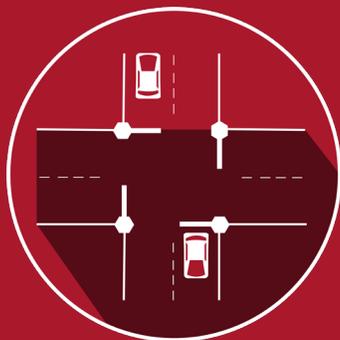


Interchange Comparison Safety Tool User Guide

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FOREWORD

The *Highway Safety Manual* has made predictive safety analysis feasible for many basic roadway elements, including freeway and ramp segments and ramp terminals. This capability raises the expectation for predicting the safety performance of more complex roadway facilities, such as interchanges. Although interchanges can be decomposed into basic road elements, the safety performance of interchanges cannot be derived by simply adding predictions from individual components.

The Federal Highway Administration (FHWA) supported a project to explore planning-level analysis of interchange configurations during alternatives analysis or Interchange Access Requests (IARs). FHWA sought to identify the most commonly considered configurations in IARs and develop a predictive model and implementation tool. The purpose of this predictive model and associated implementation tool is to use an approach with more robust considerations than a single crash modification factor and provide reliable predictions using information commonly known during interchange project planning. This tool can be used to evaluate the predicted crash frequency and severity for interchange configurations under consideration using basic inputs for the entire interchange area.

This user guide assists safety professionals in applying the predictive methodology and using the accompanying implementation tool. This guide provides details on applying the predictive method to an interchange area and how that fits into the context of the overall interchange influence area. Additionally, this user guide details where the predictive method is applicable and the required inputs and supporting calculations. Finally, this guide provides instructions on using the spreadsheet implementation tool and interpreting the spreadsheet inputs and outputs.

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Research and Development

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16. Abstract This user guide is intended for use alongside the Federal Highway Administration (FHWA) report <i>Safety Comparisons Between Interchange Types</i> (forthcoming) and the spreadsheet tool <i>FHWA Interchange Configuration Safety Comparison Tool</i> . ^(1,2) This user guide provides an overview of the data needs and workflow for using the spreadsheet tool. Additionally, it provides information on the interchange configurations for which this tool can be used and the ranges of characteristics to which it applies. Further, this guide provides an overview for finding results within the tool.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in ²	square inches	645.2	square millimeters	mm ²
ft ²	square feet	0.093	square meters	m ²
yd ²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi ²	square miles	2.59	square kilometers	km ²
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft ³	cubic feet	0.028	cubic meters	m ³
yd ³	cubic yards	0.765	cubic meters	m ³
NOTE: volumes greater than 1,000 L shall be shown in m ³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in ²	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm ²	square millimeters	0.0016	square inches	in ²
m ²	square meters	10.764	square feet	ft ²
m ²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km ²	square kilometers	0.386	square miles	mi ²
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m ³	cubic meters	35.314	cubic feet	ft ³
m ³	cubic meters	1.307	cubic yards	yd ³
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m ²	candela/m ²	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in ²

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS

A	incapacitating injury
AADT	annual average daily traffic
B	non-incapacitating injury
C	possible injury
CI	confidence interval
COV	coefficient of variation
DDI	diverging diamond interchange
FHWA	Federal Highway Administration
HOV	high-occupancy vehicle
HSM	<i>Highway Safety Manual</i>
K	fatal
KA	fatal and serious injury
KABC	fatal and injury crash categories
KABCO	injury classification scale
LT	left turn
Parclo	partial cloverleaf
PDO	property damage only
SDF	severity distribution function
SPDI	single-point diamond interchange
TDI	tight diamond interchange
VPD	vehicles per day
XR	crossroad

CHAPTER 1. INTRODUCTION

OBJECTIVE

This user guide is intended as a companion to the Federal Highway Administration (FHWA) report *Safety Comparisons Between Interchange Types* (herein referred to as “report”) and the spreadsheet tool *FHWA Interchange Configuration Safety Comparison Tool* (herein referred to as “spreadsheet tool”).^(1,2) The report contains all of the background research, modeling details, and supplementary information. All calculations can be performed within the spreadsheet tool.

BACKGROUND

The research project aimed to develop a planning-level safety assessment tool and interchange safety comparison process for FHWA and State departments of transportation to use when reviewing Interchange Justification Reports. The safety assessment allows agencies to quantify the safety performance of proposed designs against a base (or reference) condition for service interchanges.

The project team developed a spreadsheet tool to implement the methods, geometric and operational characteristics, and parameters described in the corresponding report. The spreadsheet tool provides annual crash frequency predictions for individual crash severity levels using the KABCO injury classification scale, where K represents fatal, A incapacitating injury, B non-incapacitating injury, C possible injury crashes, and O property damage only (no apparent injury). The spreadsheet tool includes an estimate of the variability of the prediction so users can assess the significance of differences among predictions for multiple interchange configuration types under consideration. The report and spreadsheet tool together provide a planning-level safety assessment tool analysts can use to compare potential safety performance effects of freeway access and interchange design decisions.

PURPOSE AND STRUCTURE OF THE GUIDE

This user guide provides detailed instructions for using the spreadsheet implementation tool and interpreting the results it provides. The user guide is organized into the following three chapters:

1. Introduction: Provides context and identifies the accompanying spreadsheet tool and report.
2. Applicability: Describes interchange configurations the spreadsheet tool can evaluate and the corresponding interchange influence areas on which the predictive model is based.
3. Spreadsheet Instructions: Describes how to use the spreadsheet tool. This chapter also explains the required inputs for the spreadsheet tool and provides references to the report for users to interpret the spreadsheet inputs and outputs.

