into Modern Roundabout

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting/Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type/Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert signalized intersection to modern roundabout</td>
<td>All settings/One or Two lanes</td>
<td>All types/All severities</td>
<td>0.52</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All types/injury</td>
<td>0.22</td>
<td>0.07</td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Signalized intersection

### AMFs for Converting Stop-Controlled Intersection to Modern Roundabout:

#### Exhibit 14-9: Safety Effects of Converting Stop-Controlled Intersections to Modern Roundabout

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting/Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type/Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert stop-controlled intersection to modern roundabout</td>
<td>All settings/One or Two lanes</td>
<td>All types/All severities</td>
<td>0.59</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All types/Injury</td>
<td>0.18</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Rural/One lane</td>
<td>All types/All severities</td>
<td>0.29</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban/One or Two lanes</td>
<td>All types/All severities</td>
<td>0.13</td>
<td>0.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban/One lane</td>
<td>All types/All severities</td>
<td>0.21</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban/One or Two lanes</td>
<td>All types/All severities</td>
<td>0.19</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Stop-controlled intersection
**AMF for Access Control for Rural Intersections**

*From TTI synthesis*

**Unsignalized Intersections:**

\[ AMF_{nd} = e^{0.056 \times (dn - 3)} \]

**Signalized Intersections:**

\[ AMF_{nd} = e^{0.046 \times (dn - 3)} \]

Where:

- \( dn \) = Number of driveways on both the major and minor road approaches within 250 feet of the intersection
- Default value = 3 driveways

**Prediction of AMF for an Unsignalized Intersection - Example:**

For 4 driveways on US route and 3 driveways on County Route

\[
AMF_{nd} = e^{0.056 \times (7 - 3)} \\
= e^{0.056 \times 4} \\
= 1.251
\]
Question:

What is the AMF for a rural Multilane Unsignalized Intersection with 8 driveways within 250 feet?

\[ \text{AMF}_{nd} = e^{0.056 \times (dn-3)} \]

\[ = ? \]

a) 0.560  

b) 1.560  

c) 1.056  

d) 1.323

Safety Prediction for a Rural Multilane Intersection: EXERCISE

4-Leg Signalized Intersection:

- 10,000 ADT and 2,500 ADT, 35 Deg Skew, left-turn lane on major road, use default values

\[ N_{bibase} = 6.447 \quad N_{1i(skew)} = ? \quad N_{2i(lt-trn)} = ? \]

\[ N_{int} = N_{bibase} \times (\text{AMF}_{1i} \times \text{AMF}_{2i} \times \ldots \times \text{AMF}_{ni})C_i \]

\[ = 6.447 \times (\text{AMF}_{1i(skew)} \times \text{AMF}_{2i(lt-trn)})(1.0) \]

\[ = 6.447 \times (\ldots) \]

\[ = ? \text{ crashes per year} \]
Safety Prediction for a Rural Multilane Intersection: EXERCISE

4-Leg Signalized Intersection:
➢ 10,000 ADT and 2,500 ADT, 35 Deg Skew, left-turn lane on major road, use default values

\[ N_{\text{bibase}} = 6.447 \quad N_{1i(\text{skew})} = 1.00 \quad N_{2i(\text{lt-trn})} = 0.82 \]

\[ N_{\text{int}} = N_{\text{bibase}} \left( AMF_{1i} \times AMF_{2i} \times \ldots \times AMF_{ni}\right)(1.0) \]

\[ = 6.447 \left( AMF_{1i(\text{skew})} \times AMF_{2i(\text{lt-trn})}\right) \]

\[ = 6.447 \left( 1.00 \times 0.82\right) \]

\[ = \ ? \text{ crashes per year} \]

Safety Predictions for Urban/Suburban Multilane Intersections
Predicting Safety Performance for Urban/Suburban At-Grade Intersections

Procedure for safety prediction for At-Grade Intersections: Combine base models, AMFs, and calibration factor

\[ N_{\text{int}} = (N_{\text{bi}} + N_{\text{pedi}} + N_{\text{bikei}}) C_i \]

\[ N_{\text{bi}} = N_{\text{bibase}} (AMF_{1i} \times AMF_{2i} \times \ldots \times AMF_{ni}) \]

\[ N_{\text{bibase}} = N_{\text{bimv}} + N_{\text{bisv}} \]

Where:
- \( N_{\text{int}} \) = Predicted number of total intersection crashes per year after application of AMF's
- \( N_{\text{bi}} \) = Predicted number of total intersection crashes per year (excluding ped and bike crashes)
- \( N_{\text{pedi}} \) = Predicted number of vehicle-ped crashes per year
- \( N_{\text{bikei}} \) = Predicted number of vehicle-bicycle collisions per year
- \( C_i \) = calibration factor for a particular geographical area
Predicting Safety Performance for Urban/Suburban At-Grade Intersections

\[ N_{bi} = N_{bibase} \left( AMF_{1i} \ AMF_{2i} \ \ldots \ AMF_{ni} \right) \]

Where:

- \( N_{bi} = \) Predicted number of total roadway segment crashes per year with AMFs applied
- \( N_{bibase} = \) Predicted number of total roadway segment crashes per year for base conditions
- \( AMF_{1i}, AMF_{2i}, \ldots, AMF_{ni} = \) Accident (Crash) modification factors for intersections

\[ N_{bibase} = N_{bimv} + N_{bisv} \]

Where:

- \( N_{bibase} = \) predicted number of total intersection-related crashes for base conditions (excludes pedestrians and bicycle related crashes)
- \( N_{bimv} = \) Predicted number of multiple-vehicle crashes per year for base conditions
- \( N_{bisv} = \) Predicted number of single-vehicle crashes per year for base conditions
Base Models and Adjustment Factors addresses four types of Intersections:

1) Three-leg intersections with STOP control on the minor road approach (3ST)
2) Three-leg signalized intersections (3SG)
3) Four-leg intersections with STOP control on the minor-road approaches (4ST)
4) Four-leg signalized intersection (4SG)

### Base Models for Urban/Suburban 2-Lane Intersections

\[ N = e^{a} \times \text{AADT}_{\text{major}}^{b} \times \text{AADT}_{\text{minor}}^{c} \]

<table>
<thead>
<tr>
<th>Two-Lane Urban</th>
<th>Control Type</th>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban 3 App</td>
<td>Signal</td>
<td>-9.85</td>
<td>0.97</td>
<td>0.18</td>
</tr>
<tr>
<td>Urban 4 App</td>
<td>TWSC</td>
<td>-3.12</td>
<td>0.27</td>
<td>0.16</td>
</tr>
<tr>
<td>Urban 4 App</td>
<td>Signal</td>
<td>-3.47</td>
<td>0.42</td>
<td>0.14</td>
</tr>
</tbody>
</table>
### Urban/Suburban Two-Lane Streets: Exercise Problem

- 4 Approach Intersection – 8,500 ADT and 3,500 ADT - Currently a 2-way STOP; What is safety effect of Signalizing?

<table>
<thead>
<tr>
<th>Urban</th>
<th>SPF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two-Way Stop</td>
<td>?</td>
</tr>
<tr>
<td>Signalized</td>
<td>?</td>
</tr>
</tbody>
</table>

### Base Models for Urban/Suburban Multilane Intersections

Four types of Collisions are considered:

1) Multiple-vehicle collisions
2) Single-vehicle collisions
3) Vehicle-pedestrian collisions
4) Vehicle-bicycle collisions
Predicting Safety Performance for Urban/Suburban Multilane Intersections

**Multiple-Vehicle NonDriveway Crashes**

\[ N_{bimv} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

Where:
- \( N_{bimv} \) = expected number of multiple vehicle intersection-related crashes per year for base conditions
- \( ADT_{maj} \) = average daily traffic volume for the major road (vpd)
- \( ADT_{min} \) = average daily traffic volume for the minor road (vpd)
- \( a, b, \) and \( c \) = regression coefficients from Exhibit 12-14

---

**Multiple-Vehicle Crashes**

\[ N_{bimv} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

Exhibit 12-14: Base Models for Multiple-Vehicle Collisions at Intersections

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Coefficients used in Equation 12-22</th>
<th>Over-dispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>( ADT_{maj} ) (b)</td>
</tr>
<tr>
<td>Total accidents</td>
<td>-13.39</td>
<td>1.11</td>
</tr>
<tr>
<td>3ST</td>
<td>-11.63</td>
<td>1.11</td>
</tr>
<tr>
<td>3SG</td>
<td>-8.97</td>
<td>0.82</td>
</tr>
<tr>
<td>4ST</td>
<td>-10.63</td>
<td>1.07</td>
</tr>
</tbody>
</table>
Predicting Safety Performance for Urban/Suburban Multilane Intersections

**Single-Vehicle NonDriveway Crashes**

\[ N_{bisv} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

Where:

- \( N_{bisv} \) = expected number of single vehicle intersection-related crashes per year for base conditions
- \( ADT_{maj} \) = average daily traffic volume for the major road (vpd)
- \( ADT_{min} \) = average daily traffic volume for the minor road (vpd)
- \( a, b, \) and \( c \) = regression coefficients from Exhibit 12-14
### Single-Vehicle Crashes

\[ N_{biv} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

#### Exhibit 12-16: Base Models for Single-Vehicle Accidents at Intersections

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Coefficients used in Equation 12-25</th>
<th>Over-dispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
<td>ADT_{maj} (b)</td>
</tr>
<tr>
<td>Total accidents</td>
<td>-6.84</td>
<td>0.16</td>
</tr>
<tr>
<td>3ST</td>
<td>-8.52</td>
<td>0.42</td>
</tr>
<tr>
<td>3SG</td>
<td>-5.40</td>
<td>0.33</td>
</tr>
<tr>
<td>4ST</td>
<td>-9.85</td>
<td>0.68</td>
</tr>
<tr>
<td>4SG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Fatal-and-Injury accidents

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Coefficients used in Equation 12-25</th>
<th>Over-dispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total accidents</td>
<td>-6.84</td>
<td>0.16</td>
</tr>
<tr>
<td>3ST</td>
<td>-8.52</td>
<td>0.42</td>
</tr>
<tr>
<td>3SG</td>
<td>-5.40</td>
<td>0.33</td>
</tr>
<tr>
<td>4ST</td>
<td>-9.85</td>
<td>0.68</td>
</tr>
<tr>
<td>4SG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Property-damage-only accidents

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Coefficients used in Equation 12-25</th>
<th>Over-dispersion parameter (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total accidents</td>
<td>-8.39</td>
<td>0.25</td>
</tr>
<tr>
<td>3ST</td>
<td>-8.58</td>
<td>0.45</td>
</tr>
<tr>
<td>3SG</td>
<td>-7.11</td>
<td>0.36</td>
</tr>
<tr>
<td>4ST</td>
<td>-10.98</td>
<td>0.78</td>
</tr>
<tr>
<td>4SG</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Safety Prediction for Base Crashes at an Urban Multilane Intersection: EXAMPLE

Four-Leg Signalized Intersection:

➢ 25,000 ADT and 5,000 ADT

\[ N_{bibase} = N_{bimv} + N_{bisv} \]

Where:

- \( N_{bimv} \): Predicted number of multiple-vehicle crashes per year for base conditions
- \( N_{bisv} \): Predicted number of single-vehicle crashes per year for base conditions

Safety Prediction for Multiple Vehicle Crashes at an Urban Multilane Intersection: EXAMPLE

Four-Leg Signalized Intersection:

➢ 25,000 ADT and 5,000 ADT

\[ N_{bimv} = \exp(a + b \ln(ADT_{maj}) + c \ln(ADT_{min})) \]

\[ N_{bimv} = \exp(-10.63 + 1.07\ln(25,000)) + 0.23\ln(5,000) \]

= \exp(-10.63 + 10.84 + 1.959)

= \exp(2.164)

= 8.71 crashes per year
Safety Prediction for Single Vehicle Crashes at an Urban Multilane Intersection: EXAMPLE

Four-Leg Signalized Intersection:
- 25,000 ADT and 5,000 ADT

\[ N_{\text{bisv}} = \exp(a + b \ln(\text{ADT}_{\text{maj}}) + c \ln(\text{ADT}_{\text{min}})) \]

\[ N_{\text{bisv}} = \exp(-9.85 + 0.68 \ln(25,000)) + 0.27 \ln(5,000) \]

\[ = \exp(-9.85 + 6.89 + 2.30) \]

\[ = \exp(-0.664) \]

\[ = 0.51 \text{ crashes per year} \]

Predicting Safety Performance for Urban/Suburban At-Grade Intersections

\[ N_{\text{bibase}} = N_{\text{bimv}} + N_{\text{bisv}} \]

