APPENDIX A. RUN-OFF-ROAD (ROR) PREDICTIVE METHOD

Appendix A: Run-Off-Road (ROR) Predictive Method

1.1 Introduction

Historically, models developed to explain the relationship between ROR crashes and roadside features and fixed objects, such as utility poles, traffic sign posts, trees, guardrail, median barriers and side-slopes, have been categorized as either *crash-based* or *encroachment-based* models. Each of these approaches has developed independent of the other, with accompanying software, research and publications to assist users with the application. Both approaches have a place in the design of highways and roadsides. The encroachment-based approach is employed by the AASHTO Roadside Design Guide. The primary objective of this chapter is to present the crash-based methods to model the frequency and severity of ROR crashes.

While these two approaches have the same basic objective (i.e., quantifying the safety of particular design decisions) each operates in fundamentally different ways and are used at different points in the design process. For this reason, this chapter is a good tool for corridor analysis and overall scoping of projects (e.g., how many ROR crashes might be avoided if we flatten the side slope, flatten a horizontal curve or widen the shoulders?) but a poor choice for detailed roadside-specific design (e.g., should the median barrier be placed at the center of the median or should two parallel runs be used at the edge of shoulder, should we use a flexible barrier system or a rigid concrete barrier, which test level barrier is appropriate?).

This chapter is presented to support corridor analysis of expected ROR crashes and initial project scoping. The reader is referred to the AASHTO Roadside Design Guide to address specific design decisions.

1.2 Run-Off-Road Crash Predictive General Form

Equation (1) shows the general form for a ROR crash predictive model. The model predicts the number of expected crashes per year of a particular severity associated with a given roadway segment edge.

$$N_{SEVERITY} = SPF_{EDGE} \cdot CMF_{ROADWAY} \cdot CMF_{ROADSIDE} \tag{1}$$

where:

$N_{SEVERITY}$	=	Annual number of ROR crashes of a particular severity associated with a given roadway segment edge.
SPF_{EDGE}	=	Safety performance function for an edge of the roadway in crashes per length of segment edge per year.
$CMF_{ROADWAY}$	=	A crash modification function that adjusts for the alignment and cross-sectional features of the roadway like grade, curvature, lane width and number of lanes.
$CMF_{ROADSIDE}$	=	A crash modification function that adjusts for the features of the roadside. Certain crash modification factors used within $CMF_{ROADSIDE}$ are chosen for a particular severity.

The specific components of Equation (1) and example problems are discussed in the following sections.

1.3 PREDICTIVE METHOD FOR ROR CRASHES

The ROR predictive method process for determining frequency of ROR crashes is presented in the flow chart in Figure 1. Applying this predictive method yields an estimate of the expected average crash frequency (and/or crash severity) for each roadway edge evaluated. The components of the predictive model in this chapter are determined and applied eight steps. Details of each step are explained in the following sections.

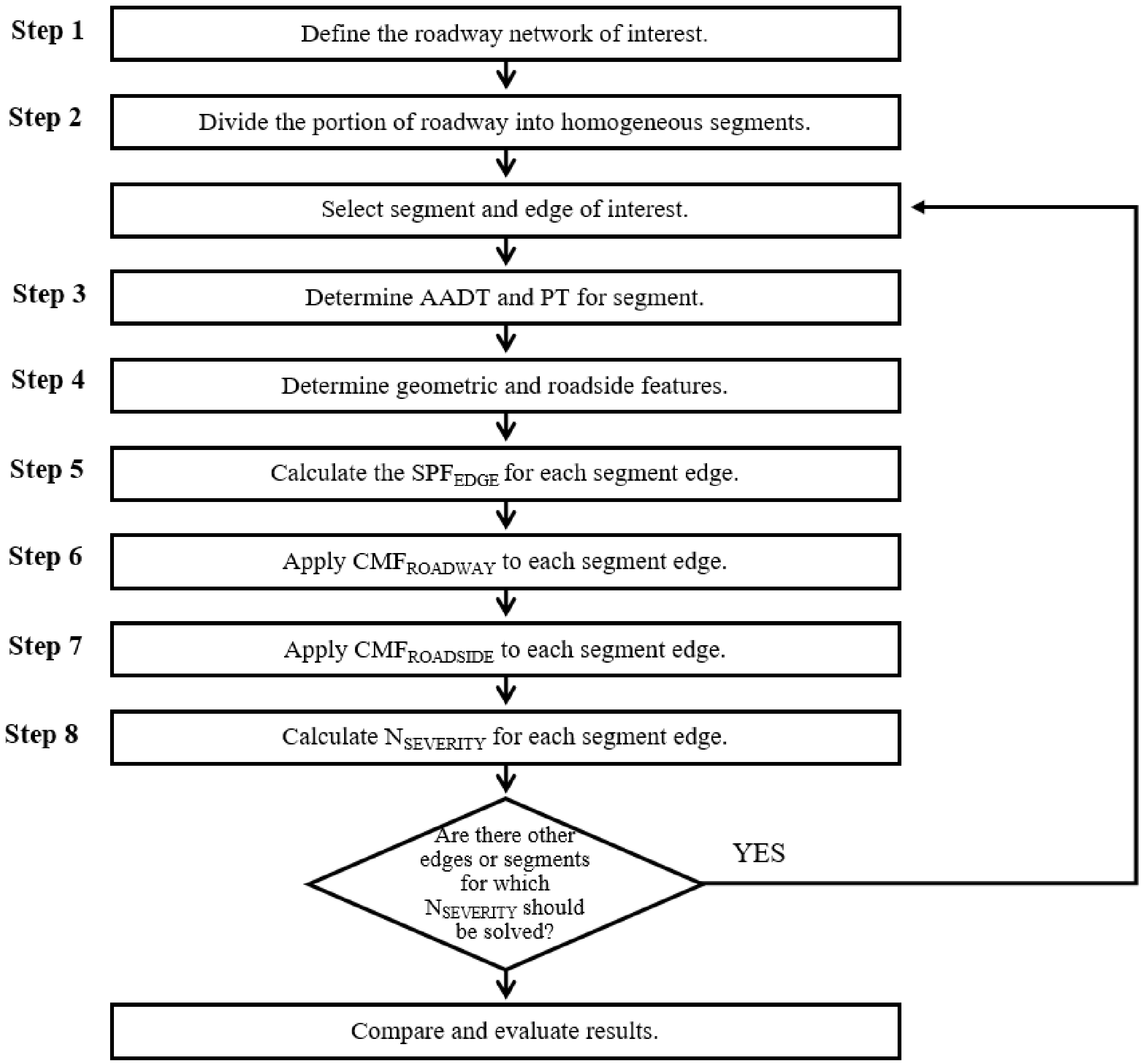


Figure 1. The ROR Predictive Method.

Step 1 – Define the roadway network of interest.
The ROR predictive method can be applied to an existing roadway, a scoping alternative for an existing roadway, or for scoping new roadways (which may be either unconstructed or yet to experience enough traffic to have observed crash data).

The limits of the roadway of interest will depend on the nature of the study. The study may be limited to only one specific segment or a group of contiguous segments. Alternatively, the ROR predictive method can be applied to a long corridor for the purposes of network screening (determining which sites require upgrading to reduce crash severity) which is discussed in the Highway Safety Manual Chapter 4.

The ROR predictive method is broadly applicable to most roadway types, including roadways in rural and urban locations, and divided and undivided roadways.

Step 2 – Define a portion of the roadway network for which the expected average ROR crash frequency will be estimated; and divide it into a homogeneous roadway segment edges.
Using the information in Step 1, the roadway is divided into individual homogeneous segment edges. The definitions and methodology for dividing the roadway into individual homogeneous roadway segments and edges for use with the ROR predictive model are provided in Section 1.4.1. When dividing a roadway facility into small homogenous segments, limiting the segment length to a minimum of 0.1 miles will decrease data collection and management efforts.

Step 3 – For the segments of interest, determine the annual average daily traffic and percent trucks during the period of interest.
Input variables for SPF_{EDGE} include bi-directional AADT in vehicles per day and percent trucks (PT) as a percentage. The AADT and PT input values may be determined by automated recording or estimated from a sample survey. Future AADT and PT values may be a forecast estimate based on appropriate land use planning and traffic volume forecasting models.

For each roadway segment the AADT is the average daily two-way, 24-hour traffic volume on that roadway segment and PT is the percentage of heavy vehicles expressed as a percent.

Step 4 – Determine geometric and roadside features for each segment of interest.
To determine the relevant data needs and avoid unnecessary data collection, it is necessary to understand the base conditions of SPF_{EDGE} in Step 5, $CMF_{ROADWAY}$ in Step 6 and $CMF_{ROADSIDE}$ in Step 7. The base conditions for each component are defined in Section 1.5 for SPF_{EDGE}, Section 1.6 for $CMF_{ROADWAY}$ and Section 1.7.1 and 1.7.2 for $CMF_{ROADSIDE}$.

The following geometric design and traffic control features are used to select a SPF and apply the appropriate modifications using $CMF_{ROADWAY}$ and $CMF_{ROADSIDE}$:

- Area type (rural or urban)
- Highway type (divided or undivided)

- Crash severity of interest (KA, KAB or F+I)
- Segment length (miles)
- Lane width (feet)
- Right shoulder width (feet)
- Posted speed limit (mph)
- Number of lanes
- Radius of horizontal curve (feet)
- Grade (percent), considering each grade from Point of Vertical Intersection (PVI) to PVI (i.e., ignoring the presence of vertical curves)
- Proportion of segment shielded by longitudinal barrier (as a decimal)
- Type of longitudinal barrier, if applicable
- Offset of longitudinal barrier, if applicable (feet)
- Density of unshielded narrow fixed objects, if applicable (number/mile)
- Offset to unshielded narrow fixed objects, if applicable (feet)
- Density of unshielded miscellaneous obstacles, if applicable (linear ft/mile)
- Offset to unshielded miscellaneous obstacles, if applicable (feet)
- Unshielded roadside slope (*x*H:1V)

Step 5 – Calculate the SPF_{EDGE} for each road segment edge.
SPF_{EDGE} (which is a statistical regression model based on observed crash data for a set of similar sites) determines the predicted average crash frequency for each segment edge. For the segment edge, calculate SPF_{EDGE} using the AADT and percent trucks determined in Step 4. SPF_{EDGE} is adjusted for on-road specific characteristics using $CMF_{ROADWAY}$ (in Step 6) and roadside characteristics using $CMF_{ROADSIDE}$ (in Step 7). The SPFs and CMFs obtained in Step 5 through Step 7 are applied to calculate the predicted average crash frequency for the selected edge and severity. The method for calculating SPF is presented in Section 1.5.

Step 6 – Apply $CMF_{ROADWAY}$ for roadway features for each roadway segment edge.
In order to account for differences between the base conditions and on-road specific roadway characteristics, $CMF_{ROADWAY}$ is used to adjust the SPF_{EDGE} estimate. An overview of $CMF_{ROADWAY}$, which is a collection of individual multipliers (i.e., individual CMFs) and guidance for their use is provided in Section C.6.4 of the Part C – Introduction and Applications Guidance. This overview includes the limitations of current knowledge related to the effects of simultaneous application of multiple countermeasures. Regarding the use of multiple countermeasures; sound engineering judgement has been used to assess the interrelationships and/or independence of the individual elements or treatments being considered for implementation within $CMF_{ROADWAY}$.

Both $CMF_{ROADWAY}$ and $CMF_{ROADSIDE}$ have the same base conditions as the SPFs used in this chapter. *Only the CMFs presented in Section 1.6 should be used as part of this chapters predictive method.*

Step 7 – Apply $CMF_{ROADSIDE}$ to each segment edge.
$CMF_{ROADSIDE}$ is used to adjust the SPF_{EDGE} estimate for each edge to account for differences between the base conditions and site-specific roadside features. This CMF proportions the shielded part of the roadside edge and the unshielded portion, ensuring that treatments for longitudinal barrier are not misapplied to unprotected segment edges and, likewise, treatments for unprotected roadside edges are not applied to those edges where longitudinal barrier are present. Regarding the use of multiple countermeasures; sound engineering judgement has been used to assess the interrelationships and/or independence of the individual elements or treatments being considered for implementation within $CMF_{ROADSIDE}$.

Step 8 – Calculate $N_{SEVERITY}$, the predicted annual number of ROR crashes associated with each roadway segment edge.
The total estimated number of crashes of a specific severity on a certain roadway edge of the segment is calculated using Equation (1). $N_{SEVERITY}$ predicts the annual number of crashes per segment edge by severity. $N_{SEVERITY}$ for each edge of the segment must be calculated separately.

1.4 ROADWAY SEGMENTS AND EDGES

1.4.1 Homogeneous Segments

A roadway segment is a section of continuous traveled way that provides two-way operation of traffic and consists of a homogeneous geometric and traffic control features. Intersections are ignored (i.e., intersections do not cause a new segment). A roadway segment begins and ends where there is a change from one homogeneous roadway feature to another. Changes to any of these characteristics cause a new segment:

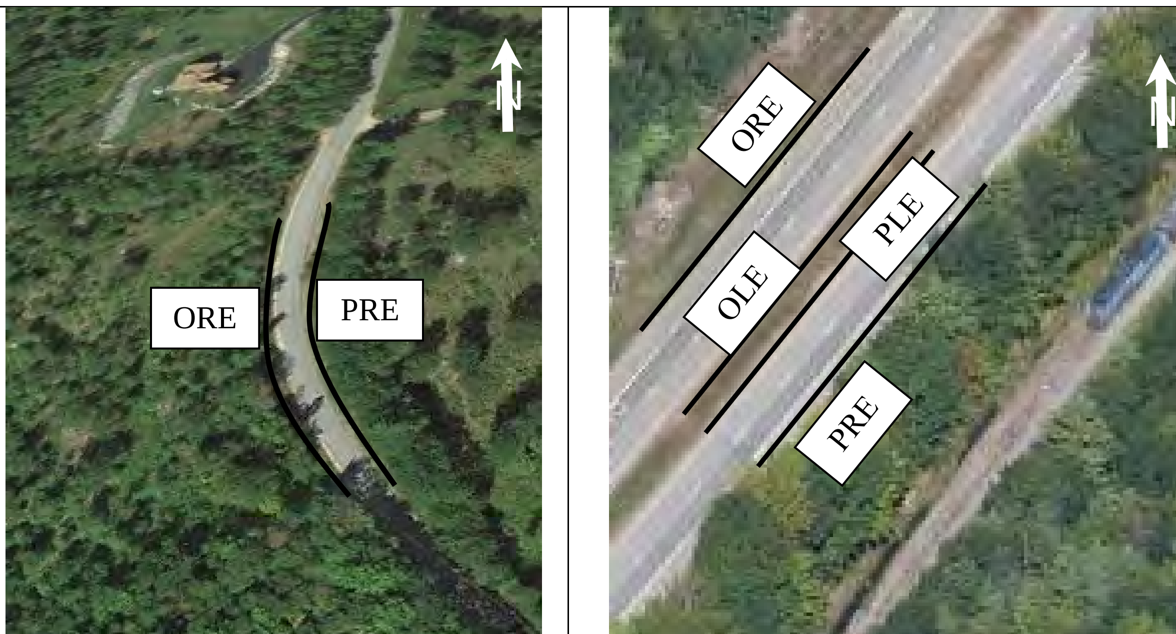
- Highway type (i.e., divided, undivided, one-way)
- AADT;
- Number of through lanes;
- Posted speed limit
- Lane width
- Horizontal curvature
- Grade (excluding vertical curvature).
- Slope of -10H:1V or flatter.
- Change in type of barrier.