CHAPTER 2. APPLICABILITY

INTERCHANGE FUNCTION

The spreadsheet tool is only valid for service interchanges, which connect freeways to local surface streets or arterials. System interchanges, which connect freeways to other freeways, were not included in the predictive model and thus are not considered in the spreadsheet tool.

INTERCHANGE CONFIGURATION

The spreadsheet tool applies to the following interchange configurations:

- Diamond interchange.
- Compressed diamond interchange.
- Roundabout diamond interchange.
- Diverging diamond interchange (DDI).
- Partial cloverleaf (parclo) type A (parclo A).
- Parclo type B (parclo B).
- Parclo type AB (parclo AB).
- Single-point diamond interchange (SPDI).
- Tight diamond interchange (TDI).

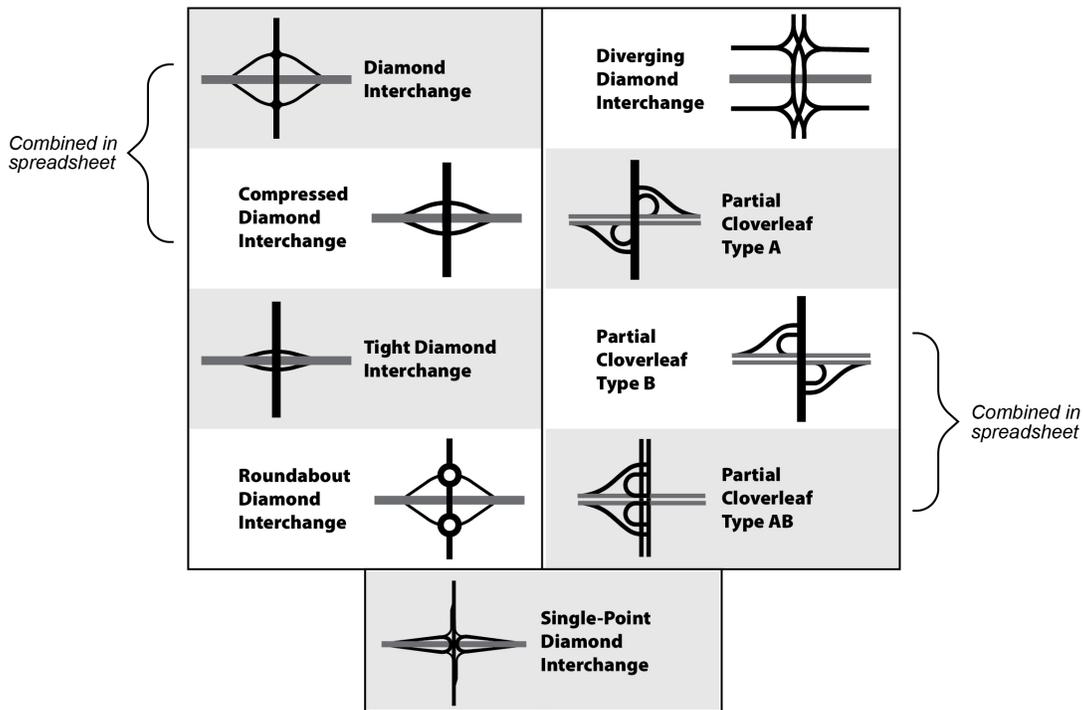
Single Roundabout Interchanges

Single roundabout interchanges are commonly considered and installed as service interchanges; however, this study found that jurisdictions that mention single roundabout interchanges are often referring to diamond interchanges with roundabouts at the crossroad ramp terminals. Single roundabout interchanges are not included in the model or spreadsheet; analysts should determine whether the diamond interchange definition fits their proposed configuration if they intend to use the spreadsheet tool.

Parclo Configurations

For the study design, data collection, and analysis, the project team focused on parclo configurations most commonly considered and installed (A2, A4, B2, B4, AB2, and AB4) and developed models with the intent of capturing any safety performance differences between these parclo types. Due to the sheer number of possible combinations, the project team did not include other parclo configurations in this research. The report includes descriptions of the parclo configurations.

The spreadsheet combines diamond interchanges and compressed diamond interchanges into one category. Parclo AB and parclo B are also combined into one category. These groupings indicate that the predictive method found no safety performance differences between the two interchange configurations. Figure 1 shows all nine interchange configurations viable for comparative analysis using the spreadsheet tool.



Source: FHWA.

Figure 1. Graphic. Interchange configurations included in the spreadsheet tool.

Not Valid for Spreadsheet Analysis

The following interchange configurations and characteristics were excluded from the predictive model and thus not suitable for analysis using the spreadsheet tool:

- Full cloverleaf interchange.
- Displaced left-turn interchange.
- Single roundabout interchange.
- Ramps to frontage road interchange.
- Braided ramp interchange.
- “Dogbone” or double roundabout interchange.
- System interchange.
- Interchange with more than six ramps.
- Interchange with direct-connection ramps.

