Interchange Safety Analysis Tool (ISAT): User Manual

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Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Foreword

This User Manual describes the usage and operation of the spreadsheet-based Interchange Safety Analysis Tool (ISAT). ISAT provides design and safety engineers with an automated tool for assessing the safety effects of geometric design and traffic control features at an existing interchange and adjacent roadway network. ISAT can also be used to predict the safety performance of design alternatives for new interchanges and prior to reconstruction of existing interchanges. The primary outputs from an analysis include: the number of predicted crashes for the entire interchange area, the number of predicted crashes by interchange element type, the number of predicted crashes by year, and the number of predicted crashes by collision type. The User Manual presents basic information for getting started with using ISAT, the general methodology that users will follow when conducting an analysis with ISAT, input requirements of the program, default data incorporated within the program and recommendations on when and how these default data should be updated by the user, output reports generated by ISAT, and general information on different applications for which ISAT can be applied. For more information on ISAT, the user is referred to the final project report for Contract No. DTFH61-05-P-00302.

Michael Trentacoste
Director, Office of Safety
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Notice

Quality Assurance Statement

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16. Abstract

This User Manual describes the usage and operation of the spreadsheet-based Interchange Safety Analysis Tool (ISAT). ISAT provides design and safety engineers with an automated tool for assessing the safety effects of geometric design and traffic control features at an existing interchange and adjacent roadway network. ISAT can also be used to predict the safety performance of design alternatives for new interchanges and prior to reconstruction of existing interchanges. The primary outputs from an analysis include: the number of predicted crashes for the entire interchange area, the number of predicted crashes by interchange element type (i.e., mainline freeway segments, ramps, ramp terminals and intersections, and crossroad roadway segments), the number of predicted crashes by year, and the number of predicted crashes by collision type.

This User Manual presents basic information for getting started with using ISAT, the general methodology that users will follow when conducting an analysis with ISAT, input requirements of the program, default data incorporated within the program and recommendations on when and how these default data should be updated by the user, output reports generated by ISAT, and general information on different applications for which ISAT can be applied. An example problem is also provided on the safety performance of a rural diamond interchange and surrounding roadway network, illustrating user inputs and generated output reports.

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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 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		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 (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		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	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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INTRODUCTION

This user manual provides detailed descriptions/instructions on the usage and operation of the spreadsheet-based Interchange Safety Analysis Tool (ISAT). ISAT was developed for performing safety assessments of interchanges and adjacent roadway segments and intersections. ISAT was developed using Microsoft® Excel® 2003 spreadsheet software.

The basic purpose of ISAT is to provide design and safety engineers with an automated tool to aid in assessing the safety effects of geometric features and traffic control options, along with traffic volumes, of an existing interchange and predicting the safety performance of a new interchange where no interchange previously existed. ISAT was developed to enable a wide range of applications, including but not limited to:

- Estimating crash frequencies, severities, and types for an existing interchange for which crash data are not available.
- Estimating the safety performance for a new interchange that has not yet been constructed.
- Estimating crash frequencies, severities, and types for a specific proposed design alternative for an existing interchange.

ISAT is intended for performing safety assessments of freeway-arterial and freeway-freeway interchanges. ISAT also provides the capability to perform safety assessments of adjoining mainline freeway segments, crossroad ramp terminals and intersections, and arterial crossroad roadway segments. It is not recommended to use ISAT to evaluate arterial-arterial interchanges. The interchange/ramp safety performance functions (SPFs) incorporated within ISAT were developed using freeway locations. It is questionable whether the models are sufficient, or directly applicable, for the more restrictive arterial settings.

Safety assessments can be performed for interchange areas where no crash data are available; and when crash data are available, ISAT can incorporate the information and provide more accurate safety estimates. Thus, ISAT can be used in both situations (i.e., when no crash data exist and when crash data are available).

ISAT uses a building-block approach to assess the safety performance of interchanges. Users input data for the interchange as a whole and for individual components of an interchange and surrounding roadway network. Safety estimates are calculated for the individual components, and these safety estimates are summed to obtain safety performance estimates for the interchange as a whole. The primary interchange elements that can be included in an analysis are:

- Mainline freeway segments (MF).
- Interchange ramps (R) and acceleration lanes (AL).
- Crossroad ramp terminals (RT) and intersections.
- Crossroad roadway segments (RS).

For analysis purposes, acceleration lanes are considered within the mainline freeway methodology. Figure 1 provides an illustration of an interchange divided into individual components suitable for an analysis. In this example the mainline freeway is broken into segments according to changes in traffic volume and ramp influence areas. Similarly, the crossroad roadway is divided at intersection locations. The ramps, acceleration lanes, and crossroad ramp terminals are considered as individual units and are not subdivided any further.

ISAT was designed to analyze the interchange elements of a single interchange, as illustrated in the example in figure 1. ISAT was also designed to analyze a system of interchanges and the elements of the surrounding roadway network. ISAT does have some limitations concerning the number of individual components that can be included in an analysis area, but in many ways it is up to the user to determine the size and/or complexity of the analysis.

The primary outputs from an analysis include:

- Number of predicted crashes for entire interchange area.
- Number of predicted crashes by interchange element type.
- Number of predicted crashes by year.
- Number of predicted crashes by collision type.

On the output reports crashes are reported for three severity levels: total (TOT), fatal and injury (FI), and property-damage only (PDO) crashes.

ISAT was developed based on existing safety knowledge and predictive relationships from previous and ongoing safety research. New safety modeling or safety evaluations were not performed as part of the research to develop the first version, or generation, of ISAT. ISAT was designed to incorporate new safety models easily in later versions of the program when they become available through future research.

The remainder of this user manual is organized as follows: the Getting Started section presents basic information for getting started with using ISAT; the Basic Analysis Procedures section presents the basic methodology that users will follow when conducting an analysis with ISAT; the Input Requirements section presents the user input requirements of the program; the Default Data section discusses the default data incorporated within the program and recommendations on when and how these default data should be updated by the user; the Output Reports section discusses the output reports generated by ISAT; and the Applications of ISAT section presents general information on different applications for which ISAT can be applied and how ISAT can be applied to analyze several common interchange types.

This user manual does not contain the detailed algorithms utilized in the calculations of the program. For detailed information on these algorithms, the user is referred to the final project report, *Safety Analysis of Interchanges.*[1]

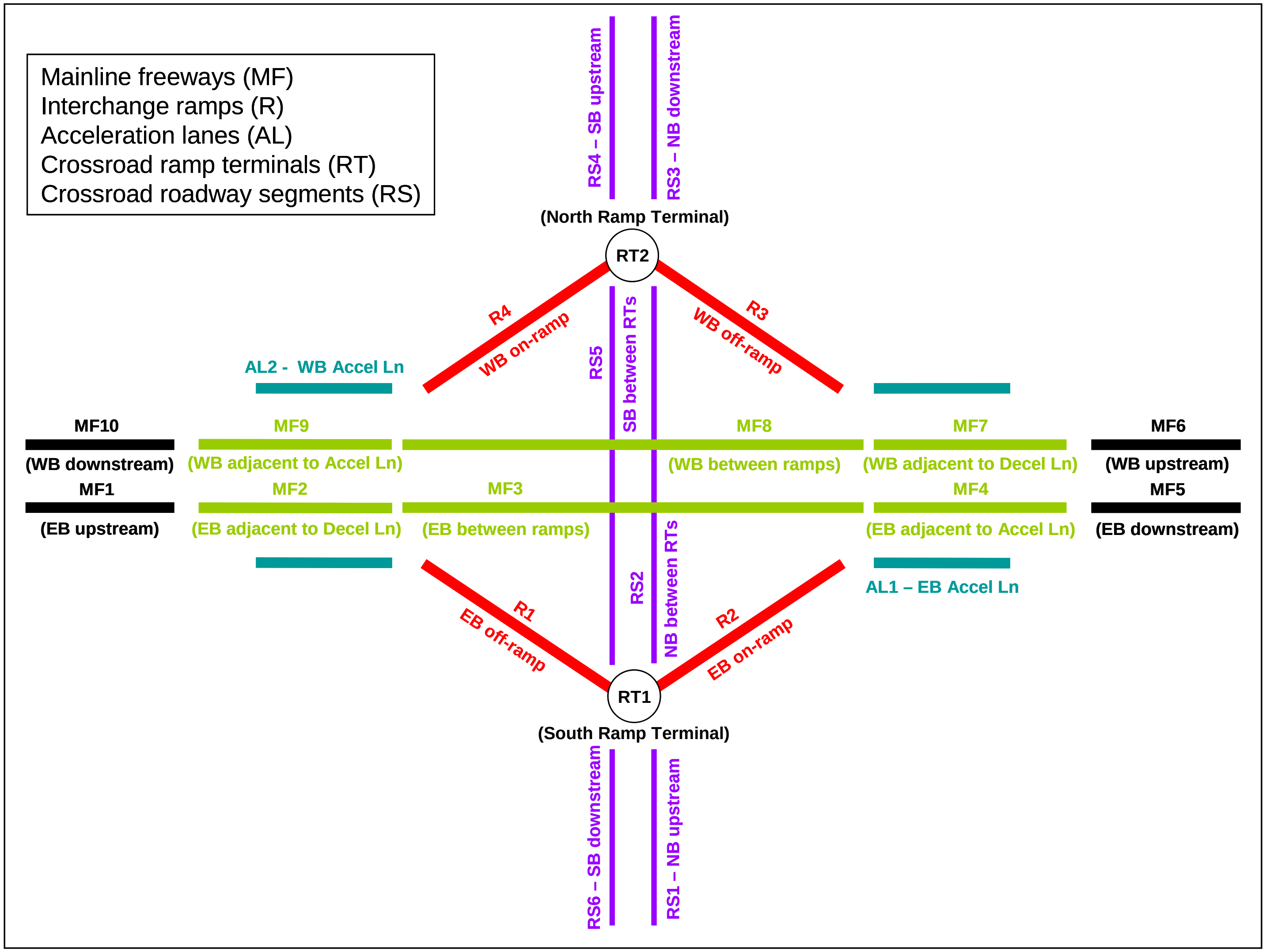


Figure 1. Example interchange illustrating individual components.

GETTING STARTED

This section provides general information on using and navigating through the ISAT software. The following issues are discussed:

- System requirements.
- Installation of ISAT software.
- Excel basics.
- Excel navigation.
- Entering data.
- Saving, printing, and clearing data.
- Modifying calibration coefficients and crash distributions.
- Ending a Microsoft Excel spreadsheet software session.

SYSTEM REQUIREMENTS

Because ISAT is an Excel spreadsheet workbook, system requirements for the ISAT software are essentially the same as those for the Microsoft Office Suite; please consult installation requirements for these products for more detailed information. Further, approximately 765 kilobytes (KB) of memory are needed for this program before data entry. Adding an interchange to the database, including consideration of all elements for that interchange, requires approximately 3.2 megabytes (MB) of additional storage. The required storage increases with the number of elements and sites entered for an interchange.

INSTALLATION OF ISAT SOFTWARE

The following procedure should be used to install the ISAT software on a computer from a CD-ROM:

1. Copy the entire folder entitled “ISAT” on the installation CD to the hard drive (usually this drive is called the “C” drive) so that it becomes a folder known as C:\ISAT.
2. Clear the “Read Only” file property of every file in C:\ISAT. This is done by right-clicking on selected files, choosing Properties from the pop-up menu, and clicking the attribute check box labeled “Read Only” on the General tab.
3. To run ISAT, click on the file name C:\ISAT.xls and follow the procedures in the Basic Analysis Procedures section of this manual.

MICROSOFT EXCEL SPREADSHEET SOFTWARE BASICS

ISAT is an Excel workbook program that operates within Microsoft Windows operating system environments: Windows 95, Windows NT 4.0, or later versions of Windows. ISAT has been developed for Excel 2003 spreadsheet software or later versions of Microsoft Excel spreadsheet software. The Installation of ISAT Software section of this manual provides instructions for installation of ISAT on a personal computer. Like many Microsoft applications, Excel spreadsheet software is easily started in various ways. From the Start button located on the task bar at the bottom of the screen, click on the Programs option and then on Microsoft Excel. Click once with the left mouse button, and in a few moments the Excel screen appears. There may also be an icon on the desktop or on a toolbar that can be clicked to start Excel. ISAT can also be started from Microsoft Windows Explorer by browsing to find ISAT's file location and double-clicking its icon.

EXCEL NAVIGATION

Open ISAT from its file location by using the Open option in the File menu. Like most Windows programs, Excel provides a host of ways to control program operations. The mouse, keyboard, menus, dialog boxes, command buttons, key combinations, and more can be used. With ISAT, there are two types of navigation: among worksheets and among cells in a worksheet.

Navigation among worksheets is accomplished by clicking the worksheet tabs at the bottom of the workbook window. Within ISAT, navigation between worksheets can also be accomplished by using hyperlinks embedded in the program. Hyperlinks are colored, underlined text elements that jump to a location in the workbook when clicked. The titles of all hyperlinks describe the type of information contained on the respective worksheet that will appear upon clicking the hyperlink, with the exception of those labeled "Home." These hyperlinks return users to the Input-General worksheet in the workbook.

The Tab key and Enter key provide the primary method of navigating through the columns and rows of a given worksheet. Tab movement generally goes from left to right across the screen, while Enter movement goes from top to bottom of a screen. To reverse the direction, or return to the previous cell, press Shift Tab or Shift Enter.

Arrow keys can also be used to move from one cell to the next. Multiple cell movement can be accomplished by using the Control key (Ctrl) with the arrow keys to move to the next cell containing text. Page Up and Page Down keys can also move through multiple cells. Finally, one can also move from one cell to another by moving the mouse pointer to the desired field and clicking the left mouse button.

The Esc key backs out of menu commands and cancels dialog boxes. Esc is a good key to press if what is happening on the screen is not desired.

ENTERING DATA

All data in ISAT are entered in cells where information may simply be typed. Alternatively, typing the first few characters of the intended entry will cause the cell to automatically select the closest match from cells in the rows immediately above. This can prove to be problematic if an automatic entry does not reflect the intentions of the user. **Care should be taken that any auto-population of cells is indicative of the user's intent.** Finally, Excel spreadsheet software allows for use of Microsoft's standard copy and paste techniques. A user may select information to be copied by clicking and dragging over the desired text. Press Ctrl+C to copy the text, move to the field/site where the information is to be copied by clicking the mouse cursor in the field (or tabbing to it), and then press Ctrl+V to paste.

If an error is made while entering data, simply use the Backspace key to delete the error and then retype the value. To edit existing or incomplete data, click an insertion point in the desired field and use normal editing techniques to make the correction. This includes the Delete key, which removes the selected characters or characters to the right of the cursor. Entire blocks of cells may be cleared simultaneously by highlighting the cells and using the Delete key. **However, if an entire row of information is no longer desired, do not delete the entire row. Calculations built into this program rely on the specific rows already in the program. Clearing information in cells rather than deleting them will preserve program integrity. This situation also applies to moving blocks of cell information by clicking and dragging. Once calculations have been performed and output reports generated, formulas may no longer be valid if cells have been moved.**

Information entered into Excel spreadsheet software is not automatically saved by the program. The user must explicitly save entered information (see the Saving, Printing, and Clearing Data section).

SAVING, PRINTING, AND CLEARING DATA

ISAT estimates safety performance for an interchange based upon data supplied by the user. Interchange data sets are created by entering data, as described above. The input data entered for an interchange may be saved at any time for later retrieval using the File/Save menu buttons at the top of the screen. The data will be saved under a user-selected file name and location. When ISAT is restarted, any data used in the previous session will still be present.

A custom menu located on the first worksheet (i.e., Input-General) provides four utility macros to clear and print interchange data used in ISAT:

- **Clear Input and Output**. This macro erases all site data from memory so the user can begin entering data for a new interchange or analysis. The program will not offer an option to save the current data set before it is cleared, so the user must manually save the file if the data are to be retrieved later.

- **Clear Output**. This macro erases all current calculations and output reports but retains all entered data. The user may generate the output reports again by clicking the Perform Calculations button.

- **Print Input**. At any time during the process of entering site data, the individual active worksheet may be printed from the File menu. However, the Print Input button on the Input-General worksheet prints each input worksheet simultaneously.

- **Print Output.** After calculations have been performed and output reports generated, this macro may be used to simultaneously print all output reports generated by the program.

MODIFYING CALIBRATION COEFFICIENTS AND CRASH DISTRIBUTIONS

ISAT makes use of SPFs from previous and ongoing safety research. As such, the calculations of the program are not initially designed to be specific to a given highway agency. However, ISAT has calibration coefficients which provide the capability to adjust the calculations performed within ISAT to better reflect local safety experience. It is recommended that, before using ISAT to perform actual safety assessments, the user modify the default calibration coefficients to better reflect local safety experience. Then, it is recommended that the calibration coefficients be updated annually. Detailed procedures for calculating appropriate calibration coefficients are provided in the Calibration Coefficients section of this manual.

ISAT is designed to calculate crash frequencies for a defined set of collision types and crash severity levels. To calculate such frequencies, ISAT makes use of crash proportion distributions. Default distributions are provided within ISAT, based upon actual crash data from Washington State. Before using ISAT to perform actual safety assessments, it is recommended that the user modify the default crash proportions based upon local crash data to better reflect local safety experience. Then, it is recommended that these proportions be updated annually. Detailed procedures for calculating the crash proportions are provided in Crash Distributions by Severity and Type section of this manual.