The segmentation process produces a set of roadway segments of varying length, each of which is homogeneous with respect to characteristics such as traffic volumes, roadway design characteristics, and traffic control features.

There is no minimum roadway segment length for application of the ROR predictive models for roadway segments. When dividing roadway facilities into small homogenous roadway segments, limiting the segment length to a minimum of 0.10 miles will minimize calculation efforts and not affect results.

1.4.2 Defining Roadside Edges

After segmenting the highway data, determine which edges will be considered in the analysis. An undivided roadway has two edges. A divided roadway, however, has four edges (two outside edges and two median edges). For the purposes of these discussions, the increasing milepost direction will hereafter be noted as the primary direction of travel and the decreasing milepost will be the opposing direction. The outside right edge in the increasing milepost direction is therefore the primary right edge (PRE). The outside right edge in the decreasing milepost direction is the opposing right edge (ORE). When a median is present, the median edge in the increasing milepost direction is the primary left edge (PLE) and the median edge in the decreasing milepost direction is the opposing left edge (OLE). Figure 2 shows these possible crash edges graphically.



a) Undivided Highway | b) Divided Highway

Figure 2. Crash Edge Definitions by Highway Type.

1.5 SAFETY PERFORMANCE FUNCTION (SPF_{EDGE})

SPF_{EDGE} is a regression model for estimating the predicted average crash frequency of individual roadway segments. In Step 5 of the ROR predictive method the SPF is calculated based on independent variables including AADT, segment length and percent trucks. The equations for calculating the SPF for divided and undivided roadways in the ROR predictive method are shown in Equations (2) & (3) while the coefficients are shown in Table 1. For undivided roadways calculate the value of SPF_{EDGE} once for right edges, for divided roadways calculate the value of SPF_{EDGE} twice, one for right edges and left edges.

$$SPF_{UNDIV} = e^{A1 \cdot AADT} \cdot e^{A2 \cdot PT} \cdot e^{A3} \cdot AADT \cdot 365 \cdot L \quad (2)$$

$$SPF_{DIV} = AADT^{A4} \cdot e^{A5 \cdot PT} \cdot e^{A6} \cdot L \quad (3)$$

Where:

SPF_{EDGE} = Frequency of ROR crashes by segment edge per year
A_n = Regression coefficients.
AADT = Annual average daily traffic (vpd)
PT = Percentage of heavy vehicles (percent)
Note for use in SPF Equation: Enter the number as a percent (i.e. for 5%; use 5, not 0.05)
L = Segment length (miles)

Table 1. SPF_{EDGE} Coefficients.

	Rural			Urban		
	Divided		Undivided	Divided		Undivided
SPF Coefficients	Right edge (outside) crashes per segment per year	Left edge (median) crashes per segment per year	Right edge crashes per segment per year	Right edge (outside) crashes per segment per year	Left edge (median) crashes per segment per year	Right edge crashes per segment per year
A1	---	---	-6.535e-05	---	---	-7.178E-05
A2	---	---	-9.441e-03	---	---	-1.156e-02
A3	---	---	-1.475e+01	---	---	-1.40E+01
A4	0.8087	1.0019	---	0.5673	0.6585	---
A5	0.0036	0.0051	---	0.0117	0.0158	---
A6	-8.5085	-10.5689	---	-5.5012	-6.5122	---

SPF_{EDGE}, like all regression models estimates the value of a dependent variable as a function of a set of independent variables. In the development of SPF_{EDGE}, the dependent variable estimated is the predicted average crash frequency for a given segment edge under base conditions and the independent variables are the AADT, segment length and percent trucks (PT) of the segment.

1.5.1 Calibration of the SPFs to Local Conditions

Some highway agencies may have performed statistically-sound studies to develop their own jurisdiction-specific SPF derived from local conditions and crash experience. When local models are not available, calibration of these models is suggested using the procedures presented in Appendix A to Part C or other documented procedures for calibration.

1.6 CRASH MODIFICATION FUNCTION FOR ROADWAY SEGMENTS ($CMF_{ROADWAY}$)

$CMF_{ROADWAY}$ accounts for roadway characteristics that modify the likelihood of a vehicle leaving the roadway. After finding the appropriate value from each table, the individual CMFs should be multiplied together to find the aggregate $CMF_{ROADWAY}$.

$$CMF_{ROADWAY} = CMF_{LW} \cdot CMF_{SW} \cdot CMF_{PSL} \cdot CMF_{NL} \cdot CMF_{RC} \cdot CMF_G \quad (4)$$

where:

CMF_{LW}	=	Crash Modification Factor for lane width (see Table 2)
CMF_{SW}	=	Crash Modification Factor for Right shoulder width (see Table 3)
CMF_{PSL}	=	Crash Modification Factor for posted speed limit (see Table 4)
CMF_{NL}	=	Crash Modification Factor for number of lanes (see Table 5)
CMF_{RC}	=	Crash Modification Function for radius of horizontal curve (see Figure 3)
CMF_G	=	Crash Modification Function for vertical grade (see Figure 4, or Figure 5)

The $CMF_{ROADWAY}$ base conditions for roadway segments are:

- Lane width — 12 feet
- Right shoulder width — 8 feet
- Posted speed limit — 55 mph
- Number of lanes — 2 undivided or 4 divided
- Radius of curvature — None (> 580 feet)
- Grade — None (± 3%)

To determine the specific CMF for each category the user refers to the appropriate table matching the row with the corresponding value for the specific segment being analyzed, then reading the value from the appropriate column for area type (i.e., rural or urban) and highway type (i.e., divided or undivided). If the segments value for a category is greater than or less than what the table provides, use the closest value for determining that CMF.

CMF_{LW} – Lane Width

The CMF_{LW} is used to adjust from the base condition of twelve-foot lanes. Table 2 displays the CMF values (and 95% confidence intervals) for rural and urban roadways that are either divided or undivided. There is a clear trend that as lane width increases, ROR crashes are expected to increase.

Table 2. Average Lane Width CMF (CMF_{LW}).

	Rural		Urban	
Avg. Lane Width	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**
10 ft or less	0.80 (0.76, 0.83)	0.84 (0.79, 0.88)	0.92 (0.90, 0.94)	0.66 (0.64, 0.67)
11 ft	0.89 (0.87, 0.91)	0.91 (0.89, 0.94)	0.96 (0.95, 0.97)	0.81 (0.80, 0.82)
12 ft	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
13 ft	1.12 (1.10, 1.15)	1.09 (1.06, 1.12)	1.04 (1.03, 1.05)	1.23 (1.22, 1.25)
14 ft	1.26 (1.21, 1.31)	1.20 (1.13, 1.26)	1.09 (1.07, 1.11)	1.52 (1.49, 1.56)
15 ft or more	1.41 (1.32, 1.50)	1.31 (1.20, 1.42)	1.13 (1.10, 1.16)	1.88 (1.81, 1.95)

CMF_{SW} – Shoulder Width

The CMF_{SW} is used to adjust from the base condition of eight-foot shoulders. Table 3 displays the CMF values (and 95% confidence intervals) for rural and urban roadways that are either divided or undivided. There is a clear trend in each of these datasets that as shoulder width increases, the expected number of ROR crashes decreases. This observation is more dominant in the rural area type than in the urban area type.

Table 3. Right Shoulder Width CMF (CMF_{SW}).

	Rural		Urban	
Right Shoulder Width	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**
2 ft or less	1.26 (1.19, 1.33)	1.56 (1.53, 1.59)	1.06 (1.04, 1.09)	1.16 (1.14, 1.19)
4 ft	1.17 (1.12, 1.21)	1.35 (1.33, 1.37)	1.04 (1.03, 1.06)	1.11 (1.09, 1.12)
6 ft	1.08 (1.06, 1.10)	1.16 (1.15, 1.17)	1.02 (1.01, 1.03)	1.05 (1.04, 1.06)
8 ft or more	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)

When generating CMFs, it was determined that the width of the left shoulder was found to be insignificant, therefore, left shoulder width is not considered in the divided roadway PLE and OLE calculations.

CMF_{PSL} – Posted Speed Limit

The CMF_{PSL} is used to adjust from the base condition of 55 miles per hour. Table 4 displays the CMF values (and 95% confidence intervals) for rural and urban roadways that are either divided or undivided. Both urban and rural divided roadways present a downward trend in ROR crash frequency as the posted speed limit increases. Similar findings for encroachment data have been documented under NCHRP 22-27. [Ray12]

Table 4. Posted Speed Limit CMF (CMF_{PSL}).

	Rural		Urban	
Posted Speed Limit	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**
25 mph or less	1.55 (1.41, 1.71)	1.08 (1.04, 1.12)	1.64 (1.56, 1.72)	1.02 (0.98, 1.05)
30 mph	1.44 (1.33, 1.57)	1.07 (1.04, 1.10)	1.51 (1.45, 1.57)	1.01 (0.98, 1.05)
35 mph	1.34 (1.26, 1.43)	1.05 (1.03, 1.08)	1.39 (1.35, 1.44)	1.01 (0.98, 1.04)
40 mph	1.25 (1.19, 1.31)	1.04 (1.02, 1.06)	1.28 (1.25, 1.31)	1.01 (0.99, 1.03)
45 mph	1.16 (1.12, 1.20)	1.03 (1.01, 1.04)	1.18 (1.16, 1.20)	1.01 (0.99, 1.02)
50 mph	1.08 (1.06, 1.09)	1.01 (1.01, 1.02)	1.09 (1.08, 1.09)	1.00 (1.00, 1.01)
55 mph	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
60 mph	0.93 (0.91, 0.94)	0.99 (0.98, 0.99)	0.92 (0.91, 0.93)	1.00 (0.99, 1.00)
65 mph	0.86 (0.84, 0.89)	0.97 (0.96, 0.99)	0.85 (0.83, 0.86)	1.00 (0.98, 1.01)
70 mph or more	0.80 (0.76, 0.84)	0.96 (0.94, 0.98)	0.78 (0.76, 0.80)	0.99 (0.97, 1.01)

CMF_{NL} – Number of Lanes

The CMF_{NL} is used to adjust from the base condition of 2 lanes for undivided and 4 lanes for divided roadways. Table 5 displays the CMF values (and 95% confidence intervals) for rural and urban roadways that are either divided or undivided. For all datasets except the rural undivided, as the number of lanes increases the expected ROR crash frequency also increases.

Table 5. Number of Lanes CMF (CMF_{NL}).

	Rural		Urban	
Number of Lanes	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**	**Divided CMF (95% C.I.)**	**Undivided CMF (95% C.I.)**
2 or less	0.83 (0.80, 0.86)	1.00 (1.00, 1.00)	0.89 (0.87, 0.90)	1.00 (1.00, 1.00)
4	1.00 (1.00, 1.00)	0.91 (0.90, 0.92)	1.00 (1.00, 1.00)	1.11 (1.10, 1.11)
6	1.20 (1.16, 1.25)	---	1.13 (1.11, 1.15)	---
8 or more	1.45 (1.34, 1.56)	---	1.27 (1.23, 1.32)	---

CMF_{RC} – Radius of Horizontal Curve

CMF_{RC} is used to adjust from the radius of horizontal curve base condition of 580 ft or flatter (i.e., more tangent). There is no standard definition of which radius is considered “large enough to be straight”, however there are practical limitations to only considering those roadways with the highest radius of curvature as straight. For these practical reasons a radius of horizontal curve of 580 ft or greater is considered the base condition. Negative numbers represent left curves relative to the direction of travel being evaluated. Figure 3 displays the CMF values for rural and urban undivided roadways.

The effect of radius of horizontal curve on ROR crashes for divided highways in both urban and rural areas shows a trend toward increasing crashes with increasing horizontal curve, however, the size effect is small, and the confidence interval is wide. Therefore, the CMF_{RC} variable is not considered for divided highways.

For undivided roadways, CMF_{RC} considers vehicles which exited the right roadway edge, in the direction of travel under consideration. This assessment included, therefore, vehicles traveling in the primary direction and exiting right and vehicles traveling in the opposing direction and exiting left (relative to the primary direction). For analysis purposes, the analyst will modify the predicted number of right edge crashes in the primary direction (PRE) then right edge crashes in the opposing direction (ORE).

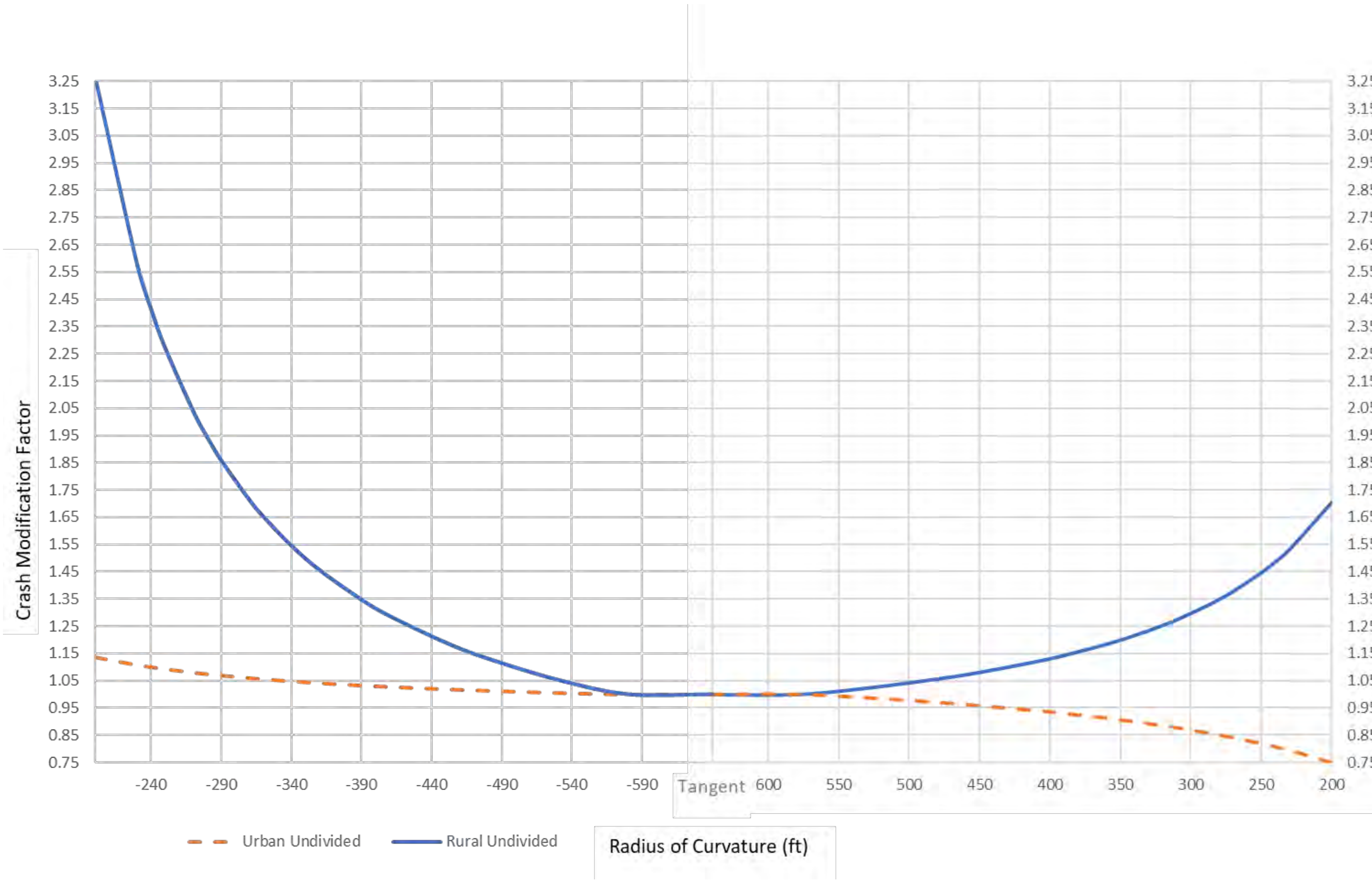


Figure 3. Radius of Curvature CMF (CMF_{RC})

CMF_G – Percent Grade

CMF_G is used to adjust from the grade base condition of ±3%. Although there is no official definition of "how flat is flat", the industry standard assumption of flat grade is considered ±3%. Negative numbers represent downhill grades relative to the direction of travel under evaluation.