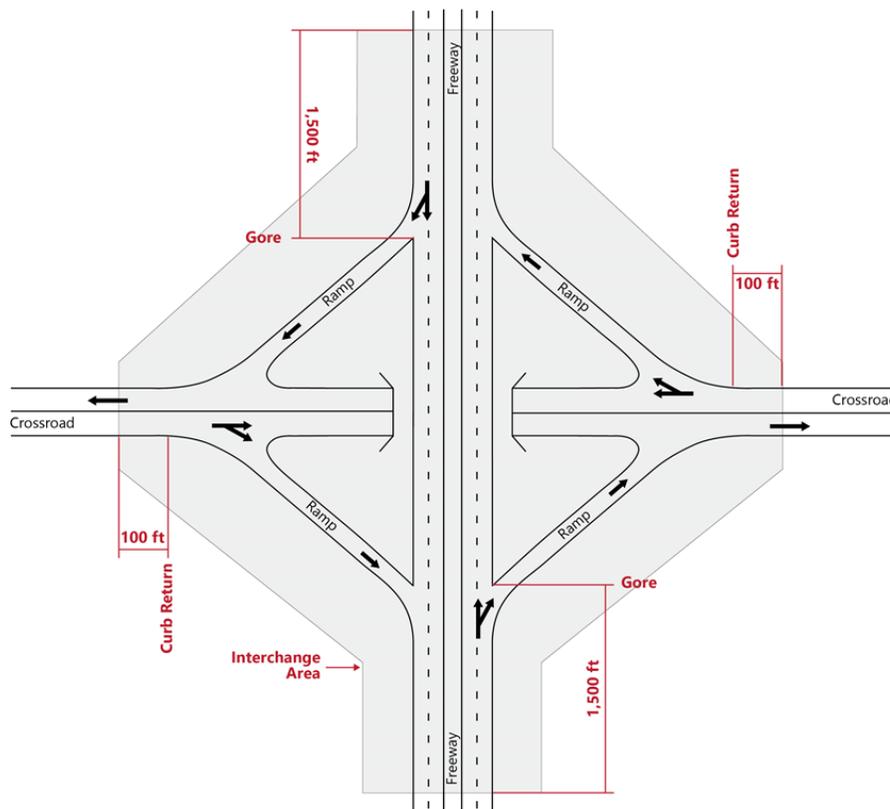
Planners often search for unique solutions to operational or safety concerns to fit local design constraints; therefore, they are encouraged to seek alternative methods for evaluating interchange configurations not included in this study.

INTERCHANGE INFLUENCE AND INTERCHANGE AREAS

The general study area, or area of influence, necessary for conducting safety and operational analysis for interchange access improvements can vary substantially in size and scope. The spreadsheet tool focuses on the interchange area rather than the interchange influence area. To eliminate variability across all nine studied interchange configurations, the interchange area applicable to the predictive model developed for this project was defined as follows:

- Freeway mainline: Includes 1,500 ft upstream and downstream of the painted gores farthest from the crossroad on either side.
- Crossroad: Includes 100 ft upstream and downstream of the gore or curb return of the outermost ramp connection for each terminal (crossroad).
- Ramps (maximum of six).
- Ramp terminals.

Figure 2 represents the interchange study area defined in this project.



Source: FHWA.

Figure 2. Graphic. Study interchange area definition.⁽³⁾

When applying the predictive models for safety comparisons, users should determine the maximum possible interchange area dimensions among the alternatives considered and apply those dimensions to all alternatives. For alternative interchanges with a smaller footprint, users would apply the *Highway Safety Manual* (HSM) predictive models to account for differences in interchange area dimensions among the alternatives.⁽⁴⁾

CRASH SEVERITIES ANALYZED

The spreadsheet tool provides separate predictions for property damage only (PDO) crashes and fatal and injury crashes (K, A, B, and C on the KABCO scale). Fatal and injury crashes are also known as KABC crashes. Additionally, the spreadsheet tool employs severity distribution functions (SDFs) to predict the probability of individual KABC crash outcomes. The resulting probability from the SDF is multiplied by the prediction for KABC crashes to determine the predicted number of crashes by severity outcome.

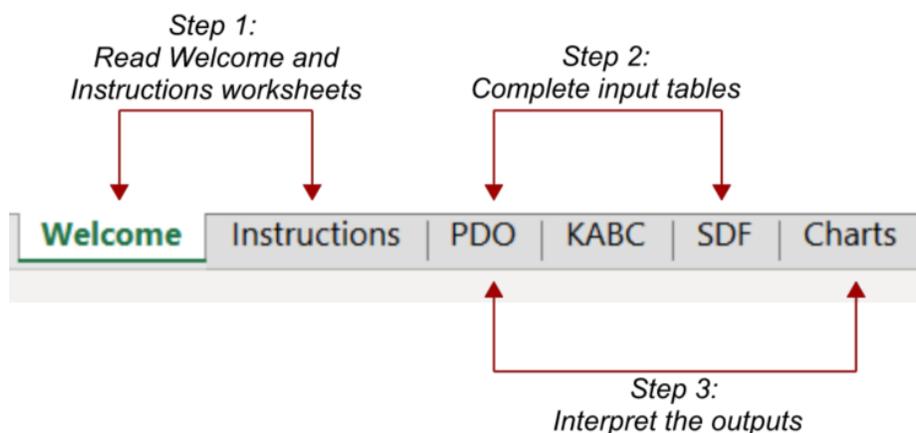
CHAPTER 3. SPREADSHEET INSTRUCTIONS

WORKFLOW

The spreadsheet tool is divided into six worksheets. Refer to the report for methodology and supporting details for the model used in the spreadsheet tool.

The Welcome and Instructions worksheets provide background information for users. The Abbreviations Used section in the Instructions worksheet defines abbreviations used in the spreadsheet and this user guide.

Users enter input in the PDO and SDF worksheets. The PDO worksheet inputs are carried through to the KABC worksheet because the predictive methodology uses the same inputs for PDO and KABC crash frequency. Users enter separate inputs in the SDF to determine the probability of individual crash severity outcomes. Each worksheet provides predicted crash outcomes, which the Charts worksheet tab summarizes. The PDO and KABC worksheets calculate the predicted crash frequency at the interchange level. The SDF worksheet calculates the impact of various interchange features on crash severity. Users can see the crash frequency results and the 95-percent confidence interval (CI) ranges on the Charts worksheet. Figure 3 is a screenshot of the various worksheets within the spreadsheet with steps 1–3 of the intended workflow listed for reference.