ENDING AN EXCEL SPREADSHEET SOFTWARE SESSION

When work with Excel is finished, quit by clicking File Exit on the menu bar or by clicking the close button at the right end of the Excel title bar. Excel will prompt the user to save the worksheet for later retrieval.

BASIC ANALYSIS PROCEDURES

The following sequence of steps should be followed to estimate the safety performance of an interchange using ISAT. Most steps will be performed each time a safety assessment is made of an interchange area. Other steps will require user input primarily on an annual basis. The general analysis procedures are as follows:

Step 1—Start Microsoft Excel spreadsheet software.
Step 2—Start ISAT.
Step 3—Review default data and update values to reflect current local conditions.
Step 4—Identify individual components of analysis area.
Step 5—Enter general interchange data.
Step 6—Enter interchange element data.
- Mainline freeway segments
- Ramps
- Crossroad ramp terminals and intersections
- Crossroad roadway segments

Step 7—Perform calculations.
Step 8—Review results.

Details on each of these steps are presented below.

STEP 1—START MICROSOFT EXCEL SPREADSHEET SOFTWARE

As stated in the Excel Basics section of this manual, Microsoft Excel spreadsheet software can be started from the Start button by clicking on the Programs option, and then on Microsoft Excel. There may also be an icon on the desktop or on a toolbar that can be clicked to start Excel.

STEP 2—START ISAT

ISAT can be started from within Excel by clicking on the File menu, clicking on the Open option, browsing to find the ISAT file location, and clicking on the ISAT file name. It is also possible to use Windows Explorer from the computer desktop to find the ISAT file location. Clicking on the ISAT file name will automatically open Excel spreadsheet software (if it is not already open) and start ISAT. Thus, with Windows Explorer the user can bypass Step 1 and go directly to Step 2.

It is also possible to set up an ISAT icon (shortcut) on the computer desktop to start ISAT without directly opening Excel spreadsheet software first. A shortcut of this type can be created from the Programs option in the Start menu or from Windows Explorer. It can then be moved to the computer desktop.

STEP 3—REVIEW DEFAULT DATA AND UPDATE VALUES TO REFLECT CURRENT LOCAL CONDITIONS

After starting the ISAT application, the worksheet labeled Input-General appears. This is the main control worksheet for ISAT and guides the user through the data entry steps and then to the data processing procedure. Initially, when no data have been entered, only the input worksheets are accessible to the user at the bottom of the screen. However, the user also has access to the default input worksheets through the active hyperlinks found on this worksheet. All subsequent hyperlinks labeled "Home" return you to this page.

Users will be able to proceed with analyses using the default data provided with the program or may substitute data obtained by their own agency that they consider more appropriate than the original default values supplied with the program. There are three types of default data:

- **Safety Performance Functions (SPFs):** An SPF is a statistical model used to predict the safety performance of specific sites based on their characteristics. An SPF is thus represented by an equation that describes the functional relationship between predicted crash frequencies and site characteristics. Default SPFs are provided for total (TOT) and fatal and injury (FI) crash severities for subtypes of each interchange element (i.e., mainline freeway segments, ramps [and acceleration lanes], crossroad ramp terminals and intersections, and crossroad roadway segments), where subtypes differ by geometrics or functional characteristics. The default values supplied with ISAT were developed through previous and ongoing safety research. In most cases, it is anticipated that ISAT users will not modify the default values associated with the SPFs, but ISAT does not prohibit the user from doing so. It is recommended that these values be changed only when an agency has better and more recent research results available, but it is also recommended that the user routinely check or verify the default values associated with default SPFs to ensure the values have not been changed prior to performing calculations. Alternatively, if the default values have been modified at some point, the user should reverify that the values are still correct.

- **Calibration Coefficients:** Calibration coefficients provide the capability to adjust the calculations performed within ISAT to better reflect local safety experience. The user should review the calibration coefficients to make sure they seem logical. If the values seem unreasonable, the user should modify the values as appropriate, which may require performing the calibration procedures as described in Calibration Coefficients section of this manual.

- **Crash Distributions:** The default crash distributions include the severity and crash type proportions for specific types of interchange elements. The user should review these distributions to make sure they appear consistent with local experience. The user should modify these values as appropriate (see the Crash Distributions by Severity and Type section).

The default input worksheets for the SPFs, calibration coefficients, and crash distributions may be accessed by using the appropriate hyperlink on the Input-General worksheet. To edit default values, simply click in the desired cell, delete the old value, and retype the new; note, however, that other cells on these worksheets are protected and cannot be modified. **Before the user changes any of the default values, it is recommended that the file be saved under a different name to avoid the possibility of permanently losing data that might be desirous for a future analysis. The buttons provided to clear input or output data will NOT return SPFs, calibration coefficients, or crash distributions to the original default values.**

STEP 4—IDENTIFY INDIVIDUAL COMPONENTS OF ANALYSIS AREA

The user will perform this step outside of the program, but it is a recommended step for organizational purposes. The user should develop a sketch of the analysis area illustrating, and numbering, each of the individual components to be considered in a given analysis. A sketch similar to figure 1 will help the user visualize the various components included in the analysis. The sketch will help the user during the data input process, primarily when inputting data for the individual components, and will help reduce the likelihood of errors during data entry. Further guidance on how to subdivide an interchange area into individual components is provided in the Input Requirements, Default Data, and Applications of ISAT sections of this manual.

STEP 5—ENTER GENERAL INTERCHANGE DATA

The user enters general information concerning the analysis on the Input-General worksheet. On this input worksheet, the user provides general information describing the analysis and whether crash data will be incorporated into the computations. The General Interchange Inputs section provides more details concerning the general input data. The user can return to the Input-General worksheet by using the Home hyperlink located in the upper left corner on all worksheets, except those associated with the output reports.

STEP 6—ENTER INTERCHANGE ELEMENT DATA

The user enters data for the individual components of the analysis area on the respective worksheets:

- Input Mainline Freeways.
- Input Ramps.
- Input Ramp Terminals.
- Input Crossroad Segments.

After all of the input data have been entered, the user should click the Home hyperlink at the upper left corner of the respective input worksheet to return to the Input-General worksheet.

STEP 7—PERFORM CALCULATIONS

Having entered all of the required input data, the Perform Calculations button on the Input-General worksheet can now be used to begin the processing calculations and generate output. Clicking this button begins the sequence of actions that performs the calculations and generates output.

STEP 8—REVIEW RESULTS

When the user clicks the Perform Calculations button on the Input-General worksheet, ISAT automatically takes the user to the first output report worksheet (i.e., Output-General). On the Output-General worksheet, output results are summarized in the following manner:

- Number of predicted crashes for entire interchange area.
- Number of predicted crashes by interchange element type.
- Number of predicted crashes by year.
- Number of predicted crashes by collision type.

On separate output worksheets for mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad roadway segments, the numbers of predicted crashes by collision type and severity level are summed across the individual components of the respective interchange elements. In a separate table results are provided for individual components of the respective interchange elements. Each of the output worksheets can be viewed by clicking on the appropriate tab found at the bottom of the workbook.

INPUT REQUIREMENTS

This section summarizes the input requirements for ISAT. The user enters geometric design, traffic control, and traffic volume data for each interchange element; these data are input into individual cells within the Excel workbook. For programming purposes input data are broken down into two categories: numeric and character. When inputting numeric values, the required units for the data are displayed for the user; it is expected that reasonable values will be entered. Unreasonable values may produce skewed results. Character input is more closely controlled than numeric. An arranged list of acceptable character input is provided to the user for each variable. This is done so that the software is capable of recognizing the text when performing calculations. A structured character input is essential to proper program function. **Either inputting characters where numeric values are expected, or entering characters other than those prescribed by ISAT, will result in various error messages and program failure.**

The user inputs data into five primary worksheets within ISAT. The worksheets are divided based on the individual interchange elements and the interchange area (i.e., analysis area) as a whole:

- General interchange inputs.
- Mainline freeway segments.
- Ramps.
- Crossroad ramp terminals and intersections.
- Crossroad segments.

The following sections present the variables required for the general interchange area as a whole and the individual interchange elements, their definitions, and appropriate inputs. Each input worksheet is designed in a similar format. The user inputs data much like adding information within a table. Variables are designated either as mandatory or optional. Mandatory variables must be filled-in by the user for processing to be performed. Optional variables provide additional or supplemental information to be used in the computations when data are available, but the computations can run to completion when optional inputs are not provided.

GENERAL INTERCHANGE INPUTS

The variables covered in this section represent data that are universal over all of the interchange elements. The input values are used in data processing algorithms for the entire interchange (or system of interchanges) and for individual components. Figure 2 illustrates the Input-General worksheet. The variables included on this worksheet are further defined in table 1. Table 1 presents the variable name, variable number, the expected input format, applicable definition, and whether the variable is mandatory or optional.

Interchange Safety Analysis Tool

General Interchange Input Data

GI1	Project description	*character*	
GI2	Analyst		
GI3	Date		
GI4	Area type	(U,R)	
GI5	Beginning year of analysis	*numeric*	
GI6	Ending year of analysis	*numeric*	

			Mainline freeways	**Ramps**	**Crossroad ramp terminals and intersections**	**Crossroad segments**
GI7	Crash data available?	(Y, N)				
GI8	Beginning year of crash data	*numeric*				
GI9	Ending year of crash data	*numeric*				
GI10	Observed number of crashes	*numeric*				

Go To Input for Mainline Freeways

Go To Input Ramps

Go To Input for Crossroad Ramp Terminals and Intersections

Go To Input for Crossroad Segments

Go To Input for Calibration Factors

Go To SPFs for Mainline Freeways

Go To SPFs for Ramps

Go To SPFs for Crossroad Ramp Terminals and Intersections

Go To SPFs for Crossroad Segments

Go To SPFs for Accel Lanes

Go To Distributions for Mainline Freeways

Go To Distributions for Ramps

Go To Distributions for Crossroad Ramp Terminals and Intersections

Go To Distributions for Crossroad Segments

Perform Calculations

Clear Input and Output

Clear Output

Print Input

Print Output

Figure 2. General Interchange Input Data screen.

Table 1. Summary of input variables for general interchange area.

Variable Name	Variable No.	Format	Definition	Type
Project description	GI1	Character	Short description that describes the project.	Optional
Analyst	GI2	Numeric	User name.	Optional
Date	GI3	Character	Date of analysis.	Optional
Area type	GI4	Character (U, R)	General character of land use surrounding the interchange, preferably based on FHWA urban area boundaries: U = Urban R = Rural	Mandatory
Begin year of analysis	GI5	Numeric (calendar year)	Value sets the first year of the period for which output reports will be created.	Mandatory
End year of analysis	GI6	Numeric (calendar year)	Value sets the final year of the period for which output reports will be created.	Mandatory
Crash data available	GI7	Character (Y, N)	Field indicates whether crash data are available for input on mainline freeway segments, ramps, ramp terminals and intersections, or crossroad roadway segments, respectively.	Mandatory
Begin year of crash data	GI8	Numeric (calendar year)	Field indicates the first year for which crash data are available for input for the respective interchange elements.	Mandatory, if GI 7 equals Y
End year of crash data	GI9	Numeric (calendar year)	Field indicates the final year for which crash data are available for input for the respective interchange elements.	Mandatory, if GI 7 equals Y
Observed number of crashes	GI10	Numeric	Field indicates the total number of observed crashes during the specified period (i.e., GI8 through GI9) across all individual mainline freeway segments, ramps, ramp terminals and intersections, and/or crossroad roadway segment included in the analysis.	Mandatory, if GI 7 equals Y

On this input worksheet, the user provides general information that is used in a number of ways. The first three variables (i.e., project description [GI1], analyst [GI2], and date [GI3]) are primarily for recording purposes, so when the user reviews an analysis he or she has a sense of why the analysis was performed, or the project to which the analysis applies, who conducted the analysis, and the date the analysis was conducted. Classifying the area type [GI4] around the interchange area is important because ISAT makes use of SPFs. Different SPFs are available for both urban and rural areas. Specifying the area type enables the tool to implement the correct SPFs for use in the processing algorithms. The user also must specify the dates for the analysis (i.e., beginning year of the analysis [GI5] and ending year of the analysis [GI6]). ISAT is designed to perform calculations only for full calendar years. Analyses over partial years or months cannot be performed, and the analysis period is limited to a maximum of 20 years.

The other types of information that the user can provide on the Input-General worksheet concern crash data. ISAT can perform calculations with or without crash data provided by the user. When no crash data are available for the analysis area (i.e., mainline freeway segments, ramps, crossroad ramp terminals and intersections, or crossroad segments), calculations are still performed using the SPFs, and the crash frequencies represent predicted values using the SPFs. When crash data are available, the crash data are combined with the predicted values from the SPFs using an Empirical Bayes methodology, so the final crash frequencies reflect combined estimates using the crash data and the predicted values (i.e., from the SPFs).

When inputting crash data, there are several points that should be kept in mind:

- The crash data are grouped according to the four major elements of the interchange area: mainline freeways, ramps, ramp terminals and intersections, and crossroad segments. Within each element, if the user indicates that crash data are available by entering "Y" into the GI7 row, the program will function properly only if numerical values are entered for the years of crash data and observed number of crashes. If the user indicates that crash data are not available by entering a "N" into the GI7 row, then no further information is necessary in the crash data input area. Any information that is entered will be ignored. Crash data can be included for any, or all, of the interchange elements without affecting the elements with no crash data available.
- The maximum allowable crash data period is 10 years; ISAT is designed to perform calculations only for full calendar years. The crash data period is completely independent of the user inputted years of analysis and can have occurred before, concurrent to, or after the analysis period.
- The observed number of crashes input by the user should reflect the crash count aggregated over all of the individual components of each interchange element. For example in figure 1, crash counts for MF1 through MF10 should be summed and included together. If crash data are available for only a portion of the individual components of a primary element within the analysis area, these data should not be considered in the analysis. For example (again referring to figure 1), if crash data are available for the eastbound mainline freeway segments (i.e., MF1 through MF5) but no crash data are available for the westbound lanes (i.e., MF6 through MF10), inputting the aggregated crash data for only 5 of the 10 mainline freeway segments included in the analysis area would lead to erroneous results. The program automatically considers the crash data to be aggregated over all of the individual components of a primary element within the analysis area. Care should be taken to input only crash data for the areas included in the analysis in order to receive accurate results.

When entering crash data, the following rules should be applied:

- Crashes that occur along or within mainline freeway segments, deceleration lanes, and acceleration lanes should be attributed to mainline freeway segments. Deceleration lanes are defined to begin at the taper and terminate at the painted nose of the gore area of the off-ramp (figure 3). Acceleration lanes are defined to begin at the painted nose of the gore area of the on-ramp and terminate at the end of the taper.

- All crashes that occur within 76.2 meters (m) (250 feet (ft)) of a crossroad ramp terminal or intersection and are classified as intersection-related should be attributed to crossroad ramp terminals and intersections. All crashes that occur within 76.2 m (250 ft) of a crossroad ramp terminal or intersection but are not classified as intersection-related should be attributed either to ramps or crossroad roadway segments.
- All crashes that occur along the ramp proper portion of an interchange ramp should be attributed to ramps. For off-ramps, the ramp proper is defined to begin at the painted nose of the gore area and terminate at the crossroad ramp terminal. For crashes that occur on the ramp proper and are within 76.2 m (250 ft) of the crossroad ramp terminal, if the crash is related to the operation of the ramp terminal (i.e., intersection-related), then the crash should be attributed to the crossroad ramp terminal, but if the crash is not related to the operation of the ramp terminal, then the crash should be attributed to the ramp. For on-ramps, the ramp proper begins at the crossroad ramp terminal and terminates at the painted nose of the gore area.
- Crashes that occur along or within arterial crossroad roadway segments should be attributed as such. The exceptions are those crashes that occur within 76.2 m (250 ft) of a ramp terminal or intersection and are intersection-related, in which case the crashes should be attributed to crossroad ramp terminals and intersections.

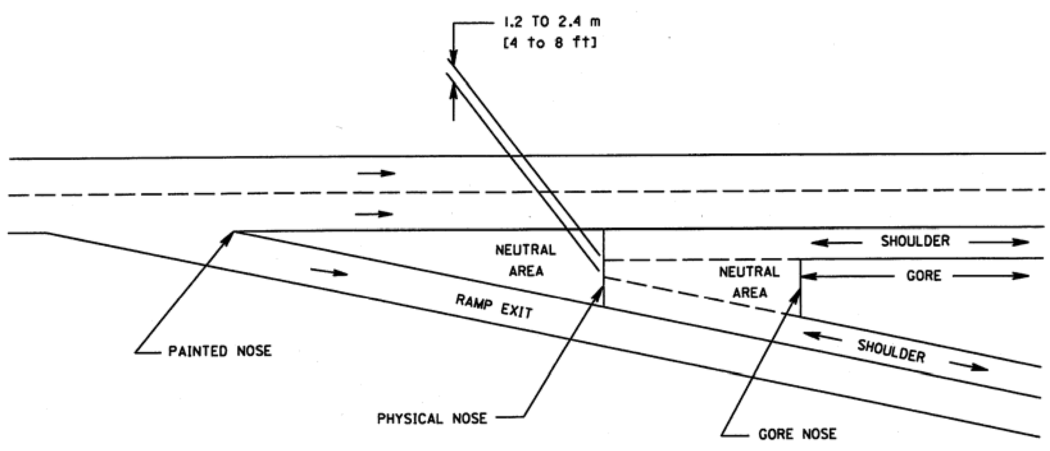


Figure 3. Typical gore area characteristics[2].