Divided Roadways Grade

The divided highway analysis for vertical grade considered cross-sectional models which included both right and left edge crashes for the urban and the rural highway types. The PG CMFs are summarized in Figure 4.

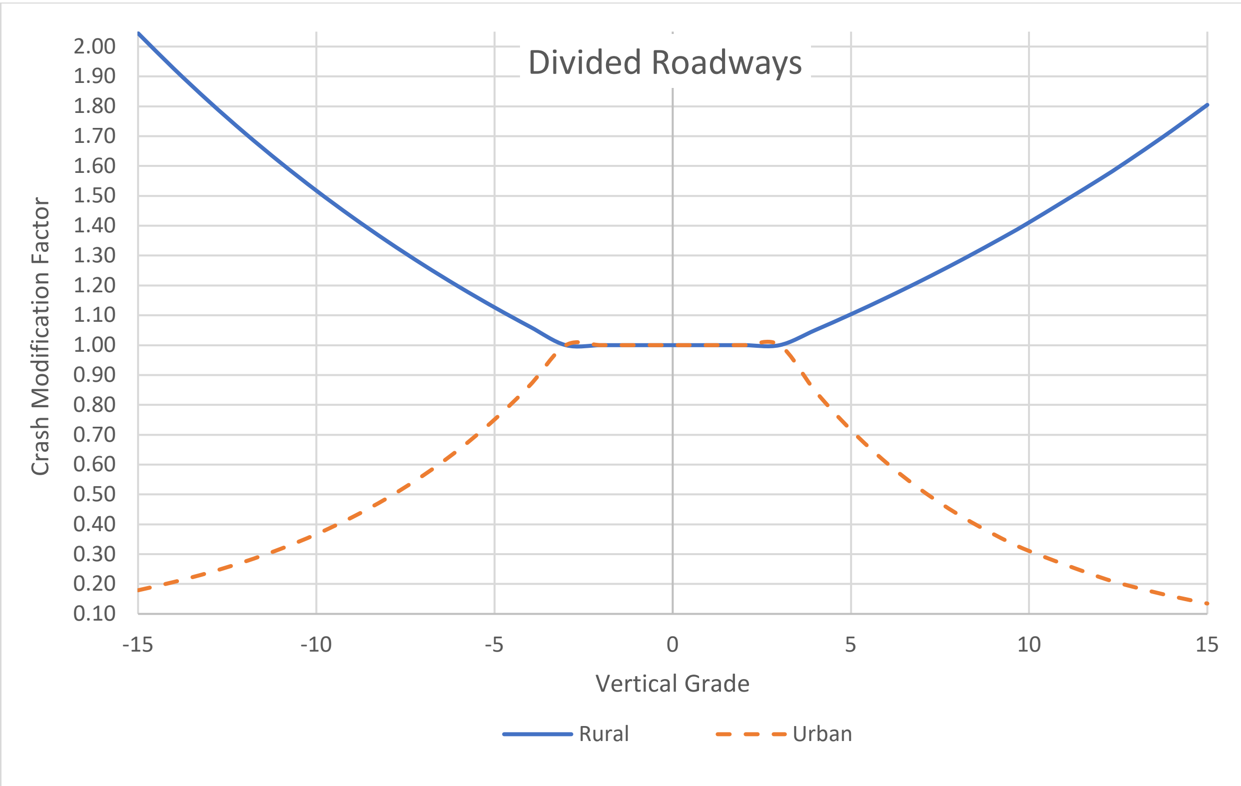


Figure 4. Vertical Grade CMF (CMF_G) for Divided Roadway Edges

Undivided Roadways Grade

For undivided roadways, CMF_G considers vehicles which exited the right roadway edge, in the direction of travel under consideration. This assessment included, therefore, vehicles traveling in the primary direction and exiting right and vehicles traveling in the opposing direction and exiting left (relative to the primary direction). For analysis purposes, the analyst will predict the number of right edge crashes in the primary direction (PRE) then right edge crashes in the opposing direction (ORE).

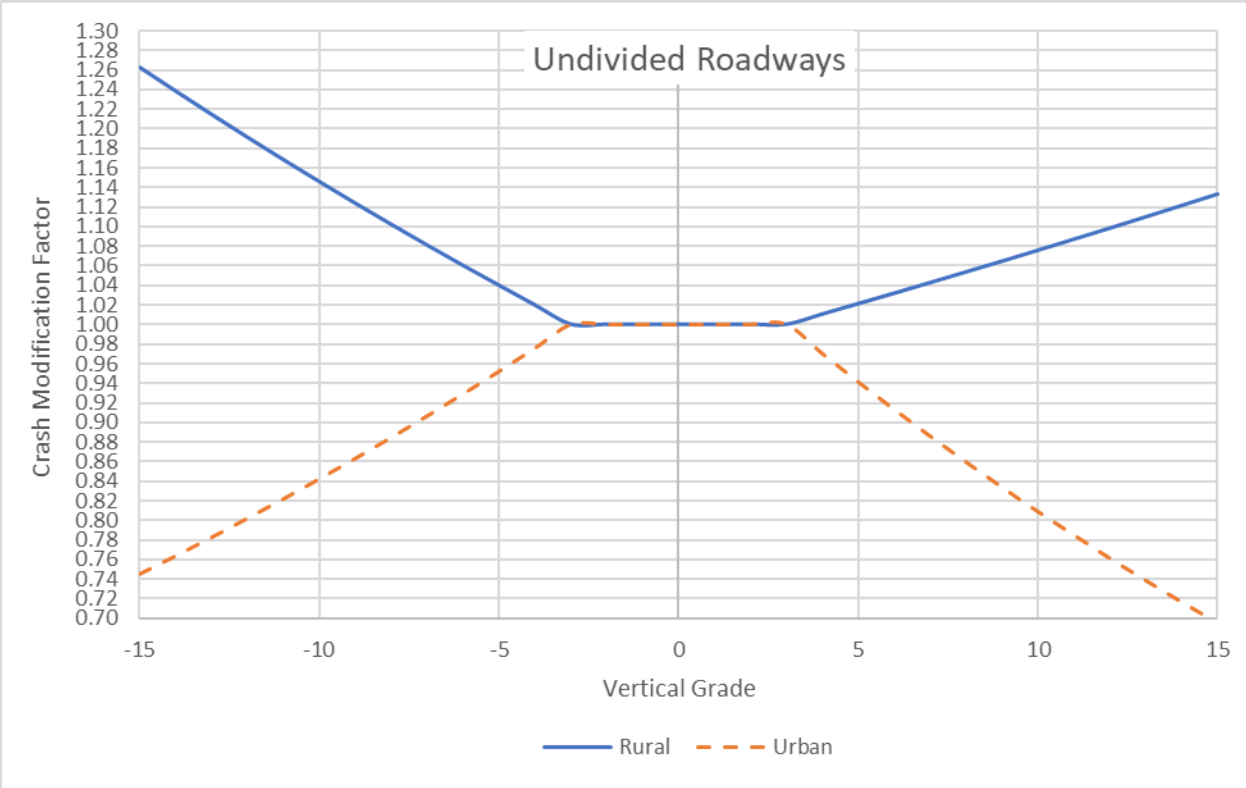


Figure 5. Vertical Grade CMF (CMF_G) for Undivided Roadway Edges

1.7 Crash Modification Function for Roadside Edges ($CMF_{ROADSIDE}$)

The severity of an ROR crash will depend on the object struck off the road and not the geometry of the roadway itself. Therefore, $CMF_{ROADSIDE}$ is a crash modification function that adjusts for the features of the roadside. This function predicts an increase or decrease in the frequency of various severity ROR crashes based on the type, density, and offset of roadside features. The roadside crash modification function, $CMF_{ROADSIDE}$, takes the following form:

$$CMF_{ROADSIDE} = \left[\beta_{SHLD} \cdot X_{SHLD} \cdot \prod_{j=1}^{m1} CMF_j\right] + \left[\beta_{UNSHLD} \cdot X_{UNSHLD} \cdot \prod_{k=1}^{m2} CMF_k\right] \quad (5)$$

Where:

X_{SHLD} = Proportion of the segment edge where longitudinal barriers are installed where $0 \leq X_{SHLD} \leq 1$.

X_{UNSHLD} = Proportion of the segment edge where there are unshielded ditches or roadside slopes and other unshielded fixed objects where $0 \leq X_{UNSHLD} \leq 1$.

Condition: 1 = $X_{SHLD} + X_{UNSHLD}$ *(100% of the segment edge is accounted for).*

β_{SHLD} = The probability of a longitudinal barrier crash of each severity associated with the segment edges where longitudinal barriers are installed. (see Table 6)

β_{UNSHLD}	=	The probability of a non-longitudinal barrier ROR crash of each severity associated with the segment edges where there are unshielded ditches, roadside slopes or fixed objects like trees, tree lines, utility poles, bridge piers, etc. (see Table 6)
CMF_j	=	Crash modification factors that modify the ROR crashes associated with longitudinal barriers. These CMFs account for characteristics like barrier type and barrier offset. (see Table 7 and Table 8)
CMF_k	=	Crash modification factors associated with unshielded roadsides. These CMFs account for characteristics like the density of narrow fixed objects, slopes, and other unshielded objects. (see Table 9, Table 10, Table 11, Table 12, and Table 13)

$CMF_{ROADSIDE}$ takes an additive form because it considers shielded and unshielded edges independently and those edges must sum to one (i.e. $X_{SHLD} + X_{UNSHLD} = 1$). CMFs that represent characteristics of the shielding longitudinal barriers (i.e., type and offset) are multiplied only by the first portion of the function since they would affect only those characteristics Likewise, characteristics that involve the unshielded roadside edges such as fixed objects and terrain are multiplied only by the second portion of the function since they only affect the proportion of the segment edge that is unshielded.

X_{SHLD} and X_{UNSHLD} are the proportion of the segment which is shielded and unshielded respectfully. These values for X_{SHLD} range from 0 (no shielding) to 1 (completely shielded). The values for $X_{UNSHLD} = 1 - X_{SHLD}$.

β_{SHLD} and β_{UNSHLD} represent the "typical" roadsides associated with the straight, flat roads at each severity level as presented in Table 6.

Table 6. $CMF_{ROADSIDE}$ Coefficients.

Area Type	Highway Type	Coefficient	KA	KAB	F+I
Rural	Divided	β_{SHLD}	0.0407	0.1891	0.2830
		β_{UNSHLD}	0.0625	0.2682	0.3829
	Undivided	β_{SHLD}	0.0645	0.2389	0.3374
		β_{UNSHLD}	0.1095	0.3589	0.4760
Urban	Divided	β_{SHLD}	0.0424	0.1873	0.2947
		β_{UNSHLD}	0.0564	0.2372	0.3606
	Undivided	β_{SHLD}	0.0737	0.2602	0.3724
		β_{UNSHLD}	0.1052	0.3417	0.4669

1.7.1 Crash Modification Factors for Shielded Segment Edges (CMF_j).

Crash modification factors that modify the ROR crashes associated with longitudinal barriers. These CMFs account for characteristics like barrier type and barrier offset.

The $CMF_{ROADSIDE}$ base conditions for shielded roadway segments are:

	Rural Divided	Rural Undivided	Urban Divided	Urban Undivided
▪ Longitudinal barrier type	W-beam	W-beam	W-beam	W-beam
▪ Longitudinal barrier offset	8 ft	10 ft	4 ft	12 ft

CMF_{j_LBT} – Longitudinal Barrier Type

CMF_{j_LBT} is used to adjust from the base condition of shielding provided by a W-beam guardrail. These results should be interpreted along with the appropriate use and structural limitations of each of these types of barriers. One would not, for example, choose to install a cable barrier in place of a concrete bridge rail to reduce crash severity because the cable barrier is designed to reduce severity by deflecting whereas the concrete is designed to be rigid and reduce deflection. A cable barrier could not deflect if used as a bridge rail, therefore, is not appropriate in that situation. While these CMF values are statistically robust, these CMFs should only be used to determine crash frequency. The AASHTO Roadside Design Guide [AASHTO11] should be referenced for the selection and placement of barriers.

Table 7. Longitudinal Barrier Type CMF (CMF_{j_LBT}).

	Rural & Urban, Divided & Undivided		
Barrier Type	**KABC CMF**	**KAB CMF**	**KA CMF**
W-beam	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
W-beam (weak post)	0.62 (0.53, 0.73)	0.38 (0.29, 0.50)	0.51 (0.30, 0.87)
High Tension Cable	0.45 (0.36, 0.57)	0.42 (0.29, 0.60)	0.31 (0.13, 0.75)
Low Tension Cable	*1.04 (0.76, 1.44)*	0.55 (0.31, 0.97)	*0.39 (0.10, 1.59)*
New Jersey Shape	1.50 (1.41, 1.61)	1.73 (1.59, 1.89)	1.38 (1.15, 1.66)
Vertical Wall Barrier	1.29 (1.13, 1.47)	1.50 (1.27, 1.76)	2.23 (1.69, 2.95)
F-shape Barrier	2.19 (1.63, 2.94)	3.13 (2.27, 4.33)	*1.52 (0.71, 3.27)*
Single Slope Barrier	1.17 (0.93, 1.48)	1.42 (1.06, 1.90)	*0.76 (0.36, 1.62)*

CMF_{j_LBO} – Longitudinal Barrier Offset

The CMF_{j_LBO} is used to adjust from the base conditions for each specific roadway type, see bullet 2 in Section Crash Modification Factors for Unshielded Segment Edges (CMF_k).1.7.1 for base conditions. Table 8 displays the CMF values (and 95% confidence intervals) by area type and highway type.