Source: FHWA.

Figure 3. Screenshot. Spreadsheet workflow.⁽²⁾

STEP 1: READ WELCOME AND INSTRUCTIONS WORKSHEETS

The Instructions worksheet provides descriptions of each worksheet and detailed descriptions for all inputs required for using the spreadsheet.

The spreadsheet identifies inputs and outputs using colors and patterns, which are described in figure 4.

<i>Color Used</i>	<i>Type of Information Required from User</i>
	Required input information.
<i>Color Used</i>	<i>Type of Information Output</i>
	Crash frequency model results. Not an input.
	Results of Severity Distribution Functions; combined with crash frequency (namely fatal and injury) results. Not an input.
	Information linked to a different worksheet. Not an input.

Source: FHWA.

Figure 4. Screenshot. Spreadsheet field coding.⁽²⁾

Users modify cells highlighted as “Required input information” on both the PDO and SDF worksheets. *These cells are the only cells in the spreadsheet intended for user modification.*

This worksheet also indicates the key crash frequency model results and the results from applying the SDFs. Additionally, this worksheet alerts users when information is linked to another worksheet.

Required input cells will alert the user if an incorrect value has been entered, and users should refer to the Instructions worksheet for additional information.

Cells are formatted to produce errors when nonconforming input is present. Users should enter values into each cell individually and not copy and paste cells to duplicate information across tables, or the conditional error formatting will be lost.

STEP 2: COMPLETE INPUT TABLES

The two input tables are located at the top of the PDO worksheet and the SDF worksheet. Users should complete *both* of the input tables before interpreting the results. The following sections provide context and additional information about the required inputs.

Interchange Configurations

Nine interchange configurations are grouped into seven outputs in the PDO worksheet and six outputs in the SDF worksheet. Users may input the same geometric and operational characteristics for all types under consideration, or they may vary input parameters when conducting a simultaneous test. The spreadsheet and predictive model use the diamond/compressed diamond combined category as the base condition, meaning the user will need to provide inputs to this category regardless of whether these interchange types are considered.

For parclo interchanges, the spreadsheet requires additional inputs on the SDF worksheet to differentiate between the various parclo configurations included in the study. Table 1 summarizes the inputs for parclo interchange configurations in the implementation spreadsheet.

Table 1. Parclo spreadsheet input summary.

Worksheet	Relevant Input Parameters	User Input in Spreadsheet
PDO	N/A	N/A
SDF	Type A or B parclo interchange (includes A2/A4/B2/B4)	1 if user is considering one of these types; 0 otherwise
	Type AB parclo interchange (includes AB2/AB4)	1 if user is considering one of these types; 0 otherwise

N/A = not applicable.

Area Type

The predictive model differentiates between rural and urban area types. Urban areas are defined as having a population greater than 5,000. Table 2 provides an example input for area type in the implementation spreadsheet.

Table 2. Required area type inputs.

Worksheet	Relevant Input Parameters	User Input in Spreadsheet
PDO	Urban area type	1 if in an urban area; 0 otherwise
SDF	N/A	N/A

Traffic Volumes

Freeway annual average daily traffic (AADT) volume, the crossroad AADT volume, and the ramp AADT volumes are all required inputs for the spreadsheet. For freeway mainline and cross streets, the AADT is the bidirectional traffic volume. The coefficient of variation (COV) of ramp volumes is also a required input for the model. The implementation spreadsheet automatically calculates this value based on user inputs of individual ramp volumes. Note that up to six ramp volumes may be entered into the spreadsheet. If the subject interchange has fewer than six ramps, then the unnecessary rows can be left blank. Table 3 provides a summary of required traffic volume inputs for crash frequency and SDF worksheets.

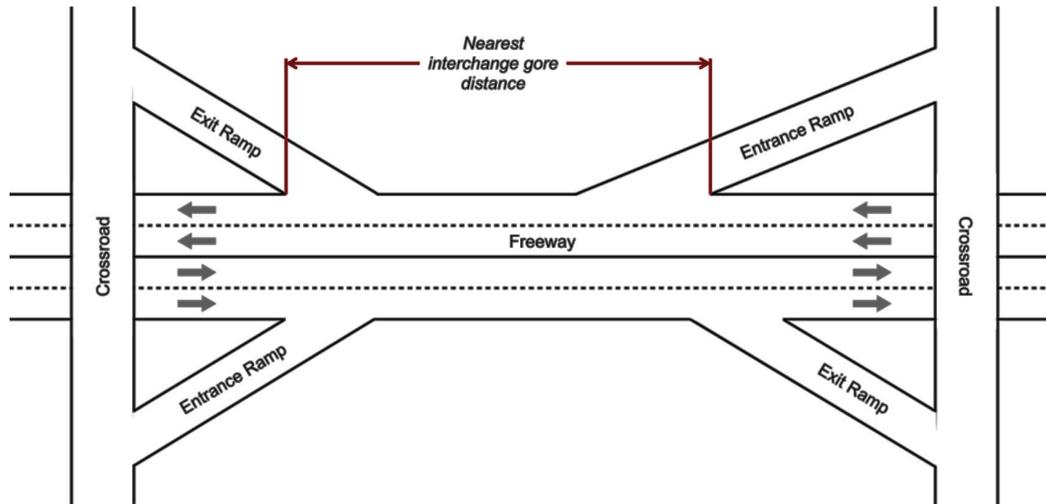
Table 3. Summary of required traffic volume inputs.