Table 2 presents the Input-General worksheet completed with sample data for a rural diamond interchange. This example will be carried throughout the remainder of this user manual. The example is based on the analysis area shown in figure 1. In this example a safety assessment is being made of an interchange for a 10-year period in the future. Five years of crash data are available for each type of interchange element and will be incorporated into the calculations.

Table 2. Example data for rural diamond interchange (Input-General).

GI1	Project Description	Character	Diamond Interchange Example 1
GI2	Analyst		MRI
GI3	Date		10/27/2006
GI4	Area type	(U,R)	R
GI5	Beginning year of analysis	numeric	2008
GI6	Ending year of analysis	numeric	2017

			Mainline Freeways	Ramps	Crossroad Ramp Terminals and Intersections	Crossroad Segments
GI7	Crash data available?	(Y, N)	Y	Y	Y	Y
GI8	Beginning year of crash data	numeric	2001	2001	2001	2001
GI9	Ending year of crash data	numeric	2005	2005	2005	2005
GI10	Observed number of crashes	numeric	65	8	18	34

MAINLINE FREEWAY SEGMENT INPUTS

The variables covered in this section represent data unique to the mainline freeway segment portion of the interchange area. The input values are used in the data processing algorithms to predict crashes along freeway mainline segments. Table 3 illustrates the Input Mainline Freeways worksheet. Table 4 provides greater detail associated with each of the mainline freeway variables.

The following information provides guidance on defining mainline freeway segments. Mainline freeway segments are considered independently in each direction of travel, either northbound, southbound, eastbound, or westbound (NB, SB, EB, or WB). Mainline freeway segments always break where traffic volumes change (i.e., near ramp gore points or at interchange influence areas). Mainline freeway segments are divided into two general classes: mainline freeway segments within an interchange area and mainline freeway segments outside an interchange area. The SPFs for mainline freeway segments within interchange areas attempt to account for the increased level of weaving, lane changing, and acceleration/deceleration that takes place immediately upstream, downstream, and between interchange ramps. The SPFs for mainline freeway segments outside an interchange area model the safety experience of basic mainline freeway segments having homogenous characteristics. In general terms, the limits of mainline freeway segments within interchange areas are defined to extend approximately 0.48 kilometer (km) (0.3 mile (mi)) upstream from the gore (i.e., painted nose of the gore area) of the first ramp of a particular interchange to approximately 0.43 km (0.3 mi) downstream from the gore (i.e., painted nose of the gore area) of the last ramp of the given interchange. Conversely, all mainline freeway segments that extend beyond these defined limits for within interchange areas are by definition mainline freeway segments outside an interchange area.

On the input worksheet for mainline freeway segments, the user provides general information for each individual mainline freeway segment to be considered in a given analysis. The first variable (i.e., segment number [MF1]) is for bookkeeping purposes. This segment number is carried through and provided on output reports if there is a particular need to investigate the expected safety experience of an individual segment. This segment number is also used so that the necessary calculations are made for appropriate segments adjacent to on-ramps. The next few variables (i.e., segment description [MF2], direction of travel [MF3], beginning MP [MF4], and ending MP [MF5]) are primarily for recording purposes so when the user reviews an analysis, the user has a sense of where the individual segment is located within the analysis area. Segment length [MF6] is one of two key predictor variables in the SPFs for mainline freeway segments; the other key predictor variable is mainline ADT. (Note: Throughout the manual, all traffic volumes are referring to annual average daily traffic volumes. For simplicity purposes, annual average daily traffic is being abbreviated ADT.) Mainline ADT [MF8], mainline ADT year [MF9], and ADT growth rate [MF10] are used to determine the appropriate mainline ADT for each given year in the analysis period. The number of through lanes [MF7] and within interchange area [MF11] are used to select the correct SPF for incorporation in the processing algorithms for the given segment. SPFs for 4-lane (2 lanes per direction), 6-lane (3-lanes per direction), and 8+ lane (4 or more lanes per direction) freeways are incorporated in ISAT. For rural areas valid inputs for number of through lanes are 2 and 3. For urban areas valid inputs

Table 3. Mainline freeway segments input data screen.

MF1	MF2	MF3	MF4	MF5	MF6	MF7	MF8	MF9	MF10	MF11
Segment Number	**Segment Description**	**Direction of Travel**	**Beginning MP**	**Ending MP**	**Length of Segment**	**Number of Through lanes (Directional)**	**Mainline ADT (Directional)**	**Mainline ADT Year**	**ADT Growth Rate**	**Within Interchange Area?**
numeric	**character**	**(NB, SB, EB, WB)**	**numeric**	**numeric**	**km (mi)**	**(2, 3, 4)**	**(veh/day)**	**numeric**	**(percent/ year)**	**(Y, N)**
1										
2										
3										
4										
5										
6										
7										

Table 4. Summary of input variables for mainline freeway segments.

Variable Name	Variable No.	Format	Definition	Type
Segment number	MF1	Numeric	Each mainline freeway segment included in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is carried through onto the output report.	Mandatory
Segment description	MF2	Character	This field is available to describe each mainline freeway segment; a typical description might be "NB mainline lanes upstream of off-ramp" or "SB mainline lanes between ramps"; this variable is not used in calculations but is carried through onto the output report.	Optional
Direction of travel	MF3	Character (NB, SB, EB, WB)	This variable corresponds to the general direction of travel for the individual segment; this variable is not used in calculations but is carried through onto the output reports.	Optional
Begin MP	MF4	Numeric	This is the beginning milepost or other applicable coordinate for the segment; this variable is not used in calculations but is carried through onto the output reports.	Optional
End MP	MF5	Numeric	This is the ending milepost or other applicable coordinate for the segment; this variable is not used in calculations but is carried through onto the output reports.	Optional
Length of segment	MF6	Numeric (mi)	This is the length of the mainline segment, specified in miles, generally to the nearest hundredth of a mile.	Mandatory
Number of through lanes	MF7	Numeric	This variable includes all lanes on the segment in a given direction [MF3] that are used by through traffic. This does not include auxiliary lanes.	Mandatory
Mainline ADT	MF8	Numeric (veh/day)	This is the best available estimate of the annual average daily traffic volume for the mainline freeway segment in the given direction of travel [MF3].	Mandatory
Mainline ADT Year	MF9	Numeric (calendar year)	This field indicates the year to which the mainline ADT [MF8] applies.	Mandatory
Traffic volume growth rate	MF10	Numeric (percent/year)	This value corresponds to the average growth rate of traffic for the given freeway mainline segment for the analysis period.	Mandatory
Within interchange area	MF11	Character (Y, N)	This field identifies whether the segment is located within an interchange area or outside. Y = segment is located within an interchange area N = segment is not located within an interchange area	Mandatory

for number of through lanes are 2, 3, and 4. The Safety Performance Functions (Mainline Freeway Segment SPFs) section provides more detail on the mainline freeway segment SPFs incorporated in ISAT.

Finally, the maximum number of mainline freeway segments that may be considered in an analysis is 50. ISAT will not consider segments numbered greater than 50, even if the user inputs the same data in the given columns.

Table 5 presents the Input Mainline Freeway worksheet, completed with sample data, for the rural diamond interchange example. Ten individual mainline freeway segments are included in this example. Six of the segments are defined to be within the interchange area, and four segments are defined to be outside of the interchange area.

RAMP INPUTS

The variables covered in this section represent data unique to the ramp portion of the interchange area. The input values are used in the data processing algorithms to predict crashes along the ramp proper section of ramps (i.e., both on- and off-ramps) and along acceleration lanes of on-ramps. Table 6 illustrates the Input Ramps worksheet. Table 7 provides greater detail associated with each of the ramp variables.

On the input worksheet for ramps, the user provides general information for each individual ramp to be considered in a given analysis. The first variable (i.e., ramp number [R1]) is for bookkeeping purposes. This number is carried through and provided on output reports if there is a particular need to investigate the expected safety experience of an individual ramp. Ramp description (R2) and direction of travel (R3) are primarily for recording purposes so when the user reviews an analysis, the user has a sense of where the ramp is located within the analysis area. Since the direction of travel on ramps is seldom a straight line or in a cardinal direction, it is recommended that the user develop a convention for assigning direction of travel to ramps (e.g., ramps are assigned the direction of travel of the associated adjacent mainline freeway segment). Ramp type (R4) and ramp configuration (R5) are used to select the correct SPF for incorporation in the processing algorithms for the given ramp. Figure 4 provides an illustration of typical ramp configurations. If a user wants to include another type of ramp in the analysis other than a diamond (D), parclo loop (PL), free-flow loop (FFL), or directional (DIR) ramp, the user should enter the ramp configuration (i.e., D, PL, FFL, or DIR) that most closely resembles the ramp of interest, recognizing that the prediction for the given ramp would be based on a SPF that was not developed for that particular ramp configuration. Ramp length (R6) is one of two key predictor variables for estimating the crash frequency on the ramp proper; the other key predictor variable is ramp ADT. Ramp ADT (R7), ramp ADT year (R8), and ramp ADT growth rate (R9) are used to determine the appropriate ramp ADT for each given year in the analysis period. Segment number for adjacent mainline freeway segment (R10) indicates the segment number (MF1) associated with the freeway segment adjacent to the speed-change lane of the given ramp. This information is most critical in the case of on-ramps with acceleration lanes because the SPFs for mainline freeway segments within interchange areas include crashes that occur on speed-change lanes (i.e., acceleration lanes), and because SPFs are available to predict

Table 5. Example data for rural diamond interchange (Input Mainline Freeways).

MF1	MF2	MF3	MF4	MF5	MF6	MF7	MF8	MF9	MF10	MF11
Segment Number	**Segment Description**	**Direction of Travel**	**Beginning MP**	**Ending MP**	**Length of Segment**	**Number of Through lanes (Directional)**	**Mainline ADT (Directional)**	**Mainline ADT Year**	**ADT Growth Rate**	**Within Interchange Area?**
numeric	**character**	**(NB, SB, EB, WB)**	**numeric**	**numeric**	**km (mi)**	**(2, 3, 4)**	**(veh/day)**	**numeric**	**(percent/ year)**	**(Y, N)**
1	EB Upstream Segment (MF1)	EB	0.000	1.000	1.61 (1.000)	2	4,000	2004	2.0	N
2	EB Segment Adjacent to Decel Lane (MF2)	EB	1.000	1.300	0.48 (0.300)	2	4,000	2004	2.0	Y
3	EB Between Ramps (MF3)	EB	1.300	1.850	0.89 (0.550)	2	3,500	2004	2.0	Y
4	EB Segment Adjacent to Accel Lane (MF4)	EB	1.850	2.150	0.48 (0.300)	2	4,500	2004	2.0	Y
5	EB Downstream Segment (MF5)	EB	2.150	3.150	1.61 (1.000)	2	4,500	2004	2.0	N
6	WB Upstream Segment (MF6)	WB	3.150	2.150	1.61 (1.000)	2	4,500	2004	2.0	N
7	WB Segment Adjacent to Decel Lane (MF7)	WB	2.150	1.850	0.48 (0.300)	2	4,500	2004	2.0	Y
8	WB Between Ramps (MF8)	WB	1.850	1.300	0.89 (0.550)	2	3,500	2004	2.0	Y
9	WB Segment Adjacent to Accel Lane (MF9)	WB	1.300	1.000	0.48 (0.300)	2	4,000	2004	2.0	Y
10	WB Downstream Segment (MF10)	WB	1.000	0.000	1.61 (1.000)	2	4,000	2004	2.0	N
11										

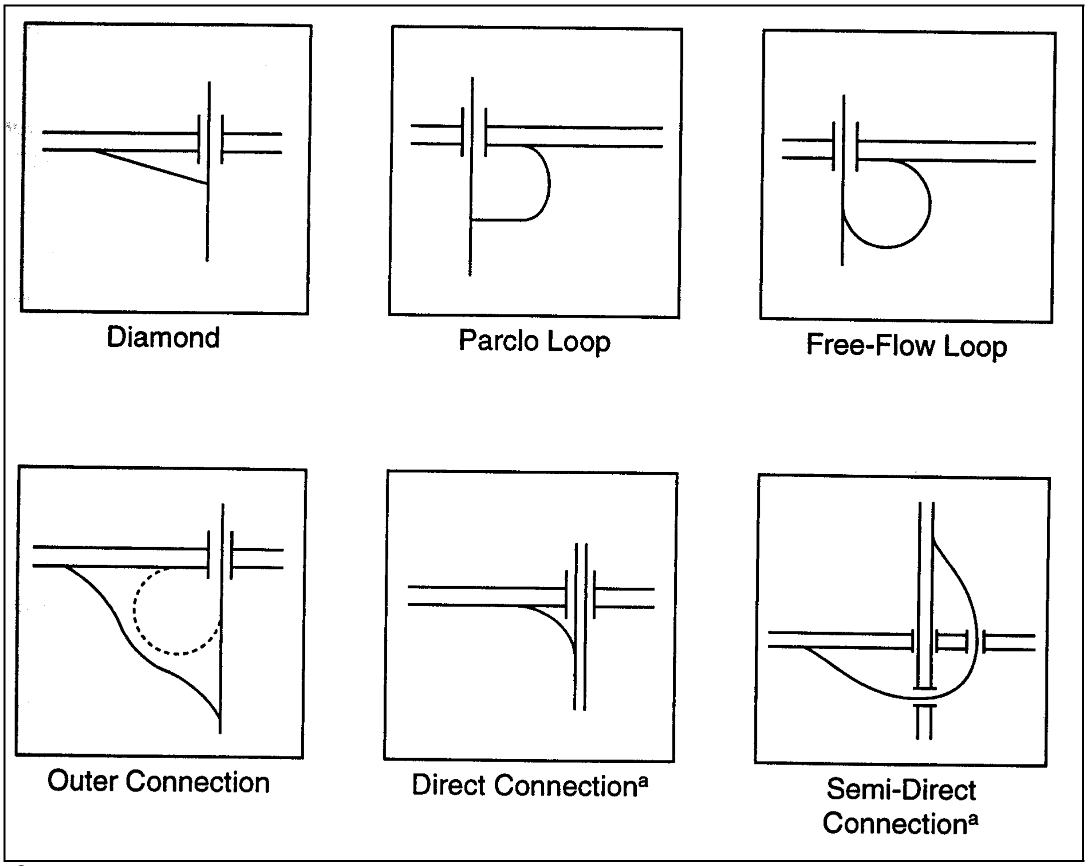
Table 6. Ramps input data screen.

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
Ramp Number	Ramp Description	Direction of Travel	Ramp Type	Ramp Configuration	Ramp Length	Ramp ADT	Ramp ADT Year	Ramp ADT Growth Rate	Segment Number for Adjacent Mainline Freeway Segment	Acceleration Lane	Acceleration Lane Length
numeric	character	(NB, SB, EB, WB)	(ON, OFF, FWY)	(D, PL, FFL, DIR)	km (mi)	(veh/day)	numeric	(percent/ year)	numeric	(Y, N)	km (mi)
1											
2											
3											
4											
5											
6											
7											

Table 7. Summary of input variables for ramps.

Variable Name	Variable No.	Format	Definition	Type
Ramp number	R1	Numeric	Each ramp included in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is carried through onto the output report.	Mandatory
Ramp description	R2	Character	This field is available to describe each ramp; a typical description might be "NB diamond off-ramp" or "SB parclo on-ramp"; this variable is not used in calculations but is carried through onto the output report.	Optional
Direction of travel	R3	Character (NB, SB, EB, WB)	This variable corresponds to the direction of travel of the ramp; this variable is not used in calculations but is carried through onto the output report.	Optional
Type of ramp	R4	Character (ON, OFF, FWY)	On-ramps service vehicles entering the mainline; off-ramps service vehicles leaving the mainline; freeway-to-freeway ramps service vehicles leaving one mainline freeway and entering another; the type of ramps are distinguished by the following codes: ON = on-ramp OFF = off-ramp FWY = freeway-to-freeway ramp	Mandatory
Ramp configuration	R5	Character (D, PL, FFL, DIR)	This variable defines the basic configuration of the ramp; the abbreviated codes correspond as follows: D = diamond ramp PL = parclo loop ramp FFL = free-flow loop ramp DIR = directional ramp	Mandatory
Ramp length	R6	Numeric (mi)	This length is measured from the gore point at the freeway ramp terminal to the crossroad ramp terminal (typically measured to the nearest hundredth of a mile).	Mandatory
Ramp ADT	R7	Numeric (veh/day)	This is the best available estimate of the annual average daily traffic volume for the ramp proper.	Mandatory
Ramp ADT year	R8	Numeric	Field indicates the year to which the ramp ADT [R7] applies.	Mandatory
Ramp ADT growth rate	R9	Numeric (percent/ year)	Value corresponds to the average growth rate of traffic for the given ramp for the analysis period.	Mandatory
Segment number for adjacent mainline freeway	R10	Numeric	The segment number (i.e., MF1) associated with the freeway segment adjacent to the speed-change lane of the given ramp.	Mandatory
Acceleration lane?	R11	Character (Y, N)	A code identifying whether there is an acceleration lane associated with the given ramp: Y = yes, there is an acceleration lane attached to the ramp N = no, there is no acceleration lane attached to the ramp	Mandatory
Length of acceleration lane	R12	Numeric (km (mi))	This distance is measured for the acceleration lane from the gore point of the ramp to the end of the taper for an acceleration lane; distances should be rounded to the nearest hundredth of a mile; if no acceleration lane is present, "0.00" should be entered in this field, and R11 should be set equal to "N."	Mandatory; when R11 equals Y.

crashes along acceleration lanes. By providing the segment number for the adjacent mainline freeway segment, crash estimates for the respective mainline freeway segment can be adjusted to account for the actual length of the adjacent acceleration lane by making certain methodological assumptions. Indicating whether the ramp has an associated acceleration lane (R11) determines whether these assumptions are applied during the processing procedures. Acceleration lane length (R12) is one of the key predictor variables of the SPF for estimating the crash frequency along an acceleration lane.