Table 8. Longitudinal Barrier Offset CMF (CMF_{j_LBO}).

	Rural		Urban	
	Divided	Undivided	Divided	Undivided
Offset	CMF (95% C.I.)	CMF (95% C.I.)	CMF (95% C.I.)	CMF (95% C.I.)
4 ft or less	1.55 (1.54, 1.55)	1.34 (1.33, 1.34)	1.79 (1.78, 1.80)	1.00 (1.00, 1.00)
6 ft	1.34 (1.33, 1.34)	1.16 (1.15, 1.16)	1.55 (1.54, 1.55)	0.86 (0.86, 0.87)
8 ft	1.16 (1.15, 1.16)	1.00 (1.00, 1.00)	1.34 (1.33, 1.34)	0.75 (0.75, 0.75)
10 ft	1.00 (1.00, 1.00)	0.86 (0.86, 0.87)	1.16 (1.15, 1.16)	0.65 (0.64, 0.65)
15 ft	0.70 (0.69, 0.70)	0.60 (0.60, 0.60)	0.80 (0.80, 0.81)	0.45 (0.45, 0.45)
20 ft	0.48 (0.48, 0.49)	0.42 (0.42, 0.42)	0.56 (0.56, 0.56)	0.31 (0.31, 0.32)
25 ft	0.34 (0.33, 0.34)	0.29 (0.29, 0.29)	0.39 (0.39, 0.39)	0.22 (0.21, 0.22)
30 ft	0.23 (0.23, 0.24)	0.20 (0.20, 0.21)	0.27 (0.27, 0.27)	0.15 (0.15, 0.15)
35 ft	0.16 (0.16, 0.17)	0.14 (0.14, 0.14)	0.19 (0.19, 0.19)	0.11 (0.10, 0.11)
40 ft	0.11 (0.11, 0.12)	0.10 (0.10, 0.10)	0.13 (0.13, 0.13)	0.07 (0.07, 0.07)
45 ft	0.08 (0.08, 0.08)	0.07 (0.07, 0.07)	0.09 (0.09, 0.09)	0.05 (0.05, 0.05)
50 ft or more	0.05 (0.05, 0.06)	0.05 (0.05, 0.05)	0.06 (0.06, 0.06)	0.04 (0.03, 0.04)

1.7.2 Crash Modification Factors for Unshielded Segment Edges (CMF_k).

Crash modification factors associated with unshielded roadsides. These CMFs account for characteristics like the density of narrow fixed objects, slopes, and other unshielded objects. The $CMF_{ROADSIDE}$ base conditions for unshielded roadway segments are:

	Rural Divided	Rural Undivided	Urban Divided	Urban Undivided
▪ Narrow fixed object density	33/mile	33/mile	28/mile	44/mile
▪ Narrow fixed object offset	30 ft	38 ft	7 ft	17 ft
▪ Miscellaneous obstacle density	600 ft/mile	450 ft/mile	300 ft/mile	500 ft/mile
▪ Miscellaneous obstacle offset	45 ft	45 ft	7 ft	15 ft
▪ Slope	-10H:1V	-10H:1V	-10H:1V	-10H:1V

Narrow fixed object density is expressed as the number of NFOs per mile. Miscellaneous obstacle density is expressed as the linear footage/mile. Since most segments are not an even 1.00-mile-long the density (i.e., number of NFOs per mile) can be calculated by using the Equation (6). The process is identical for miscellaneous obstacles where density is equal to linear feet per mile. Since NFOs and miscellaneous obstacles can vary individually in offset within a segment, the average offset (rounded down) to the nearest available CMF value should be used.

$$\frac{\#\,NFO}{Segment\ L\ (miles)} = \frac{x}{1\ Mile} \tag{6}$$

CMF_{k_FO} – Narrow Fixed Object Density

The CMF_{k_FO} is used to adjust from the base conditions for each specific area type and highway type, see bullet 1 in Section 1.7.2 for base conditions. Table 9 displays the CMF values (and 95% confidence intervals) by area type and highway type.

Table 9. Narrow Fixed Object Density CMF (CMF_{k_FO}).

	Rural		**Urban**	
	Divided	**Undivided**	**Divided**	**Undivided**
Density	**CMF (95% C.I.)**	**CMF (95% C.I.)**	**CMF (95% C.I.)**	**CMF (95% C.I.)**
1 per mile	0.86 (0.86, 0.86)	0.86 (0.86, 0.86)	0.88 (0.88, 0.88)	0.82 (0.82, 0.82)
5 per mile	0.88 (0.88, 0.88)	0.88 (0.88, 0.88)	0.90 (0.90, 0.90)	0.83 (0.83, 0.83)
10 per mile	0.90 (0.90, 0.90)	0.90 (0.90, 0.90)	0.92 (0.92, 0.92)	0.85 (0.85, 0.85)
20 per mile	0.94 (0.94, 0.94)	0.94 (0.94, 0.94)	0.96 (0.96, 0.96)	0.89 (0.89, 0.89)
30 per mile	0.99 (0.99, 0.99)	0.99 (0.99, 0.99)	1.01 (1.01, 1.01)	0.94 (0.94, 0.94)
40 per mile	1.03 (1.03, 1.03)	1.03 (1.03, 1.03)	1.06 (1.06, 1.06)	0.98 (0.98, 0.98)
50 per mile	1.08 (1.08, 1.08)	1.08 (1.08, 1.08)	1.11 (1.11, 1.11)	1.03 (1.03, 1.03)
60 per mile	1.14 (1.14, 1.14)	1.14 (1.14, 1.14)	1.16 (1.16, 1.16)	1.08 (1.08, 1.08)
70 per mile	1.19 (1.19, 1.19)	1.19 (1.19, 1.19)	1.22 (1.22, 1.22)	1.13 (1.13, 1.13)
80 per mile	1.25 (1.25, 1.25)	1.25 (1.25, 1.25)	1.28 (1.28, 1.28)	1.18 (1.18, 1.18)
90 per mile	1.31 (1.31, 1.31)	1.31 (1.31, 1.31)	1.34 (1.34, 1.34)	1.24 (1.24, 1.24)
100 per mile	1.37 (1.37, 1.37)	1.37 (1.37, 1.37)	1.40 (1.40, 1.40)	1.30 (1.30, 1.30)
200 per mile	2.19 (2.19, 2.20)	2.19 (2.19, 2.20)	2.25 (2.24, 2.25)	2.08 (2.08, 2.09)
250 per mile	2.78 (2.77, 2.78)	2.78 (2.77, 2.78)	2.84 (2.84, 2.85)	2.64 (2.63, 2.64)
300 per mile	3.51 (3.51, 3.52)	3.51 (3.51, 3.52)	3.60 (3.59, 3.60)	3.34 (3.33, 3.34)
400 per mile	5.62 (5.61, 5.64)	5.62 (5.61, 5.64)	5.76 (5.74, 5.77)	5.34 (5.33, 5.35)
500 per mile	9.00 (8.97, 9.03)	9.00 (8.97, 9.03)	9.21 (9.18, 9.24)	8.55 (8.52, 8.57)

CMF_{k_NO} – Narrow Fixed Object Offset

The CMF_{k_NO} is used to adjust from the base conditions for each specific area type and highway type, see bullet 2 in Section Crash Modification Factors for Unshielded Segment Edges (CMF_k).1.7.2 for base conditions. Table 10 displays the CMF values (and 95% confidence intervals) by area type and highway type.

Table 10. Narrow Fixed Object Offset CMF (CMF_{k_NO}).

	Rural		Urban	
	Divided	**Undivided**	**Divided**	**Undivided**
Offset	**CMF (95% C.I.)**	**CMF (95% C.I.)**	**CMF (95% C.I.)**	**CMF (95% C.I.)**
4 ft or less	2.08 (2.07, 2.08)	2.60 (2.59, 2.61)	1.09 (1.09, 1.09)	1.44 (1.44, 1.44)
6 ft	1.96 (1.96, 1.97)	2.46 (2.45, 2.47)	1.03 (1.03, 1.03)	1.36 (1.36, 1.36)
8 ft	1.86 (1.85, 1.86)	2.33 (2.32, 2.33)	0.97 (0.97, 0.97)	1.29 (1.29, 1.29)
10 ft	1.76 (1.75, 1.76)	2.20 (2.19, 2.21)	0.92 (0.92, 0.92)	1.22 (1.22, 1.22)
15 ft	1.53 (1.52, 1.53)	1.91 (1.91, 1.92)	0.80 (0.80, 0.80)	1.06 (1.06, 1.06)
20 ft	1.32 (1.32, 1.33)	1.66 (1.66, 1.66)	0.69 (0.69, 0.69)	0.92 (0.92, 0.92)
25 ft	1.15 (1.15, 1.15)	1.44 (1.44, 1.44)	0.60 (0.60, 0.60)	0.80 (0.80, 0.80)
30 ft	1.00 (1.00, 1.00)	1.25 (1.25, 1.25)	0.52 (0.52, 0.52)	0.69 (0.69, 0.69)
35 ft	0.87 (0.87, 0.87)	1.09 (1.09, 1.09)	0.45 (0.45, 0.46)	0.60 (0.60, 0.60)
40 ft	0.75 (0.75, 0.76)	0.95 (0.95, 0.95)	0.40 (0.39, 0.40)	0.52 (0.52, 0.52)
45 ft	0.66 (0.65, 0.66)	0.82 (0.82, 0.82)	0.34 (0.34, 0.34)	0.45 (0.45, 0.46)
50 ft or more	0.57 (0.57, 0.57)	0.71 (0.71, 0.71)	0.30 (0.30, 0.30)	0.40 (0.39, 0.40)

CMF_{k_MD} – Miscellaneous Obstacle Density

The CMF_{k_MD} is used to adjust from the base conditions for each specific area type and highway type, see bullet 3 in Section Crash Modification Factors for Unshielded Segment Edges (CMF_k).1.7.2 for base conditions. Table 11 displays the CMF values (and 95% confidence intervals) by area type and highway type.

Table 11. Miscellaneous Obstacle Density CMF (CMF_{k_MD}).

	Rural		Urban	
	Divided	Undivided	Divided	Undivided
Density	CMF (95% C.I.)	CMF (95% C.I.)	CMF (95% C.I.)	CMF (95% C.I.)
50 ft/mile	0.65 (0.65, 0.65)	0.73 (0.73, 0.73)	0.82 (0.82, 0.82)	0.71 (0.71, 0.71)
100 ft/mile	0.68 (0.68, 0.68)	0.76 (0.76, 0.76)	0.86 (0.86, 0.86)	0.73 (0.73, 0.73)
200 ft/mile	0.73 (0.73, 0.73)	0.82 (0.82, 0.82)	0.93 (0.93, 0.93)	0.79 (0.79, 0.79)
300 ft/mile	0.79 (0.79, 0.79)	0.89 (0.89, 0.89)	1.00 (1.00, 1.00)	0.86 (0.86, 0.86)
400 ft/mile	0.86 (0.86, 0.86)	0.96 (0.96, 0.96)	1.08 (1.08, 1.08)	0.93 (0.93, 0.93)
450 ft/mile	0.89 (0.89, 0.89)	1.00 (1.00, 1.00)	1.12 (1.12, 1.12)	0.96 (0.96, 0.96)
500 ft/mile	0.93 (0.93, 0.93)	1.04 (1.04, 1.04)	1.17 (1.17, 1.17)	1.00 (1.00, 1.00)
600 ft/mile	1.00 (1.00, 1.00)	1.12 (1.12, 1.12)	1.26 (1.26, 1.26)	1.08 (1.08, 1.08)
700 ft/mile	1.08 (1.08, 1.08)	1.21 (1.21, 1.21)	1.36 (1.36, 1.36)	1.17 (1.17, 1.17)
800 ft/mile	1.17 (1.17, 1.17)	1.31 (1.31, 1.31)	1.47 (1.47, 1.47)	1.26 (1.26, 1.26)
1000 ft/mile	1.36 (1.36, 1.36)	1.53 (1.53, 1.53)	1.72 (1.72, 1.72)	1.47 (1.47, 1.47)
2000 ft/mile	2.95 (2.94, 2.96)	3.31 (3.31, 3.32)	3.72 (3.71, 3.73)	3.19 (3.18, 3.19)
3000 ft/mile	6.39 (6.37, 6.41)	7.18 (7.15, 7.20)	8.06 (8.03, 8.09)	6.90 (6.88, 6.93)
4000 ft/mile	13.84 (13.77, 13.91)	15.54 (15.46, 15.62)	17.45 (17.36, 17.54)	14.95 (14.88, 15.02)
5000 ft/mile	29.97 (29.79, 30.16)	33.66 (33.44, 33.87)	37.79 (37.55, 38.04)	32.38 (32.18, 32.59)

CMF_{k_MO} – Miscellaneous Obstacle Offset

The CMF_{k_MO} is used to adjust from the base conditions for each specific area type and highway type, see bullet 4 in Section Crash Modification Factors for Unshielded Segment Edges (CMF_k).1.7.2 for base conditions. Table 12 displays the CMF values (and 95% confidence intervals) by area type and highway type.

Table 12. Miscellaneous Obstacle Offset CMF (CMF_{k_MO}).