Worksheet	Relevant Input Parameters	User Input in Spreadsheet
PDO	Freeway AADT	Volume in vpd
	XR AADT	Volume in vpd
	Total ramp AADT	Volume in vpd
	COV of ramp volumes	Calculated in spreadsheet (requires individual ramp AADTs)
SDF	Freeway AADT $\geq 200,000$ vpd	1 if freeway through lanes carry more than 200,000 vpd; 0 otherwise
	XR AADT greater than or equal to 30,000 vpd	1 if crossroad through lanes carry more than 30,000 vpd; 0 otherwise

vpd = vehicles per day; XR = crossroad.

Freeway Characteristics

The distance between adjacent gore areas along the freeway is accounted for in the predictive model as a factor that increases crash frequency. This distance is also accounted for in the SDF as a factor that increases the probability of fatal and serious injury (KA) severity crashes within the crash distribution. The nearest interchange gore distance is measured from the closest gore areas between adjacent interchanges in the same direction of travel. Figure 5 describes this parameter.



Source: FHWA.

Figure 5. Illustration. Nearest interchange gore distance.

The predictive model accounts for managed lanes on the freeway as a factor associated with increased crash frequency when at least one managed lane is present within the defined interchange area. In this case, managed lanes refer to high-occupancy vehicle (HOV) or high-occupancy toll lanes. This methodology development did not include other managed lane strategies, such as part-time shoulder use, reversible, contraflow, or bus-only lanes. The spreadsheet input is a yes or no response from the user regarding whether one or more managed lanes are within the interchange area.

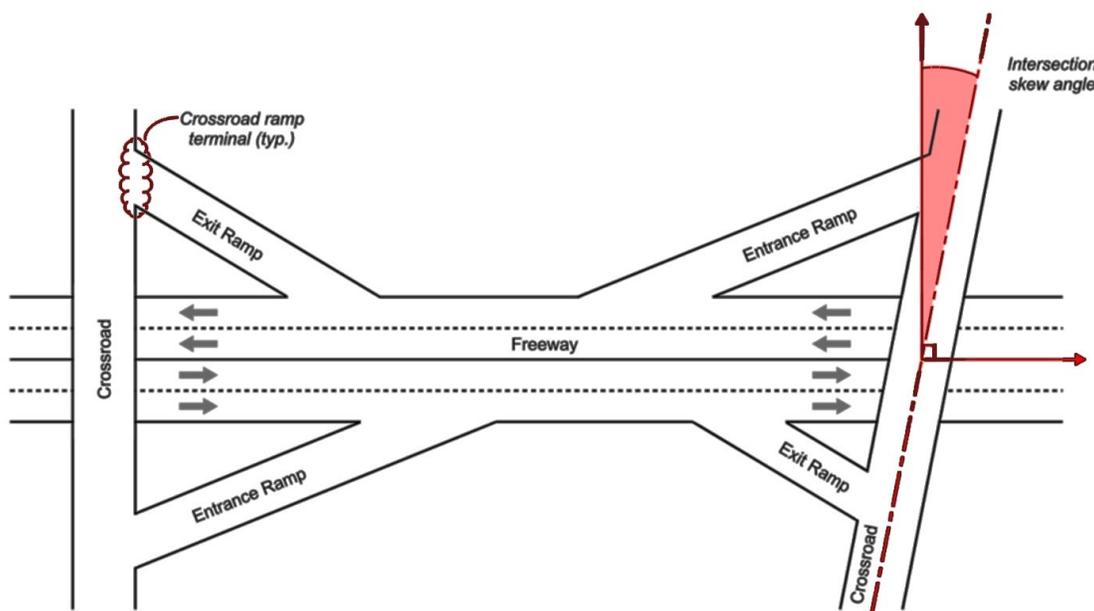
The number of through lanes on the freeway is accounted for in the predictive model to evaluate AADT per lane as well as a factor specifically accounting for the effect of the number of lanes. The base condition is four or fewer through lanes on the freeway (in both directions combined), meaning spreadsheet output is affected when five or more lanes are input. Users input the number of freeway through lanes (bidirectional total) as a whole number value. The SDF worksheet uses a yes or no input to account for the number of through lanes, depending on whether the total is greater than or equal to eight lanes. Table 4 provides a summary of freeway lane information inputs.

Table 4. Summary of freeway lane information inputs.

Worksheet	Relevant Input Parameters	User Input in Spreadsheet
PDO	Nearest interchange gore distance within 0.5 mi	1 if distance ≤ 0.5 mi; 0 otherwise (figure 5)
	Managed lanes on freeway	1 if there are any managed lanes within the defined interchange area; 0 otherwise
	Freeway number of through lanes (bidirectional total)	Total number of through lanes on the freeway within defined interchange area (do not include auxiliary or managed lanes)
SDF	Freeway posted speed limit	Enter speed limit in mph
	Nearest interchange gore distance within 0.25 mi	1 if distance ≤ 0.25 mi; 0 otherwise (see figure 5)
	Freeway has eight or more lanes (bidirectional total)	1 if freeway has ≥ 8 through lanes; 0 otherwise (do not include auxiliary or managed lanes)

Crossroad Characteristics

The intersection skew angle is measured as the angle between the crossroad centerline and the freeway centerline at the interchange. The skew angle between crossroad and freeway is accounted for in the predictive model as a factor associated with an increase in crash frequency when the skew angle is greater than 30 degrees. Figure 6 describes this parameter.