Where:
- \( N_{\text{bibase}} \) = predicted number of total intersection-related crashes for base conditions (excludes pedestrians and bicycle related crashes)
- \( N_{\text{bimv}} \) = Predicted number of multiple-vehicle crashes per year for base conditions
- \( N_{\text{bisv}} \) = Predicted number of single-vehicle crashes per year for base conditions
Safety Prediction for Base Crashes at an Urban Multilane Intersection: EXAMPLE

Four-Leg Signalized Intersection:
- 25,000 ADT and 5,000 ADT

\[
N_{bibase} = N_{bimv} + N_{bisv}
\]

\[
N_{bibase} = 8.71 + 0.51
\]

\[
= 9.22 \text{ crashes per year}
\]

Predicting Safety Performance for Urban/Suburban At-Grade Intersections

\[
N_{bi} = N_{bibase} (AMF_{1i} AMF_{2i} \ldots AMF_{ni})
\]

Where:
- \( N_{bi} = \) Predicted number of total roadway segment crashes per year with AMFs applied
- \( N_{bibase} = \) Predicted number of total roadway segment crashes per year for base conditions
- \( AMF_{1i}, AMF_{2i}, .. AMF_{ni} = \) Accident (Crash) modification factors for intersections
### AMFs for Presence of Left-Turn Lanes at Urban/Suburban Multilane Intersections:

#### Exhibit 12-22: Accident Modification Factor (AMF$_{a}$) for Installation of Left-Turn Lanes on Intersection Approaches

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Intersection traffic control</th>
<th>Number of approaches with left-turn lanes*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One approach</td>
</tr>
<tr>
<td>Three-leg intersection</td>
<td>Minor-road STOP control</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.03</td>
</tr>
<tr>
<td>Four-leg intersection</td>
<td>Minor-road STOP control</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>Traffic signal</td>
<td>0.90</td>
</tr>
</tbody>
</table>

* STOP-controlled approaches are not considered in determining the number of approaches with left-turn lanes.

* Stop signs present on minor-road approaches only.

### AMFs for Type of Left-Turn Signal Phasing at Urban/Suburban Multilane Intersections:

#### Exhibit 12-23: Accident Modification Factor (AMF$_{a}$) for Type of Left-turn Signal Phasing

<table>
<thead>
<tr>
<th>Type of left-turn signal phasing</th>
<th>AMF$_{a}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permissive</td>
<td>1.00</td>
</tr>
<tr>
<td>Protected (permissive or protected)</td>
<td>0.99</td>
</tr>
<tr>
<td>Protected (protected)</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Note: Use AMF$_{a}$ = 1.00 for all unsignalized intersections. If several approaches to a signalized intersection have left-turn phasing, the values of AMF$_{a}$ for each approach should be multiplied together.

If several approaches have left-turn phasing:

- AMF values for each approach should be multiplied together
AMFs for Presence of Right-Turn Lanes at Urban/Suburban Multilane Intersections:

Exhibit 12-24: Accident Modification Factor (AMF_{4i}) for

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Type of traffic control</th>
<th>Number of approaches with right-turn lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>One approach</td>
</tr>
<tr>
<td>Three-leg intersection</td>
<td>Minor-road STOP control/ Traffic signal</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.96</td>
</tr>
<tr>
<td>Four-leg intersection</td>
<td>Minor-road STOP control/ Traffic signal</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.96</td>
</tr>
</tbody>
</table>

- STOP-controlled approaches are not considered in determining the number of approaches with right-turn lanes.
- STOP signs present on minor road approaches only.

AMF for Prohibiting Right-Turn On Red at Urban/Suburban Multilane Intersections:

\[ \text{AMF}_{4i} = (0.98)^{n_{\text{prohib}}} \]

Where,

\[ \text{AMF}_{4i} = \text{AMF for the effect of prohibiting right turns on red on total crashes} \]

\[ n_{\text{prohib}} = \text{number of signalized intersection approaches for which right turn on red is prohibited} \]

- Example: For 2 approaches, \( n=2 \)

\[ \text{AMF}_{4i} = (0.98)^2 = 0.96 \]
AMFs for Lighting at Urban/Suburban Multilane Intersections:

\[ \text{AMF}_{5i} = 1 - 0.38P_{ni} \]

Where:

\[ \text{AMF}_{5i} = \text{AMF for the effect of lighting on total crashes} \]
\[ P_{ni} = \text{proportion of total crashes for unlighted intersections that occur at night} \]

<table>
<thead>
<tr>
<th>Intersection Type</th>
<th>Proportion of accidents that occur at night</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ST</td>
<td>VALUES</td>
</tr>
<tr>
<td>4ST</td>
<td>FORTHCOMING</td>
</tr>
<tr>
<td>4SG</td>
<td></td>
</tr>
</tbody>
</table>

[Note: Values for this table will be provided in Draft 3]

AMFs for Providing Intersection Lighting:

Exhibit 14-25: Safety Effects of Providing Highway Illumination

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide Intersection illumination</td>
<td>All settings All types</td>
<td>Unspecified</td>
<td>All types Nighttime Injury excluding Fatal</td>
<td>0.62</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pedestrian Nighttime Injury</td>
<td>0.58</td>
<td>0.2*</td>
</tr>
</tbody>
</table>

Base Condition: An intersection without lighting

NOTE:

Bold text is used for the most reliable AMFs. These AMFs have a standard error of 0.1 or less.

AMF applies to nighttime injury crashes only
AMF for Lighting * From earlier editions of HSM

\[
AMF_{5i} = 1 - ((1 - 0.36 P_{fni} - 0.72 p_{ini} - 0.83 p_{pni}) p_{ni})
\]

Where:

- \( P_{fni} \) = proportion of total nighttime crashes for unlighted intersections that involve a fatality
- \( p_{ini} \) = proportion of total nighttime crashes for unlighted intersections that involve a nonfatal injury
- \( p_{pni} \) = proportion of total nighttime crashes for unlighted intersections that involve PDO crashes only
- \( p_{ni} \) = proportion of total crashes for unlighted intersections that occur at night

AMF for Intersection Lighting * From earlier editions of HSM

\[
AMF_{5i} = 1 - ((1 - 0.36 P_{fnr} - 0.72 p_{inr} - 0.83 p_{pnr}) p_{nr})
\]

These are default values for nighttime crash proportions; replace with local information

If light installation increases the density of roadside fixed objects, adjust AMF_{2r}

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Proportion of total nighttime accidents by severity level</th>
<th>Proportion of accidents that occur at night</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal ( p_{f} )</td>
<td>Injury ( p_{i} )</td>
</tr>
<tr>
<td>3ST</td>
<td>0.001</td>
<td>0.334</td>
</tr>
<tr>
<td>3SG</td>
<td>0.001</td>
<td>0.393</td>
</tr>
<tr>
<td>4ST</td>
<td>0.040</td>
<td>0.860</td>
</tr>
<tr>
<td>4SG</td>
<td>0.003</td>
<td>0.328</td>
</tr>
</tbody>
</table>
**AMF for Lighting**

*Example: For 4 Approach Signalized Intersection Signalized (4SG) with no lighting:*

\[
\text{AMF}_{5i} = 1 - \left( (1 - 0.36 \ p_{\text{fnr}} - 0.72 \ p_{\text{lnr}} - 0.83 \ p_{\text{pnr}}) \ p_{\text{nr}} \right) \\
= 1 - \left( (1 - 0.36 \times 0.003 - 0.72 \times 0.328 - 0.83 \times 0.670) \times 0.200 \right) \\
= 1.00 \text{ as the base condition is unlit}
\]

*Example: For 4 Approach Signalized Intersection Signalized (4SG) with lighting:*

\[
\text{AMF}_{5i} = 1 - \left( (1 - 0.36 \ p_{\text{fnr}} - 0.72 \ p_{\text{lnr}} - 0.83 \ p_{\text{pnr}}) \ p_{\text{nr}} \right) \\
= 1 - \left( (1 - 0.36 \times 0.003 - 0.72 \times 0.328 - 0.83 \times 0.670) \times 0.200 \right) \\
= 0.826
\]
Safety Prediction for an Urban Multilane Intersection applying AMFs: EXAMPLE

Four-Leg Signalized Intersection:
- 25,000 ADT and 5,000 ADT
- Lt & Rt Turn Lanes on Major Approaches
- Protected Left-Turn Phasing on Major Road

\[ N_{\text{bibase}} = 9.22 \text{ crashes/yr} \]

\[ \text{AMF}_{\text{lttrn}} = \ ? \quad \text{AMF}_{\text{rttrn}} = \ ? \quad \text{AMF}_{\text{prolf}} = \ ? \]

\[ N_{\text{bi}} = N_{\text{bibase}} \times (\text{AMF}_{1i} \times \text{AMF}_{2i} \times \ldots \times \text{AMF}_{ni}) \]
Four-Leg Signalized Intersection:
- 25,000 ADT and 5,000 ADT
- Lt & Rt Turn Lanes on Major Approaches
- Protected Left-Turn Phasing on Major Road

\[ N_{bi} = N_{bibase} (AMF_{1i} AMF_{2i} \ldots AMF_{ni}) \]
\[ = 9.22 (0.81 \times 0.92 \times 0.88) \]
\[ = 6.05 \text{ crashes per year} \]

Predicting Safety Performance for Urban/Suburban At-Grade Intersections

\[ N_{int} = (N_{bi} + N_{pedi} + N_{bikel}) C_i \]

Where:
- \( N_{int} \) = Predicted number of total intersection crashes per year after application of AMF's
- \( N_{bi} \) = Predicted number of total intersection crashes per year (excluding ped and bike crashes)
- \( N_{pedi} \) = Predicted number of vehicle-ped crashes per year
- \( N_{bikel} \) = Predicted number of vehicle-bicycle collisions per year
- \( C_i \) = calibration factor for a particular geographical area
Prediction of the Number of Vehicle-Pedestrian Collisions at Urban/Suburban Intersections:

Two Separate Procedures base on Intersection Type:

- **Signalized Intersections**
  \[ N_{pedi} = N_{pedbase}(AMF_{1p}AMF_{2p}AMP_{3p}) \]

- **Stop – Controlled Intersections**
  \[ N_{pedi} = N_{bi} \times f_{pedi} \]

Prediction of the Number of Vehicle-Pedestrian Collisions at **Signalized** Urban/Suburban Intersections:

\[ N_{pedi} = N_{pedbase} \times (AMF_{1p} \times AMF_{2p} \times AMF_{3p}) \]

Where,

- \( N_{pedbase} \) = predicted number of vehicle pedestrian collisions per year for base conditions
- \( AMF_{1p} \ldots AMF_{3p} \) = AMFs for vehicle-pedestrian collisions
Prediction of the Number of Vehicle-Pedestrian Collisions at Signalized Urban/Suburban Intersections:

\[ N_{\text{pedbase}} = \exp \left[ a + b \ln(ADT_{\text{tot}}) + c \ln(ADT_{\text{maj}}/ADT_{\text{min}}) + d \ln(\text{PedVol}) + e \, (n_{\text{lanesx}}) \right] \]

Where,

- \( ADT_{\text{tot}} \) = Sum of ADT for major and minor roads (vpd)
- \( \text{PedVol} \) = Sum of daily pedestrian volumes crossing each intersection leg (pedestrians/day)
- \( n_{\text{lanesx}} \) = Maximum # of traffic lanes crossed by peds
- \( a, b, c, d, e \) = regression coefficients, Exhibit 12-18

**Exhibit 12-18: Base Models for Vehicle-Pedestrian Collisions at Signalized Intersections**

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Coefficients used in Equation 12-30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intercept (a)</td>
</tr>
<tr>
<td>Total accidents</td>
<td>–6.60</td>
</tr>
<tr>
<td>3SG</td>
<td>–9.53</td>
</tr>
</tbody>
</table>

**Values for a, b, c, d, & e Regression Coefficients**
Predicting the Number of Vehicle-Pedestrian Collisions at Signalized Urban/Suburban Intersections:

\[ N_{\text{pedi}} = N_{\text{pedbase}} \times (\text{AMF}_{1p} \times \text{AMF}_{2p} \times \text{AMF}_{3p}) \]

**AMF}_{1p} --** accounts for the presence of bus stops (Exhibit 12-26)

**AMF}_{2p} --** accounts for the presence of schools (Exhibit 12-27)

**AMF}_{3p} --** accounts for the number of alcohol establishments (Exhibit 12-28)

### Intersections AMFs for Signalized Urban/Suburban Intersections:

**Exhibit 12-26: Accident Modification Factor (AMF) for Number of Bus Stops within 1,000ft of the Intersection**

<table>
<thead>
<tr>
<th>Number of Bus Stops within 1,000ft of Intersection</th>
<th>AMF_{1p}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>1 or 2</td>
<td>2.78</td>
</tr>
<tr>
<td>3 or more</td>
<td>4.15</td>
</tr>
</tbody>
</table>