	Rural		Urban	
	Divided	**Undivided**	**Divided**	**Undivided**
Offset	**CMF (95% C.I.)**	**CMF (95% C.I.)**	**CMF (95% C.I.)**	**CMF (95% C.I.)**
4 ft or less	2.41 (2.39, 2.43)	2.41 (2.39, 2.43)	1.07 (1.07, 1.07)	1.27 (1.26, 1.27)
6 ft	2.31 (2.29, 2.32)	2.31 (2.29, 2.32)	1.02 (1.02, 1.02)	1.21 (1.21, 1.21)
8 ft	2.21 (2.20, 2.22)	2.21 (2.20, 2.22)	0.98 (0.98, 0.98)	1.16 (1.16, 1.16)
10 ft	2.12 (2.10, 2.13)	2.12 (2.10, 2.13)	0.94 (0.94, 0.94)	1.11 (1.11, 1.11)
15 ft	1.90 (1.89, 1.91)	1.90 (1.89, 1.91)	0.84 (0.84, 0.84)	1.00 (1.00, 1.00)
20 ft	1.71 (1.70, 1.72)	1.71 (1.70, 1.72)	0.76 (0.76, 0.76)	0.90 (0.90, 0.90)
25 ft	1.54 (1.53, 1.54)	1.54 (1.53, 1.54)	0.68 (0.68, 0.68)	0.81 (0.81, 0.81)
30 ft	1.38 (1.38, 1.38)	1.38 (1.38, 1.38)	0.61 (0.61, 0.61)	0.73 (0.72, 0.73)
35 ft	1.24 (1.24, 1.24)	1.24 (1.24, 1.24)	0.55 (0.55, 0.55)	0.65 (0.65, 0.65)
40 ft	1.11 (1.11, 1.11)	1.11 (1.11, 1.11)	0.49 (0.49, 0.50)	0.59 (0.58, 0.59)
45 ft	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	0.44 (0.44, 0.45)	0.53 (0.52, 0.53)
50 ft or more	0.90 (0.90, 0.90)	0.90 (0.90, 0.90)	0.40 (0.39, 0.40)	0.47 (0.47, 0.48)

CMF_{k_S} – Roadside Slope

The CMF_{k_S} from the base condition of -10H:1V roadside slope. Table 13 displays the CMF values. Base conditions are the same for each area and highway type (i.e., flat traversable terrain 10H:1V or flatter). The slope CMF values also do not vary by area or highway type.

Table 13. Roadside Slope CMF (CMF_{k_MO}).

Slope	**CMF**
-10H:1V or flatter	1.00
-6H:1V	1.98
-4H:1V	3.83
-3H:1V	5.68
-2H:1V	9.21

1.8 WORKBOOK/SAMPLE PROBLEMS

In this section, four problems are presented using the ROR predictive method. A sample problem has been selected for each area type (i.e., rural and urban) and highway type (i.e., undivided and divided).

Problem No.	Page No.	Description
Blank		Blank worksheets to copy and re-use as needed
1		Rural undivided roadway
2		Rural divided roadway
3		Urban undivided roadway
4		Urban divided roadway

1.8.1 Blank Worksheets

Worksheet A

General Information		**Location Information**	
Analyst		Roadway	
Agency		Roadway Segment	
Date Performed		Jurisdiction	
		Analysis Year	

Input Data	**Base Condition**				**PRE**	**PLE**	**ORE**	**OLE**
Road location (rural, urban)	R	R	U	U				
Divided or undivided	D	U	D	U				
Segment length	--							
AADT	--							
Percent trucks	--							
Lane width (ft)	12							
Right Shoulder width (ft)	8							
Posted Speed limit (mph)	55							
Number of lanes	4	2	4	2				
Radius of curvature (ft)	580							
Grade	±3							
% of segment that is shielded								
Longitudinal barrier type	W-beam							
Longitudinal barrier offset (ft)	8	10	4	12				
NFO density (/mi)	33	33	28	44				
NFO offset (ft)	30	38	7	17				
Misc. obstacle density (ft/mi)	600	450	300	500				
Misc. obstacle offset (ft)	45	45	7	15				
Slope (*x*H:1V)	-10H:1V or flatter							
Crash severity of interest	--	--	--	--				

Worksheet B - Divided

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AADT	**Coefficient A4**	**Coefficient A5**	**PT**	**Coefficient A6**	**Segment L**	**SPF_{EDGE}**
		from Table 1	from Table 1		from Table 1		from Eq. (3)[1]
Right Edge							
Left Edge							

Note 1: $SPF_{EDGE} = (1)^{(2)} * e^{(3)*(4)} * e^{(5)} * (6)$

Worksheet B - Undivided

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Coefficient A1	**AADT**	**Coefficient A2**	**PT**	**Coefficient A3**	**Segment L**	**SPF_{EDGE}**
	from Table 1		from Table 1		from Table 1		from Eq. (2)[1]
Right Edge							

Note 1: $SPF_{EDGE} = e^{(1)*(2)} * e^{(3)*(4)} * e^{(5)} * (1) * 365 * (6)$

Worksheet C

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CMF for Lane Width	**CMF for Shoulder Width**	**CMF for Posted Speed Limit**	**CMF for Number of Lanes**	**CMF for Radius of Curve**	**CMF for Grade**	**$CMF_{ROADWAY}$**
	from Table 2	from Table 3	from Table 4	from Table 5	from Figure 3	from Figure 4 or Figure 5	from Eq. (4)[1]
PRE							
PLE							
ORE							
OLE							

Note 1: $CMF_{ROADWAY} = (1) * (2) * (3) * (4) * (5) * (6)$

Worksheet D

	(1)	(2)	(3)	(4)	(5)
	Probability of a LB Crash	**Portion of the Segment Edge that is Shielded**	**CMF for LB Type**	**CMF for LB Offset**	**$CMF_{ROADSIDE\_j}$ for Shielded Portion**
	from Table 6		from Table 7	from Table 8	from Eq. (5)[1]
PRE					
PLE					
ORE					
OLE					

Note 1: $CMF_{ROADSIDE\_j} = (1) * (2) * (3) * (4)$

Worksheet E

	(1)	(2)	(3)	(4)
	Probability of a Non-LB ROR Crash	**Portion of the Segment Edge that is Unshielded**	**CMF for NFO Density**	**CMF for NFO Offset**
	from Table 6		from Table 9	from Table 10
PRE				
PLE				
ORE				
OLE				

	(5)	(6)	(7)	(8)
	CMF for Misc. Density	**CMF for Misc. Offset**	**CMF for Roadside Slope**	**$CMF_{ROADSIDE\_k}$ for Unshielded Portion**
	from Table 11	from Table 12	from Table 13	from Eq. (5)[1]
PRE				
PLE				
ORE				
OLE				

Note 1: $CMF_{ROADSIDE\_k}$ = (1) * (2) * (3) * (4) * (5) * (6) * (7)

Worksheet F

	(1)	(2)	(3)	(4)	(5)
	SPF_{EDGE}	**$CMF_{ROADWAY}$**	**$CMF_{ROADSIDE}$ for Shielded Portion**	**$CMF_{ROADSIDE}$ for Unshielded Portion**	**$N_{SEVERITY}$**
	(7) from Worksheet B	(7) from Worksheet C	(5) from Worksheet D	(8) from Worksheet E	from Eq. (1)[1]
PRE					
PLE					
ORE					
OLE					

Note 1: $N_{SEVERITY}$ = (1) * (2) * [(3) + (4)]

1.8.2 Sample Problem 1

The Site/Facility
Figure 6 shows a photograph of the rural undivided roadway segment looking in the primary direction. The segment ends just prior to the longitudinal barrier.

Figure 6. Sample Problem - Rural Undivided Roadway

The Question
What is the predicted KAB crash frequency of for each roadway edge?

The Facts

- 0.02-mi length
- 1,229 veh/day
- 5% trucks
- 10-ft lane width
- 2-ft right shoulder width
- 55 mph posted speed limit
- 2 lanes
- 204-ft radius of curvature (in primary direction)
- -16% grade (in primary direction)

- % of segment that is shielded: PRE = 0, ORE = 0
- LB type: PRE = none, ORE = none
- LB offset: PRE = none, ORE = none
- NFO density: PRE = 300/mile, ORE = 300/mile
- NFO offset: PRE = 15 ft, ORE = 15 ft
- Misc. density: PRE = none, ORE = none
- Misc. offset: PRE = none, ORE = none
- Slope: PRE = -2H:1V, ORE = -2H:1V
- KAB crashes

Results
Using the ROR predictive method steps as outlined below, the predicted average KAB crash frequency for each roadside edge of the segment will be calculated. $N_{SEVERITY}$ for Sample Problem 1 on the PRE is 0.189 KAB crashes per year while the ORE is 0.334 KAB crashes per year.

Steps

Step 1-4
Steps 1-4 are essentially information gathering steps. The necessary information for Sample Problem 1 has been distilled from state records and displayed in "The Facts" section above.

Step 5
SPF_{EDGE} is calculated for the segment. Sample Problem 1 is an undivided road way and only the SPF_{EDGE} value for right edges will be calculated and applied to the primary right edge and the opposing right edge. SPF_{EDGE} for undivided roadways is calculated using Equation (2) with coefficients found in Table 1.

$$SPF_{UNDIV} = e^{A1 \cdot AADT} \cdot e^{A2 \cdot PT} \cdot e^{A3} \cdot AADT \cdot 365 \cdot L$$

$$SPF_{UNDIV} = e^{(-0.00006535*1229)} * e^{(-0.009441*5)} * e^{-14.75} * 1229 * 365 * 0.02$$

$SPF_{UNDIV} = 0.0031$ right edge crashes per year

Step 6

$CMF_{ROADWAY}$ is calculated by multiplying the roadway specific CMFs as shown in Equation (4). Roadway specific CMFs can be found by using the tables and figures in Section 1.6

$$CMF_{ROADWAY(PRE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{RC} * CMF_{G}$$

$$CMF_{ROADWAY(PRE)} = 0.84 * 1.56 * 1.00 * 1.00 * 1.65 * 1.27$$

$$CMF_{ROADWAY(PRE)} = 2.75$$

$$CMF_{ROADWAY(ORE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{RC} * CMF_{G}$$

$$CMF_{ROADWAY(ORE)} = 0.84 * 1.56 * 1.00 * 1.00 * 3.25 * 1.14$$

$$CMF_{ROADWAY(ORE)} = 4.86$$

Step 7

$CMF_{ROADSIDE}$ for the shielded portion of the roadway segment is calculated using the first half of Equation (5). Values relating to the shielded portion are found in Sections 1.7 and 1.7.1.

$$CMF_{ROADSIDE\_j(PRE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$$

$$CMF_{ROADSIDE\_j(PRE)} = 0.2389 * 0 * 0$$

$$CMF_{ROADSIDE\_j(PRE)} = 0.00$$

$$CMF_{ROADSIDE\_j(ORE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(ORE)})$$

$$CMF_{ROADSIDE\_j(ORE)} = 0.2389 * 0 * 0$$

$$CMF_{ROADSIDE\_j(ORE)} = 0.00$$

$CMF_{ROADSIDE}$ for the unshielded portion of the roadway segment is calculated using the second half of Equation (5). Values relating to the unshielded portion are found in Sections 1.7 and 1.7.2.

$$CMF_{ROADSIDE\_k(PRE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(PRE)})$$

$$CMF_{ROADSIDE\_k(PRE)} = 0.3589 * 1.00 * 3.51 * 1.91 * 9.21$$

$$CMF_{ROADSIDE\_k(PRE)} = 22.16$$

$$CMF_{ROADSIDE\_k(ORE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(ORE)})$$

$$CMF_{ROADSIDE\_k(ORE)} = 0.3589 * 1.00 * 3.51 * 1.91 * 9.21$$

$$CMF_{ROADSIDE\_k(ORE)} = 22.16$$

Step 8

$N_{SEVERITY}$ is calculated using Equation (1).

$$N_{SEVERITY(PRE)} = SPF_{EDGE} * CMF_{ROADWAY(PRE)} * (CMF_{ROADSIDE\_j(PRE)} + CMF_{ROADSIDE\_k(PRE)})$$

$$N_{SEVERITY(PRE)} = 0.0031 * 2.75 * (0.00 + 22.16)$$

$N_{SEVERITY(PRE)} = 0.189$ KAB crashes per year

$$N_{SEVERITY(ORE)} = SPF_{EDGE} * CMF_{ROADWAY(ORE)} * (CMF_{ROADSIDE\_j(ORE)} + CMF_{ROADSIDE\_k(ORE)})$$

$$N_{SEVERITY(ORE)} = 0.0031 * 4.86 * (0.00 + 22.16)$$

$N_{SEVERITY(ORE)} = 0.334$ KAB crashes per year

Worksheets

The step-by-step instructions above are provided to illustrate the ROR predictive method for calculating the predicted average crash frequency for a given severity on a specific segment. To apply the ROR predictive method steps to multiple segments, a series of seven worksheets are provided for determining predicted average crash frequency. The seven worksheets include:

- Worksheet A – General information and input data
- Worksheet B – Calculation of SPF_{EDGE}
- Worksheet C – Calculation of $CMF_{ROADWAY}$
- Worksheet D – Calculation of $CMF_{ROADSIDE\_j}$
- Worksheet E – Calculation of $CMF_{ROADSIDE\_k}$
- Worksheet F – Calculation of $N_{SEVERITY}$

Worksheet A

Worksheet A is a summary of general information about the roadway segment, analysis, input data (i.e., “The Facts”), for Sample Problem 1.

General Information		**Location Information**	
Analyst		Roadway	
Agency		Roadway Segment	
Date Performed		Jurisdiction	
		Analysis Year	

Input Data	**Base Condition**				**PRE**	**PLE**	**ORE**	**OLE**
Road location (rural, urban)	R	R	U	U	Rural			
Divided or undivided	D	U	D	U	Undivided			
Segment length (mi)	--				0.02			
AADT	--				1229			
Percent trucks	--				5%			
Lane width (ft)	12				10			
Right Shoulder width (ft)	8				2			
Posted Speed limit (mph)	55				55			
Number of lanes	4	2	4	2	2			
Radius of curvature (ft)	580				204		-204	
Grade	±3				-16		16	
% of segment that is shielded	--	--	--	--	0%		0%	
Longitudinal barrier type	W-beam				--		--	
Longitudinal barrier offset (ft)	8	--	4	12	--		--	
NFO density (/mi)	33	33	28	44	300		300	
NFO offset (ft)	30	38	7	17	15		15	
Misc. obstacle density (ft/mi)	600	450	300	500	--		--	
Misc. obstacle offset (ft)	45	45	7	15	--		--	
Slope (*x*H:1V)	-10				-2		-2	
Crash severity of interest	--	--	--	--	KAB		KAB	

Worksheet B

In Step 5 of the ROR predictive method, SPF_{EDGE} is calculated using Equation (2) (for undivided roadways). Column 7 of Worksheet B will be the final SPF used for both the primary right edge (PRE) and opposing right edge (ORE) of the segment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Coefficient A1	**AADT**	**Coefficient A2**	**PT**	**Coefficient A3**	**Segment L**	**SPF_{EDGE}**
	from Table 1		from Table 1		from Table 1		from Eq. (2)[1]
Right Edge	-6.535e-05	1229	-9.441e-03	5	-14.75	0.02	0.0031

Note 1: $SPF_{EDGE} = e^{(1)*(2)} * e^{(3)*(4)} * e^{(5)} * (1) * 365 * (6)$

Worksheet C

In Step 6 of the ROR predictive method $CMF_{ROADWAY}$ is calculated using Equation (4). Column 7 of Worksheet C is the final CMF value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CMF for Lane Width	**CMF for Shoulder Width**	**CMF for Posted Speed Limit**	**CMF for Number of Lanes**	**CMF for Radius of Curve**	**CMF for Grade**	**$CMF_{ROADWAY}$**
	from Table 2	from Table 3	from Table 4	from Table 5	from Figure 3	from Figure 4 or Figure 5	from Eq. (4)[1]
PRE	0.84	1.56	1.00	1.00	1.65	1.27	2.75
PLE							
ORE	0.84	1.56	1.00	1.00	3.25	1.14	4.86
OLE							