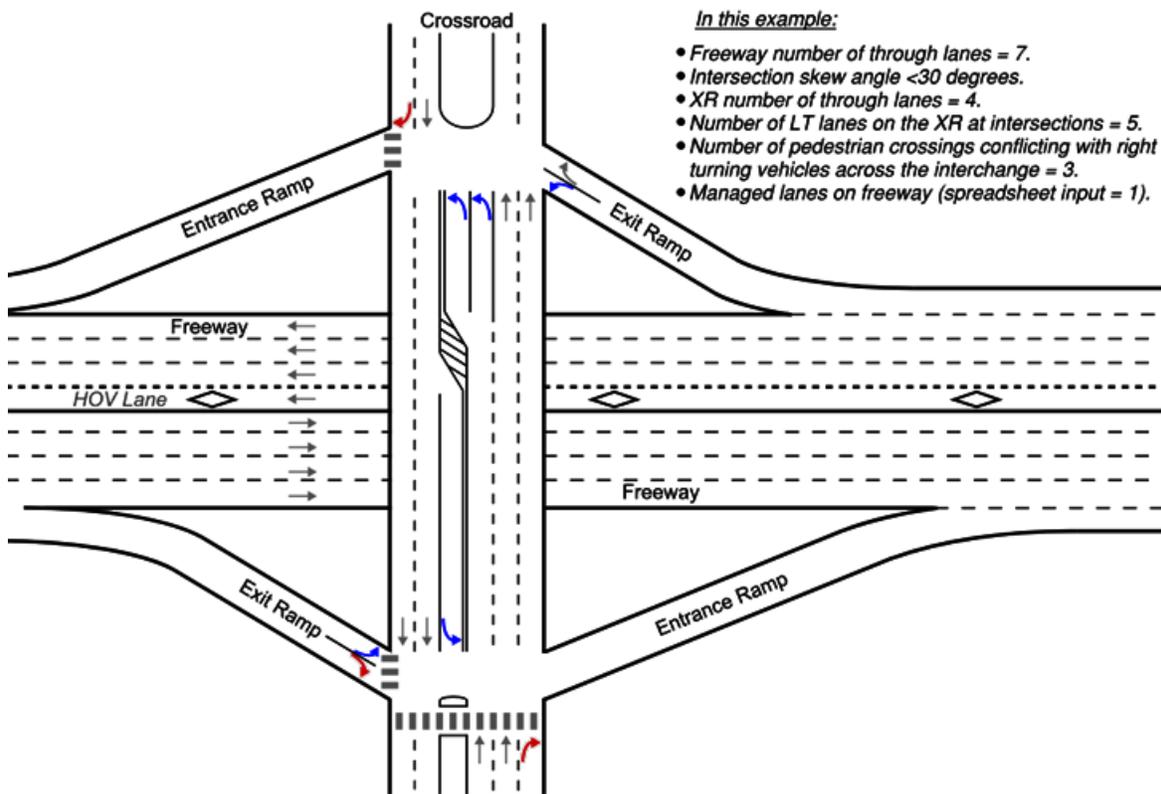


Source: FHWA.
typ = typical.

Figure 6. Illustration. Intersection skew calculation.

The predictive model accounts for the interchange's total number of through lanes on the crossroad to evaluate AADT per lane and a factor specifically accounting for the effect of the number of lanes. The base condition for the SDF is four or fewer through lanes, meaning spreadsheet output is affected when five or more lanes are input. Users input the total number of crossroad through lanes (bidirectional total) as a whole number value. The number of through lanes on the crossroad is included in the SDF as a factor that moves the severity distribution toward more severe crash outcomes when more lanes are present. Users input yes or no as to whether the bidirectional total is four or more through lanes.

Left-turn lanes on the crossroad are accounted for in the predictive model as a factor associated with a decrease in crash frequency. The PDO worksheet accepts values ranging from zero to seven total left-turn lanes on the crossroad. This value includes all left-turn lanes from the ramp terminals onto the crossroad and from the crossroad onto the ramps. Figure 7 provides more details.



Source: FHWA.
 LT = left turn.

Figure 7. Illustration. Example interchange spreadsheet inputs.

The SDF worksheet accounts for the distance from crossroad ramp terminals to adjacent intersections along the crossroad. The distance is measured from the centerline of the ramp terminal to the nearest intersection outside the defined interchange area. Figure 6 illustrates the usual location of a typical crossroad ramp terminal.

The number of pedestrian crossings conflicting with right-turning vehicles across the interchange is accounted for in the SDF as a factor that moves the severity distribution toward a higher probability of more severe outcomes. Users input a value from 0 to 7, representing the total number of conflicts present. A conflict is defined as a right-turn movement intersecting with a pedestrian movement. If there are multiple adjacent right-turn movements from a single leg of an intersection within the interchange area, users should count it as one conflict point if the right-turn movements cross paths with a pedestrian movement.

Figure 7 provides an example of various crossroad characteristics at an interchange required for spreadsheet input. Table 5 summarizes input requirements for crossroad characteristics and features.

Table 5. Summary of crossroad characteristic inputs.

Worksheet	Relevant Input Parameters	User Input in the Spreadsheet
PDO	Intersection skew angle >30 degrees	1 if angle between XR and freeway is >30 degrees; 0 otherwise
	XR number of through lanes (bidirectional total)	Total number of through lanes on the XR within the defined interchange area
	Number of LT lanes on the XR at intersections	Total number of LT lanes on the XR within the defined interchange area (0 minimum, 7 maximum)
SDF	XR posted speed limit	Enter speed limit in mph
	Nearest XR adjacent intersection (signal or roundabout) within 0.10 mi of ramp terminal	1 if the nearest intersection along the XR is ≤ 0.10 mi from any of the XR ramp terminals; 0 otherwise
	Number of pedestrian crossings conflicting with right-turning vehicles across the interchange	Total number of pedestrian crossings that right-turning vehicles conflict with within the defined interchange area; 0 otherwise
	XR has four or more lanes (bidirectional total)	1 if XR has ≥ 4 through lanes; 0 otherwise

Figure 8 provides a snapshot of the User Input section of the PDO worksheet. In this sheet, the user can enter data for any interchange configurations for comparison. However, as noted in the Interchange Configurations section, data must be entered for the diamond/compressed option since the calculations work from this configuration as the baseline. Also, as noted, changes made in the PDO worksheet will automatically update the KABC worksheet.