**Exhibit 12-27: Accident Modification Factor (AMF) for the Presence of Schools near the Intersection**

<table>
<thead>
<tr>
<th>Presence of Schools within 1,000ft of the Intersection</th>
<th>AMF_{2p}</th>
</tr>
</thead>
<tbody>
<tr>
<td>No School Present</td>
<td>1.00</td>
</tr>
<tr>
<td>School Present</td>
<td>1.35</td>
</tr>
</tbody>
</table>

**Exhibit 12-28: Accident Modification Factor (AMF) for Number of Alcohol Establishments within 1,000ft of the Intersection**

<table>
<thead>
<tr>
<th>Number of Alcohol Establishments within 1,000ft of the Intersection</th>
<th>AMF_{3p}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>1-8</td>
<td>1.12</td>
</tr>
<tr>
<td>9 or more</td>
<td>1.56</td>
</tr>
</tbody>
</table>
### Safety Prediction for Pedestrian Collisions at an Urban Multilane Intersection: EXAMPLE

**Four-Leg Signalized Intersection:**
- 25,000 ADT and 5,000 ADT
- Pedestrian Volume = 300 peds/day
- Four lanes each direction on Major Road
- One Bus Stop in NE Quadrant
- One Convenient Store in SE Quadrant that sales alcohol

\[
N_{\text{pedi}} = N_{\text{pedbase}} (\text{AMF}_{1p} \times \text{AMF}_{2p} \times \text{AMF}_{3p})
\]

\[
N_{\text{pedbase}} = \exp[a + b \ln(\text{ADT}_{\text{tot}}) + c \ln(\text{ADT}_{\text{maj}}/\text{ADT}_{\text{min}}) + d \ln(\text{PedVol}) + e \ (n_{\text{lanesq}})]
\]

\[
= \exp[-9.53 + 0.40 \ln(30,000) + 0.26 \times \ln(25,000/5,000) + 0.45 \ln(300) + 0.04(8)]
\]

\[
= \exp(-2.2101) = 0.122 \text{ crashes per year}
\]

### Intersections AMFs for Signalized Urban/Suburban Intersections:

**Exhibit 12-26: Accident Modification Factor (AMF_{1p}) for Number of bus stops within 1,000 ft of the intersection**

<table>
<thead>
<tr>
<th>Number of bus stops within 1,000 ft of the intersection</th>
<th>AMF_{1p}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>1 or 2</td>
<td>2.78</td>
</tr>
<tr>
<td>3 or more</td>
<td>4.15</td>
</tr>
</tbody>
</table>

**Exhibit 12-27: Accident Modification Factor (AMF_{2p}) for the Presence of Schools near the Intersection**

<table>
<thead>
<tr>
<th>Presence of schools within 1,000 ft of the intersection</th>
<th>AMF_{2p}</th>
</tr>
</thead>
<tbody>
<tr>
<td>No school present</td>
<td>1.00</td>
</tr>
<tr>
<td>School present</td>
<td>1.35</td>
</tr>
</tbody>
</table>

**Exhibit 12-28: Accident Modification Factor (AMF_{3p}) for Number of alcohol sales establishments within 1,000 ft of the intersection**

<table>
<thead>
<tr>
<th>Number of alcohol sales establishments within 1,000 ft of the intersection</th>
<th>AMF_{3p}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>1-8</td>
<td>1.12</td>
</tr>
<tr>
<td>9 or more</td>
<td>1.56</td>
</tr>
</tbody>
</table>
Safety Prediction for Veh-Ped Collisions at an Urban Multilane Intersection: EXAMPLE

Four-Leg Signalized Intersection:
- 25,000 ADT and 5,000 ADT
- Pedestrian Volume = 300 peds/day
- Four lanes each direction on Major Road
- One Bus Stop in NE Quadrant
- One Convenient Store in SE Quadrant that sales alcohol

\[ N_{\text{pedi}} = N_{\text{pedbase}} (AMF_{1p} \times AMF_{2p} \times AMF_{3p}) \]

\[ N_{\text{pedbase}} = 0.122 \text{ crashes per year} \]

\[ N_{\text{pedi}} = 0.122 \times (2.78 \times 1.00 \times 1.12) \]

\[ = 0.380 \text{ crashes per year} \]

Prediction of the Number of Vehicle-Pedestrian Collisions at Stop-Controlled Urban/Suburban Intersections:

\[ N_{\text{pedi}} = N_{\text{bi}} \times f_{\text{pedi}} \]

- \( N_{\text{bi}} = \) Predicted number of total roadway segment crashes per year
- \( f_{\text{pedi}} = \) Pedestrian safety adjustment factor, Exhibit 12-20

Exhibit 12-20: Pedestrian Safety Adjustment Factors for STOP-controlled Intersections

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Pedestrian safety adjustment factor ((f_{\text{pedi}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ST</td>
<td>0.006</td>
</tr>
<tr>
<td>4ST</td>
<td>0.016</td>
</tr>
</tbody>
</table>
Prediction of the Number of Vehicle-Bicycle Collisions at Urban/Suburban Intersections:

\[ N_{\text{bike}} = N_{\text{bi}} \times f_{\text{bike}} \]

- \( N_{\text{bi}} = \) Predicted number of total roadway segment crashes per year
- \( f_{\text{pedi}} = \) Bicycle safety adjustment factor, Exhibit 12-21

**Exhibit 12-21: Bicycle Safety Adjustment Factors for Intersections**

<table>
<thead>
<tr>
<th>Road type</th>
<th>Bicycle safety adjustment factor ((f_{\text{bike}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ST</td>
<td>0.004</td>
</tr>
<tr>
<td>3S5</td>
<td>0.010</td>
</tr>
<tr>
<td>4ST</td>
<td>0.006</td>
</tr>
<tr>
<td>4S5</td>
<td>0.013</td>
</tr>
</tbody>
</table>

**Safety Prediction for Vehicle-Bicycle Collisions at an Urban/Suburban Intersection: EXAMPLE**

*Four-Leg Signalized Intersection:*
- 25,000 ADT and 5,000 ADT
- Pedestrian Volume = 300 peds/day
- Four lanes each direction on Major Road
- One Bus Stop in NE Quadrant
- One Convenient Store in SE Quadrant that sales alcohol

\( N_{\text{bi}} = 6.05 \text{ crashes per year} \)

\[ N_{\text{bike}} = N_{\text{bi}} \times f_{\text{bike}} \]

\[ N_{\text{bike}} = 6.05 \times 0.013 \]

\[ = 0.079 \text{ crashes per year} \]
Predicting Total Safety Performance for Urban/Suburban At-Grade Intersections

Four-Leg Signalized Intersection:
- 25,000 ADT and 5,000 ADT
- Pedestrian Volume = 300 peds/day
- Four lanes each direction on Major Road
- One Bus Stop in NE Quadrant
- One Convenient Store in SE Quadrant that sales alcohol

\[
N_{int} = (N_{bi} + N_{pedi} + N_{bkie}) C_i
\]
\[
= (6.05 + 0.380 + 0.079) 1.0
\]
\[
= 6.51 \text{ crashes per year}
\]
AMFs for Converting 4-Leg Intersection to Two 3-Leg Intersections:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion of four-leg intersection into two T-intersections</td>
<td>Urban Four-leg</td>
<td>Minor-road traffic &gt;30% of total entering</td>
<td>All types Injury</td>
<td>0.67</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-injury</td>
<td>0.90*</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor-road traffic = 15-30% of total entering</td>
<td>All types Injury</td>
<td>0.75</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-injury</td>
<td>1.00*</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor-road traffic &lt;15% of total entering</td>
<td>All types Injury</td>
<td>1.15</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types Non-injury</td>
<td>1.15</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Base Condition: Urban four-leg intersection with minor-road stop control

Roundabouts are proven safety-effective in the rural and urban environment

*NCHRP 500, Strategy 17.1 F3 – Provide Roundabouts

-Lee Road and US 23, Michigan
### AMFs for Converting Signalized Intersection to Modern Roundabout:

**Exhibit 14.8: Safety Effects of Converting Signalized Intersections into Modern Roundabout**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting/Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type/Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert signalized intersection to modern roundabout</td>
<td>Urban/One or Two lanes</td>
<td>Unscheduled</td>
<td>All types/All severities</td>
<td>0.99</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Suburban/Two lanes</td>
<td></td>
<td>All types/Injury</td>
<td>0.40</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All settings/One or Two lanes</td>
<td></td>
<td>All types/All severities</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types/All severities</td>
<td>0.52</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types/Injury</td>
<td>0.22</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Base Condition: Signalized intersection

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

*Observed variability suggests that this treatment could result in a benefit, detriment, or no safety effect.

---

### AMFs for Converting Stop-Controlled Intersection to Modern Roundabout:

**Exhibit 14.9: Safety Effects of Converting Stop-Controlled Intersections to Modern Roundabout**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting/Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type/Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert intersection with side-road stop control to modern roundabout</td>
<td>All settings/One or Two lanes</td>
<td>Unscheduled</td>
<td>All types/All severities</td>
<td>0.56</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Rural/One lane</td>
<td></td>
<td>All types/Injury</td>
<td>0.18</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Urban/One or Two lanes</td>
<td></td>
<td>All types/All severities</td>
<td>0.29</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Urban/One lane</td>
<td></td>
<td>All types/Injury</td>
<td>0.83</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Suburban/One or Two lanes</td>
<td></td>
<td>All types/All severities</td>
<td>0.52</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Suburban/One lane</td>
<td></td>
<td>All types/All severities</td>
<td>0.37</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Suburban/Two lanes</td>
<td></td>
<td>All types/All severities</td>
<td>0.22</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Stop/One lane</td>
<td></td>
<td>All types/Injury</td>
<td>0.83</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Stop/Two lanes</td>
<td></td>
<td>All types/All severities</td>
<td>0.08</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All types/Injury</td>
<td></td>
<td>All types/All severities</td>
<td>0.29</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All types/All severities</td>
<td></td>
<td>All types/Injury</td>
<td>0.42</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All types/All severities</td>
<td></td>
<td>All types/Injury</td>
<td>0.07</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>All types/Injury</td>
<td></td>
<td>All types/All severities</td>
<td>0.32</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Base Condition: Stop-controlled intersection

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

*Observed variability suggests that this treatment could result in a benefit, detriment, or no safety effect.
**AMFs for Converting Minor-Road Stop Control to All-Way Stop Control:**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert minor-road stop control to all-way stop control</td>
<td>Urban</td>
<td>Unspecified</td>
<td>Right-angle</td>
<td>0.25</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>MUTCD warrants are not met</td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rear-end</td>
<td>0.02</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pedestrian</td>
<td>0.57</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types</td>
<td>0.30</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All types</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Intersection with minor-road stop control meeting MUTCD warrants for an all-way stop controlled intersection.

\[
\text{AMF}_{\text{total}} = (0.30 - 1.0)0.321 + 1.0 = 0.775
\]

**AMFs for Prohibiting Left-Turns and/or U-Turns:**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Setting Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prohibit left-turns with &quot;No Left Turn&quot; sign</td>
<td>Urban and suburban arterial and Four-leg intersections and median crossovers</td>
<td>Entering AADT 19,435 to 42,000 vpd</td>
<td>Left-turn</td>
<td>0.36</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All intersection crashes</td>
<td>0.32</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prohibit left-turns and U-turns with &quot;No Left Turn&quot; and &quot;No U-Turn&quot; signs</td>
<td></td>
<td></td>
<td>Left-turn and U-turn crashes</td>
<td>0.23</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All intersection crashes</td>
<td>0.28</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>All severities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Base Condition: Not specified and therefore not known for this edition of the HSM.

Notes:
- Bold text is used for the most reliable AMFs. These AMFs have a standard error of 0.1 or less.
Access Management – Unsignalized Median Openings

“… there is no indication that U-turns at unsignalized median openings constitute a major safety concern.”

“Access management strategies that increase U-turn volumes at unsignalized median openings can be used safely and effectively.”