[a] When used in directional interchanges.

Figure 4. Typical ramp configurations[3].

Finally, the maximum number of ramps that may be considered in an analysis is 50. ISAT will not consider ramps numbered greater than 50, even if the user inputs the same data in the given columns.

Table 8 presents the Input Ramp worksheet completed with sample data for the rural diamond interchange example. Four individual ramps are included in this example.

CROSSROAD RAMP TERMINALS AND INTERSECTIONS INPUTS

The variables covered in this section represent input data unique to crossroad ramp terminals and intersections near the interchange area. The area associated with the crossroad ramp terminal or intersection is defined as the area within 7.62 m (250 ft) of the intersection on each approach leg.

The input values are used in the data processing algorithms for predicting crashes associated with the crossroad ramp terminal or intersection. Table 9 illustrates the Input Ramp Terminals worksheet; the included variables are listed below in table 10 along with the expected input format in parentheses accompanied by applicable definitions.

On the input worksheet for crossroad ramp terminals and intersections, the user provides general information for each individual crossroad ramp terminal and intersection to be considered in a given analysis. The first variable (i.e., terminal number [RT1]) is for bookkeeping purposes. This number is carried through and provided on output reports if there is a particular need to investigate the expected safety experience of an individual ramp terminal or intersection. Terminal description [RT2] is primarily for recording purposes so when the user reviews an analysis, the user has a sense of where the ramp terminal or intersection is located within the analysis area. Type of traffic control [RT3] and number of legs [RT4] are used to select the correct SPF for incorporation in the processing algorithms for the given ramp terminal or intersection. SPFs for 3- and 4-leg STOP-controlled and signalized intersections are incorporated in ISAT. The Safety Performance Functions (Crossroad Ramp Terminals and Intersections SPFs) section provides more detail on the crossroad ramp terminal and intersection SPFs incorporated in ISAT. Major-road or crossroad segment ADT [RT5], major-road or crossroad segment ADT year [RT6], major-road or crossroad segment growth rate [RT7], minor-road or ramp ADT [RT8], minor-road or ramp ADT year [RT9], and minor-road ramp growth rate [RT10] are used to determine the appropriate major-road and minor-road ADT for each given year in the analysis period. Terminal type [RT11] is used to distinguish whether the terminal operates as a ramp terminal or a conventional intersection. The primary difference in the calculations between classifying a terminal as either a ramp terminal or intersection is as follows:

- When the terminal type is entered as RT (i.e., ramp terminal), the value for the minor-road ADT entered into the SPF calculations is the actual value input by the user [RT8] taking into consideration the yearly growth factor, etc.

- When the terminal type is entered as CI (i.e., conventional intersection), the value for the minor-road ADT entered into the SPF calculations is 2 times the actual value input by the user [RT8] taking into consideration the yearly growth factor, etc. (i.e., 2 × ADT).

Table 8. Example data for rural diamond interchange (Input Ramps).

R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12
Ramp Number	**Ramp Description**	**Direction of Travel**	**Ramp Type**	**Ramp Configuration**	**Ramp Length**	**Ramp ADT**	**Ramp ADT Year**	**Ramp ADT Growth Rate**	**Segment Number for Adjacent Mainline Freeway Segment**	**Acceleration Lane**	**Acceleration Lane Length**
numeric	**character**	**(NB, SB, EB, WB)**	**(ON, OFF, FWY)**	**(D, PL, FFL, DIR)**	**km (mi)**	**(veh/day)**	**numeric**	**(percent/ year)**	**numeric**	**(Y, N)**	**km (mi)**
1	EB Off-Ramp (R1)	EB	OFF	D	0.48 (0.300)	500	2004	2.0	2	N	
2	EB On-Ramp (R2)	EB	ON	D	0.56 (0.350)	1,000	2004	2.0	4	Y	0.32 (0.200)
3	WB Off-Ramp (R3)	WB	OFF	D	0.48 (0.300)	1,000	2004	2.0	7	N	
4	WB On-Ramp (R4)	WB	ON	D	0.56 (0.350)	500	2004	2.0	9	Y	0.32 (0.200)
5											

Table 9. Crossroad ramp terminal and intersection input data screen.

RT1	RT2	RT3	RT4	RT5	RT6	RT7	RT8	RT9	RT10	RT11
Terminal Number	**Terminal Description**	**Type of Traffic Control**	**Number of Legs**	**Major-Road or Crossroad Segment ADT (Directional)**	**Major-Road or Crossroad Segment ADT Year**	**Major-Road or Crossroad Segment Growth Rate**	**Minor-Road or Ramp ADT (Directional)**	**Minor-Road or Ramp ADTYyear**	**Minor-Road or Ramp Growth Rate**	**Terminal Type**
numeric	**character**	**(SG, ST)**	**(3, 4)**	**(veh/day)**	**numeric**	**(percent/year)**	**(veh/day)**	**numeric**	**(percent/year)**	**(RT, CI)**
1										
2										
3										
4										
5										
6										
7										

Table 10. Summary of input variables for crossroad ramp terminals and intersections.

Variable Name	Variable No.	Format	Definition	Type
Terminal number	RT1	Numeric	Each crossroad ramp terminal and intersection included in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is carried through onto the output reports.	Mandatory
Terminal description	RT2	Character	This field is used to describe each crossroad ramp terminal and intersection; a typical description might be "NB diamond off-ramp/NB diamond on-ramp and Main St." or "SB parclo on-ramp and 1st Ave."; this variable is not used in calculations but is carried through onto the output report.	Optional
Type of traffic control	RT3	Character (SG, ST)	Field is a code identifying the type of traffic control for the crossroad ramp terminal or intersection: SG = signalized intersection ST = STOP-control on the ramp or minor roadway; no control on the major crossroad	Mandatory
Number of legs	RT4	Numeric (3, 4)	Field is a code identifying the number of legs of the crossroad ramp terminal or intersection. In determining the number of legs, the user should consider whether it is most appropriate to treat each ramp that is served by the terminal as an individual leg. 3 = three-legs 4 = four-legs	Mandatory
Major-road or crossroad segment ADT (directional)	RT5	Numeric (veh/day)	This is the best available estimate of the annual average daily traffic volume for the major-road in a given direction. It is recommended that the maximum directional volume of the major-road approaches be entered here.	Mandatory
Major-road or crossroad segment ADT year	RT6	Numeric	Field indicates the year to which the major-road ADT applies.	Mandatory
Major-road or crossroad segment ADT growth rate	RT7	Numeric (percent/yr)	Value corresponds to the average growth rate of traffic for the given major-road for the analysis period.	Mandatory
Minor-road or ramp ADT (directional)	RT8	Numeric (veh/day)	This is the best available estimate of the annual average daily traffic volume for the minor-road or ramp proper. It is recommended that the maximum directional volume of the minor-road (or ramp) approaches be entered here.	Mandatory
Minor-road or ramp ADT year	RT9	Numeric	Field indicates the year to which the minor-road or ramp ADT applies.	Mandatory
Minor-road or ramp ADT growth rate	RT10	Numeric (percent/year)	Value corresponds to the average growth rate of traffic for the given minor-road or ramp for the analysis period.	Mandatory
Terminal type	RT11	Character (RT, CI)	This variable distinguishes whether the terminal is a ramp terminal or a conventional intersection and impacts the value of the minor-road ADT entered into the SPF calculations and calculations for million entering vehicles (MEV). RT = ramp terminal CI = conventional intersection	Mandatory

Finally, the maximum number of crossroad ramp terminals and intersections that may be considered in an analysis is 50. ISAT will not consider additional terminals/intersections numbered greater than 50, even if the user inputs the same data in the respective columns.

Table 11 presents the Input Ramp Terminals worksheet completed with sample data for the rural diamond interchange example. Two crossroad ramp terminals are included in the example. Both have STOP-control on the minor-road/ramp approach.

CROSSROAD SEGMENT INPUTS

The variables covered in this section represent input data unique to the crossroad segment portion of the interchange area. The input values are used in the data processing algorithms for predicting crashes associated with crossroad segments. Table 12 illustrates the Input Crossroad Segments worksheet; the included variables are listed below in table 13 along with the expected input format in parentheses accompanied by applicable definitions.

The input variables for arterial crossroad roadway segments are very similar to the inputs for mainline freeway segments. In particular, crossroad roadway segments are considered independently in each direction of travel, either NB, SB, EB, or WB, similar to mainline freeway segments. The primary differences are as follows:

- Acceptable values for number of through lanes for arterial crossroad roadway segments are 1, 2, or 3 lanes per direction of travel.
- Specifying the presence of a median [RS8] is necessary to select the correct SPF for incorporation in the processing algorithms for the given segment.

Table 14 presents the Input Crossroad Segments worksheet completed with sample data for the rural diamond interchange example. Six arterial crossroad segments (i.e., 3 in each direction of travel) are included in the example. The arterial roadway is an undivided section with 1 through lane in the NB and SB directions.

Table 11. Example data for rural diamond interchange (Input Ramp Terminals).

RT1	RT2	RT3	RT4	RT5	RT6	RT7	RT8	RT9	RT10	RT11
Terminal Number	**Terminal Description**	**Type of Traffic Control**	**Number of Legs**	**Major-Road or Crossroad Segment ADT (Directional)**	**Major-Road or Crossroad Segment ADT Year**	**Major-Road or Crossroad Segment Growth Rate**	**Minor-Road or Ramp ADT (Directional)**	**Minor-Road or Ramp ADT Year**	**Minor-Road or Ramp Growth Rate**	**Terminal Type**
numeric	**character**	**(SG, ST)**	**(3, 4)**	**(veh/day)**	**numeric**	**(percent/year)**	**(veh/day)**	**numeric**	**(percent/year)**	**(RT, CI)**
1	South Ramp Terminal (RT1)	ST	4	2,000	2004	2.0	500	2004	2.0	RT
2	North Ramp Terminal (RT2)	ST	4	2,000	2004	2.0	1,000	2004	2.0	RT
3										

Table 12. Arterial crossroad roadway segment input data screen.

RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	RS11
Segment Number	**Segment Description**	**Direction of Travel**	**Beginning MP**	**Ending MP**	**Length of Segment**	**Number of Through Lanes (Directional)**	**Presence of Median (Divided, Undivided)**	**Major-Road ADT (Directional)**	**Major-Road ADT Year**	**Major-Road ADT Growth Rate**
numeric	**character**	**(NB, SB, EB, WB)**	**numeric**	**numeric**	**km (mi)**	**(1, 2, 3)**	**(D, U)**	**(veh/day)**	**numeric**	**(percent/year)**
1										
2										
3										
4										
5										
6										
7										

Table 13. Summary of input variables for crossroad roadway segments.

Variable Name	Variable No.	Format	Definition	Type
Segment number	RS1	Numeric	Each crossroad roadway segment included in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is carried through onto the output reports.	Mandatory
Segment description	RS2	Character	This field is used to describe each crossroad roadway segment; a typical description might be “Main St. east of crossroad ramp terminal” or “Main St. between diamond-ramp terminals”; this variable is not used in calculations but is carried through onto the output report.	Optional
Direction of travel	RS3	Character (NB, SB, EB, WB)	This variable corresponds to the general direction of travel for the individual segment; this variable is not used in calculations but is carried through onto the output reports.	Optional
Begin MP	RS4	Numeric	This is the beginning milepost or other applicable coordinate for the segment; this variable is not used in calculations but is carried through onto the output reports.	Optional
End MP	RS5	Numeric	This is the ending milepost or other applicable coordinate for the segment; this variable is not used in calculations but is carried through onto the output reports.	Optional
Length of roadway segment	RS6	Numeric (km (mi))	This is the length of the crossroad roadway segment, specified in miles, generally to the nearest hundredth of a mile. The length of a roadway segment adjacent to a ramp terminal or intersection should be measured from the center of the ramp terminal or intersection; do not deduct the 7.62-m (250-ft) distance referred to in the crossroad ramp terminal discussion.	Mandatory
Number of through lanes (directional)	RS7	Numeric (1, 2, 3)	This variable includes all lanes used by through traffic in a given direction of travel [RS3]; it does not include auxiliary lanes or exclusive turn lanes.	Mandatory
Presence of median	RS8	Character (D, U)	A divided roadway signifies that a raised or depressed median, or a flush median at least 1.22 m (4 ft) in width, is present between the lanes in opposing directions of travel; all other roadways should be considered undivided: D = divided roadway U = undivided roadway	Mandatory
Major-road ADT (directional)	RS9	Numeric (veh/day)	This is the best available estimate of the annual average daily traffic volume for the given direction [RS3] of the crossroad roadway segment.	Mandatory
Major-road ADT year	RS10	Numeric	Field indicates the year to which the crossroad ADT [RS9] applies.	Mandatory
Major-road ADT growth rate	RS11	Numeric (percent/ year)	Value corresponds to the average growth rate of traffic for the given crossroad segment for the analysis period.	Mandatory

Table 14. Example data for rural diamond interchange (Input Crossroad Segments).

RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	RS11
Segment Number	**Segment Description**	**Direction of Travel**	**Beginning MP**	**Ending MP**	**Length of Segment**	**Number of Through Lanes (Directional)**	**Presence of Median (Divided, Undivided)**	**Major-Road ADT (Directional)**	**Major-Road ADT Year**	**Major-Road ADT Growth Rate**
numeric	**character**	**(NB, SB, EB, WB)**	**numeric**	**numeric**	**km (mi)**	**(1, 2, 3)**	**(D, U)**	**(veh/day)**	**numeric**	**(percent/year)**
1	NB Upstream Segment (RS1)	NB	0.000	0.500	0.500	1	U	2,000	2004	2.0
2	NB Between Ramp Terminals (RS2)	NB	0.500	0.700	0.200	1	U	1,500	2004	2.0
3	NB Downstream Segment (RS3)	NB	0.700	1.200	0.500	1	U	2,000	2004	2.0
4	SB Upstream Segment (RS4)	SB	1.200	0.700	0.500	1	U	2,000	2004	2.0
5	SB Between Ramp Terminals (RS5)	SB	0.700	0.500	0.200	1	U	1,500	2004	2.0
6	SB Downstream Segment (RS6)	SB	0.500	0.000	0.500	1	U	2,000	2004	2.0
7										

DEFAULT DATA

This section presents the default data that are provided with ISAT. These data include:

- Safety performance functions (SPFs).
- Calibration coefficients.
- Crash distributions by severity and type.

In the case of default SPFs, it is anticipated that most ISAT users will not modify the default coefficients of the SPFs. In other words, it is expected that in most instances ISAT will be run utilizing the default SPFs. In this respect, users will very seldom change the values associated with the default SPFs. Concerning the default calibration coefficients and crash distributions by severity and type, the user should modify these default values to more accurately reflect the safety experience of their local/State agency prior to using ISAT to perform actual safety assessments. Then, it is recommended that the user modify these default values on an annual basis. The user can modify the default data by clicking on the hyperlinks located on the Input-General worksheet. Five hyperlinks are provided to access the default SPFs, one hyperlink is provided to access the default calibration coefficients, and four hyperlinks are provided to access the default crash distributions. The following sections present more detailed information on each type of default data provided within ISAT and further explain the need to modify these default data.

SAFETY PERFORMANCE FUNCTIONS (SPFs)

For many years, statistical techniques have been applied to predict the crash experience along roadway segments and at intersections. These statistical models are developed using crash and inventory databases, selecting an appropriate functional form for the model, and using regression techniques to estimate the values of the coefficients and parameters in the model. Historically, these models were developed with multiple regression techniques. More recently, Poisson and negative binomial (NB) analyses have been used because theoretically they are better suited to crash data with low-frequency observations. These statistical models are often referred to as safety performance functions (SPFs).