Crash Frequency Design and Operational Input Table for Interchange Configurations (Note: Data for column C must be entered and data for columns D through I can be entered for comparative analysis)							
Input Characteristic	Diamond/Compressed	Roundabout Diamond	DDI	Parclo B, AB	Parclo A	SPDI	TDI
Urban area type (1 = yes, 0 = no)	0	0	0	0	0	0	0
Intersection skew angle >30 degrees (1 = yes, 0 = no)	0	0	0	0	0	0	0
Nearest interchange gore distance within 0.5 mi (1 = yes, 0 = no)	0	0	0	0	0	0	0
Managed lanes on freeway (1 = yes, 0 = no)	0	0	0	0	0	0	0
Freeway AADT (value in vehicles/day)	60,000	60,000	60,000	60,000	60,000	60,000	60,000
Freeway no. of through lanes (bidirectional total) (no.)	4	4	4	4	4	4	4
XR AADT (value in vehicles/day)	5,000	5,000	5,000	5,000	5,000	5,000	5,000
XR no. of through lanes (bidirectional total) (no.)	4	4	4	4	4	4	4
Total ramp AADT (value in vehicles/day)	20,000	20,000	20,000	20,000	20,000	20,000	20,000
COV of ramp volumes (see below) (decimal #, calculation)	0	0	0	0	0	0	0
Number of LT lanes on the XR at intersections (no.)	0	0	0	0	0	0	0
<div style="border: 1px solid black; padding: 5px; width: fit-content;"> This is the base condition. Analysts must fill out Column C even if this interchange type is not under consideration. </div>		NOTE: Changes to the table above will be reflected on the KABC worksheet.					
Coefficient of Variation (COV) of Ramp Calculation Tool							
Ramp Number (Note: Only enter AADT for number of ramps in alternative)	Ramp AADT (Note		COV Component	Component Value	Notes		
Ramp 1 AADT =	500		Std. Deviation	0.00			
Ramp 2 AADT =	500		Mean	500	NOTE: Range of acceptable COV values is 0 to 1.15.		
Ramp 3 AADT =	500		COV	0.00	Use this value for COV inputs in table		
Ramp 4 AADT =	500						
Ramp 5 AADT =							
Ramp 6 AADT =							
NOTE: Leave input cells blank for any ramps not included in analysis.							

Source: FHWA.
Std = standard.

Figure 8. Screenshot. User input from PDO worksheet.⁽²⁾

Additionally, users are directed to review the Applicability section of the PDO worksheet. As shown in figure 9, this section includes the AADT ranges for each interchange configuration available in the tool. For each configuration, the recommended minimum and maximum AADT values are included for the freeway, crossroad, entrance ramps, and exit ramps. Caution should be used when interpreting results outside these bounds, and further consideration of the operational merits should be taken. For example, roundabout diamond interchanges generally had lower volumes and may not operate well at volumes higher than those used to develop the model.

Applicable AADT Bounds by Interchange Component for Model for Interchange Configurations (Note: Do not edit this table)								
Interchanges studied in building this model had volumes falling into the following ranges:								
Interchange Component	Diamond	Compressed Diamond	Roundabout Diamond	DDI	Parclo Type AB	Parclo Type A or B	SPDI	TDI
Freeway AADT (minimum)	5,000	23,100	5,000	29,000	5,500	6,400	21,000	17,000
Freeway AADT (maximum)	210,000	236,000	94,600	191,000	300,000	144,000	261,000	207,300
XR AADT (minimum)	350	11,000	750	2,000	200	3,700	3,700	3,200
XR AADT (maximum)	40,500	52,900	22,500	47,000	57,000	68,000	64,000	55,000
Total entrance volume (minimum)	100	6,800	850	2,000	200	50	3,100	4,000
Total entrance volume (maximum)	33,400	25,500	20,400	38,500	29,100	34,400	70,000	36,500
Total exit volume (minimum)	125	4,250	800	2,000	175	50	3,200	4,500
Total exit volume (maximum)	24,500	22,500	20,900	45,000	27,200	39,600	75,000	36,700

Source: FHWA.

Figure 9. Screenshot. Applicability section.⁽²⁾

STEP 3: INTERPRET THE OUTPUTS

As shown in figure 10, the primary output of the spreadsheet is in the Model Output section on the PDO worksheet. This section provides the predicted crash frequency for each interchange configuration in units of crashes per year. Results are split into PDO severity-level crashes, combined KABC severity-level crashes, and the total (KABC plus PDO) interchange crashes. These values are based on the predictive model developed for this project and are applicable over the entire interchange area; the model does not determine the location of the predicted crashes

within the interchange. Chapter 5 in the report provides background information on the predictive model.