1. Conventional Midblock Median Opening
   Type 1c—Conventional Midblock Median Opening With Left-Turn Lanes and Loons

*For urban arterial corridors, median opening accident rates are substantially lower for midblock median openings than for median openings at three- and four-leg intersections
2. Directional Midblock Median Opening without Left-Turn Lanes

Type 2a—Directional Midblock Median Opening Without Left-Turn Lanes

Type 2b—Directional Midblock Median Opening With Left-Turn Lanes

3. Directional Midblock Median Opening with Left-Turn Lanes

Type 2c—Directional Midblock Median Opening With Left-Turn Lanes and Loons
4. **Directional Median Opening for Left Turns from Major Road at 3-Leg Int**

Type 4a—Directional Median Opening for Left Turns From Major Road at Three-Leg Intersection

*Average median opening accident rates for directional three-leg median openings are about 48 percent lower than for conventional three-leg median openings*

5. **Directional Median Opening for 4-Leg Intersection**

Type 6a—Directional Median Opening for Left Turns From Major Road at Four-Leg Intersection

*Average median opening accident rates for directional four-leg median openings are about 15 percent lower than for conventional four-leg intersections*
5. **Directional Median Opening for 4-Leg Intersection**
   Type 2b—Directional Midblock Median Opening With Left-Turn Lanes

34th Street, Clearwater, Florida

Type 6a—Directional Median Opening for 4-approach Intersection, Carson City NV
5. **Directional Median Opening for 4-Leg Intersection**

Type 6a—Directional Midblock Median Opening for Left Turns from Major Road at Four-Leg Intersection

Route 395, Carson City, NV

6. **Michigan Indirect Left Turn Geometry**

**Synthesis of the Median U-Turn Intersection Treatment, Safety, and Operational Benefits**

Publication No.: FHWA-HRT-07-033

- more than 684 kilometers (km) (425 miles (mi)) of “boulevards” with over 700 directional crossovers on the Michigan State highway system.
6. Michigan Indirect Left Turn Geometry

Some of the advantages cited include:
- Reduced delay and better progression for through traffic on the major arterial.
- Increased capacity at the main intersection.
- Fewer stops for through traffic, especially where there are STOP-controlled directional crossovers.
- Fewer and more separated conflict points.
- Two-phase signal control allows shorter cycle lengths, thereby permitting more flexibility in traffic signal progression.
- **Total crash reduction of 24 percent.**
- As the traffic signal density increases, divided highways with exclusive directional crossovers had 50 percent lower crash rates.

Safety Effects of Replacing Left-Turn with Right-Turn/U-Turn Combination on High Volume Multilane Highways:

<table>
<thead>
<tr>
<th>AMFs based on:</th>
<th>Treatment</th>
<th>Setting/Intersection type</th>
<th>Traffic Volume</th>
<th>Accident type Severity</th>
<th>AMF</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AADT &gt; 34,000</td>
<td>Replace direct left-turn with right-turn/U-turn</td>
<td>Unspecified/Unsignalized intersections-access points on 4-, 6-, and 8-lane divided arterial</td>
<td>Arterial AADT &gt; 34,000 vpd</td>
<td>All types All severities</td>
<td>0.80</td>
<td>0.1</td>
</tr>
<tr>
<td>40 &lt; Speed &lt; 55</td>
<td></td>
<td>Unspecified/Unsignalized intersections-access points on 4-lane divided arterial</td>
<td>Minor road/access point volume unspecified</td>
<td>All types Non-injury</td>
<td>0.89</td>
<td>0.2</td>
</tr>
<tr>
<td>No on-street parking</td>
<td></td>
<td>Unspecified/Unsignalized intersections-access points on 8-lane divided arterial</td>
<td></td>
<td>All types Injury</td>
<td>0.64</td>
<td>0.2</td>
</tr>
<tr>
<td>Segment lengths 0.1 to 0.25 mi</td>
<td></td>
<td>Unspecified/Unsignalized intersections-access points on 6-lane divided arterial</td>
<td></td>
<td>All types All severities</td>
<td>0.49</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Base Conditions: An unsignalized intersection providing for direct left-turns.
Is this Intersection as ‘safe’ as it could be?

Discussion

- What are some Traffic Signal Features/Equipment that affect Safety?
- Let’s list them

Nominal and Substantive Safety

Example:

1st Step

Nominal Safety – Two Indications for Major Movement

2nd Step

+Add Primary Head per Lane
CRF = 28% Total Crashes
CRF = 46% Rt Angle Crashes
= Substantive Safety
Predicting Highway Safety for Intersections on Multilane Highways

Outcomes:

- Detailed the Quantitative safety research on Intersections
- Described the draft HSM Models for prediction of Intersection Crash Performance

Questions and Discussion
Safety and Operational Effects of Geometric Design Features for Multilane Highways Workshop

Exercise III – Prediction of Safety Performance for Multilane Intersections and Comparison to Actual Safety Performance

- Session #7

Exercise III – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:

- Apply Multilane Intersection Crash Prediction models
- Compare predicted safety performance to actual safety performance
Exercise III – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Intersection Information:

Three Signalized intersections with single left turn lanes (no right turn lanes):
- Bloomingdale Road 16,100 AADT
- Shopping Center (north and south) 2,400 AADT
- Main Street-Glen Ellyn 16,700 AADT

IL 64 North Avenue is 37,000 ADT

Exercise III – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Intersection Information:

Nine minor street intersections (all “T” intersections) with no left turn lanes – stop control of minor street approach:

<table>
<thead>
<tr>
<th>ADT 700</th>
<th></th>
<th>ADT 1,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mildred Av</td>
<td>Western Av</td>
<td>Pearl Av</td>
</tr>
<tr>
<td>Evergreen Av</td>
<td>Newton Av</td>
<td></td>
</tr>
<tr>
<td>Virginia Av</td>
<td>Diane Av</td>
<td></td>
</tr>
<tr>
<td>Amy Av</td>
<td>Bernice Av</td>
<td></td>
</tr>
</tbody>
</table>
Exercise III – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Study Section:

<table>
<thead>
<tr>
<th></th>
<th>Total Crashes</th>
<th>Injury Crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rdwy Segment</td>
<td>200</td>
<td>62</td>
<td>136</td>
<td>64</td>
</tr>
<tr>
<td>Intersections:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bloomingdale Rd</td>
<td>170</td>
<td>68</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Main St-Glen Ellyn</td>
<td>146</td>
<td>45</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td>Totals:</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>

Exercise III – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

1. Predict the Crash Performance for the intersections using the Rural Multilane intersection models for the following:
   a. Bloomingdale Road (signalized)
   b. Shopping Center (signalized)
   c. Main Street-Glen Ellyn (signalized)
   d. Eight “T” non-signalized intersections (700 ADT)
   e. One “T” non-signalized intersection (1,500 ADT)
Exercise III – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

2. Total the predicted crash performance for all intersections

- Bloomingdale Road (signalized)
- Shopping Center (signalized)
- Main Street-Glen Ellyn (signalized)
- Eight “T” non-signalized intersections (700 ADT)
- One “T” non-signalized intersection (1,500 ADT)

Total: ?

Exercise III – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

3. Compare the actual Intersection Safety Performance to the Predicted Safety Performance:

- Actual Safety Performance = 111 +? per year
- Predicted Safety Performance = ? per year
- Safer than Predicted ?? YES/NO
Exercise III – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn
Outcomes:

- Applied Multilane Intersection Crash Prediction models
- Compare predicted safety performance to actual safety performance

Questions and Discussion
GROUP EXERCISE “III”
Prediction of Safety Performance for Multilane Intersections and Comparison to Actual Safety Performance

IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.

Study Section:  Bloomingdale Road to Main Street-Glen Ellyn
Length of Section = 0.97 miles
ADT = 37,000 AADT

Three Signalized intersections with single left turn lanes (no right turn lanes):
- Bloomingdale Road  16,100 AADT
- Shopping Center (north and south)  2,400 AADT
- Main Street-Glen Ellyn  16,700 AADT

Total number of Unsignalized Intersections with left turn lanes = 0

Nine minor street intersections (all “T” intersections) with no left turn lanes – stop control of minor street approach:
- Mildred Av
- Evergreen Av
- Amy Av
- Virginia Av
- Western Av
- Newton Av
- Bernice Av
- Pearl Av
- Diane Av


<table>
<thead>
<tr>
<th>Segment</th>
<th>Total crashes</th>
<th>Injury crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloomingdale Road</td>
<td>170</td>
<td>68</td>
<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Main Street-Glen Ellyn</td>
<td>146</td>
<td>45</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>
1. Predict the Crash Performance for the intersections using the Rural Multilane intersection models for the following:
   a. Bloomingdale Road (signalized)
   b. Shopping Center (signalized)
   c. Main Street-Glen Ellyn (signalized)
   d. Eight “T” non-signalized intersections (700 ADT)
   e. One “T” non-signalized intersection (1,500 ADT)

   a. Bloomingdale Road (signalized)

   \[ N_{\text{rural}} = \exp(a + b \ln(ADT_{\text{Major}}) + c \ln(AADT_{\text{Minor}})) \]

   \[ = \exp(-7.423 + 0.722 \ln(37,000) + 0.337 \ln(16,100)) \]

   \[ = \exp( \phantom{-} \phantom{-} \phantom{-} ) \]

   \[ = \phantom{-} \phantom{-} \phantom{-} \text{crashes per year} \]

   b. Shopping Center (signalized)

   \[ N_{\text{rural}} = \exp(a + b \ln(ADT_{\text{Major}}) + c \ln(AADT_{\text{Minor}})) \]

   \[ = \exp(-7.423 + 0.722 \ln(37,000) + 0.337 \ln(2,400)) \]

   \[ = \exp( \phantom{-} \phantom{-} \phantom{-} ) \]

   \[ = \phantom{-} \phantom{-} \phantom{-} \text{crashes per year} \]
c. Main Street-Glen Ellyn (signalized)

\[ N_{\text{rural}} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}_{\text{c Minor}})) \]

\[ = \exp(-7.423 + 0.722\ln(37,000) + 0.337\ln(16,700)) \]

\[ = \exp( \quad + \quad + \quad ) \]

\[ = \exp( \quad ) \]

\[ = \quad \text{crashes per year} \]

d. Eight “T” stop control of approach at 700 ADT

\[ N_{\text{rural}} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}_{\text{c Minor}})) \]

\[ = \exp(-13.098 + 1.204\ln(37,000) + 0.236\ln(700)) \]

\[ = \exp( \quad + \quad + \quad ) \]

\[ = \exp( \quad ) \]

\[ = \quad \text{crashes per year each} \]

\[ = 8 \times \quad \text{crashes per year} \]

\[ = \quad \text{crashes per year} \]
e. One “T” stop control of approach at 1500 ADT

\[ N_{\text{rural}} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}_{\text{Minor}})) \]

\[ = \exp(-13.098 + 1.204 \ln(37,000) + 0.236 \ln(1,500)) \]

\[ = \exp( \quad + \quad + \quad ) \]

\[ = \exp( \quad ) \]

\[ = \quad \text{crashes per year} \]

2. Predict the Crash Performance for the intersections using the Rural Multilane intersection models for the following:

a. Bloomingdale Road (signalized)

b. Shopping Center (signalized)

c. Main Street-Glen Ellyn (signalized)

d. Eight “T” non-signalized intersections (700 ADT)

e. One “T” non-signalized intersection (1,500 ADT)

**Total Predicted Intersection Crashes**
3. Compare the actual Intersection Safety Performance to the Predicted Safety Performance

Actual Safety Performance = 334 + ? crashes in 3 years

= 111 + ? crashes per year

Predicted Segment Crashes per year =

Safer than Actual? Yes or No?
Safety and Operational Effects of Geometric Design Features for Multilane Highways Workshop

Exercise IV – Prediction of Safety Performance for Urban/Suburban Multilane Highway and Comparison to Actual Safety Performance

- Session #8

Exercise IV – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:

➤ Apply Urban/Suburban Multilane Crash Prediction model
➤ Compare predicted safety performance to actual safety performance
IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.
Exercise IV – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Study Section:

<table>
<thead>
<tr>
<th></th>
<th>Total Crashes</th>
<th>Injury Crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rdwy Segment</td>
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<td>Intersections:</td>
<td></td>
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<td><strong>180</strong></td>
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<td><strong>163</strong></td>
</tr>
</tbody>
</table>
Exercise IV – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

**Proposed Design Cross-Section:**
- 6 12-foot wide lanes with 42 foot wide curbed and landscaped median dividing the opposing directions of travel
- 12 foot wide paved shoulders
- 12 foot wide left turn lanes at all major intersections + 2 side street intersections

| Total number of Unsignalized Intersections with left turn lanes | 2 |
| Total number of Unsignalized Intersections with no median opening nor turn lanes | 7 |