Note 1: $CMF_{ROADWAY}$ = (1) * (2) * (3) * (4) * (5) * (6)

Worksheet D

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_j}$ is calculated for shielded portion of road segment using the first part of Equation (5). Column 5 of worksheet D is the final $CMF_{ROADSIDE\_j}$ value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)	(5)
	Probability of a LB Crash	**Portion of the Segment Edge that is Shielded**	**CMF for LB Type**	**CMF for LB Offset**	**$CMF_{ROADSIDE\_j}$ for Shielded Portion**
	from Table 6		from Table 7	from Table 8	from Eq. (5)[1]
PRE	0.2389	0.00	---	---	0.00
PLE					
ORE	0.2389	0.00	---	---	0.00
OLE					

Note 1: $CMF_{ROADSIDE\_j}$ = (1) * (2) * (3) * (4)

Worksheet E

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_k}$ is calculated for the unshielded portion of road segment using the second part of Equation (5). Column 8 of worksheet E is the final $CMF_{ROADSIDE\_k}$ value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)
	Probability of a Non-LB ROR Crash	**Portion of the Segment Edge that is Unshielded**	**CMF for NFO Density**	**CMF for NFO Offset**
	from Table 6		from Table 9	from Table 10
PRE	0.3589	1.00	3.51	1.91
PLE				
ORE	0.3589	1.00	3.51	1.91
OLE				

	(5)	(6)	(7)	(8)
	CMF for Misc. Density	**CMF for Misc. Offset**	**CMF for Roadside Slope**	**$CMF_{ROADSIDE\_k}$ for Unshielded Portion**
	from Table 11	from Table 12	from Table 13	from Eq. (5)[1]
PRE	---	---	9.21	22.16
PLE				
ORE	---	---	9.21	22.16
OLE				

Note 1: $CMF_{ROADSIDE\_k}$ = (1) * (2) * (3) * (4) * (5) * (6) * (7)

Worksheet F

	(1)	(2)	(3)	(4)	(5)
	SPF_{EDGE}	**$CMF_{ROADWAY}$**	**$CMF_{ROADSIDE}$ for Shielded Portion**	**$CMF_{ROADSIDE}$ for Unshielded Portion**	**$N_{SEVERITY}$**
	(7) from Worksheet B	(7) from Worksheet C	(5) from Worksheet D	(8) from Worksheet E	from Eq. (1)[1]
PRE	0.0031	2.75	0.00	22.16	0.189
PLE					
ORE	0.0031	4.86	0.00	22.16	0.334
OLE					

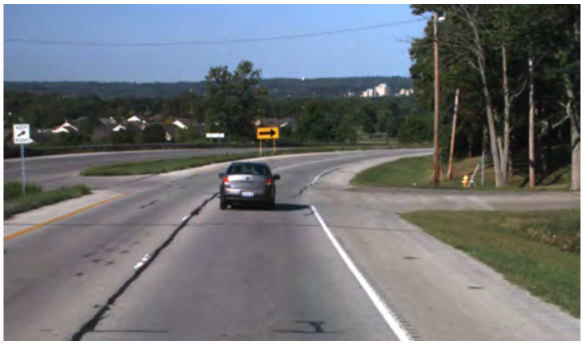
Note 1: $N_{SEVERITY}$ = (1) * (2) * [(3) + (4)]

1.8.3 Sample Problem 2

The Site/Facility

Figure 7 shows a photograph of the rural divided roadway segment looking in the primary direction (left) and opposing direction (right).

a) Primary direction, looking in primary direction.



b) Opposing direction, looking in opposing direction.

Figure 7. Sample Problem - Rural Divided Roadway

The Question

What is the predicted KA crash frequency of for each roadway edge?

The Facts

- 0.14-mi length
- 17,570 veh/day
- 10% trucks
- 12-ft lane width
- 8-ft right shoulder width
- 55 mph posted speed limit
- 4 lanes
- -1145-ft radius of curvature (in primary direction)
- 4% grade (in primary direction)
- % of segment that is shielded: PRE = 100, PLE = 0, ORE = 0, OLE = 0
- LB type: PRE = W-beam, PLE = none, ORE = none, OLE = none
- LB offset: PRE = 8, PLE = none, ORE = none, OLE = none
- NFO density: PRE = none, PLE = 20, ORE = 250, OLE = 20
- NFO offset: PRE = none, PLE = 8, ORE = 40, OLE = 8
- Misc. density: PRE = none, PLE = none, ORE = none, OLE = none
- Misc. offset: PRE = 100 none PLE = none, ORE = none, OLE = none
- Slope: PRE = -2H:1V, PLE = -4H:1V, ORE = -4H:1V, OLE = -4H:1V
- KA crashes

Results
Using the ROR predictive method steps as outlined below, the predicted average KA crash frequency for each roadside edge of the segment will be calculated. $N_{SEVERITY}$ for Sample Problem 2 on the PRE is 0.004 KA crashes per year while the PLE is 0.030 KA crashes per year. $N_{SEVERITY}$ for Sample Problem 2 on the ORE is 0.042 KA crashes per year while the OLE is 0.030 KA crashes per year.

Steps

Step 1-4
Steps 1-4 are essentially information gathering steps. The necessary information for Sample Problem 2 has been distilled from state records and displayed in "The Facts" section above.

Step 5
SPF_{EDGE} is calculated for the segment. Sample Problem 2 is a divided roadway and SPF_{EDGE} for right edges will be calculated and applied to the primary right edge and the opposing right edge while SPF_{EDGE} for left edges will be calculated and applied to the primary left edge and opposing left edge. SPF_{EDGE} for divided roadways is calculated using Equation (2) with coefficients found in Table 1.

$$SPF_{DIV(RE)} = AADT^{A4} \cdot e^{A5 \cdot PT} \cdot e^{A6} \cdot L$$

$$SPF_{DIV(RE)} = 17570^{(0.8087)} * e^{(0.0036*10)} * e^{-8.5085} * 0.14$$

$SPF_{DIV(RE)} = 0.0793$ right edge crashes per year

$$SPF_{DIV(LE)} = AADT^{A4} \cdot e^{A5 \cdot PT} \cdot e^{A6} \cdot L$$

$$SPF_{DIV(LE)} = 17570^{(1.0019)} * e^{(0.0051*10)} * e^{-10.5689} * 0.14$$

$SPF_{DIV(LE)} = 0.0678$ left edge crashes per year

Step 6
$CMF_{ROADWAY}$ is calculated by multiplying the roadway specific CMFs as shown in Equation (4). Roadway specific CMFs can be found by using the tables and figures in Section 1.6.

$CMF_{ROADWAY(PRE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(PRE)} = 1.00 * 1.00 * 1.00 * 1.00 * 1.05$

$CMF_{ROADWAY(PRE)} = 1.05$

$CMF_{ROADWAY(PLE)} = CMF_{LW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(PLE)} = 1.00 * 1.00 * 1.00 * 1.05$

$CMF_{ROADWAY(PLE)} = 1.05$

$CMF_{ROADWAY(ORE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(ORE)} = 1.00 * 1.00 * 1.00 * 1.00 * 1.06$

$CMF_{ROADWAY(ORE)} = 1.06$

$CMF_{ROADWAY(OLE)} = CMF_{LW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(OLE)} = 1.00 * 1.00 * 1.00 * 1.06$

$CMF_{ROADWAY(OLE)} = 1.06$

Step 7

$CMF_{ROADSIDE}$ for the shielded portion of the roadway segment is calculated using the first half of Equation (5). Values relating to the shielded portion are found in Sections 1.7 and 1.7.1.

$CMF_{ROADSIDE\_j(PRE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(PRE)} = 0.0407 * 1.00 * 1.00 * 1.16$

$CMF_{ROADSIDE\_ j(PRE)} = 0.05$

$CMF_{ROADSIDE\_j(PLE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(PLE)} = 0.0407 * 0 * 0$

$CMF_{ROADSIDE\_ j(PLE)} = 0.00$

$CMF_{ROADSIDE\_j(ORE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(ORE)})$

$CMF_{ROADSIDE\_ j(ORE)} = 0.0407 * 0 * 0$

$CMF_{ROADSIDE\_ j(ORE)} = 0.00$

$CMF_{ROADSIDE\_j(OLE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(OLE)} = 0.0407 * 0 * 0$

$CMF_{ROADSIDE\_ j(OLE)} = 0.00$

$CMF_{ROADSIDE}$ for the unshielded portion of the roadway segment is calculated using the second half of Equation (5). Values relating to the unshielded portion are found in Sections 1.7 and 1.7.2.

$CMF_{ROADSIDE\_k(PRE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(PRE)})$

$CMF_{ROADSIDE\_ k(PRE)} = 0.0625 * 0 * 0$

$CMF_{ROADSIDE\_ k(PRE)} = 0.00$

$CMF_{ROADSIDE\_k(PLE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(PRE)})$

$CMF_{ROADSIDE\_ k(PLE)} = 0.0625 * 1.00 * 0.94 * 1.86 * 3.83$

$CMF_{ROADSIDE\_ k(PLE)} = 0.42$

$CMF_{ROADSIDE\_k(ORE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(ORE)})$

$CMF_{ROADSIDE\_ k(ORE)} = 0.0625 * 1.00 * 2.78 * 0.75 * 3.83$

$CMF_{ROADSIDE\_ k(ORE)} = 0.50$

$CMF_{ROADSIDE\_k(OLE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(ORE)})$

$CMF_{ROADSIDE\_ k(OLE)} = 0.0625 * 1.00 * 0.94 * 1.86 * 3.83$

$CMF_{ROADSIDE\_ k(OLE)} = 0.42$

Step 8
$N_{SEVERITY}$ is calculated using Equation (1).

$N_{SEVERITY(PRE)} = SPF_{EDGE} * CMF_{ROADWAY(PRE)} * (CMF_{ROADSIDE\_j(PRE)} + CMF_{ROADSIDE\_k(PRE)})$

$N_{SEVERITY(PRE)} = 0.0793 * 1.05 * (0.05 + 0.00)$

$N_{SEVERITY(PRE)} = 0.004$ KA crashes per year

$N_{SEVERITY(PLE)} = SPF_{EDGE} * CMF_{ROADWAY(PRE)} * (CMF_{ROADSIDE\_j(PRE)} + CMF_{ROADSIDE\_k(PRE)})$

$N_{SEVERITY(PLE)} = 0.0678 * 1.05 * (0.00 + 0.42)$

$N_{SEVERITY(PLE)} = 0.030$ KA crashes per year

$N_{SEVERITY(ORE)} = SPF_{EDGE} * CMF_{ROADWAY(ORE)} * (CMF_{ROADSIDE\_j(ORE)} + CMF_{ROADSIDE\_k(ORE)})$

$N_{SEVERITY(ORE)} = 0.0793 * 1.06 * (0.00 + 0.50)$

$N_{SEVERITY(ORE)} = 0.042$ KA crashes per year

$N_{SEVERITY(OLE)} = SPF_{EDGE} * CMF_{ROADWAY(ORE)} * (CMF_{ROADSIDE\_j(ORE)} + CMF_{ROADSIDE\_k(ORE)})$

$N_{SEVERITY(OLE)} = 0.0678 * 1.06 * (0.00 + 0.42)$

$N_{SEVERITY(OLE)} = 0.030$ KA crashes per year

Worksheets
The step-by-step instructions above are provided to illustrate the ROR predictive method for calculating the predicted average crash frequency for a given severity on a specific segment. To apply the ROR predictive method steps to multiple segments, a series of seven worksheets are provided for determining predicted average crash frequency. The seven worksheets include:

- Worksheet A – General information and input data
- Worksheet B – Calculation of SPF_{EDGE}
- Worksheet C – Calculation of $CMF_{ROADWAY}$
- Worksheet D – Calculation of $CMF_{ROADSIDE\_j}$
- Worksheet E – Calculation of $CMF_{ROADSIDE\_k}$
- Worksheet F – Calculation of $N_{SEVERITY}$

Worksheet A

Worksheet A is a summary of general information about the roadway segment, analysis, input data (i.e., "The Facts"), for Sample Problem 2.

General Information		**Location Information**	
Analyst		Roadway	
Agency		Roadway Segment	
Date Performed		Jurisdiction	
		Analysis Year	

Input Data	**Base Condition**				**PRE**	**PLE**	**ORE**	**OLE**
Road location (rural, urban)	R	R	U	U	Rural			
Divided or undivided	D	U	D	U	Divided			
Segment length	--				0.14			
AADT	--				17570			
Percent trucks	--				10			
Lane width (ft)	12				12			
Right Shoulder width (ft)	8				8			
Posted Speed limit (mph)	55				55			
Number of lanes	4	2	4	2	4			
Radius of curvature (ft)	580 or greater				-1145	-1145	1145	1145
Grade	±3				4	4	-4	-4
% of segment that is shielded	--	--	--	--	100	0	0	0
Longitudinal barrier type	W-beam				W-beam	--	--	--
Longitudinal barrier offset (ft)	8	10	4	12	8	--	--	--
NFO density (/mi)	33	33	28	44	--	20	250	20
NFO offset (ft)	30	38	7	17	--	8	40	8
Misc. obstacle density (ft/mi)	600	450	300	500	--	--	--	--
Misc. obstacle offset (ft)	45	45	7	15	--	--	--	--
Slope (*x*H:1V)	-10H:1V or flatter				--	-4	-4	-4
Crash severity of interest	--	--	--	--	KA	KA	KA	KA

Worksheet B

In Step 5 of the ROR predictive method, SPF_{EDGE} is calculated using Equation (3) (for divided roadways). Column 7 of Worksheet B will be the final SPF used for right edges and left edges of the segment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AADT	**Coefficient A4**	**Coefficient A5**	**PT**	**Coefficient A6**	**Segment L**	**SPF_{EDGE}**
		from Table 1	from Table 1		from Table 1		from Eq. (3)[1]
Right Edge	17570	0.8087	0.0036	10	-8.5085	0.14	0.0793
Left Edge	17570	1.0019	.00051	10	-10.5689	0.14	0.0678

Note 1: $SPF_{EDGE} = (1)^{(2)} * e^{(3)*(4)} * e^{(5)} * (6)$

Worksheet C

In Step 6 of the ROR predictive method $CMF_{ROADWAY}$ is calculated using Equation (4). Column 7 of Worksheet C is the final CMF value used for each edge separately. Shoulder width is not considered for left edge divided roadways. The effect of radius of horizontal curve on ROR crashes on divided highways is not considered.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CMF for Lane Width	**CMF for Shoulder Width**	**CMF for Posted Speed Limit**	**CMF for Number of Lanes**	**CMF for Radius of Curve**	**CMF for Grade**	**$CMF_{ROADWAY}$**
	from Table 2	from Table 3	from Table 4	from Table 5	from Figure 3	from Figure 4 or Figure 5	from Eq. (4)[1]
PRE	1.00	1.00	1.00	1.00	--	1.05	1.05
PLE	1.00	--	1.00	1.00	--	1.05	1.05
ORE	1.00	1.00	1.00	1.00	--	1.06	1.06
OLE	1.00	--	1.00	1.00	--	1.06	1.06

Note 1: $CMF_{ROADWAY}$ = (1) * (2) * (3) * (4) * (5) * (6)

Worksheet D

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_j}$ is calculated for shielded portion of road segment using the first part of Equation (5). Column 5 of worksheet D is the final $CMF_{ROADSIDE\_j}$ value used for each edge separately.