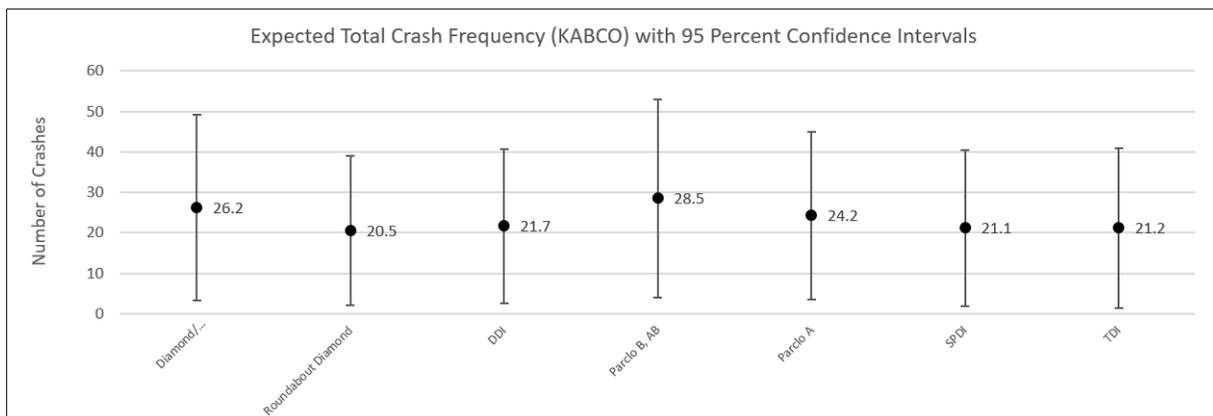
Model Output Table for KABC, PDO, and KABC Crashes for Interchange Configurations (Note: Do not edit this table)							
	Diamond/ Compressed	Roundabout Diamond	DDI	Parclo B, AB	Parclo A	SPDI	TDI
Predicted Crash Frequency							
PDO: 95 percent CI LB (crashes/year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PDO: Expected PDO crash frequency (crashes/year)	19.74	15.52	15.74	20.95	17.11	16.38	17.17
PDO: 95 percent CI UB (crashes/year)	41.28	32.83	33.27	43.71	36.02	34.55	36.14
KABC: 95 percent CI LB (crashes/year)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KABC: Expected KABC crash frequency (from KABC sheet) (crashes/year)	6.47	4.95	5.96	7.58	7.12	4.77	3.98
KABC: 95 percent CI UB (crashes/year)	14.46	11.42	13.43	16.67	15.75	11.05	9.47
KABC: 95 percent CI LB (crashes/year)	3.23	1.99	2.63	4.02	3.44	1.91	1.41
KABC: Expected total crash frequency (KABC + PDO) (crashes/year)	26.21	20.47	21.69	28.53	24.23	21.14	21.15
KABC: 95 percent CI UB (crashes/year)	49.18	38.95	40.75	53.04	45.02	40.37	40.90

Source: FHWA.
LB = lower bounds; UB = upper bounds.

Figure 10. Screenshot. Model output from PDO worksheet.⁽²⁾

The PDO worksheet also provides the 95-percent CIs as a range of values between lower and upper bounds for the crash frequency results. CIs are a measure of statistical certainty: the wider the range, the more caution should be used in applying the model results. Additionally, the predictive model results suggest that while there may be a difference based on the expected value, the differences may not be statistically different, which should be considered when evaluating the safety effects of each interchange configuration.

The Charts worksheet displays the model output in a visual format. Charts show the predicted crash frequency and 95-percent CI upper and lower bounds for PDO, KABC, and combined KABC plus PDO results. Figure 11 provides an example chart from the worksheet highlighting predicted total (KABC plus PDO) crashes for each configuration and applicable 95-percent CIs.



Source: FHWA.

Figure 11. Graph. Total crash frequency from Charts worksheet.⁽²⁾

As shown in figure 12, the SDF worksheet provides a breakdown of the SDF results by interchange configuration. The worksheet predicts the proportion of KABC crashes, given that a crash has occurred. Results are combined for K and A severity levels. These proportions are multiplied by KABC crash frequency on the KABC tab to provide a prediction for crash frequency by severity level.

SDF Model Proportions by Severity Outcome for Interchange Configurations (Note: Do not edit this table)						
Crash Severity Probability	Diamond/ Compressed	Roundabout Diamond	DDI	Parclo	SPDI	TDI
Probability of KA severity outcome	0.0527	0.0258	0.0276	0.0366	0.0276	0.0276
Probability of B severity outcome	0.1662	0.0813	0.1094	0.1155	0.1094	0.1094
Probability of C severity outcome	0.7811	0.8929	0.8630	0.8479	0.8630	0.8630

Source: FHWA.

Figure 12. Screenshot. SDF model output.⁽²⁾

Calibration

The predictive model provided in this worksheet is based on data from five States. As with other predictive models, local conditions may dictate that safety performance will differ by jurisdiction, and calibration is necessary for using the results to compare differences in terms of the number of crashes. If the tool is used without calibrations, users are encouraged to consider the relative (or percent) difference between alternatives in terms of safety benefits. Users can refer to appendix A of the HSM Part C predictive method for the calibration procedure.⁽⁴⁾

Additional Guidance on Predictive Method

Users are encouraged to conduct evaluations within the parameters presented for interchange configurations discussed in this guide. However, the predictive method may not be applicable in some situations, or unique circumstances may not fit within the criteria for using the predictive method. In these situations, if crash prediction is necessary, users should consider applying the predictive method from chapters 18 and 19 of the HSM.⁽⁴⁾ If data required for the chapter 18 and 19 predictive method are unavailable, and users opt to employ this tool, they should document any assumptions made, noting specific situations where the models have been extended for analysis. Further documentation should include additional factors that may contribute to a potential bias in safety estimation.

Practitioners should exercise caution when making decisions based purely on safety prediction models. *Refer to the Conclusions and Recommendations section (chapter 7) of the report for additional insight into the applicability of model results to planning-level decisionmaking.*

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