- Pearl + Evergreen
- Mildred Av
- Diane Av
- Virginia Av
- Bernice Av
- Amy Av
- Western Ave
- Newton Ave

Exercise IV – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

**Proposed Design Cross-Section:**
- Highway illumination on both sides at 200 foot spacing of 400watt HPS on 40 foot mounting height on breakaway poles; Utility poles relocated out of clear zone to right-of-way line
- Parking is prohibited

<table>
<thead>
<tr>
<th>Signalized Intersections:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloomingdale Road (150 peds/day)</td>
</tr>
<tr>
<td>150 pedestrians per day</td>
</tr>
<tr>
<td>Four 12’ lanes + 12’ shoulder each direction</td>
</tr>
<tr>
<td>1 alcohol sales within 1,000 ft</td>
</tr>
<tr>
<td>1 bus stop within 1,000 ft</td>
</tr>
<tr>
<td>Shopping Center (north and south)</td>
</tr>
<tr>
<td>Main Street-Glen Ellyn</td>
</tr>
</tbody>
</table>
Exercise IV – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

Study Section:


<table>
<thead>
<tr>
<th></th>
<th>Total crashes</th>
<th>Injury crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
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<tbody>
<tr>
<td>Segment</td>
<td>200</td>
<td>62</td>
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<tr>
<td>Bloomingdale Rd</td>
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</tr>
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<td><strong>Total</strong></td>
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<td><strong>371</strong></td>
<td><strong>163</strong></td>
</tr>
</tbody>
</table>

Exercise IV – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

1. Predict the Crash Performance for the segment using the Suburban Multilane Divided model (4D) for the following:
   a. Base Model Multiple Vehicle Non-Driveway
   b. Base Model Single Vehicle Non-Driveway
   c. Driveway Related Crashes
   d. AMF’s for Parking, Roadside Objects, and Lighting
   e. Predicted Crashes with AMF’s Applied
   f. Pedestrian Crashes
   g. Bicycle Crashes
   h. Total Predicted Crashes for Segment
From the Crash Prediction analysis, perform the following:

Is the Predicted Safety performance for the geometrics for IL 64 (Driveways, parking, and lighting) safer than the Actual Safety Performance value?

Actual Safety Performance = ?
Predicted Safety Performance = ?
Safer than Predicted YES/NO

2. Predict the Crash Performance for the Proposed Intersection Design for Bloomingdale Road at IL 64 using the Urban model (4SG):
   a. Base Model for Multiple Vehicle collisions
   b. Base Model for Single Vehicle collisions
   c. AMF’s for left turn and right turn lanes and Lighting
   d. Predicted Crashes with AMF’s Applied
   e. Predicted Crashes for Peds and Bikes
   f. Total Predicted Crashes for Intersection
   g. Combined Roadway & Intersection Crashes
Exercise IV – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

From the Crash Prediction analysis, perform the following:

Is the Predicted Safety performance for the geometrics for IL 64 (Driveways, parking, and lighting) safer than the Actual Safety Performance value?

Actual Safety Performance = ?
Predicted Safety Performance = ?
Safer than Predicted = YES/NO

Exercise V – IL 64 North Ave from Bloomingdale Rd to Main St – Glen Ellyn

From the Crash Prediction analysis, perform the following:

Is the Predicted Safety performance for the geometrics for IL 64 (Driveways, parking, and lighting) safer than the actual Safety Performance value?

Actual Safety Performance =
Predicted Safety Performance =
Safer than actual =
Exercise V – IL 64 North Avenue from Bloomingdale Road to Main Street-Glen Ellyn

Outcomes:
- Applied Suburban Multilane Crash Prediction model
- Compared predicted safety performance to actual safety performance

Questions and Discussion
GROUP EXERCISE “IV”

IL 64, DuPage County, Illinois:

**Study Section:** Bloomingdale Road to Main Street-Glen Ellyn
- Length of Section = 0.97 miles
- ADT = 37,000 AADT
- No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi

**Driveways – all right-in/right-out**
- Residential driveways: 7
- Minor commercial driveways (less than 50 parking spaces): 7
- Major commercial driveways (more than 50 parking spaces): 11
- Total # of Driveways: 25

**Proposed Design Cross-Section for Evaluation:**
- 6 12-foot wide lanes with 42 foot wide curbed and landscaped median dividing the opposing directions of travel - Use 4D
- 12 foot wide paved shoulders
- 12 foot wide left turn lanes at all major intersections + 2 side street intersections
- Total Lanes on IL-64 is 5 lanes each direction
- Total number of Unsignalized Intersections with left turn lanes: 2
  - Evergreen Av
  - Pearl Ave
- Total number of Unsignalized Intersections with no median opening nor turn lanes: 7
  - Mildred Av
  - Diane Av
  - Virginia Av
  - Bernice Av
  - Amy Av
  - Western Ave
  - Newton Ave

Highway illumination on both sides at 200 foot spacing of 400watt HPS on 40 foot mounting height on breakaway poles; Utility poles relocated out of clear zone to right-of-way line
Parking is prohibited

**Signalized Intersections:**
- Bloomingdale Road: 16,100 AADT
- Shopping Center (north and south): 2,400 AADT
- Main Street-Glen Ellyn: 16,700 AADT

**Actual Safety Performance of Previous X-Section:**
- 3-years crash data 1986, 1987, 1988

<table>
<thead>
<tr>
<th>Segment</th>
<th>Total crashes</th>
<th>Injury crashes</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bloomingdale Road</td>
<td>170</td>
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<td>122</td>
<td>48</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>18</td>
<td>5</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Main Street-Glen Ellyn</td>
<td>146</td>
<td>45</td>
<td>100</td>
<td>46</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>534</strong></td>
<td><strong>180</strong></td>
<td><strong>371</strong></td>
<td><strong>163</strong></td>
</tr>
</tbody>
</table>

Exercise V – Prediction of Crashes for IL 64-North Avenue proposed Design as a Suburban Multilane Highway
Predict the Crash Performance for the following:

1. Proposed Cross-Section for Segment as Suburban Multilane 4D:

   a. **Urban Multilane Base Model Single Vehicle Non-Driveway:**

      \[ N_{brmv} = e^{(a + b \ln ADT + \ln L)} \]

      \[ = e^{(\phantom{\ln ADT} + \phantom{\ln L})} \]

      \[ = e^{(\phantom{\ln ADT} + \phantom{\ln L})} \]

      \[ = e^{(\phantom{\ln ADT} + \phantom{\ln L})} \]

      \[ = \phantom{e^{\phantom{\ln ADT} + \phantom{\ln L}}} \text{crashes per year} \]

   b. **Proposed Cross-Section Urban Multilane Base Model Single Vehicle Non-Driveway**

      \[ N_{brsv} = e^{(a + b \ln ADT + \ln L)} \]

      \[ = e^{(\phantom{\ln ADT} + \phantom{\ln L})} \]

      \[ = e^{(\phantom{\ln ADT} + \phantom{\ln L})} \]

      \[ = e^{(\phantom{\ln ADT} + \phantom{\ln L})} \]

      \[ = \phantom{e^{\phantom{\ln ADT} + \phantom{\ln L}}} \text{crashes per year} \]
c. Driveway Related Crashes

\[ N_{brdwu} = \text{SUM} \left( n_j N_j \left( \frac{\text{ADT}}{15,000} \right)^{1.106} \right) \]

\[ = \begin{array}{c}
11 \\
+ 7 \\
+ 0 \\
+ 0 \\
+ 0 \\
+ 0 \\
+ 0
\end{array} \times 0.053 \left( \frac{37,000}{15,000} \right)^{1.106} \\
\]

\[ + \begin{array}{c}
7 \\
0 \\
0 \\
7 \\
0 \\
0 \\
0
\end{array} \times 0.017 \left( \frac{37,000}{15,000} \right)^{1.106} \\
\]

\[ + \begin{array}{c}
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{array} \times 0.057 \left( \frac{37,000}{15,000} \right)^{1.106} \\
\]

\[ + \begin{array}{c}
0 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{array} \times 0.008 \left( \frac{37,000}{15,000} \right)^{1.106} \\
\]

\[ = \text{crashes per year} \]

\[ N_{brbase} = N_{\text{Multipe Vehicle (non-driveway)}} + N_{\text{Single Vehicle (non-driveway)}} + N_{brdw} \]

\[ = \begin{array}{c}
\end{array} + \begin{array}{c}
\end{array} + \begin{array}{c}
\end{array} \]

\[ = \text{crashes per year} \]

d. AMF’s for Parking (AMF_{1r}), Roadside Objects (AMF_{2r}), and Lighting (AMF_{3r})

\[ AMF_{1r} = 1 + P_{pk}^* (f_{pk} - 1.0) \]

Where parking is prohibited, Ppk is zero

\[ = 1 + \begin{array}{c}
\end{array}^* (f_{pk} - 1.0) \]

\[ = 1.00 \]
\[ AMF_{2r} = f_{offset} \times D_{fo} \times p_{fo} + (1 - p_{fo}) \]

For street lighting poles at 200 foot spacing on 2 sides located 18 feet from travel lane, \( f_{offset} = 0.06 \) \( p_{fo} = 0.036 \)

\[
= \quad x \quad 2 \quad x \quad (5280/ \quad )\quad x \\
= \quad + (1 - \quad )
\]

\[ AMF_{3r} = 1 - ((1 - 0.36 P_{fnr} - 0.72 p_{inr} - 0.83 p_{pnr}) \quad p_{nr}) \]

For 4D: \( P_{fnr} = 0.004 \), \( p_{fnr} = 0.281 \), \( p_{pnr} = 0.715 \), \( p_{nr} = 0.203 \)

\[
= \quad
\]

e. Predicted Crashes with AMF’s Applied

\[ N_{br} = N_{brbase} \times AMF_{1r} \times AMF_{2r} \times AMF_{3r} \]

\[
= \quad x \quad x \quad x \quad \\
= \quad \text{crashes per year}
\]

f. Pedestrian Crashes

\[ N_{pedr} = N_{br} \times f_{pedr} \quad \text{for 4D, } f_{pedr} = 0.006 \]

\[
= \quad x \quad \\
= \quad \text{crashes per year}
\]
**g. Bicycle Crashes**

\[ N_{\text{biker}} = N_{\text{br}} \times f_{\text{biker}} \quad \text{for 4U, } f_{\text{biker}} = 0.011 \]

\[ = \underline{\phantom{0}} \times \underline{\phantom{0}} \]

\[ = \underline{\phantom{0}} \text{ crashes per year} \]

**h. Proposed Base Roadway Predicted Crashes for Segment (multilane Suburban 4D)**

\[ N_{\text{total}} = N_{\text{br}} + N_{\text{pedr}} + N_{\text{biker}} \]

\[ = \underline{\phantom{0}} + \underline{\phantom{0}} + \underline{\phantom{0}} \]

\[ = \underline{\phantom{0}} \text{ crashes per year} \]

Is the Predicted Safety Performance for the proposed Divided Multilane Cross-Section safer than Actual Safety Performance value?