ISAT makes use of SPFs for predicting and/or estimating crash frequencies for individual components of an interchange and the surrounding roadway network. Safety estimates are calculated for the individual components, and these safety estimates are summed to obtain safety performance estimates for the interchange as a whole. Within ISAT default SPFs are provided for the following primary interchange elements that can be included in an analysis area:

- Mainline freeway segments.
- Interchange ramps (and acceleration lanes).
- Crossroad ramp terminals and intersections.
- Crossroad roadway segments.

ISAT was developed using existing knowledge of SPFs or knowledge acquired from other ongoing safety research projects. During the development of ISAT, a review of the technical literature on safety assessment of freeway interchanges was conducted. This review focused on quantitative information that was potentially applicable for use in ISAT. Specifically, interchange-safety-related literature was reviewed to identify quantitative SPFs which could potentially be incorporated into ISAT. The review included both engineering and statistical considerations. The SPFs selected for incorporation into ISAT were obtained from the following primary sources:

> *Development of Safety Performance Functions for SafetyAnalyst Interim Tools*[4]
> *SafetyAnalyst* is a set of computerized analytical tools being developed for FHWA to aid State and local highway agencies in highway safety management. The main purpose of *SafetyAnalyst* is to improve a highway agency's systemwide programming of site-specific safety improvements. *SafetyAnalyst* incorporates state-of-the-art safety management approaches for guiding the decision-making process to identify safety improvement needs and has a strong basis in cost-effectiveness analysis. *SafetyAnalyst* will help highway agencies get the greatest possible safety benefit from each dollar spent in the name of safety.

> *Statistical Models for Interchange Ramps and Speed-Change Lanes*[3]
> The objective of this research was to develop statistical models for defining the relationship between traffic crashes and highway geometric design elements and traffic volumes for interchange ramps and speed-change lanes. The models were developed using Highway Safety Information System (HSIS) data for interchange ramps and speed-change lanes in the State of Washington. Additional geometric design features were obtained from a review of interchange diagrams, aerial photographs, and other existing highway agency files.

It is important to recognize that the accuracy of ISAT is only as good as the safety knowledge on which it is based. The default SPFs provided within ISAT were selected for incorporation in the tool based primarily for the following reasons: (1) statistical validity of the models, (2) criticality of the components based upon engineering judgment, and (3) methodological consistency.

Due to the comprehensive process for selecting SPFs for incorporation within ISAT, it is anticipated that most users will run the program utilizing the default SPFs; however, the program does not prohibit users from modifying the coefficients of the default SPFs. If users have models that better reflect local safety experience, users can replace the default coefficients with new values. This should only be done if the models were developed with the same functional form as the default SPFs. The following sections provide information on the sources of the default SPFs, their functional form, and select coefficients and parameters of the models.

Mainline Freeway Segment SPFs

The default SPFs for mainline freeway segments provided within ISAT are located on the SPFs Mainline Freeways worksheet and are accessible only through the Go To SPFs for Mainline Freeways hyperlink on the Input-General worksheet. The default SPFs for mainline freeway segments were developed for use within *SafetyAnalyst*. These SPFs predict the number of crashes that may occur on mainline freeway segments. SPFs are provided for two unique types of mainline freeway segments:

- Mainline freeway segments within an interchange area.
- Mainline freeway segments outside an interchange area.

As described in the Mainline Freeway Segment Inputs section, the SPFs for mainline freeway segments within interchange areas attempt to account for the increased level of weaving, lane changing, and acceleration/deceleration that takes place immediately upstream, downstream, and between interchange ramps. The SPFs for mainline freeway segments outside an interchange area model the safety experience of basic mainline freeway segments having homogenous characteristics. In these homogeneous segments, the number of through lanes remains the same, the traffic volume remains the same throughout the segment because there are no ramps associated with the segment, and the primary movements include lane changes between through lanes.

The limits of mainline freeway segments within interchange areas are defined in general terms to extend approximately 0.48 km (0.3 mi) upstream from the gore of the first ramp of a particular interchange to approximately 0.48 km (0.3 mi) downstream from the gore of the last ramp of the given interchange. All mainline freeway segments beyond these boundaries are by definition mainline freeway segments outside an interchange area.

The SPFs for mainline freeway segments within interchange areas include crashes that occur on the speed-change lanes (i.e., deceleration and acceleration lanes) adjacent to the mainline freeway segment through lanes, but the SPFs do not predict crashes that occur on the ramp proper (i.e., downstream from the gore point for off-ramps and upstream from the gore point for on-ramps). Because the SPFs for mainline freeway segments within interchange areas include crashes that occur on speed-change lanes, certain methodological assumptions are made within ISAT so that crashes are not double counted on mainline freeway segments and acceleration lanes.

Table 15 presents the coefficients and parameters of the default SPFs for mainline freeway segments provided within ISAT. Table 15 also shows the functional form of the models. In general, all models included in ISAT were developed using NB regression. Table 16 defines the coefficients and parameters of the defaults SPFs. Twenty SPFs for mainline freeway segments are provided within ISAT and are a function of the following:

- Area type.
- Interchange area (i.e., within or outside interchange area).
- Number of lanes.
- Severity level.

Portions of the SPFs Mainline Freeways worksheet are protected. In other words, if the user tries to modify the value of a protected cell, a message will appear indicating the cell is protected, and the user is restricted from modifying the default value in the given cell. On the SPFs Mainline Freeways worksheet, the cells with column headings for SPF No., Area type, Interchange area, Number of through lanes, and Severity level are protected. The user may only modify the default values for the Log intercept (a), Coeff of log ADT (b), dispersion parameter, and Max ADT.

Ramp SPFs

Two sets of default SPFs associated with ramps are provided within ISAT. The default SPFs used to predict the safety performance for the ramp proper are located on the SPFs Ramp worksheet and are accessible only through the Go To SPFs for Ramps hyperlink on the Input-General worksheet. The default SPFs used to predict the safety performance for acceleration lanes are located on the SPFs Accel Lanes worksheet and are accessible only through the Go To SPFs for Accel Lanes hyperlink provided on the Input-General worksheet. The default SPFs for the ramp proper were developed for use within *SafetyAnalyst*. The default SPFs for acceleration lanes were developed by Bauer and Harwood.[3]

Table 17 presents the coefficients and parameters of the default SPFs for ramps (i.e., ramp proper) provided within ISAT. Table 17 also shows the functional form of the models. Table 18 defines the coefficients and parameters of the defaults SPFs. Twenty-eight SPFs for ramps (i.e., ramp proper) are provided within ISAT and are a function of the following:

- Area type.
- Ramp type.
- Ramp configuration.
- Severity level.

The ramp SPFs within *SafetyAnalyst* were developed by combining the data for rural and urban areas; thus, separate ramp SPFs are not necessarily available for rural and urban areas. For consistency purposes the SPFs are presented by area type, but the coefficients and parameters are the same for both area types.

Portions of the SPFs Ramps worksheet are protected. The user may only modify the default values for the Log intercept (a), Coeff of ADT_{ramp} (b), Coeff of ramp length (e), dispersion parameter, and Max ADT.

Table 15. SPF Coefficients and parameters for mainline freeway segments.

SPF No.	Area Type	Interchange Area	Number of Through Lanes (Directional)	Severity Level	Log Intercept (a)	Coeff of Log ADT (b)	Dispersion Parameter	Max ADT
numeric	**(U, R)**	**(Y, N)**	**(2, 3, 4)**	**(TOT, FI)**	**numeric**	**numeric**	**numeric**	**(veh/day)**
SafetyAnalyst Roadway Segment SPF								
$N = e^{a} \times ADT^{b} \times SL$								
DMF1	**DMF2**	**DMF3**	**DMF4**	**DMF5**	**DMF6**	**DMF7**	**DMF8**	**DMF9**
1	R	Y	2	TOT	–7.28	0.92	0.45	60,621
2	R	Y	3	TOT	–10.05	1.14	0.42	197,798
3	U	Y	2	TOT	–11.23	1.30	0.81	241,255
4	U	Y	3	TOT	–11.25	1.28	0.60	255,154
5	U	Y	4	TOT	–26.76	2.58	0.52	233,323
6	R	Y	2	FI	–8.68	0.94	0.58	60,621
7	R	Y	3	FI	–12.07	1.22	0.39	197,798
8	U	Y	2	FI	–12.89	1.38	0.79	241,255
9	U	Y	3	FI	–13.62	1.42	0.55	255,154
10	U	Y	4	FI	–25.63	2.42	0.53	233,323
11	R	N	2	TOT	–6.46	0.79	0.17	60,621
12	R	N	3	TOT	–9.67	1.07	0.24	190,403
13	U	N	2	TOT	–7.85	1.00	0.99	151,038
14	U	N	3	TOT	–5.96	0.78	0.48	241,255
15	U	N	4	TOT	–16.24	1.67	0.45	223,088
16	R	N	2	FI	–8.86	0.9	0.10	60,621
17	R	N	3	FI	–11.67	1.17	0.21	190,403
18	U	N	2	FI	–8.82	1.02	1.15	151,038
19	U	N	3	FI	–7.60	0.85	0.54	241,255
20	U	N	4	FI	–19.16	1.85	0.52	223,088

Table 16. Definitions of coefficients and parameters of SPFs for mainline freeway segments.

Variable Name	Variable No.	Format	Definition
SPF No.	DMF1	Numeric	Each SPF is identified by a sequential integer, starting with 1; this variable is not used in calculations but is useful for organization.
Area type	DMF2	Character (U, R)	General character of land use surrounding the interchange, preferably based on FHWA urban area boundaries: U = Urban R = Rural
Interchange area	DMF3	Character (Y, N)	A code identifying whether the segment is located within the interchange area: Y = yes, segment is located within the interchange area N = no, segment is not located within the interchange area
Number of through lanes (directional)	DMF4	Numeric (2, 3, 4)	This field includes all lanes on the segment *in a given direction* that are used by through traffic; it does not include auxiliary lanes.
Severity level	DMF5	Character (TOT, FI)	A code identifying the crash severity level: TOT = total crashes FI = fatal and injury crashes
Log intercept (a)	DMF6	Numeric	Intercept of SPF.
Coefficient of log ADT (b)	DMF7	Numeric	Coefficient of log ADT parameter (this ADT is bi-directional).
Dispersion parameter	DMF8	Numeric	Dispersion parameter associated with negative binomial regression.
Max ADT	DMF9	Numeric (veh/day)	The maximum traffic volume for which the coefficients of the SPF were calibrated/calculated.

Table 17. SPF Coefficients and parameters for ramps.

SPF No.	Area Type	Ramp Type	Ramp Configuration	Severity Level	Log Intercept (a)	Coeff of ADT_{Ramp} (b)	Coeff of Ramp Length (e)	Dispersion Parameter	Max ADT
numeric	(R, U)	(ON, OFF, FWY)	(D, PL, FFL, DIR)	(TOT, FI)	numeric	numeric	numeric	numeric	(veh/day)
SafetyAnalyst Ramp Proper SPF									
$N = e^a \times ADT_{Ramp}^b \times RL^e$									
DR1	**DR2**	**DR3**	**DR4**	**DR5**	**DR6**	**DR7**	**DR8**	**DR9**	**DR10**
1	R	OFF	D	TOT	–3.17	0.45	1.0	1.49	22,566
2	R	ON	D	TOT	–8.28	1.03	1.0	2.57	24,966
3	R	OFF	PL	TOT	–4.50	0.73	1.0	1.17	22,538
4	R	ON	PL	TOT	–2.11	0.43	1.0	1.77	20,403
5	R	OFF	FFL	TOT	–4.50	0.73	1.0	1.17	22,538
6	R	ON	FFL	TOT	–2.11	0.43	1.0	1.77	20,403
7	R	FWY	DIR	TOT	–1.80	0.45	1.0	1.67	37,474
8	U	OFF	D	TOT	–3.17	0.45	1.0	1.49	22,566
9	U	ON	D	TOT	–8.28	1.03	1.0	2.57	24,966
10	U	OFF	PL	TOT	–4.50	0.73	1.0	1.17	22,538
11	U	ON	PL	TOT	–2.11	0.43	1.0	1.77	20,403
12	U	OFF	FFL	TOT	–4.50	0.73	1.0	1.17	22,538
13	U	ON	FFL	TOT	–2.11	0.43	1.0	1.77	20,403
14	U	FWY	DIR	TOT	–1.80	0.45	1.0	1.67	37,474
15	R	OFF	D	FI	–6.88	0.78	1.0	2.21	22,566
16	R	ON	D	FI	–14.40	1.61	1.0	3.44	24,966
17	R	OFF	PL	FI	–3.63	0.53	1.0	1.71	22,538
18	R	ON	PL	FI	–3.37	0.44	1.0	0.82	20,403
19	R	OFF	FFL	FI	–3.63	0.53	1.0	1.71	22,538
20	R	ON	FFL	FI	–3.37	0.44	1.0	0.82	20,403
21	R	FWY	DIR	FI	–2.80	0.46	1.0	1.89	37,474
22	U	OFF	D	FI	–6.88	0.78	1.0	2.21	22,566
23	U	ON	D	FI	–14.40	1.61	1.0	3.44	24,966
24	U	OFF	PL	FI	–3.63	0.53	1.0	1.71	22,538
25	U	ON	PL	FI	–3.37	0.44	1.0	0.82	20,403
26	U	OFF	FFL	FI	–3.63	0.53	1.0	1.71	22,538
27	U	ON	FFL	FI	–3.37	0.44	1.0	0.82	20,403
28	U	FWY	DIR	FI	–2.80	0.46	1.0	1.89	37,474

Table 18. Definitions of coefficients and parameters of SPFs for ramps.

Variable Name	Variable No.	Format	Definition
SPF No.	DR1	Numeric	Each SPF included in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is useful for organization.
Area type	DR2	Character (U, R)	General character of land use surrounding the interchange, preferably based on FHWA urban area boundaries: U = Urban R = Rural
Ramp type	DR3	Character (ON, OFF, FWY)	The type of ramps are distinguished by the following codes: ON = on-ramp OFF = off-ramp FWY = freeway-to-freeway ramp
Ramp configuration	DR4	Character (D, PL, FFL, DIR)	This variable defines the basic geometric design of the ramp; the abbreviated codes correspond as follows: D = diamond ramp PL = parclo loop ramp FFL = free-flow loop ramp DIR = directional ramp
Severity level	DR5	Character (TOT, FI)	This variable identifies the crash severity level: TOT = total crashes FI = fatal and injury crashes
Log intercept (a)	DR6	Numeric	Intercept of SPF.
Coefficient of log ADT (b)	DR7	Numeric	Coefficient of log ADT (ramp) parameter.
Coefficient of ramp length (e)	DR8	Numeric	Coefficient of ramp length parameter.
Dispersion parameter	DR9	Numeric	Dispersion parameter associated with negative binomial regression.
Max ADT	DR10	Numeric (veh/day)	The maximum traffic volume of the ramp for which the coefficients of the SPF apply.

Table 19 presents the coefficients and parameters of the default SPFs for acceleration lanes provided within ISAT. Table 19 also shows the functional form of the models. Table 20 defines the coefficients and parameters of the defaults SPFs. Four SPFs for acceleration lanes are provided within ISAT and are a function of the following:

- Area type.
- Severity level.

Portions of the SPFs Accel Lanes worksheet are protected. The user may only modify the default values for the Constant (C), Log intercept (a), Coeff of ADT_{Ramp} (b), Coeff of length (c), Coeff of $ADT_{Freeway}$ (d), dispersion parameter, and mean length.

Table 19. SPF Coefficients and parameters for acceleration lanes.

SPF No.	Area Type	Severity Level	Constant (C)	Log Intercept (a)	Coeff of ADT_{Ramp} (b)	Coeff of Length (c)	Coeff of $ADT_{Freeway}$ (d)	Dispersion Parameter	Mean Length
numeric	(R, U)	(TOT, FI)	numeric	numeric	numeric	numeric	numeric	numeric	km (mi)
Bauer and Harwood Acceleration Lane SPF									
$N = C \times e^{a} \times ADT_{Ramp}^{\ b} \times e^{c \times ALL} \times ADT_{Freeway}^{\ d}$									
DAL1	**DAL2**	**DAL3**	**DAL4**	**DAL5**	**DAL6**	**DAL7**	**DAL8**	**DAL9**	**DAL10**
1	R	TOT	0.44	-7.19	0.78	-2.59	0.13	0.66	0.16 (0.1)
2	U	TOT	0.44	-6.82	0.78	-2.59	0.13	0.66	0.16 (0.1)
3	R	FI	0.55	-10.68	0.91	-4.55	0.29	0.52	0.16 (0.1)
4	U	FI	0.55	-10.68	0.91	-4.55	0.29	0.52	0.16 (0.1)

Table 20. Definitions of coefficients and parameters of SPFs for acceleration Lanes.