	(1)	(2)	(3)	(4)	(5)
	Probability of a LB Crash	**Portion of the Segment Edge that is Shielded**	**CMF for LB Type**	**CMF for LB Offset**	**$CMF_{ROADSIDE\_j}$ for Shielded Portion**
	from Table 6		from Table 7	from Table 8	from Eq. (5)[1]
PRE	0.0407	1.00	1.00	1.16	0.05
PLE	0.0407	0.00	---	---	0.00
ORE	0.0407	0.00	---	---	0.00
OLE	0.0407	0.00	---	---	0.00

Note 1: $CMF_{ROADSIDE\_j}$ = (1) * (2) * (3) * (4)

Worksheet E

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_k}$ is calculated for the unshielded portion of road segment using the second part of Equation (5). Column 8 of worksheet E is the final $CMF_{ROADSIDE\_k}$ value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)
	Probability of a Non-LB ROR Crash	**Portion of the Segment Edge that is Unshielded**	**CMF for NFO Density**	**CMF for NFO Offset**
	from Table 6		from Table 9	from Table 10
PRE	0.0625	0.00	---	---
PLE	0.0625	1.00	0.94	1.86
ORE	0.0625	1.00	2.78	0.75
OLE	0.0625	1.00	0.94	1.86

	(5)	(6)	(7)	(8)
	CMF for Misc. Density	**CMF for Misc. Offset**	**CMF for Roadside Slope**	**$CMF_{ROADSIDE\_k}$ for Unshielded Portion**
	from Table 11	from Table 12	from Table 13	from Eq. (5)[1]
PRE	---	---	---	0.00
PLE	---	---	3.83	0.42
ORE	---	---	3.83	0.50
OLE	---	---	3.83	0.42

Note 1: $CMF_{ROADSIDE\_k}$ = (1) * (2) * (3) * (4) * (5) * (6) * (7)

Worksheet F

	(1)	(2)	(3)	(4)	(5)
	SPF_{EDGE}	**$CMF_{ROADWAY}$**	**$CMF_{ROADSIDE}$ for Shielded Portion**	**$CMF_{ROADSIDE}$ for Unshielded Portion**	**$N_{SEVERITY}$**
	(7) from Worksheet B	(7) from Worksheet C	(5) from Worksheet D	(8) from Worksheet E	from Eq. (1)[1]
PRE	0.0793	1.05	0.05	0.00	0.004
PLE	0.0678	1.05	0.00	0.42	0.030
ORE	0.0793	1.06	0.00	0.50	0.042
OLE	0.0678	1.06	0.00	0.42	0.030

Note 1: $N_{SEVERITY}$ = (1) * (2) * [(3) + (4)]

1.8.4 Sample Problem 3

The Site/Facility

Figure 8 shows a photograph of the urban undivided roadway segment looking in the primary direction.

Figure 8. Sample Problem - Urban Undivided Roadway

The Question

What is the predicted F+I crash frequency of for each roadway edge?

The Facts

- 0.05-mi length
- 1,120 veh/day
- 10% trucks
- 10-ft lane width
- 4-ft right shoulder width
- 40 mph posted speed limit
- 2 lanes
- 409-ft radius of curvature (in primary direction)
- 8% grade (in primary direction)
- % of segment that is shielded: PRE = 26, ORE = 0
- LB type: PRE = W-beam, ORE = none
- LB offset: PRE = 4, ORE = none
- NFO density: PRE = 200/mile, ORE = 400/mile
- NFO offset: PRE = 25 ft, ORE = 20 ft
- Misc. density: PRE = none, ORE = 800
- Misc. offset: PRE = none, ORE = 50

- Slope: PRE = -3H:1V, ORE = -4H:1V
- F+I crashes

Results
Using the ROR predictive method steps as outlined below, the predicted average F+I crash frequency for each roadside edge of the segment will be calculated. $N_{SEVERITY}$ for Sample Problem 3 on the PRE is 0.028 F+I crashes per year while the ORE is 0.049 F+I crashes per year.

Steps

Step 1-4
Steps 1-4 are essentially information gathering steps. The necessary information for Sample Problem 1 has been distilled from state records and displayed in "The Facts" section above.

Step 5
SPF_{EDGE} is calculated for the segment. Sample Problem 2 is an undivided roadway and only the SPF_{EDGE} value for right edges will be calculated and applied to the primary right edge and the opposing right edge. SPF_{EDGE} for undivided roadways is calculated using Equation (2) with coefficients found in Table 1.

$$SPF_{UNDIV} = e^{A1 \cdot AADT} \cdot e^{A2 \cdot PT} \cdot e^{A3} \cdot AADT \cdot 365 \cdot L$$

$$SPF_{UNDIV} = e^{(-0.00007178 * 1120)} * e^{(-0.01156 * 10)} * e^{-14} * 1120 * 365 * 0.05$$

$$SPF_{UNDIV} = 0.0140 \text{ right edge crashes per year}$$

Step 6
$CMF_{ROADWAY}$ is calculated by multiplying the roadway specific CMFs as shown in Equation (4). Roadway specific CMFs can be found by using the tables and figures in Section 1.6.

$CMF_{ROADWAY(PRE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{RC} * CMF_{G}$

$CMF_{ROADWAY(PRE)} = 0.66 * 1.11 * 1.01 * 1.00 * 0.94 * 0.86$

$CMF_{ROADWAY(PRE)} = 0.60$

$CMF_{ROADWAY(ORE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{RC} * CMF_{G}$

$CMF_{ROADWAY(ORE)} = 0.66 * 1.11 * 1.01 * 1.00 * 1.03 * 0.88$

$CMF_{ROADWAY(ORE)} = 0.67$

Step 7
$CMF_{ROADSIDE}$ for the shielded portion of the roadway segment is calculated using the first half of Equation (5). Values relating to the shielded portion are found in Sections 1.7 and 1.7.1.

$CMF_{ROADSIDE\_j(PRE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(PRE)} = 0.3724 * 0.26 * 1.00 * 1.00$

$CMF_{ROADSIDE\_ j(PRE)} = 0.10$

$CMF_{ROADSIDE\_j(ORE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(ORE)})$

$CMF_{ROADSIDE\_ j(ORE)} = 0.3724 * 0 * 0$

$CMF_{ROADSIDE\_ j(ORE)} = 0.00$

$CMF_{ROADSIDE}$ for the unshielded portion of the roadway segment is calculated using the second half of Equation (5). Values relating to the unshielded portion are found in Sections 1.7 and 1.7.2.

$CMF_{ROADSIDE\_k(PRE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(PRE)})$

$CMF_{ROADSIDE\_ k(PRE)} = 0.4669 * 0.74 * 2.08 * 0.80 * 5.68$

$CMF_{ROADSIDE\_ k(PRE)} = 3.27$

$CMF_{ROADSIDE\_k(ORE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(ORE)})$

$CMF_{ROADSIDE\_ k(ORE)} = 0.4669 * 1.00 * 5.34 * 0.92 * 1.26 * 0.47 * 3.83$

$CMF_{ROADSIDE\_ k(ORE)} = 5.20$

Step 8

$N_{SEVERITY}$ is calculated using Equation (1).

$N_{SEVERITY(PRE)} = SPF_{EDGE} * CMF_{ROADWAY(PRE)} * (CMF_{ROADSIDE\_j(PRE)} + CMF_{ROADSIDE\_k(PRE)})$

$N_{SEVERITY(PRE)} = 0.0140 * 0.60 * (0.10 + 3.27)$

$N_{SEVERITY(PRE)} = 0.028$ F+I crashes per year

$N_{SEVERITY(ORE)} = SPF_{EDGE} * CMF_{ROADWAY(ORE)} * (CMF_{ROADSIDE\_j(ORE)} + CMF_{ROADSIDE\_k(ORE)})$

$N_{SEVERITY(ORE)} = 0.0140 * 0.67 * (0.00 + 5.20)$

$N_{SEVERITY(ORE)} = 0.049$ F+I crashes per year

Worksheets

The step-by-step instructions above are provided to illustrate the ROR predictive method for calculating the predicted average crash frequency for a given severity on a specific segment. To apply the ROR predictive method steps to multiple segments, a series of seven worksheets are provided for determining predicted average crash frequency. The seven worksheets include:

- Worksheet A – General information and input data

- Worksheet B – Calculation of SPF_{EDGE}
- Worksheet C – Calculation of $CMF_{ROADWAY}$
- Worksheet D – Calculation of $CMF_{ROADSIDE\_j}$
- Worksheet E – Calculation of $CMF_{ROADSIDE\_k}$
- Worksheet F – Calculation of $N_{SEVERITY}$

Worksheet A

Worksheet A is a summary of general information about the roadway segment, analysis, input data (i.e., “The Facts”), for Sample Problem 3.

General Information		**Location Information**	
Analyst		Roadway	
Agency		Roadway Segment	
Date Performed		Jurisdiction	
		Analysis Year	

Input Data	**Base Condition**				**PRE**	**PLE**	**ORE**	**OLE**
Road location (rural, urban)	R	R	U	U	Urban			
Divided or undivided	D	U	D	U	Undivided			
Segment length (mi)	--				0.05			
AADT	--				1120			
Percent trucks	--				10			
Lane width (ft)	12				10			
Right Shoulder width (ft)	8				4			
Posted Speed limit (mph)	55				40			
Number of lanes	4	2	4	2	2			
Radius of curvature (ft)	580				409		-409	
Grade	±3				8		-8	
% of segment that is shielded	--	--	--	--	26		0	
Longitudinal barrier type	W-beam				W-beam		--	
Longitudinal barrier offset (ft)	8	--	4	12	4		--	
NFO density (/mi)	33	33	28	44	200		400	
NFO offset (ft)	30	38	7	17	25		20	
Misc. obstacle density (ft/mi)	600	450	300	500	--		800	
Misc. obstacle offset (ft)	45	45	7	15	--		50	
Slope (*x*H:1V)	-10				-3		-4	
Crash severity of interest	--	--	--	--	F+I		F+I	

Worksheet B

In Step 5 of the ROR predictive method, SPF_{EDGE} is calculated using Equation (2) (for undivided roadways). Column 7 of Worksheet B will be the final SPF used for both the primary right edge (PRE) and opposing right edge (ORE) of the segment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Coefficient A1	**AADT**	**Coefficient A2**	**PT**	**Coefficient A3**	**Segment L**	**SPF_{EDGE}**
	from Table 1		from Table 1		from Table 1		from Eq. (2)[1]
Right Edge	-0.00007178	1120	-0.01156	10	14.0	0.05	0.0140

Note 1: $SPF_{EDGE} = e^{(1)*(2)} * e^{(3)*(4)} * e^{(5)} * (1) * 365 * (6)$

Worksheet C

In Step 6 of the ROR predictive method $CMF_{ROADWAY}$ is calculated using Equation (4). Column 7 of Worksheet C is the final CMF value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CMF for Lane Width	**CMF for Shoulder Width**	**CMF for Posted Speed Limit**	**CMF for Number of Lanes**	**CMF for Radius of Curve**	**CMF for Grade**	**$CMF_{ROADWAY}$**
	from Table 2	from Table 3	from Table 4	from Table 5	from Figure 3	from Figure 4 or Figure 5	from Eq. (4)[1]
PRE	0.66	1.11	1.01	1.00	0.94	0.86	0.60
PLE							
ORE	0.66	1.11	1.01	1.00	1.03	0.88	0.67
OLE							

Note 1: $CMF_{ROADWAY} = (1) * (2) * (3) * (4) * (5) * (6)$

Worksheet D

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_j}$ is calculated for shielded portion of road segment using the first part of Equation (5). Column 5 of worksheet D is the final $CMF_{ROADSIDE\_j}$ value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)	(5)
	Probability of a LB Crash	**Portion of the Segment Edge that is Shielded**	**CMF for LB Type**	**CMF for LB Offset**	**$CMF_{ROADSIDE\_j}$ for Shielded Portion**
	from Table 6		from Table 7	from Table 8	from Eq. (5)[1]
PRE	0.3724	0.26	1.00	1.00	0.10
PLE					
ORE	0.3724	0.00	--	--	0.00
OLE					

Note 1: $CMF_{ROADSIDE\_j} = (1) * (2) * (3) * (4)$

Worksheet E

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_k}$ is calculated for the unshielded portion of road segment using the second part of Equation (5). Column 8 of worksheet E is the final $CMF_{ROADSIDE\_k}$ value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)
	Probability of a Non-LB ROR Crash	**Portion of the Segment Edge that is Unshielded**	**CMF for NFO Density**	**CMF for NFO Offset**
	from Table 6		from Table 9	from Table 10
PRE	0.4669	0.74	2.08	0.80
PLE				
ORE	0.4669	1.00	5.34	0.92
OLE				

	(5)	(6)	(7)	(8)
	CMF for Misc. Density	**CMF for Misc. Offset**	**CMF for Roadside Slope**	**$CMF_{ROADSIDE\_k}$ for Unshielded Portion**
	from Table 11	from Table 12	from Table 13	from Eq. (5)[1]
PRE	--	--	5.68	3.27
PLE				
ORE	1.26	0.47	3.83	5.20
OLE				

Note 1: $CMF_{ROADSIDE\_k}$ = (1) * (2) * (3) * (4) * (5) * (6) * (7)

Worksheet F

	(1)	(2)	(3)	(4)	(5)
	SPF_{EDGE}	**$CMF_{ROADWAY}$**	**$CMF_{ROADSIDE}$ for Shielded Portion**	**$CMF_{ROADSIDE}$ for Unshielded Portion**	**$N_{SEVERITY}$**
	(7) from Worksheet B	(7) from Worksheet C	(5) from Worksheet D	(8) from Worksheet E	from Eq. (1)[1]
PRE	0.0140	0.60	0.10	3.27	0.028
PLE					
ORE	0.0140	0.67	0.00	5.20	0.049
OLE					

Note 1: $N_{SEVERITY}$ = (1) * (2) * [(3) + (4)]

1.8.5 Sample Problem 4

The Site/Facility

Figure 9 shows a photograph of the urban divided roadway segment looking in the primary direction.

Figure 9. Sample Problem - Urban Divided Roadway

The Question

What is the predicted KA crash frequency of for each roadway edge?