**Actual Safety Performance**

\[ = 200 \text{ crashes in 3 years} \]

\[ = 66.7 \text{ crashes per year} \]

**Predicted Segment Crashes per year**

\[ \underline{\phantom{0}} \]

**Safer than Actual Safety Performance?**

Yes or No?
2. Proposed Signalized Intersection of Glen Ellyn Road Road at IL 64 with:
- Dual-Left Turn lanes on IL 64 – Single Left Turn lanes on Glen Ellyn Road
- “Protected Left Turn” phasing on all 4 approaches
- Right Turn lanes on all 4 approaches
- Overhead Signals with Signal Head per Lane + 2 Signal Indications for each left turn movement
- Lighting

a. Urban Multilane (multiple vehicle crashes w/o ped & bike)

\[ \text{\( N_{\text{bimv}} = \exp(a + b \ln(ADT_{\text{Major}}) + c \ln(ADT_{\text{Minor}}) \)} \]

\[ = \exp(-10.63 + 1.07 \ln(37,000) + 0.23 \ln(16,100)) \]

\[ = \exp( \phantom{-} + \phantom{+ \ln(37,000)} + \phantom{+ \ln(16,100)} ) \]

\[ = \exp( \phantom{-} ) \]

\[ = \phantom{-} \text{crashes per year} \]

b. Urban Multilane (single vehicle crashes w/o ped & bike)

\[ \text{\( N_{\text{bisv}} = \exp(a + b \ln(ADT_{\text{Major}}) + c \ln(ADT_{\text{Minor}}) \)} \]

\[ = \exp(-9.85 + 0.68 \ln(37,000) + 0.27 \ln(16,100)) \]

\[ = \exp( \phantom{-} + \phantom{+ \ln(37,000)} + \phantom{+ \ln(16,100)} ) \]

\[ = \exp( \phantom{-} ) \]

\[ = \phantom{-} \text{crashes per year} \]
Exercise V – Prediction of Crashes for IL 64-North Avenue proposed Design as a Suburban Multilane Highway

\[ N_{\text{bibase}} = N_{\text{bimv}} + N_{\text{bisv}} + N_{\text{brdwu}} \]

\[ = \boxed{\phantom{0}} + \boxed{\phantom{0}} \]

\[ = \boxed{\phantom{0}} \text{ crashes per year} \]

c. AMF’s

- \( \text{AMF}_{1i} \) (lttnln) = 0.81 for left turn lanes on both major road approaches
- \( \text{AMF}_{2i} \) (prot turn) = 0.944 = 0.78 protected left-turn lanes on four approaches
- \( \text{AMF}_{3i} \) (rttnln) = 0.92 for right turn lanes on major road approaches
- \( \text{AMF}_{4i} \) (Prob rttrn) = none = 1.00

\[ \text{AMF}_{5i} = 1 - ((1 - 0.36 P_{\text{fni}} - 0.72 P_{\text{ini}} - 0.83 P_{\text{pni}}) P_{\text{ni}}) \]

For 4SG intersection type, Exhibit 10-22,

\[ P_{\text{fni}} = 0.003 \]
\[ P_{\text{ini}} = 0.328 \]
\[ P_{\text{pni}} = 0.670 \]
\[ P_{\text{ni}} = 0.200 \]

\[ = 1 - ((1 - 0.36 \times 0.003 - 0.72 \times 0.328 - 0.83 \times 0.670 ) \times 0.200) \]

\[ = \boxed{\phantom{0}} \]

d. Total Predicted Crashes for Bloomingdale and IL 64

\[ N_{\text{bi}} = N_{\text{bibase}} \times \text{AMF}_{\text{lttnln}} \times \text{AMF}_{\text{rttnln}} \times \text{AMF}_{5i} \]

\[ = \boxed{\phantom{0}} \times \boxed{\phantom{0}} \times \boxed{\phantom{0}} \times \boxed{\phantom{0}} \times \boxed{\phantom{0}} \]

\[ = \boxed{\phantom{0}} \text{ crashes per year} \]
e. Urban Multilane Ped and Bike (single vehicle crashes w/o ped & bike)

1). $N_{pedbase} = \exp(a + b \ln(ADT_{tot}) + c \ln(ADT_{maj}/ADT_{min}) + d \ln(PedVol)) + e(n_{lanesx})$

$$= \exp(-9.53 + 0.40\ln(53,100) + 0.26\ln(37,000/16,100) + 0.45\ln(150) + 0.04(10))$$

$$= \exp(\phantom{(-9.53 + 0.40\ln(53,100) + 0.26\ln(37,000/16,100) + 0.45\ln(150) + 0.04(10)})$$

$$= \phantom{\exp(-9.53 + 0.40\ln(53,100) + 0.26\ln(37,000/16,100) + 0.45\ln(150) + 0.04(10))}$$

$$= \phantom{\exp(-9.53 + 0.40\ln(53,100) + 0.26\ln(37,000/16,100) + 0.45\ln(150) + 0.04(10))} \text{crashes per year}$$

2) $N_{pedi} = N_{pedbase} \times (AMF_{1p} \times AMF_{2p} \times AMF_{3p})$

AMF for Bus Stops: $AMF_{1p} = 2.78$
AMF for School presence (None): $AMF_{2p} = 1.00$
AMF for Alcohol Sales presence: $AMF_{3p} = 1.12$

$$= 0.10(\phantom{N_{pedbase} \times AMF_{1p} \times AMF_{2p} \times AMF_{3p}})$$

$$= \phantom{N_{pedbase} \times AMF_{1p} \times AMF_{2p} \times AMF_{3p}} \text{crashes per year}$$

3) $N_{bikei} = N_{bi} \times f_{bikei}$

$N_{bi} = 8.77$, $f_{bikei} = 0.013$

$$N_{bikei} = \phantom{N_{bi} \times f_{bikei}} \text{crashes per year}$$

Exercise V – Prediction of Crashes for IL 64-North Avenue proposed Design as a Suburban Multilane Highway
f. Total predicted crashes for Bloomingdale Intersection:

\[ N_{\text{int}} = (N_{\text{bi}} + N_{\text{pedi}} + N_{\text{bikei}})C_i \]

Letting \( C_i = 1.0 \)

\[ = \boxed{\phantom{0}} + \boxed{\phantom{0}} + \boxed{\phantom{0}} \]

\[ = \boxed{\phantom{0}} \text{ crashes per year} \]

Is the Predicted Safety Performance for the proposed design for the Intersection of IL 64 with Bloomingdale Road safer than the Actual Safety Performance value?

Actual Safety Performance = \boxed{170 \text{ crashes in 3 years}}

\[ = \boxed{56.7 \text{ crashes per year}} \]

Predicted Intersection Crashes per year = \boxed{\phantom{0}}

(For proposed improvements)

Safer than Actual Safety Performance? \boxed{\phantom{0}}

Yes or No?

f. Total predicted crashes for combined Roadway and Bloomingdale Intersection

\[ N_{t(\text{predicted})} = \text{Sum } N_{rs} + \text{Sum } N_{\text{int}} \]

\[ = \boxed{\phantom{0}} + \boxed{\phantom{0}} \]

\[ = \boxed{\phantom{0}} \text{ crashes per year} \]

\[ N_{t(\text{actual})} = \frac{200 + 107}{3} = 123.3 \text{ crashes per year} \]
NHI Course No. 380070B
Safety Effects of Geometric Design Features for Multilane Highways
Workshop

Post Test

Name: ________________________________ Date: ____________________

Directions: Please circle and/or fill in the answer for each question.

1. Substantive Safety is?
   (A) One of the crash statistical values
   (B) A subset of nominal safety
   (C) The total Accident Experience
   (D) The actual crash frequency and severity for a highway or roadway

2. Rural multilane highways are defined as?
   (A) Places outside of cities of populations greater than 50,000
   (B) Places located more than 5.0 miles away from the incorporated boundary of any city or town
   (C) Places outside the boundaries of urban places where the population is less than 5000 inhabitants
   (D) Places that are suburban as well as rural

3. Countermeasures with AMF values less than 1.00 indicates which of the following:
   (A) Lowers the crash frequency with application of the countermeasure
   (B) Raises the crash frequency with application of the countermeasure
   (C) Evidence of regression to the mean
   (D) Imply that an incorrect correlation factor was applied.

4. List at least four geometric features that have specific AMF values or equations to compute AMF values for rural multilane highways:

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
5. For urban/suburban highways and streets, the term Multilane means:
   (A) Facilities with more than two through lanes
   (B) Facilities with three, or more, through lanes
   (C) Facilities with four, or more, through lanes
   (D) Facilities with six, or more, through lanes

6. For urban/suburban highways and streets, the total predicted number of crashes consists of:
   (A) Predicted Crash Frequency of the Baseline Model multiplied by the Correction Factor
   (B) Predicted Crash Frequency for the entire arterial street/roadway plus the predicted number of total intersection related crashes
   (C) Predicted segment crashes multiplied by the AMF’s
   (D) The sum of the predicted crashes for undivided and divided roadways

7. List at least four geometric features that have specific AMF values or equations to compute AMF values for urban/suburban multilane streets:

__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

8. The greatest predictor of crash risk at an intersection is?
   (A) the number of stop signs
   (B) the number of signal indications
   (C) traffic volume
   (D) the approach speeds

9. For urban/suburban multilane street intersections, the predicted number of total intersection crashes is?
   (A) \[ N = e^a \times \text{AADT}_{\text{major}} \times \text{AADT}_{\text{minor}} \]
   (B) the predicted number of multivehicle crashes plus the predicted number of single vehicle crashes plus the predicted number of pedestrian and bicycle crashes
   (C) based on the model for traffic signal control only
   (D) based on the approach speeds

10. The AMF for Converting a Signalized Intersection to a Modern Roundabout for total crashes in “All Settings with one or two lanes” is: (see Exhibit 14-8)
    (A) 0.99
    (B) 1.10
    (C) 0.33
    (D) 0.52
GROUP EXERCISE “I”

IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St. Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.

Cross-Section:
4 12-foot wide lanes with double yellow centerline dividing the opposing directions of travel
8 foot wide aggregate shoulders
12 foot wide left turn lanes at all major intersections
No left turn lanes at minor street intersections nor at commercial driveways
No highway illumination other than some minor intersection lighting by local municipalities and the County Highway Department

Study Section: Bloomingdale Road to Main Street-Glen Ellyn
Length of Section = 0.97 miles
ADT = 37,000 AADT
No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi
Driveways:
Residential driveways 7
Minor commercial driveways (less than 50 parking spaces) 7
Major commercial driveways (more than 50 parking spaces) 10
Total # of Driveways 24

Total number of Unsignalized Intersections with left turn lanes 0
Total number of Unsignalized Intersections without turn lanes 9
Mildred Av Diane Av
Virginia Av Evergreen Av
Bernice Av Amy Av
Western Ave Newton Ave
Pearl Ave

Side slope = 1:6
Trees and Power poles 18.0 feet from edge of pavement; Hazard Rating of 5.0

Signalized Intersections:
Bloomingdale Road 16,100 AADT
Shopping Center (north and south) 2,400 AADT
Main Street-Glen Ellyn 16,700 AADT
**Substantive Safety Performance:** 3-years crash data 1986, 1987, 1988

<table>
<thead>
<tr>
<th>Segment</th>
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<th>Injury crashes</th>
<th>Day</th>
<th>Night</th>
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<td>Segment</td>
<td>200</td>
<td>62</td>
<td>136</td>
<td>64</td>
</tr>
<tr>
<td>Bloomingdale Road</td>
<td>170</td>
<td>68</td>
<td>122</td>
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<td>Total</td>
<td>534</td>
<td>180</td>
<td>371</td>
<td>163</td>
</tr>
</tbody>
</table>

1. **Compute the Severity Index**

\[
\text{Severity Index} = \frac{\text{Number of Fatal + Injury Crashes}}{\text{Total Number of Crashes}}
\]

**Segment:**

\[
\frac{62}{200} = \frac{31}{100} = 31\%
\]

**Intersections:**

\[
\frac{118}{334} = \frac{35}{100} = 35\%
\]

Is the Severity Index higher or lower than normal?

(For comparison see slide 3-14)

2. **Predict the Crash Performance for the following:**

a. **Rural Multilane Base Model for IL 64 (excluding curves and on-grade sections)**

\[
N_{br} = e^{(a + b \ln \text{ADT} + \ln L)}
\]

\[
= e^{(-11.6546 + 1.3124 + 37000 \ln 0.97)}
\]

\[
= e^{(-11.6546 + 13.804 + -0.0304)}
\]

\[
= e^{2.1196}
\]

\[
= 8.328 \text{ crashes per year}
\]
b. AMF for Lane Width (12 ft)

\[
\text{AMF}_{1\text{ru}} = 1.00
\]

AMF for Shoulder Width (8 ft)

\[
\text{AMF}_{\text{wra}} = 0.87
\]

AMF for Shoulder Type (aggregate)

\[
\text{AMF}_{\text{tra}} = 1.02
\]

\[
\text{AMF}_{2\text{ru}} = 0.87 \times 1.02 -1.0) \times 0.35 + 1.0
\]

\[
= 0.961
\]

AMF for Side Slope (1:6)

\[
\text{AMF}_{\text{ss}} = 1.06
\]

AMF for Horizontal Curves: none

\[
\text{AMF}_{\text{curve}} = 1.00
\]

AMF for Horizontal Clearance

\[
\text{AMF}_{\text{hc}} = (e^{-0.0137 \times (\text{Whc} - 30)} -1.0) \times Ps + 1.0
\]

\[
= e^{-0.0137 \times (18 - 30) -1.0) \times 0.27 + 1
\]

\[
= e^{-0.0137 \times (-12) -1.0) \times 0.27 + 1
\]
AMF for Driveway Density (Access Control)

\[ AMF_{dd} = (e^{b(D_d - D_{base})} - 1.0) \cdot Ps + 1.0 \]

\[ = e^{(0.034 \cdot (24.74 - 5) - 1.0)} \cdot 1 + 1 \]

\[ = e^{0.6712} \cdot 1 + 1 \]

\[ = 1.9565 \]

c. Rural Multilane Base Model with AMF’s for Lane Width, Shoulder Width, Side Slope, Horizontal Curves, Horizontal Clearance, Access Density

- AMF for Lane Width = 1.00 (see chart on Lane Widths)
- Combined AMF for Shoulder = 0.961 (AMF_{2ru})
- AMF for Side Slope = 1.06 (see exhibit)
- AMF for Horizontal Curves = 1.00 (see exhibit)
- AMF for Horizontal Clearance = 1.0482 (calculate using AMF_{hc} equation)
- AMF for Driveway Access = 1.9565 (calculate using AMF_{dd} equation)
\[ N = N_{br} \times AMF_{1ru} \times AMF_{2ru} \times AMF_{ss} \times AMF_{curve} \times \]
\[ \times AMF_{horclr} \times AMF_{dd} \]
\[ = 8.328 \times 1.00 \times 0.961 \times 1.06 \]
\[ \times 1.00 \times 1.048 \times 1.957 \]
\[ N_{seg} = 17.39 \text{ crashes per year} \]

3. Is the Actual Safety Performance of the geometrics for IL 64 (Lane Width, Shoulder Width and Type, Horizontal Clearance and Driveway Density) safer than predicted value?