Variable Name	Variable No.	Format	Definition
SPF No.	DAL1	Numeric	Each SPF in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is useful for organization.
Area type	DAL2	Character (U, R)	General character of land use surrounding the interchange, preferably based on FHWA urban area boundaries: U = Urban R = Rural
Severity level	DAL3	Character (TOT, FI)	This variable identifies the crash severity level: TOT = total crashes FI = fatal and injury crashes
Constant (C)	DAL4	Numeric	This constant is provided because the SPFs were developed to predict crashes for a 3-year period. The constant scales the prediction to an annual basis. The constant also accounts for a ramp length term (i.e., the length of the ramp proper) in the original form of the SPF.
Log intercept (a)	DAL5	Numeric	Intercept of SPF.
Coefficient of log ADT_{Ramp} (b)	DAL6	Numeric	Coefficient of log ADT (ramp) parameter.
Coefficient of length (c)	DAL7	Numeric	Coefficient of acceleration lane length (ALL) parameter.
Coefficient of log $ADT_{Freeway}$ (d)	DAL8	Numeric	Coefficient of log ADT (freeway) parameter (this ADT is directional).
Dispersion parameter	DAL9	Numeric	Dispersion parameter associated with negative binomial regression.
Mean length	DAL10	Numeric (mi)	Mean length of acceleration lanes used to develop SPFs.

Crossroad Ramp Terminal and Intersection SPFs

The default SPFs for crossroad ramp terminals and intersections provided within ISAT are located on the SPFs Ramp Terminals worksheet and are accessible only through the Go To SPFs for Ramp Terminals hyperlink on the Input-General worksheet. The default SPFs for crossroad ramp terminals and intersections were developed for use within *SafetyAnalyst*. Technically, these SPFs were developed using data for conventional at-grade intersections, but due to the lack of any suitable safety prediction models developed specifically for crossroad ramp terminals, these models are used to predict crashes at both crossroad ramp terminals and conventional intersections defined as part of an analysis area.

Table 21 presents the coefficients and parameters of the default SPFs for crossroad ramp terminals and intersections provided within ISAT. Table 21 also shows the functional form of the models. Table 22 defines the coefficients and parameters of the defaults SPFs. Sixteen SPFs for crossroad ramp terminals and intersections are provided within ISAT and are a function of the following:

- Area type.
- Type of traffic control.
- Number of legs.
- Severity level.

Portions of the SPFs Ramp Terminals worksheet are protected. The cells with column headings for SPF No., Area type, Type of traffic control, Number of legs, and Severity level are protected. The user may only modify the default values for the Log intercept (a), Coeff of $ADT_{major\ rd}$ (b), Coeff of $ADT_{off\text{-}ramp}$ (c), dispersion parameter, Max $ADT_{major\ rd}$, and Max $ADT_{off\text{-}ramp}$.

Crossroad Segment SPFs

The default SPFs for arterial crossroad segments provided within ISAT are located on the SPFs Crossroad Segments worksheet and are accessible only through the Go To SPFs for Crossroad Segments hyperlink on the Input-General worksheet. The default SPFs for arterial crossroad segments were developed for use within *SafetyAnalyst*. These SPFs predict the number of crashes that may occur on urban and rural arterial streets. These predictions include crashes that occur at intersections located on the crossroad roadway segments and are not related to the operation of the intersections; however the predictions do not include crashes that occur at intersections located on the crossroad roadway segments and are related to the operation of the intersections (i.e., these intersection related crashes are included in the predictions for crossroad ramp terminals and intersections).

Table 21. SPF Coefficients and parameters for crossroad ramp terminals and intersections.

SPF No.	**Area Type**	**Type of Traffic Control**	**Number of Legs**	**Severity Level**	**Log Intercept (a)**	**Coeff of $ADT_{major\ rd}$ (b)**	**Coeff of $ADT_{off\text{-}ramp}$ (c)**	**Dispersion Parameter**	**Max $ADT_{major\ rd}$**	**Max $ADT_{off\text{-}ramp}$**
numeric	**(U, R)**	**(SG, ST)**	**(3, 4)**	**(TOT, FI)**	**numeric**	**numeric**	**numeric**	**numeric**	**(veh/day)**	**(veh/day)**
SafetyAnalyst Ramp Terminal SPF										
$N = e^{a} \times ADT_{major\ rd}^{b} \times ADT_{off\text{-}ramp}^{c}$										
DRT1	**DRT2**	**DRT3**	**DRT4**	**DRT5**	**DRT6**	**DRT7**	**DRT8**	**DRT9**	**DRT10**	**DRT11**
1	R	ST	3	TOT	–8.78	0.71	0.24	1.07	28,500	27,000
2	R	SG	3	TOT	–6.57	0.66	0.20	0.33	36400	11500
3	R	ST	4	TOT	–8.96	0.65	0.47	0.70	35,500	26,700
4	R	SG	4	TOT	–6.57	0.66	0.20	0.33	36,400	11,500
5	U	ST	3	TOT	–5.35	0.34	0.28	1.28	68,000	18,900
6	U	SG	3	TOT	–9.85	0.97	0.18	0.23	50,000	25,807
7	U	ST	4	TOT	–3.12	0.27	0.16	0.86	58,870	81,000
8	U	SG	4	TOT	–3.47	0.42	0.14	0.32	75,000	81,000
9	R	ST	3	FI	–9.35	0.71	0.21	1.23	28,500	27,000
10	R	SG	3	FI	–7.83	0.75	0.14	0.50	36400	11500
11	R	ST	4	FI	–9.36	0.66	0.40	0.00	35,500	26,700
12	R	SG	4	FI	–7.83	0.75	0.14	0.50	36,400	11,500
13	U	ST	3	FI	–8.45	0.49	0.39	1.23	68,000	18,900
14	U	SG	3	FI	–10.22	0.91	0.21	0.27	50,000	25,807
15	U	ST	4	FI	–4.35	0.29	0.19	0.99	58,870	81,000
16	U	SG	4	FI	–5.11	0.49	0.16	0.30	75,000	81,000

Table 22. Definitions of coefficients and parameters of SPFs for crossroad ramp terminals and intersections.

Variable Name	Variable No.	Format	Definition
SPF No.	DRT1	Numeric	Each SPF included in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is useful for organization.
Area type	DRT2	Character (U, R)	General character of land use surrounding the interchange, preferably based on FHWA urban area boundaries: U = Urban R = Rural
Type of traffic control	DRT3	Character (SG, ST)	A code identifying the type of traffic control for the crossroad ramp terminal or intersection: SG = signalized intersection ST = STOP-control on the ramp or minor roadway; no control on the major crossroad
Number of legs	DRT4	Numeric (3,4)	A code identifying the number of legs of the crossroad ramp terminal or intersection. In determining the number of legs, the user should consider whether it is most appropriate to treat each ramp that is served by the terminal as an individual leg. 3 = three-legs 4 = four-legs
Severity level	DRT5	Character (TOT, FI)	A code identifying the crash severity level: TOT = total crashes FI = fatal and injury crashes
Log intercept (a)	DRT6	Numeric	Intercept of SPF.
Coefficient of log $ADT_{major\ rd}$ (b)	DRT7	Numeric	Coefficient of log ADT (major rd) (bi-directional) ($ADT_{major\ rd}$ is calculated 2 × major rd ADT [RT5]).
Coefficient of log $ADT_{off\text{-}ramp}$ (c)	DRT8	Numeric	Coefficient of log ADT (off-ramp) ($ADT_{off\text{-}ramp}$ is minor-road or ramp ADT [RT8] when terminal type [RT11] is RT. $ADT_{off\text{-}ramp}$ is 2 × minor-road or ramp ADT [RT8] when terminal type [RT11] is CI.)
Dispersion parameter	DRT9	Numeric	Dispersion parameter associated with negative binomial regression.
Max $ADT_{major\ rd}$	DRT10	Numeric (veh/day)	The maximum traffic volume on the crossroad for which the coefficients of the SPF apply.
Max $ADT_{off\text{-}ramp}$	DRT11	Numeric (veh/day)	The maximum traffic volume on the ramp for which the coefficients of the SPF apply.

Table 23 presents the coefficients and parameters of the default SPFs for arterial crossroad segments provided within ISAT. Table 23 also shows the functional form of the models. Table 24 defines the coefficients and parameters of the defaults SPFs. Twenty SPFs for crossroad roadway segments are provided within ISAT and are a function of the following:

- Area type.
- Number of through lanes.
- Median type.
- Severity level.

Portions of the SPFs Crossroad Segments worksheet are protected. The cells with column heads for SPF No., Area type, Number of through lanes, Median, and Severity level are protected. The user may only modify the default values for the Log intercept (a), Coeff of log ADT (b), dispersion parameter, and Max ADT.

CALIBRATION COEFFICIENTS

ISAT makes use of SPFs from previous and ongoing safety research. SPFs developed for *SafetyAnalyst*, and as part of research conducted by Bauer and Harwood[3], are incorporated into the program. The SPFs for *SafetyAnalyst* are based upon data from California, Minnesota, Ohio, and Washington. Bauer and Harwood[3] used data from Washington to formulate their statistical models. As such, the SPFs in ISAT are valid only for application to the States and time periods for which the models were developed. However, ISAT includes calibration coefficients that allow the SPFs developed for one particular State and one particular time period to be applied to other areas and time periods. By adjusting the calibration coefficients within ISAT based upon local crash data, the calculations within ISAT are more directly applicable to the user's own agency and more useful safety predictions are obtained, better reflecting the local safety experience.

It is recommended that one of the first steps a user should take when beginning to work with ISAT, and definitely before using ISAT to perform actual safety assessments, is modify the calibration coefficients based upon an agency's own crash data. Subsequently, these calibration coefficients should be updated on an annual basis.

Table 23. SPF coefficients and parameters for crossroad segments.

SPF No.	Area Type	Number of Through Lanes (Directional)	Median	Severity Level	Log Intercept (a)	Coeff of Log ADT (b)	Dispersion Parameter	Max ADT
numeric	(U, R)	(1, 2, 3)	(D, U)	(TOT, FI)	numeric	numeric	numeric	(veh/day)
SafetyAnalyst Crossroad Segment SPF								
$N = e^a \times ADT^b \times SL$								
DRS1	DRS2	DRS3	DRS4	DRS5	DRS6	DRS7	DRS8	DRS9
1	R	1	U	TOT	–3.56	0.55	0.45	30,025
2	R	2	U	TOT	–2.58	0.44	1.28	42,638
3	R	3	U	TOT	–2.58	0.44	1.28	42,638
4	R	2	D	TOT	–8.21	0.93	0.47	31,188
5	R	3	D	TOT	–8.21	0.93	0.47	31,188
6	U	1	U	TOT	–7.16	0.84	4.40	29,850
7	U	2	U	TOT	–10.24	1.29	0.85	57,901
8	U	3	U	TOT	–10.24	1.29	0.85	57,901
9	U	2	D	TOT	–11.85	1.34	5.91	77,735
10	U	3	D	TOT	–11.85	1.34	5.91	77,735
11	R	1	U	FI	–4.89	0.53	0.45	30,025
12	R	2	U	FI	–4.96	0.60	1.06	42,638
13	R	3	U	FI	–4.96	0.60	1.06	42,638
14	R	2	D	FI	–10.31	1.03	0.33	31,188
15	R	3	D	FI	–10.31	1.03	0.33	31,188
16	U	1	U	FI	–8.84	0.89	4.54	29,850
17	U	2	U	FI	–12.07	1.39	0.81	57,901
18	U	3	U	FI	–12.07	1.39	0.81	57,901
19	U	2	D	FI	–14.87	1.52	5.81	77,735
20	U	3	D	FI	–14.87	1.52	5.81	77,735

Table 24. Definitions of coefficients and parameters of SPFs for crossroad segments.

Variable Name	Variable No.	Format	Definition
SPF No.	DRS1	Numeric	Each SPF in the analysis must be identified by a sequential integer, starting with 1; this variable is not used in calculations but is useful for organization.
Area type	DRS2	Character (U, R)	General character of land use surrounding the interchange, preferably based on FHWA urban area boundaries: U = Urban R = Rural
Number of through lanes	DRS3	Numeric (1, 2, 3)	A code identifying the number of through lanes *in a given direction* on the crossroad segment.
Median	DRS4	Character (U, D)	A code identifying whether a median is present on the crossroad segment: U = the segment is undivided D = the segment is divided
Severity level	DRS5	Character (TOT, FI)	A code identifying the crash severity level: TOT = total crashes FI = fatal and injury crashes
Log intercept (a)	DRS6	Numeric	Intercept of SPF.
Coefficient of log ADT (b)	DRS7	Numeric	Coefficient of log ADT parameter (this ADT is bi-directional).
Dispersion parameter	DRS8	Numeric	Dispersion parameter with negative binomial regression.
Max ADT	DRS9	Numeric (veh/day)	The maximum traffic volume on the crossroad for which the coefficients of the SPF apply.

The calibration coefficients adjust the predicted number of total and fatal and injury crashes, calculated within ISAT, to account for differences in crash patterns in different geographical areas that are not directly addressed by the SPFs. These differences may be related to differences in:

- Driver population and trip purposes.
- Climate.
- Animal populations.
- Crash reporting thresholds.
- Crash investigation practices.

The calibration coefficients are intended to account for these differences and provide crash predictions that are comparable to the estimates that a highway agency would obtain had the SPFs in ISAT been developed using their own crash records system.

Tables 25 through 28 show the specific SPFs for mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad roadway segments that need calibration coefficients. The nominal or default value of the calibration coefficients is shown in the tables as 1.00 for each of the SPFs. This nominal value for each SPF needs to be replaced with a calculated value appropriate for the highway agency applying the model. In general terms, calibration coefficients greater than 1.00 apply to agencies that experience more crashes than predicted by the default SPFs. Calibration coefficients less than 1.00 apply to agencies that experience fewer crashes than predicted by the default SPFs. A procedure for calculating calibration coefficients is presented below.

Calibration Procedure

This calibration procedure is applicable to each SPF (i.e., each row) in tables 25 through 28. Thus, in total this procedure should be carried out 20 times to calibrate the mainline freeway segment SPFs, 28 times to calibrate the ramp SPFs, 20 times to calibrate the crossroad ramp terminal and intersection SPFs, and 20 times to calibrate the crossroad roadway segment SPFs. The calibration procedure described below makes use of ISAT, but the procedure could be performed externally without making use of ISAT. The nomenclature used for describing the calibration procedure is defined in table 29.

Table 25. Calibration coefficients for mainline freeway segment SPFs.

CCMF1	CCMF2	CCMF3	CCMF4	CCMF5	CCMF6
SPF No.	Area Type	Interchange Area	Number of Through Lanes (Directional)	Severity Level	Calibration Coefficients
1	R	Y	2	TOT	1.000
2	R	Y	3	TOT	1.000
3	U	Y	2	TOT	1.000
4	U	Y	3	TOT	1.000
5	U	Y	4	TOT	1.000
6	R	Y	2	FI	1.000
7	R	Y	3	FI	1.000
8	U	Y	2	FI	1.000
9	U	Y	3	FI	1.000
10	U	Y	4	FI	1.000
11	R	N	2	TOT	1.000
12	R	N	3	TOT	1.000
13	U	N	2	TOT	1.000
14	U	N	3	TOT	1.000
15	U	N	4	TOT	1.000
16	R	N	2	FI	1.000
17	R	N	3	FI	1.000
18	U	N	2	FI	1.000
19	U	N	3	FI	1.000
20	U	N	4	FI	1.000

NOTE: The default values of 1.00 for the calibration coefficients should be replaced with calculated values appropriate for specific highway agencies.

Table 26. Calibration coefficients for ramp SPFs.

CCR1	CCR2	CCR3	CCR4	CCR5	CCR6
SPF No.	Area Type	Type of Ramp	Ramp Configuration	Severity Level	Calibration Coefficients
1	R	OFF	D	TOT	1.000
2	R	ON	D	TOT	1.000
3	R	OFF	PL	TOT	1.000
4	R	ON	PL	TOT	1.000
5	R	OFF	FFL	TOT	1.000
6	R	ON	FFL	TOT	1.000
7	R	FWY	DIR	TOT	1.000
8	U	OFF	D	TOT	1.000
9	U	ON	D	TOT	1.000
10	U	OFF	PL	TOT	1.000
11	U	ON	PL	TOT	1.000
12	U	OFF	FFL	TOT	1.000
13	U	ON	FFL	TOT	1.000
14	U	FWY	DIR	TOT	1.000
15	R	OFF	D	FI	1.000
16	R	ON	D	FI	1.000
17	R	OFF	PL	FI	1.000
18	R	ON	PL	FI	1.000
19	R	OFF	FFL	FI	1.000
20	R	ON	FFL	FI	1.000
21	R	FWY	DIR	FI	1.000
22	U	OFF	D	FI	1.000
23	U	ON	D	FI	1.000
24	U	OFF	PL	FI	1.000
25	U	ON	PL	FI	1.000
26	U	OFF	FFL	FI	1.000
27	U	ON	FFL	FI	1.000
28	U	FWY	DIR	FI	1.000

NOTE: The default values of 1.00 for the calibration coefficients should be replaced with calculated values appropriate for specific highway agencies.

Table 27. Calibration coefficients for crossroad ramp terminal and intersection SPFs.

CCRT1	CCRT2	CCRT3	CCRT4	CCRT5	CCRT6
SPF No.	Area Type	Type of Traffic Control	Number of Legs	Severity Level	Calibration Coefficients
1	R	ST	3	TOT	1.000
2	R	SG	3	TOT	1.000
3	R	ST	4	TOT	1.000
4	R	SG	4	TOT	1.000
5	U	ST	3	TOT	1.000
6	U	SG	3	TOT	1.000
7	U	ST	4	TOT	1.000
8	U	SG	4	TOT	1.000
9	R	ST	3	FI	1.000
10	R	SG	3	FI	1.000
11	R	ST	4	FI	1.000
12	R	SG	4	FI	1.000
13	U	ST	3	FI	1.000
14	U	SG	3	FI	1.000
15	U	ST	4	FI	1.000
16	U	SG	4	FI	1.000

Note: The default values of 1.00 for the calibration coefficients should be replaced with calculated values appropriate for specific highway agencies.