The Facts

- 0.19-mi length
- 10,210 veh/day
- 10% trucks
- 12-ft lane width
- 8-ft right shoulder width
- 55 mph posted speed limit
- 4 lanes
- 1432-ft radius of curvature (in primary direction)
- -4% grade (in primary direction)
- % of segment that is shielded: PRE = 0, PLE = 0, ORE = 0, OLE = 0
- LB type: PRE = none, PLE = none, ORE = none, OLE = none
- LB offset: PRE = none, PLE = none, ORE = none, OLE = none
- NFO density: PRE = 400, PLE = 10, ORE = 300, OLE = 100
- NFO offset: PRE = 25, PLE = 10, ORE = 35, OLE = 10
- Misc. density: PRE = none, PLE = none, ORE = none, OLE = none
- Misc. offset: PRE = 100 none PLE = none, ORE = none, OLE = none

- Slope: PRE = -2H:1V, PLE = -3H:1V, ORE = -2H:1V, OLE = -4H:1V
- KA crashes

Results
Using the ROR predictive method steps as outlined below, the predicted average KA crash frequency for each roadside edge of the segment will be calculated. $N_{SEVERITY}$ for Sample Problem 4 on the PRE is 0.257 KA crashes per year while the PLE is 0.034 KA crashes per year. $N_{SEVERITY}$ for Sample Problem 4 on the ORE is 0.117 KA crashes per year while the OLE is 0.022 KA crashes per year.

Steps

Step 1-4
Steps 1-4 are essentially information gathering steps. The necessary information for Sample Problem 2 has been distilled from state records and displayed in "The Facts" section above.

Step 5
SPF_{EDGE} is calculated for the segment. Sample Problem 4 is a divided roadway and SPF_{EDGE} for right edges will be calculated and applied to the primary right edge and the opposing right edge while SPF_{EDGE} for left edges will be calculated and applied to the primary left edge and opposing left edge. SPF_{EDGE} for divided roadways is calculated using Equation (2) with coefficients found in Table 1.

$$SPF_{DIV(RE)} = AADT^{A4} \cdot e^{A5 \cdot PT} \cdot e^{A6} \cdot L$$

$$SPF_{DIV(RE)} = 10210^{(0.5673)} * e^{(0.0117*10)} * e^{-5.5012} * 0.19$$

$$SPF_{DIV(RE)} = 0.1640 \text{ right edge crashes per year}$$

$$SPF_{DIV(LE)} = AADT^{A4} \cdot e^{A5 \cdot PT} \cdot e^{A6} \cdot L$$

$$SPF_{DIV(LE)} = 10210^{(0.6585)} * e^{(0.0158*10)} * e^{-6.5122} * 0.19$$

$$SPF_{DIV(LE)} = 0.1442 \text{ left edge crashes per year}$$

Step 6
$CMF_{ROADWAY}$ is calculated by multiplying the roadway specific CMFs as shown in Equation (4). Roadway specific CMFs can be found by using the tables and figures in Section 1.6.

$CMF_{ROADWAY(PRE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(PRE)}$ = 1.00 * 1.00 * 1.00 * 1.00 * 0.87

$CMF_{ROADWAY(PRE)}$ = 0.87

$CMF_{ROADWAY(PLE)} = CMF_{LW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(PLE)} = 1.00 * 1.00 * 1.00 * 0.87$

$CMF_{ROADWAY(PLE)} = 0.87$

$CMF_{ROADWAY(ORE)} = CMF_{LW} * CMF_{SW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(ORE)} = 1.00 * 1.00 * 1.00 * 1.00 * 0.85$

$CMF_{ROADWAY(ORE)} = 0.85$

$CMF_{ROADWAY(OLE)} = CMF_{LW} * CMF_{PSL} * CMF_{NL} * CMF_{G}$

$CMF_{ROADWAY(OLE)} = 1.00 * 1.00 * 1.00 * 0.85$

$CMF_{ROADWAY(OLE)} = 0.85$

Step 7

$CMF_{ROADSIDE}$ for the shielded portion of the roadway segment is calculated using the first half of Equation (5). Values relating to the shielded portion are found in Sections 1.7 and 1.7.1.

$CMF_{ROADSIDE\_j(PRE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(PRE)} = 0.0424 * 0 * 0$

$CMF_{ROADSIDE\_ j(PRE)} = 0.00$

$CMF_{ROADSIDE\_j(PLE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(PLE)} = 0.0424 * 0 * 0$

$CMF_{ROADSIDE\_ j(PLE)} = 0.00$

$CMF_{ROADSIDE\_j(ORE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(ORE)})$

$CMF_{ROADSIDE\_ j(ORE)} = 0.0424 * 0 * 0$

$CMF_{ROADSIDE\_ j(ORE)} = 0.00$

$CMF_{ROADSIDE\_j(OLE)} = (\beta_{SHLD} * X_{SHLD} * CMF_{j(PRE)})$

$CMF_{ROADSIDE\_ j(OLE)} = 0.0424 * 0 * 0$

$CMF_{ROADSIDE\_ j(OLE)} = 0.00$

$CMF_{ROADSIDE}$ for the unshielded portion of the roadway segment is calculated using the second half of Equation (5). Values relating to the unshielded portion are found in Sections 1.7 and 1.7.2.

$CMF_{ROADSIDE\_k(PRE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(PRE)})$

$CMF_{ROADSIDE\_k(PRE)} = 0.0564 * 1.00 * 5.76 * 0.60 * 9.21$

$CMF_{ROADSIDE\_k(PRE)} = 1.80$

$CMF_{ROADSIDE\_k(PLE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(PRE)})$

$CMF_{ROADSIDE\_k(PLE)} = 0.0564 * 1.00 * 0.92 * 0.92 * 5.68$

$CMF_{ROADSIDE\_k(PLE)} = 0.27$

$CMF_{ROADSIDE\_k(ORE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(ORE)})$

$CMF_{ROADSIDE\_k(ORE)} = 0.0564 * 1.00 * 3.60 * 0.45 * 9.21$

$CMF_{ROADSIDE\_k(ORE)} = 0.84$

$CMF_{ROADSIDE\_k(OLE)} = (\beta_{UNSHLD} * X_{UNSHLD} * CMF_{k(ORE)})$

$CMF_{ROADSIDE\_k(OLE)} = 0.0564 * 1.00 * 0.92 * 0.92 * 3.83$

$CMF_{ROADSIDE\_k(OLE)} = 0.18$

Step 8

$N_{SEVERITY}$ is calculated using Equation (1).

$N_{SEVERITY(PRE)} = SPF_{EDGE} * CMF_{ROADWAY(PRE)} * (CMF_{ROADSIDE\_j(PRE)} + CMF_{ROADSIDE\_k(PRE)})$

$N_{SEVERITY(PRE)} = 0.1640 * 0.87 * (0.00 + 1.80)$

$N_{SEVERITY(PRE)} = 0.257$ KA crashes per year

$N_{SEVERITY(PLE)} = SPF_{EDGE} * CMF_{ROADWAY(PRE)} * (CMF_{ROADSIDE\_j(PRE)} + CMF_{ROADSIDE\_k(PRE)})$

$N_{SEVERITY(PLE)} = 0.1442 * 0.87 * (0.00 + 0.27)$

$N_{SEVERITY(PLE)} = 0.034$ KA crashes per year

$N_{SEVERITY(ORE)} = SPF_{EDGE} * CMF_{ROADWAY(ORE)} * (CMF_{ROADSIDE\_j(ORE)} + CMF_{ROADSIDE\_k(ORE)})$

$N_{SEVERITY(ORE)} = 0.1640 * 0.85 * (0.00 + 0.84)$

$N_{SEVERITY(ORE)} = 0.117$ KA crashes per year

$N_{SEVERITY(OLE)} = SPF_{EDGE} * CMF_{ROADWAY(ORE)} * (CMF_{ROADSIDE\_j(ORE)} + CMF_{ROADSIDE\_k(ORE)})$

$N_{SEVERITY(OLE)} = 0.1442 * 0.85 * (0.00 + 0.18)$

$N_{SEVERITY(OLE)} = 0.022$ KA crashes per year

Worksheets

The step-by-step instructions above are provided to illustrate the ROR predictive method for calculating the predicted average crash frequency for a given severity on a specific segment. To apply the ROR predictive method steps to multiple segments, a series of seven worksheets are provided for determining predicted average crash frequency. The seven worksheets include:

- Worksheet A – General information and input data
- Worksheet B – Calculation of SPF_{EDGE}
- Worksheet C – Calculation of $CMF_{ROADWAY}$
- Worksheet D – Calculation of $CMF_{ROADSIDE\_j}$
- Worksheet E – Calculation of $CMF_{ROADSIDE\_k}$
- Worksheet F – Calculation of $N_{SEVERITY}$

Worksheet A

Worksheet A is a summary of general information about the roadway segment, analysis, input data (i.e., "The Facts"), for Sample Problem 4.

General Information		**Location Information**	
Analyst		Roadway	
Agency		Roadway Segment	
Date Performed		Jurisdiction	
		Analysis Year	

Input Data	**Base Condition**				**PRE**	**PLE**	**ORE**	**OLE**
Road location (rural, urban)	R	R	U	U	Urban			
Divided or undivided	D	U	D	U	Divided			
Segment length	--				0.19			
AADT	--				10210			
Percent trucks	--				10			
Lane width (ft)	12				12			
Right Shoulder width (ft)	8				8			
Posted Speed limit (mph)	55				55			
Number of lanes	4	2	4	2	4			
Radius of curvature (ft)	580 or greater				1432	1432	-1432	-1432
Grade	±3				-4	-4	4	4
% of segment that is shielded	--	--	--	--	0	0	0	0
Longitudinal barrier type	W-beam				--	--	--	--
Longitudinal barrier offset (ft)	8	--	--	--	--	--	--	--
NFO density (/mi)	33	33	28	44	400	10	300	10
NFO offset (ft)	30	38	7	17	25	10	35	10
Misc. obstacle density (ft/mi)	600	450	300	500	--	--	--	--
Misc. obstacle offset (ft)	45	45	7	15	--	--	--	--
Slope (*x*H:1V)	-10H:1V or flatter				-2	-3	-2	-4
Crash severity of interest	--	--	--	--	KA	KA	KA	KA

Worksheet B

In Step 5 of the ROR predictive method, SPF_{EDGE} is calculated using Equation (3) (for divided roadways). Column 7 of Worksheet B will be the final SPF used for right edges and left edges of the segment.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AADT	**Coefficient A4**	**Coefficient A5**	**PT**	**Coefficient A6**	**Segment L**	**SPF_{EDGE}**
		from Table 1	from Table 1		from Table 1		from Eq. (3)[1]
Right Edge	10210	0.5673	0.0117	10	-5.5012	0.19	0.1640
Left Edge	10210	0.6585	0.0158	10	-6.5122	0.19	0.1442

Note 1: $SPF_{EDGE} = (1)^{(2)} * e^{(3)*(4)} * e^{(5)} * (6)$

Worksheet C

In Step 6 of the ROR predictive method $CMF_{ROADWAY}$ is calculated using Equation (4). Column 7 of Worksheet C is the final CMF value used for each edge separately. Shoulder width is not considered for left edge divided roadways. The effect of radius of horizontal curve on ROR crashes on divided highways is not considered.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	CMF for Lane Width	**CMF for Shoulder Width**	**CMF for Posted Speed Limit**	**CMF for Number of Lanes**	**CMF for Radius of Curve**	**CMF for Grade**	**$CMF_{ROADWAY}$**
	from Table 2	from Table 3	from Table 4	from Table 5	from Figure 3	from Figure 4 or Figure 5	from Eq. (4)[1]
PRE	1.00	1.00	1.00	1.00	--	0.87	0.87
PLE	1.00	--	1.00	1.00	--	0.87	0.87
ORE	1.00	1.00	1.00	1.00	--	0.85	0.85
OLE	1.00	--	1.00	1.00	--	0.85	0.85

Note 1: $CMF_{ROADWAY}$ = (1) * (2) * (3) * (4) * (5) * (6)

Worksheet D

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_j}$ is calculated for shielded portion of road segment using the first part of Equation (5). Column 5 of worksheet D is the final $CMF_{ROADSIDE\_j}$ value used for each edge separately.

	(1)	(2)	(3)	(4)	(5)
	Probability of a LB Crash	**Portion of the Segment Edge that is Shielded**	**CMF for LB Type**	**CMF for LB Offset**	**$CMF_{ROADSIDE\_j}$ for Shielded Portion**
	from Table 6		from Table 7	from Table 8	from Eq. (5)[1]
PRE	0.0424	0.00	--	--	0.00
PLE	0.0424	0.00	--	--	0.00
ORE	0.0424	0.00	--	--	0.00
OLE	0.0424	0.00	--	--	0.00

Note 1: $CMF_{ROADSIDE\_j}$ = (1) * (2) * (3) * (4)

Worksheet E

In Step 7 of the ROR predictive method $CMF_{ROADSIDE\_k}$ is calculated for the unshielded portion of road segment using the second part of Equation (5). Column 8 of worksheet E is the final $CMF_{ROADSIDE\_k}$ value used for PRE and ORE separately.

	(1)	(2)	(3)	(4)
	Probability of a Non-LB ROR Crash	**Portion of the Segment Edge that is Unshielded**	**CMF for NFO Density**	**CMF for NFO Offset**
	from Table 6		from Table 9	from Table 10
PRE	0.0564	1.00	5.76	0.60
PLE	0.0564	1.00	0.92	0.92
ORE	0.0564	1.00	3.60	0.45
OLE	0.0564	1.00	0.92	0.92

	(5)	(6)	(7)	(8)
	CMF for Misc. Density	**CMF for Misc. Offset**	**CMF for Roadside Slope**	**$CMF_{ROADSIDE\_k}$ for Unshielded Portion**
	from Table 11	from Table 12	from Table 13	from Eq. (5)[1]
PRE	--	--	9.21	1.80
PLE	--	--	5.68	0.27
ORE	--	--	9.21	0.84
OLE	--	--	3.83	0.18

Note 1: $CMF_{ROADSIDE\_k}$ = (1) * (2) * (3) * (4) * (5) * (6) * (7)

Worksheet F

	(1)	(2)	(3)	(4)	(5)
	SPF_{EDGE}	**$CMF_{ROADWAY}$**	**$CMF_{ROADSIDE}$ for Shielded Portion**	**$CMF_{ROADSIDE}$ for Unshielded Portion**	**$N_{SEVERITY}$**
	(7) from Worksheet B	(7) from Worksheet C	(5) from Worksheet D	(8) from Worksheet E	from Eq. (1)[1]
PRE	0.1640	0.87	0.00	1.80	0.257
PLE	0.1442	0.87	0.00	0.27	0.034
ORE	0.1640	0.85	0.00	0.84	0.117
OLE	0.1442	0.85	0.00	0.18	0.022

Note 1: $N_{SEVERITY}$ = (1) * (2) * [(3) + (4)]