Actual Safety Performance = 200 crashes/ 3 years
\[ = 66.67 \text{ crashes per year} \]

Predicted Segment Crashes per year = 17.39

Is the Actual Safety Performance of the 4-lane undivided geometrics for IL 64 North Avenue (Lane Width, Shoulder Width and Type, Horizontal Clearance and Driveway Density) safer than predicted value?

No
GROUP EXERCISE “II”

IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.

Cross-Section:
- 4 12-foot wide lanes with double yellow centerline dividing the opposing directions of travel
- 8 foot wide aggregate shoulders
- 12 foot wide left turn lanes at all major intersections

Study Section: Bloomingdale Road to Main Street-Glen Ellyn
Length of Section = 0.97 miles
ADT = 37,000 AADT
No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi

Driveways:
- Residential driveways 7
- Minor commercial driveways (less than 50 parking spaces) 7
- Major commercial driveways (more than 50 parking spaces) 11
- Total # of Driveways 25

Total number of Unsignalized Intersections with left turn lanes 0
Total number of Unsignalized Intersections without turn lanes 9
- Mildred Av
- Diane Av
- Virginia Av
- Evergreen Av
- Bernice Av
- Amy Av
- Western Ave
- Newton Ave
- Pearl Ave

No left turn lanes at minor street intersections nor at commercial driveways
No highway illumination other than some minor intersection lighting by local municipalities and the County Highway Department
Parking is prohibited
Trees and Power poles 18.0 feet from edge of pavement; Hazard Rating of 5.0

Signalized Intersections:
- Bloomingdale Road 16,100 AADT
- Shopping Center (north and south) 2,400 AADT
- Main Street-Glen Ellyn 16,700 AADT
### Actual Safety Performance:

3-years crash data 1986, 1987, 1988

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1. Predict the Crash Performance for the following:

a. **Suburban Multilane Base Model Multiple Vehicle Non-Driveway:**

\[
N_{brmv} = e^{(a + b \ln ADT + \ln L)}
\]

\[
= e^{(-11.53 + 1.33 \ln 37000 + \ln 0.97)}
\]

\[
= e^{(-11.53 + 13.99 - 0.0305)}
\]

\[
= e^{2.429}
\]

\[
= 11.4 \text{ crashes per year}
\]

b. **Suburban Multilane Base Model Single Vehicle Non-Driveway:**

\[
N_{brsv} = e^{(a + b \ln ADT + \ln L)}
\]

\[
= e^{(-7.89 + 0.81 \ln 37000 + \ln 0.97)}
\]

\[
= e^{(-7.89 + 8.5 - 0.0305)}
\]

\[
= e^{0.5997}
\]

\[
= 1.8 \text{ crashes per year}
\]
c. Driveway Related Crashes:

\[ N_{\text{brdwy}} = \text{SUM} (n_j N_j (\text{ADT}/15,000)^t) \]

\[ = 11 \times 0.202 \left( \frac{37,000}{15,000} \right)^{1.172} + 7 \times 0.064 \left( \frac{37,000}{15,000} \right)^{1.172} + 0 \times 0.220 \left( \frac{37,000}{15,000} \right)^{1.172} + 0 \times 0.029 \left( \frac{37,000}{15,000} \right)^{1.172} + 0 \times 0.106 \left( \frac{37,000}{15,000} \right)^{1.172} + 7 \times 0.020 \left( \frac{37,000}{15,000} \right)^{1.172} + 0 \times 0.032 \left( \frac{37,000}{15,000} \right)^{1.172} \]

\[ = 8.1 \text{ crashes per year} \]

\[ N_{\text{brbase}} = N_{\text{brmv(non-driveway)}} + N_{\text{brsv(non-driveway)}} + N_{\text{brdwy}} \]

\[ = 11.4 + 1.8 + 8.1 \]

\[ = 21.3 \]

d. AMF’s for Parking, Roadside Objects, and Lighting:

\[ \text{AMF}_{1r} = 1 + P_{pk} \times (f_{pk} - 1.0) \]  
Where parking is prohibited, Ppk is zero

\[ = 1 + \text{zero} \times (f_{pk} - 1.0) \]

\[ = 1.00 \]
AMF$_{2r}$ = $f_{offset}$ x $D_{fo}$ x $p_{fo}$ + (1 – $p_{fo}$)

For power poles at 160 foot spacing one side located 18 feet from travel lane, $f_{offset}$ = 0.061, $p_{fo}$ = 0.037

= $0.061$ x $(5280/160) x 0.037$

+ (1 – $0.037$)

= 1.037

AMF$_{3r}$ = 1- ((1 – 0.36 $P_{fnr}$ – 0.72 $p_{inr}$ – 0.83 $p_{pnr}$) $p_{nr}$)

Base condition is no lighting, hence, AMF$_{3r}$ = 1.000

= 1.00

e. Predicted Crashes with AMF’s Applied

$N_{br}$ = $N_{brbase}$ x AMF$_{1r}$ x AMF$_{2r}$ x AMF$_{3r}$

= $21.3$ x 1.00 x 1.037 x 1.00

= 22.1 crashes per year
f. Pedestrian Crashes

\[ N_{pedr} = N_{br} \times f_{pedr} \quad \text{for 4U, } f_{pedr} = 0.008 \]

\[
= \begin{array}{c}
22.1 \\
\end{array} \times \begin{array}{c}
0.008 \\
\end{array} \\
= \begin{array}{c}
0.18 \\
\end{array} \text{ crashes per year}
\]

g. Bicycle Crashes

\[ N_{biker} = N_{br} \times f_{biker} \quad \text{for 4U, } f_{biker} = 0.01 \]

\[
= \begin{array}{c}
22.1 \\
\end{array} \times \begin{array}{c}
0.01 \\
\end{array} \\
= \begin{array}{c}
0.22 \\
\end{array} \text{ crashes per year}
\]

h. Base Roadway Crashes for Segment (multilane Suburban 4U)

\[ N_{br} = N_{br} + N_{pedr} + N_{biker} \]

\[
= \begin{array}{c}
22.1 \\
\end{array} + \begin{array}{c}
0.18 \\
\end{array} + \begin{array}{c}
0.22 \\
\end{array} \\
= \begin{array}{c}
22.5 \\
\end{array} \text{ crashes per year}
\]
Is the Actual Safety Performance for the geometrics for IL 64 (Driveway, Parking, and Lighting) safer than predicted value?

Actual Safety Performance = \[
\begin{align*}
\text{200 crashes in 3 years} \\
= 66.7 \text{ crashes per year}
\end{align*}
\]

Predicted Segment Crashes per year = \[
\begin{align*}
22.5
\end{align*}
\]

Safer than predicted value? No

Actual safety performance is (66.7/22.5): 3 X’s > predicted crashes!
GROUP EXERCISE “III”
Prediction of Safety Performance for Multilane Intersections and Comparison to Actual Safety Performance

IL 64, DuPage County, Illinois:
IL Route 64, an east-west state highway initiates at Lake Michigan in the City of Chicago and terminates at the Mississippi River at the west border of Illinois. In DuPage County, 1987 population of 780,000, IL Route 64 is known as North Avenue traversing the cities of Elmhurst and Villa Park and through rural unincorporated areas west to St.Charles Illinois in Kane County. IL Route 64 was improved to 4 lanes in the 1960’s throughout this length with intersection improvements at major crossroads such as other state routes and county routes consisting of left turn lanes and traffic signal control during the 1960’s and 1970’s.

Study Section: Bloomingdale Road to Main Street-Glen Ellyn
Length of Section  = 0.97 miles
ADT    = 37,000 AADT

Three Signalized intersections with single left turn lanes (no right turn lanes):
Bloomingdale Road    16,100 AADT
Shopping Center (north and south)   2,400 AADT
Main Street-Glen Ellyn      16,700 AADT

Total number of Unsignalized Intersections with left turn lanes  0

Nine minor street intersections (all “T” intersections) with no left turn lanes – stop control of minor street approach :
ADT 700                   ADT 1,500
Mildred Av              Western Av
Evergreen Av            Newton Av
Amy Av                 Bernice Av
Virginia Av            Diane Av


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1. Predict the Crash Performance for the intersections using the Rural Multilane intersection models for the following:
   a. Bloomingdale Road (signalized)
   b. Shopping Center (signalized)
   c. Main Street-Glen Ellyn (signalized)
   d. Eight “T” non-signalized intersections (700 ADT)
   e. One “T” non-signalized intersection (1,500 ADT)

a. Bloomingdale Road (signalized)

\[ N_{rural} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}_{\text{Minor}})) \]
\[ = \exp(-7.423 + 0.722\ln(37,000) + 0.337\ln(16,100)) \]
\[ = \exp(3.435) \]
\[ = 31.05 \text{ crashes per year} \]

b. Shopping Center (signalized)

\[ N_{rural} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}_{\text{Minor}})) \]
\[ = \exp(-7.423 + 0.722\ln(37,000) + 0.337\ln(2,400)) \]
\[ = \exp(2.794) \]
\[ = 16.35 \text{ crashes per year} \]
c. Main Street-Glen Ellyn (signalized)

\[ N_{\text{rural}} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}^{c}_{\text{Minor}})) \]

\[ = \exp(-7.423 + 0.722\ln(37,000) + 0.337\ln(16,700)) \]

\[ = \exp(\text{3.448}) \]

\[ = 31.43 \text{ crashes per year} \]

d. Eight “T” stop control of approach at 700 ADT

\[ N_{\text{rural}} = \exp(a + b \ln(\text{ADT}_{\text{Major}}) + c \ln(\text{AADT}^{c}_{\text{Minor}})) \]

\[ = \exp(-13.098 + 1.204\ln(37,000) + 0.236\ln(700)) \]

\[ = \exp(\text{1.112}) \]

\[ = 3.04 \text{ crashes per year each} \]

\[ = 8 \times 3.04 \text{ crashes per year} \]

\[ = 24.32 \text{ crashes per year} \]
e. One “T” stop control of approach at 1500 ADT

\[ N_{rural} = \exp(a + b \ln(ADT_{Major}) + c \ln(AADT_{Minor}) \]

\[ = \exp(-13.098 + 1.204\ln(37,000) + 0.236\ln(1,500)) \]

\[ = \exp(\begin{array}{c}
-13.098 \\
+ \\
+ \\
\end{array}
\begin{array}{c}
12.664 \\
1.726 \\
1.292 \\
\end{array}) \]

\[ = \exp(3.64) \text{ crashes per year} \]

2. Predict the Crash Performance for the intersections using the Rural Multilane intersection models for the following:

a. Bloomingdale Road (signalized) \hspace{1cm} 31.05

b. Shopping Center (signalized) \hspace{1cm} 16.35

c. Main Street-Glen Ellyn (signalized) \hspace{1cm} 31.43

d. Eight “T” non-signalized intersections (700 ADT) \hspace{1cm} 24.32

e. One “T” non-signalized intersection (1,500 ADT) \hspace{1cm} 3.64

Total Predicted Intersection Crashes \hspace{1cm} 106.79
3. Compare the actual Intersection Safety Performance to the Predicted Safety Performance

Actual Safety Performance = 334 + ? crashes in 3 years

= 111 + ? crashes per year

Predicted Segment Crashes per year = 106.79

Safer than Actual? No
GROUP EXERCISE “IV”

IL 64, DuPage County, Illinois:

Study Section: Bloomingdale Road to Main Street-Glen Ellyn
Length of Section = 0.97 miles
ADT = 37,000 AADT
No Horizontal Curves; 2.8% vertical curve west of Shopping Center for 0.35 mi