Table 28. Calibration coefficients for crossroad segment SPFs.

CCRS1	CCRS2	CCRS3	CCRS4	CCRS5	CCRS6
SPF No.	Area Type	Number of Through Lanes (Directional)	Median	Severity Level	Calibration Coefficients
1	R	1	U	TOT	1.000
2	R	2	U	TOT	1.000
3	R	3	U	TOT	1.000
4	R	2	D	TOT	1.000
5	R	3	D	TOT	1.000
6	U	1	U	TOT	1.000
7	U	2	U	TOT	1.000
8	U	3	U	TOT	1.000
9	U	2	D	TOT	1.000
10	U	3	D	TOT	1.000
11	R	1	U	FI	1.000
12	R	2	U	FI	1.000
13	R	3	U	FI	1.000
14	R	2	D	FI	1.000
15	R	3	D	FI	1.000
16	U	1	U	FI	1.000
17	U	2	U	FI	1.000
18	U	3	U	FI	1.000
19	U	2	D	FI	1.000
20	U	3	D	FI	1.000

NOTE: The default values of 1.00 for the calibration coefficients should be replaced with calculated values appropriate for specific highway agencies.

Table 29. Nomenclature for calibration procedures.

Term	Explanation
i	Subscript to represent site i
y	Subscript to represent the year y The first year of the analysis period is considered Year 1 (i.e., y=1) The last year of the analysis period is considered Year Y (i.e., y=Y)
TOT	Subscript to denote total crashes
FI	Subscript to denote fatal and injury crashes
O_{iy}	**Observed** number of crashes at site i during year y
O	Total number of **observed** crashes for the entire analysis period across all individual sites of the interchange element of interest
N_{iy}	**Predicted** number of crashes at a site i during year y
N_A	Total number of **predicted** crashes for the entire analysis period across all individual sites of the interchange element of interest
C	Calibration coefficient

Step 1. Select sites for use in applying the calibration procedures.

Select up to a maximum of 50 sites of the same type for use in applying the calibration procedures. There is no specific number of sites that must be selected in this step, in part because the number of sites that should be included is dependent upon the next step (i.e., select analysis years). As a general rule of thumb, at least 20 sites are desirable, and selecting more sites should increase the accuracy of the predictions output by ISAT.

Step 2. Select the analysis years for applying the calibration procedures.

Two approaches could be considered when performing this step. One approach would be to limit the analysis period to the most recent year for which a full calendar year of crash data are available. If this approach is taken, the calibration coefficients and calculations will specifically reflect the crash trends of the selected calendar year.

The second approach is to select multiple years for the analysis period. It is recommended that up to the 10 most recent years for which crash data are available for the selected sites be included in the analysis. If this approach is taken, the calibration coefficients and calculations will not specifically reflect crash trends for the most recent year of crash data, but rather reflect the average crash trend over the collective analysis years. This second approach (i.e., multiple years) is preferred over calibrating the SPFs based upon the most recent year crash data.

A couple of issues should be considered collectively when selecting sites and analysis years on which to base the calibration coefficients:

- The sites should not have undergone reconstruction at any point during this time period.
- The analysis period has to be same for all sites.

Step 3. Predict the total number of crashes across the selected sites and analysis years.

On the Input-General worksheet, the user will input data for variables G1 through G4. The beginning and ending year of analysis coincide with the analysis years as selected in *Step 2*. For variable G5 (i.e., crash data available), a value of "N" should be provided for each primary element (i.e., mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad segments).

On the respective input worksheet either for mainline freeway segments, ramps, crossroad ramp terminals and intersections, or crossroad segments, the user should input data for the sites selected in *Step 1*.

As part of *Step 3*, the calibration coefficient for the respective site subtype should be modified to the default value of 1.00.

Having entered all of the input data, the user can click the Perform Calculations button. The table for number of predicted crashes by interchange element type will show the number of predicted crashes for the respective interchange element type for both total and fatal and injury crash levels. Because data were input for only one subtype of the given interchange element, the predicted values are applicable to the given subtype, and these values are truly predicted values because no crash data were considered in the analysis. This calculation is represented as:

$$N_A = \sum_i \sum_y N_{iy} \quad \textbf{(Eq. 1)}$$

Step 4. Determine the total number of observed crashes across the selected sites and analysis years.

This step is performed externally to ISAT and is represented as:

$$O = \sum_i \sum_y O_{iy} \quad \textbf{(Eq. 2)}$$

When determining the number of observed crashes across selected sites, the same rules for attributing crashes to particular interchange element types should be followed as explained in the General Interchange Inputs section of this manual. The rules are summarized here as follows:

- Crashes that occur along or within mainline freeway segments, deceleration lanes, and acceleration lanes should be attributed to mainline freeway segments.
- All crashes that occur within 76.2 m (250 ft) of a crossroad ramp terminal or intersection and are classified as intersection-related should be attributed to crossroad ramp terminals and intersections. All crashes that occur within 76.2 m (250 ft) of a crossroad ramp terminal or intersection but are not classified as intersection-related should be attributed either to ramps or crossroad roadway segments.
- All crashes that occur along the ramp proper portion of an interchange ramp should be attributed to ramps. For crashes that occur on the ramp proper and are within 76.2 m (250 ft) of the crossroad ramp terminal, if the crash is related to the operation of the ramp terminal (i.e., intersection-related), then the crash should be attributed to the crossroad ramp terminal, but if the crash is not related to the operation of the ramp terminal, then the crash should be attributed to the ramp.
- Crashes that occur along or within arterial crossroad roadway segments should be attributed as such, except those crashes that occur within 76.2 m (250 ft) of a ramp terminal or intersection and are intersection-related, in which case the crashes should be attributed to crossroad ramp terminals and intersections.

Step 5. Compute the calibration coefficient such that:

$$C = \frac{O}{N_A} = \frac{\sum_i \sum_y O_{iy}}{\sum_i \sum_y N_{iy}} \quad \textbf{(Eq. 3)}$$

This is the value of the calibration coefficient that would be entered into the calibration table for the respective SPF.

Calibration Example

This example illustrates the general calibration procedure for calculating the calibration coefficient for the mainline freeway segment SPF No. 1. Table 15 shows that SPF No. 1 for mainline freeway segments is used to predict crash frequencies for the following situation:

Interchange element:	Mainline freeway segment
Area type:	Rural
Interchange area:	Yes
Number of through lanes (directional):	2
Severity level:	TOT

Step 1. Select sites for use in applying the calibration procedures.

In this hypothetical example, 20 sites were selected (i.e., 10 sites on I-80 and 10 sites on I-79).

Step 2. Select the analysis years for applying the calibration procedures.

Five years of crash data were used, from 2001 through 2005.

Step 3. Predict the total number of crashes across the selected sites and analysis years.

Table 30 shows the type of data input on the Input-General worksheet. In this case, descriptive data are input for variables G1 through G4, and when asked about the availability of crash data, the input is "N" even though crash data are actually available. If crash data were entered on the Input-General worksheet, then the output would be an EB-adjusted expected value representing a weighted average of the predicted values from the SPF and the observed crash totals. By not including the crash data in these calculations, the output results represent predicted values using mainline freeway segment SPF No. 1.

Table 31 shows the type of data to be entered on the Input Mainline Freeways worksheet. Data for 20 sites are entered into this worksheet. To reiterate, these sites should all be of the same type. In this example, these sites are rural mainline freeway segments within interchange area that have 2 through lanes in the designated direction.

Having entered all of the input data on the Input-General and Input Mainline Freeways worksheets, the calculations are performed by clicking the Perform Calculations button on the Input-General worksheet. Table 32 shows a portion of the output report generated for this example. In this case the table of interest is the number of predicted crashes by interchange element type which shows the number of predicted crashes for the four interchange element types. In this example data were input only for mainline freeway segments. Table 32 indicates that 55.1 total crashes were predicted to occur on these 20 sites during the 5 year period from 2001 to 2005.

$$N_A = 55.1\ TOT\ crashes \quad \textbf{(Eq. 4)}$$

Step 4. Determine the total number of observed crashes across the selected sites and analysis years.

Assume that 60 total crashes were observed at these 20 sites during the period from 2001 through 2005.

$$O = 60\,TOT\ crashes \qquad \textbf{(Eq. 5)}$$

Step 5. Compute the calibration coefficient.

Plugging the predicted and observed values into equation 3 yields:

$$C = \frac{O}{N_A} = \frac{60}{55.1} = 1.089 \qquad \textbf{(Eq. 6)}$$

This value would then be entered into the calibration table for mainline freeway segments SPF No. 1 as illustrated in table 33. This procedure would be repeated for each SPF for mainline freeway segments, and the resulting calculated value would be entered as appropriate into the calibration table. Similarly, this procedure would be repeated for each SPF for ramps, crossroad ramp terminals and intersections, and crossroad roadway segments.

Table 30. Example data for calibration procedure (Input-General).

GI1	Project description	character	MF (calibration)
GI2	Analyst		MRI
GI3	Date		2/20/2007
GI4	Area type	(U,R)	R
GI5	Beginning year of analysis	numeric	2001
GI6	Ending year of analysis	numeric	2005

			Mainline Freeways	**Ramps**	**Crossroad Ramp Terminals and Intersections**	**Crossroad Segments**
GI7	Crash data available?	(Y, N)	N	N	N	N
GI8	Beginning year of crash data	numeric				
GI9	Ending year of crash data	numeric				
GI10	Observed number of crashes	numeric				

Table 31. Example data for calibration procedure (Input Mainline Freeways).

MF1	MF2	MF3	MF4	MF5	MF6	MF7	MF8	MF9	MF10	MF11
Segment Number	**Segment Description**	**Direction of Travel**	**Beginning MP**	**Ending MP**	**Length of Segment**	**Number of Through Lanes (Directional)**	**Mainline ADT (Directional)**	**Mainline ADT Year**	**ADT Growth Rate**	**Within Interchange Area?**
numeric	**character**	**(NB, SB, EB, WB)**	**numeric**	**numeric**	**km (mi)**	**(2, 3, 4)**	**(veh/day)**	**numeric**	**(percent/ year)**	**(Y, N)**
1	EB I-80	EB	1.000	1.350	0.350	2	4,000	2004	2.0	Y
2	EB I-80	EB	10.000	10.400	0.400	2	4,000	2004	2.0	Y
3	EB I-80	EB	50.000	50.500	0.500	2	3,500	2004	2.0	Y
4	EB I-80	EB	100.000	100.400	0.400	2	4,500	2004	2.0	Y
5	EB I-80	EB	150.000	150.500	0.500	2	4,500	2004	2.0	Y
6	WB I-80	WB	25.000	25.500	0.500	2	4,500	2004	2.0	Y
7	WB I-80	WB	75.000	75.400	0.400	2	4,500	2004	2.0	Y
8	WB I-80	WB	125.000	125.400	0.400	2	3,500	2004	2.0	Y
9	WB I-80	WB	175.000	175.500	0.500	2	4,000	2004	2.0	Y
10	WB I-80	WB	225.000	225.350	0.350	2	4,000	2004	2.0	Y
11	NB I-79	NB	5.000	5.500	0.500	2	3,000	2005	2.0	Y
12	NB I-79	NB	40.000	40.400	0.400	2	3,250	2005	2.0	Y
13	NB I-79	NB	80.000	80.500	0.500	2	4,000	2005	2.0	Y
14	NB I-79	NB	120.000	120.500	0.500	2	3,700	2005	2.0	Y
15	NB I-79	NB	170.000	170.400	0.400	2	3,000	2005	2.0	Y
16	SB I-79	SB	10.000	10.400	0.400	2	4,000	2005	2.0	Y
17	SB I-79	SB	60.000	60.350	0.350	2	4,250	2005	2.0	Y
18	SB I-79	SB	130.000	130.350	0.350	2	4,500	2005	2.0	Y
19	SB I-79	SB	180.000	180.400	0.400	2	4,000	2005	2.0	Y
20	SB I-79	SB	200.000	200.500	0.500	2	3,800	2005	2.0	Y

Table 32. Example output report for calibration procedure.

General Interchange Information

Project description:	MF (calibration)
Analyst:	MRI
Date:	2/20/2007
Area type:	Rural
Beginning year of analysis period:	2001
Ending year of analysis period:	2005

	Mainline Freeway Segments	Ramps	Crossroad Ramp Terminals and Intersections	Crossroad Segments
Crash data available:	N	N	N	N
Beginning year of crash data:				
Ending year of crash data:				

Number of Predicted Crashes for Entire Interchange Area					
Number of Predicted Crashes During Analysis Period			**Average Number of Predicted Crashes per Year During Analysis Period**		
Total	FI	PDO	Total	FI	PDO
55.1	16.3	38.9	11.0	3.3	7.8

Number of Predicted Crashes by Interchange Element Type

Interchange Element Type	Number of Sites	Number of Predicted Crashes During Analysis Period			MVMT	MEV	Crash Rate
		Total	**FI**	**PDO**			**(per MVMT or MEV)**
Mainline freeway segments	20	55.1	16.3	38.9	59.691		0.923
Ramps	0						
Crossroad ramp terminals & ints	0						
Crossroad segments	0						
Total	20	55.1	16.3	38.9	59.691		0.923

Table 33. Example calibration procedure (Input Calibration Worksheet).

CCMF1	CCMF2	CCMF3	CCMF4	CCMF5	CCMF6
SPF No.	**Area Type**	**Interchange Area**	**Number of Through Lanes (Directional)**	**Severity Level**	**Calibration Coefficients**
1	R	Y	2	TOT	1.089
2	R	Y	3	TOT	
3	U	Y	2	TOT	
4	U	Y	3	TOT	
5	U	Y	4	TOT	
6	R	Y	2	FI	
7	R	Y	3	FI	
8	U	Y	2	FI	
9	U	Y	3	FI	
10	U	Y	4	FI	
11	R	N	2	TOT	
12	R	N	3	TOT	
13	U	N	2	TOT	
14	U	N	3	TOT	
15	U	N	4	TOT	
16	R	N	2	FI	
17	R	N	3	FI	
18	U	N	2	FI	
19	U	N	3	FI	
20	U	N	4	FI	

Three comments concerning this procedure are worth noting:

- SPFs for a particular site subtype are provided for two severity levels, total and fatal and injuries. The output from *Step 3* provides predicted values for both severity levels. In the example above, the predicted number of fatal and injury crashes for the 20 sites is 16.3 crashes for the 5 year period (Table 32). Thus, the output for a particular subtype of interchange element could be used in calculating the calibration coefficients for both SPFs (i.e., TOT and FI).

- In terms of efficiency, it is possible that when using ISAT to calculate the predicted values for calibration purposes, data could be entered for 4 subtypes of interchange elements as long as they were for different types of elements (i.e., mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad roadway segments). In this case, the output report could be used for calculating the calibration coefficients for up to 8 SPFs (i.e., 2 for each interchange element) in one iteration.

- In *Step 3* it is noted that when performing the calibration procedures, the calibration coefficient for the respective site subtype should be the default value of 1.00. This is important so that the predicted values from the SPFs (i.e., N_A) are not scaled/adjusted prior to calculating the calibration coefficient.

CRASH DISTRIBUTIONS BY SEVERITY AND TYPE

This section provides the default distributions of crash severity and crash type for specific types of interchange elements. The default distributions are based upon crash data from Washington State. The crash distributions are used to predict crash frequencies for 3 severity levels (i.e., TOT, FI, and PDO) and 13 crash types. The crash types are classified as either single-vehicle crashes (SV) or multiple-vehicle crashes (MV). In general terms these crash proportions are multiplied by the predicted or estimated values for total and fatal and injury crashes to obtain the number of crashes of a specified collision type and severity. The number of PDO crashes is estimated by subtracting fatal and injury crashes from total crashes.

It is recommended that one of the first steps a user should do when beginning to work with ISAT, and definitely before using ISAT to perform actual safety assessments, is modify the crash distributions based upon an agency's own crash data. Subsequently, these crash distributions should be updated on an annual basis.

The crash proportions are calculated as follows. The calculations apply to a given type of site and severity level. The classifications of subtypes for which crash distributions are necessary are somewhat different than the subtypes of SPFs for the respective interchange elements. In some cases, multiple subtypes are aggregated together for calculating crash proportions so the crash proportions are applied to multiple subtypes of interchange elements. In calculating the crash type proportions, it is assumed that crash data are available for Y years at I sites of a given subtype in a given jurisdiction (e.g., State). The terms in the calculations are defined in table 34. The proportions, $P_{(CT/TOT)}$ and $P_{(CT/FI)}$, are computed across all sites I of a given subtype as follows:

Table 34. Nomenclature for crash distribution calculations.