Driveways – all right-in/right-out
Residential driveways 7
Minor commercial driveways (less than 50 parking spaces) 7
Major commercial driveways (more than 50 parking spaces) 11
Total # of Driveways 25

Proposed Design Cross-Section for Evaluation:
6 12-foot wide lanes with 42 foot wide curbed and landscaped median dividing the opposing directions of travel - Use 4D
12 foot wide paved shoulders
12 foot wide left turn lanes at all major intersections + 2 side street intersections
Total Lanes on IL-64 is 5 lanes each direction
Total number of Unsignalized Intersections with left turn lanes 2
Evergreen Av Pearl Ave

Total number of Unsignalized Intersections with no median opening nor turn lanes 7
Mildred Av Diane Av
Virginia Av
Bernice Av Amy Av
Western Ave Newton Ave

Highway illumination on both sides at 200 foot spacing of 400watt HPS on 40 foot mounting height on breakaway poles; Utility poles relocated out of clear zone to right-of-way line
Parking is prohibited

Signalized Intersections:
Bloomingdale Road 16,100 AADT
Shopping Center (north and south) 2,400 AADT
Main Street-Glen Ellyn 16,700 AADT

Actual Safety Performance of Previous X-Section: 3-years crash data 1986, 1987, 1988

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Exercise V – Prediction of Crashes for IL 64-North Avenue proposed Design as a Suburban Multilane Highway
Predict the Crash Performance for the following:

1. Proposed Cross-Section for Segment as Suburban Multilane 4D:

   a. **Urban Multilane Base Model Single Vehicle Non-Driveway:**

      \[
      N_{brmv} = e^{(a + b \ln \text{ADT} + \ln L)}
      \]

      \[
      = e^{(-11.88 + 1.36 \ln 37000 + \ln 0.97)}
      \]

      \[
      = e^{(-11.88 + 14.31 - 0.0305)}
      \]

      \[
      = e^{2.395}
      \]

      \[
      = 11.0 \text{ crashes per year}
      \]

   b. **Proposed Cross-Section Urban Multilane Base Model Single Vehicle Non-Driveway**

      \[
      N_{brsv} = e^{(a + b \ln \text{ADT} + \ln L)}
      \]

      \[
      = e^{(-4.59 + 0.47 \ln 37000 + \ln 0.97)}
      \]

      \[
      = e^{(-4.59 + 4.944 - 0.0305)}
      \]

      \[
      = e^{0.3233}
      \]

      \[
      = 1.4 \text{ crashes per year}
      \]
c. Driveway Related Crashes

\[ N_{brdwu} = \text{SUM} \left( n_j N_j \left( \frac{\text{ADT}}{15,000} \right)^{1.106} \right) \]

\[ = 11 \times 0.053 \left( \frac{37,000}{15,000} \right)^{1.106} + 7 \times 0.017 \left( \frac{37,000}{15,000} \right)^{1.106} + 0 \times 0.057 \left( \frac{37,000}{15,000} \right)^{1.106} + 0 \times 0.008 \left( \frac{37,000}{15,000} \right)^{1.106} + 0 \times 0.028 \left( \frac{37,000}{15,000} \right)^{1.106} + 0 \times 0.005 \left( \frac{37,000}{15,000} \right)^{1.106} + 0 \times 0.008 \left( \frac{37,000}{15,000} \right)^{1.106} \]

\[ = 2.0 \quad \text{crashes per year} \]

\[ N_{brbase} = N_{\text{Multiple Vehicle (non-driveway)}} + N_{\text{Single Vehicle (non-driveway)}} + N_{\text{brdwy}} \]

\[ = 11.0 + 1.4 + 2.0 \]

\[ = 14.4 \quad \text{crashes per year} \]

d. AMF's for Parking (AMF\(_{1r}\)), Roadside Objects (AMF\(_{2r}\)), and Lighting (AMF\(_{3r}\))

\[ \text{AMF}_{1r} = 1 + P_{pk} \times (f_{pk} - 1.0) \]

Where parking is prohibited, Ppk is zero

\[ = 1 + 0 \times (f_{pk} - 1.0) \]

\[ = 1.00 \]
\[ AMF_{2r} = f_{\text{offset}} \times D_{\text{fo}} \times p_{\text{fo}} + (1 - p_{\text{fo}}) \]

For street lighting poles at 200 foot spacing on 2 sides located 18 feet from travel lane, \( f_{\text{offset}} = 0.06 \) \( p_{\text{fo}} = 0.036 \)

\[ = 0.06 \times 2 \times 5280/200 \times 0.036 \]

\[ + (1 - 0.036) \]

\[ = 1.078 \]

\[ AMF_{3r} = 1 - (1 - 0.36 P_{\text{fnr}} - 0.72 p_{\text{inr}} - 0.83 p_{\text{pnr}}) \times p_{\text{nr}} \]

For 4D: \( P_{\text{fnr}} = 0.004 \), \( p_{\text{fnr}} = 0.281 \), \( p_{\text{pnr}} = 0.715 \), \( p_{\text{nr}} = 0.203 \)

\[ = 0.959 \]

e. Predicted Crashes with AMF’s Applied

\[ N_{\text{br}} = N_{\text{brbase}} \times AMF_{1r} \times AMF_{2r} \times AMF_{3r} \]

\[ = 14.4 \times 1.000 \times 1.078 \times 0.959 \]

\[ = 14.9 \] crashes per year

f. Pedestrian Crashes

\[ N_{\text{pedr}} = N_{\text{br}} \times f_{\text{pedr}} \quad \text{for 4D, } f_{\text{pedr}} = 0.006 \]

\[ = 14.9 \times 0.006 \]

\[ = 0.09 \] crashes per year
g. Bicycle Crashes

\[ N_{\text{biker}} = N_{\text{br}} \times f_{\text{biker}} \]

for 4U, \( f_{\text{biker}} = 0.011 \)

\[ = \frac{14.9}{0.011} \times 0.11 \]

\[ = 0.16 \text{ crashes per year} \]

h. Proposed Base Roadway Predicted Crashes for Segment (multilane Suburban 4D)

\[ N_{\text{total}} = N_{\text{br}} + N_{\text{pedr}} + N_{\text{biker}} \]

\[ = \frac{14.9}{0.09} + 0.16 \]

\[ = 15.2 \text{ crashes per year} \]

Is the Predicted Safety Performance for the proposed Divided Multilane Cross-Section safer than Actual Safety Performance value?

Actual Safety Performance = 200 crashes in 3 years

= 66.7 crashes per year

Predicted Segment Crashes per year = 15.2

Safer than Actual Safety Performance? Yes
2. Proposed Signalized Intersection of Glen Ellyn Road Road at IL 64 with:
   - Dual-Left Turn lanes on IL 64 – Single Left Turn lanes on Glen Ellyn Road
   - “Protected Left Turn” phasing on all 4 approaches
   - Right Turn lanes on all 4 approaches
   - Overhead Signals with Signal Head per Lane + 2 Signal Indications for each left turn movement
   - Lighting

   a. Urban Multilane (multiple vehicle crashes w/o ped & bike)

   \[ N_{brmv} = \exp(a + b \ln(ADT_{Major}) + c \ln(ADT_{Minor})) \]

   \[ = \exp(-10.63 + 1.07 \ln(37,000) + 0.23 \ln(16,100)) \]

   \[ = \exp(-10.63 + 1.07 \times 11.25 + 0.23 \times 2.228) \]

   \[ = \exp(2.164) \]

   \[ = 17.34 \text{ crashes per year} \]

   b. Urban Multilane (single vehicle crashes w/o ped & bike)

   \[ N_{bisv} = \exp(a + b \ln(ADT_{Major}) + c \ln(ADT_{Minor})) \]

   \[ = \exp(-9.85 + 0.68 \ln(37,000) + 0.27 \ln(16,100)) \]

   \[ = \exp(-9.85 + 0.68 \times 7.15 + 0.27 \times 2.62) \]

   \[ = \exp(-0.082) \]

   \[ = 0.92 \text{ crashes per year} \]
\[ N_{\text{bibase}} = N_{\text{bimv}} + N_{\text{bisv}} + N_{\text{brdwu}} \]

\[ = 17.34 + 0.92 \]

\[ = 18.26 \text{ crashes per year} \]

c. AMF’s

\[ \text{AMF}_{1i} (\text{lttnln}) = 0.81 \text{ for left turn lanes on both major road approaches} \]
\[ \text{AMF}_{2i} (\text{prot turn}) = 0.94 = 0.78 \text{ protected left-turn lanes on four approaches} \]
\[ \text{AMF}_{3i} (\text{rttnln}) = 0.92 \text{ for right turn lanes on major road approaches} \]
\[ \text{AMF}_{4i} (\text{Prob rttrn}) = \text{none} = 1.00 \]

\[ \text{AMF}_{5i} = 1 - ((1 - 0.36 \cdot p_{\text{fni}} - 0.72 \cdot p_{\text{ini}} - 0.83 \cdot p_{\text{pni}}) \cdot p_{\text{ni}}) \]

For 4SG intersection type, Exhibit 10-22,

\[ p_{\text{fni}} = 0.003 \]
\[ p_{\text{ini}} = 0.328 \]
\[ p_{\text{pni}} = 0.670 \]
\[ p_{\text{ni}} = 0.200 \]

\[ = 1 - ((1 - 0.36 \times 0.003 - 0.72 \times 0.328 - 0.83 \times 0.670) \times 0.200) \]

\[ = 0.826 \]

d. Total Predicted Crashes for Bloomingdale and IL 64

\[ N_{\text{bi}} = N_{\text{bibase}} \times \text{AMF}_{\text{lttnln}} \times \text{AMF}_{\text{rttnln}} \times \text{AMF}_{5i} \]

\[ = 18.26 \times 0.81 \times 0.92 \times 0.78 \times 0.826 \]

\[ = 8.77 \text{ crashes per year} \]
e. Urban Multilane Ped and Bike (single vehicle crashes w/o ped & bike)

1) \( N_{\text{pedbase}} = \exp(a + b \ln(ADT_{\text{tot}}) + c \ln(ADT_{\text{maj}}/ADT_{\text{min}}) + d \ln(\text{PedVol}) + e(n_{\text{lanes}}) \)

\[
= \exp(-9.53 + 0.40\ln(53,100) + 0.26\ln(37,000/16,100) + 0.45\ln(150) + 0.04(10))
\]

\[
= \exp(-9.53 + 4.35 + 0.216 + 2.25 + 0.4)
\]

\[
= \exp(-2.3069)
\]

\[
= 0.10 \text{ crashes per year}
\]

2) \( N_{\text{pedi}} = N_{\text{pedbase}} (\text{AMF}_{1p} \times \text{AMF}_{2p} \times \text{AMF}_{3p}) \)

AMF for Bus Stops: \( \text{AMF}_{1p} = 2.78 \)
AMF for School presence (None): \( \text{AMF}_{2p} = 1.00 \)
AMF for Alcohol Sales presence: \( \text{AMF}_{3p} = 1.12 \)

\[
= 0.10(2.78 \times 1.00 \times 1.12)
\]

\[
= 0.311 \text{ crashes per year}
\]

3) \( N_{\text{bikei}} = N_{\text{bi}} \times f_{\text{bikei}} \)

\( N_{\text{bi}} = 8.77, f_{\text{bikei}} = 0.013 \)

\[
N_{\text{bikei}} = 8.77 \times 0.013
\]

\[
= 0.114 \text{ crashes per year}
\]
f. Total predicted crashes for Bloomingdale Intersection:

\[ N_{\text{int}} = (N_{\text{bi}} + N_{\text{pedi}} + N_{\text{bikei}})C_i \]

Letting \( C_i = 1.0 \)

\[
\begin{align*}
&= 8.77 + 0.311 + 0.114 \\
&= 9.20 \text{ crashes per year}
\end{align*}
\]

Is the Predicted Safety Performance for the proposed design for the Intersection of IL 64 with Bloomingdale Road safer than the Actual Safety Performance value?

Actual Safety Performance = 170 crashes in 3 years

= 56.7 crashes per year

Predicted Intersection Crashes per year = 9.20
(For proposed improvements)

Safer than Actual Safety Performance? Yes

f. Total predicted crashes for combined Roadway and Bloomingdale Intersection

\[ N_{t(\text{predicted})} = \text{Sum } N_{rs} + \text{Sum } N_{\text{int}} \]

\[
\begin{align*}
&= 15.20 + 9.20 \\
&= 24.40 \text{ crashes per year}
\end{align*}
\]

\[ N_{t(\text{actual})} = (200 + 107)/3 = 123.3 \text{ crashes per year} \]