Term	Explanation
i	Subscript to represent site i
y	Subscript to represent the year y The first year of the analysis period is considered Year 1 (i.e., y=1) The last year of the analysis period is considered Year Y (i.e., y=Y)
TOT	Subscript to denote total crashes
FI	Subscript to denote fatal and injury crashes
CT	Subscript to denote crash type
O_{iy}	**Observed** number of crashes at site i during year y
$P_{(CT/TOT)}$	Calculated proportion of crashes of the crash type of interest for all TOT crashes for all years of available data
$P_{(CT/FI)}$	Calculated proportion of crashes of the crash type of interest for all FI crashes for all years of available data

$$P_{(CT/TOT)} = \frac{\sum_i \sum_y O_{iy(CT/TOT)}}{\sum_i \sum_y O_{iy(TOT)}} \quad (7)$$

$$P_{(CT/FI)} = \frac{\sum_i \sum_y O_{iy(CT/FI)}}{\sum_i \sum_y O_{iy(FI)}} \quad (8)$$

The default distributions provided within ISAT for total and fatal and injury crashes are the same. This is not a requirement of the program. It is up to the user to determine whether or not providing the actual proportions for the two severity levels is desirable.

Crash Distributions for Mainline Freeways

The default crash distributions for mainline freeway segments provided within ISAT are located on the Distributions Mainline Freeways worksheet and are accessible only through the Go To Distributions for Mainline Freeways hyperlink on the Input-General worksheet. Table 35 illustrates the crash distributions for mainline freeways. For a given group of crash types (i.e., 13 crash types) and subtype, the sum of the proportions should equal 1.00.

Portions of the Distributions Mainline Freeways worksheet are protected. The user may only modify the default values for the mainline freeway segment subtypes (i.e., mainline freeway outside interchange area and mainline freeway within interchange area).

Crash Distributions for Ramps

The default crash distributions for ramps provided within ISAT are located on the Distributions Ramps worksheet and are accessible only through the Go To Distributions for Ramps hyperlink on the Input-General worksheet. Table 36 illustrates the crash distributions for ramps. For a given group of crash types (i.e., 13 crash types) and subtype, the sum of the proportions should equal 1.00.

Portions of the Distributions Ramps worksheet are protected. The user may only modify the default values for the ramp subtypes (i.e., diamond off-ramp, diamond on-ramp, parclo off-ramp, parlco on-ramp, free-flow off-ramp, free-flow on-ramp, and directional ramp).

Table 35. Proportions of crashes by severity and type for mainline freeways.

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	Mainline Freeway Outside Interchange Area	Mainline Freeway Within Interchange Area
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric
CPF1	**CPF2**	**CPF3**	**CPF4**	**CPF5**	**CPF6**	**CPF7**
1	Fixed object	SV	R	TOT	0.176	0.266
2	Animal	SV	R	TOT	0.206	0.018
3	Pedestrian	SV	R	TOT	0.001	0.000
4	Bicyclist	SV	R	TOT	0.000	0.000
5	Parked car	SV	R	TOT	0.013	0.000
6	Overturn	SV	R	TOT	0.295	0.108
7	Other single-vehicle	SV	R	TOT	0.086	0.149
8	Rear-End	MV	R	TOT	0.115	0.225
9	Head-On	MV	R	TOT	0.006	0.006
10	Angle	MV	R	TOT	0.012	0.020
11	Sideswipe, same direction	MV	R	TOT	0.052	0.113
12	Sideswipe, opposite direction	MV	R	TOT	0.004	0.004
13	Other multiple-vehicle	MV	R	TOT	0.034	0.091
1	Fixed object	SV	U	TOT	0.223	0.237
2	Animal	SV	U	TOT	0.013	0.009
3	Pedestrian	SV	U	TOT	0.009	0.003
4	Bicyclist	SV	U	TOT	0.003	0.001
5	Parked car	SV	U	TOT	0.018	0.012
6	Overturn	SV	U	TOT	0.052	0.047
7	Other single-vehicle	SV	U	TOT	0.016	0.021
8	Rear-End	MV	U	TOT	0.410	0.462
9	Head-On	MV	U	TOT	0.003	0.002
10	Angle	MV	U	TOT	0.083	0.017
11	Sideswipe, same direction	MV	U	TOT	0.113	0.138
12	Sideswipe, opposite direction	MV	U	TOT	0.007	0.003
13	Other multiple-vehicle	MV	U	TOT	0.050	0.048
1	Fixed object	SV	R	FI	0.176	0.266
2	Animal	SV	R	FI	0.206	0.018
3	Pedestrian	SV	R	FI	0.001	0.000
4	Bicyclist	SV	R	FI	0.000	0.000
5	Parked car	SV	R	FI	0.013	0.000
6	Overturn	SV	R	FI	0.295	0.108
7	Other single-vehicle	SV	R	FI	0.086	0.149
8	Rear-End	MV	R	FI	0.115	0.225
9	Head-On	MV	R	FI	0.006	0.006
10	Angle	MV	R	FI	0.012	0.020
11	Sideswipe, same direction	MV	R	FI	0.052	0.113
12	Sideswipe, opposite direction	MV	R	FI	0.004	0.004
13	Other multiple-vehicle	MV	R	FI	0.034	0.091

Table 35. Proportions of crashes by severity and type for mainline freeways. (Continued)

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	Mainline Freeway Outside Interchange Area	Mainline Freeway Within Interchange Area
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric
CPF1	CPF2	CPF3	CPF4	CPF5	CPF6	CPF7
1	Fixed object	SV	U	FI	0.223	0.237
2	Animal	SV	U	FI	0.013	0.009
3	Pedestrian	SV	U	FI	0.009	0.003
4	Bicyclist	SV	U	FI	0.003	0.001
5	Parked car	SV	U	FI	0.018	0.012
6	Overturn	SV	U	FI	0.052	0.047
7	Other single-vehicle	SV	U	FI	0.016	0.021
8	Rear-End	MV	U	FI	0.410	0.462
9	Head-On	MV	U	FI	0.003	0.002
10	Angle	MV	U	FI	0.083	0.017
11	Sideswipe, same direction	MV	U	FI	0.113	0.138
12	Sideswipe, opposite direction	MV	U	FI	0.007	0.003
13	Other multiple-vehicle	MV	U	FI	0.050	0.048

Crash Distributions for Crossroad Ramp Terminals and Intersections

The default crash distributions for crossroad ramp terminals and intersections provided within ISAT are located on the Distributions Ramp Terminals worksheet and are accessible only through the Go To Distributions for Ramp Terminals hyperlink on the Input-General worksheet. Table 37 illustrates the crash distributions for crossroad ramp terminals and intersections. For a given group of crash types (i.e., 13 crash types) and subtype, the sum of the proportions should equal 1.00.

Portions of the Distributions Ramp Terminals worksheet are protected. The user may only modify the default values for the crossroad ramp terminal and intersection subtypes (i.e., 3-leg STOP-controlled [3ST], 4-leg STOP-controlled [4ST], 3-leg signalized [3SG], and 4-leg signalized [4SG]).

Crash Distributions for Crossroad Segments

The default crash distributions for crossroad segments provided within ISAT are located on the Distributions Crossroad Segment worksheet and are accessible only through the Go To Distributions for Crossroad Segments hyperlink on the Input-General worksheet. Table 38 illustrates the crash distributions for crossroad segments. For a given group of crash types (i.e., 13 crash types) and subtype, the sum of the proportions should equal 1.00.

Portions of the Distributions Crossroad Segment worksheet are protected. The user may only modify the default values for the arterial crossroad roadway segment subtypes (i.e., 1-lane undivided, 2-lane undivided, 3-lane undivided, 2-lane divided, and 3-lane divided).

Table 36. Proportions of crashes by severity and type for ramps.

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	Diamond Off-Ramp	Diamond On-Ramp	Parclo Off-Ramp	Parclo On-Ramp	Free-Flow Off-Ramp	Free-Flow On-Ramp	Directional Ramp
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric	numeric	numeric	numeric	numeric	numeric
CPR1	**CPR2**	**CPR3**	**CPR4**	**CPR5**	**CPR6**	**CPR7**	**CPR8**	**CPR9**	**CPR10**	**CPR11**	**CPR12**
1	Fixed object	SV	R	TOT	0.215	0.383	0.292	0.250	0.286	0.355	0.397
2	Animal	SV	R	TOT	0.005	0.005	0.000	0.000	0.000	0.000	0.005
3	Pedestrian	SV	R	TOT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Bicyclist	SV	R	TOT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Parked car	SV	R	TOT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Overturn	SV	R	TOT	0.055	0.137	0.092	0.295	0.357	0.370	0.107
7	Other single-vehicle	SV	R	TOT	0.103	0.178	0.092	0.136	0.143	0.171	0.184
8	Rear-End	MV	R	TOT	0.476	0.150	0.432	0.091	0.143	0.026	0.179
9	Head-On	MV	R	TOT	0.002	0.000	0.000	0.023	0.000	0.000	0.010
10	Angle	MV	R	TOT	0.017	0.016	0.031	0.045	0.071	0.013	0.013
11	Sideswipe, same direction	MV	R	TOT	0.074	0.068	0.015	0.023	0.000	0.039	0.054
12	Sideswipe, opposite direction	MV	R	TOT	0.006	0.000	0.000	0.023	0.000	0.026	0.005
13	Other multiple-vehicle	MV	R	TOT	0.047	0.063	0.046	0.114	0.000	0.000	0.046
1	Fixed object	SV	U	TOT	0.150	0.206	0.280	0.225	0.250	0.292	0.294
2	Animal	SV	U	TOT	0.001	0.000	0.001	0.000	0.000	0.000	0.000
3	Pedestrian	SV	U	TOT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Bicyclist	SV	U	TOT	0.000	0.000	0.000	0.001	0.000	0.000	0.000
5	Parked car	SV	U	TOT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Overturn	SV	U	TOT	0.016	0.036	0.063	0.057	0.040	0.051	0.033
7	Other single-vehicle	SV	U	TOT	0.056	0.077	0.097	0.080	0.082	0.100	0.108
8	Rear-End	MV	U	TOT	0.614	0.421	0.366	0.347	0.518	0.381	0.362
9	Head-On	MV	U	TOT	0.002	0.003	0.016	0.007	0.004	0.003	0.002
10	Angle	MV	U	TOT	0.009	0.020	0.018	0.039	0.010	0.015	0.014
11	Sideswipe, same direction	MV	U	TOT	0.084	0.176	0.086	0.193	0.061	0.109	0.128
12	Sideswipe, opposite direction	MV	U	TOT	0.003	0.011	0.012	0.008	0.003	0.005	0.004
13	Other multiple-vehicle	MV	U	TOT	0.065	0.050	0.061	0.043	0.032	0.044	0.055

Table 36. Proportions of crashes by severity and type for ramps. (Continued)

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	Diamond Off-Ramp	Diamond On-Ramp	Parclo Off-Ramp	Parclo On-Ramp	Free-Flow Off-Ramp	Free-Flow On-Ramp	Directional Ramp
		(SV, MV)	**(R, U)**	**(TOT, FI)**	**numeric**	**numeric**	**numeric**	**numeric**	**numeric**	**numeric**	**numeric**
CPR1	**CPR2**	**CPR3**	**CPR4**	**CPR5**	**CPR6**	**CPR7**	**CPR8**	**CPR9**	**CPR10**	**CPR11**	**CPR12**
1	Fixed object	SV	R	FI	0.215	0.383	0.292	0.250	0.286	0.355	0.397
2	Animal	SV	R	FI	0.005	0.005	0.000	0.000	0.000	0.000	0.005
3	Pedestrian	SV	R	FI	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Bicyclist	SV	R	FI	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Parked car	SV	R	FI	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Overturn	SV	R	FI	0.055	0.137	0.092	0.295	0.357	0.370	0.107
7	Other single-vehicle	SV	R	FI	0.103	0.178	0.092	0.136	0.143	0.171	0.184
8	Rear-End	MV	R	FI	0.476	0.150	0.432	0.091	0.143	0.026	0.179
9	Head-On	MV	R	FI	0.002	0.000	0.000	0.023	0.000	0.000	0.010
10	Angle	MV	R	FI	0.017	0.016	0.031	0.045	0.071	0.013	0.013
11	Sideswipe, same direction	MV	R	FI	0.074	0.068	0.015	0.023	0.000	0.039	0.054
12	Sideswipe, opposite direction	MV	R	FI	0.006	0.000	0.000	0.023	0.000	0.026	0.005
13	Other multiple-vehicle	MV	R	FI	0.047	0.063	0.046	0.114	0.000	0.000	0.046
1	Fixed object	SV	U	FI	0.150	0.206	0.280	0.225	0.250	0.292	0.294
2	Animal	SV	U	FI	0.001	0.000	0.001	0.000	0.000	0.000	0.000
3	Pedestrian	SV	U	FI	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Bicyclist	SV	U	FI	0.000	0.000	0.000	0.001	0.000	0.000	0.000
5	Parked car	SV	U	FI	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Overturn	SV	U	FI	0.016	0.036	0.063	0.057	0.040	0.051	0.033
7	Other single-vehicle	SV	U	FI	0.056	0.077	0.097	0.080	0.082	0.100	0.108
8	Rear-End	MV	U	FI	0.614	0.421	0.366	0.347	0.518	0.381	0.362
9	Head-On	MV	U	FI	0.002	0.003	0.016	0.007	0.004	0.003	0.002
10	Angle	MV	U	FI	0.009	0.020	0.018	0.039	0.010	0.015	0.014
11	Sideswipe, same direction	MV	U	FI	0.084	0.176	0.086	0.193	0.061	0.109	0.128
12	Sideswipe, opposite direction	MV	U	FI	0.003	0.011	0.012	0.008	0.003	0.005	0.004
13	Other multiple-vehicle	MV	U	FI	0.065	0.050	0.061	0.043	0.032	0.044	0.055

Table 37. Proportions of crashes by severity and type for crossroad ramp terminals and intersections.

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	3ST	4ST	3SG	4SG
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric	numeric	numeric
CPT1	**CPT2**	**CPT3**	**CPT4**	**CPT5**	**CPT6**	**CPT7**	**CPT8**	**CPT9**
1	Fixed object	SV	R	TOT	0.126	0.049	0.095	0.024
2	Animal	SV	R	TOT	0.021	0.009	0.000	0.005
3	Pedestrian	SV	R	TOT	0.001	0.003	0.010	0.011
4	Bicyclist	SV	R	TOT	0.003	0.005	0.010	0.009
5	Parked car	SV	R	TOT	0.006	0.006	0.000	0.005
6	Overturn	SV	R	TOT	0.060	0.027	0.029	0.007
7	Other single-vehicle	SV	R	TOT	0.068	0.100	0.019	0.068
8	Rear-End	MV	R	TOT	0.268	0.169	0.541	0.282
9	Head-On	MV	R	TOT	0.015	0.014	0.000	0.016
10	Angle	MV	R	TOT	0.299	0.472	0.229	0.422
11	Sideswipe, same direction	MV	R	TOT	0.055	0.060	0.019	0.053
12	Sideswipe, opposite direction	MV	R	TOT	0.014	0.013	0.010	0.010
13	Other multiple-vehicle	MV	R	TOT	0.064	0.073	0.038	0.088
1	Fixed object	SV	U	TOT	0.048	0.033	0.050	0.026
2	Animal	SV	U	TOT	0.017	0.008	0.012	0.002
3	Pedestrian	SV	U	TOT	0.011	0.009	0.008	0.013
4	Bicyclist	SV	U	TOT	0.010	0.010	0.014	0.013
5	Parked car	SV	U	TOT	0.003	0.002	0.001	0.002
6	Overturn	SV	U	TOT	0.012	0.008	0.011	0.005
7	Other single-vehicle	SV	U	TOT	0.043	0.074	0.021	0.043
8	Rear-End	MV	U	TOT	0.355	0.234	0.557	0.471
9	Head-On	MV	U	TOT	0.003	0.007	0.006	0.011
10	Angle	MV	U	TOT	0.375	0.483	0.241	0.300
11	Sideswipe, same direction	MV	U	TOT	0.039	0.041	0.026	0.041
12	Sideswipe, opposite direction	MV	U	TOT	0.006	0.007	0.003	0.005
13	Other multiple-vehicle	MV	U	TOT	0.078	0.084	0.050	0.068
1	Fixed object	SV	R	FI	0.126	0.049	0.095	0.024
2	Animal	SV	R	FI	0.021	0.009	0.000	0.005
3	Pedestrian	SV	R	FI	0.001	0.003	0.010	0.011
4	Bicyclist	SV	R	FI	0.003	0.005	0.010	0.009
5	Parked car	SV	R	FI	0.006	0.006	0.000	0.005
6	Overturn	SV	R	FI	0.060	0.027	0.029	0.007
7	Other single-vehicle	SV	R	FI	0.068	0.100	0.019	0.068
8	Rear-End	MV	R	FI	0.268	0.169	0.541	0.282
9	Head-On	MV	R	FI	0.015	0.014	0.000	0.016
10	Angle	MV	R	FI	0.299	0.472	0.229	0.422
11	Sideswipe, same direction	MV	R	FI	0.055	0.060	0.019	0.053
12	Sideswipe, opposite direction	MV	R	FI	0.014	0.013	0.010	0.010
13	Other multiple-vehicle	MV	R	FI	0.064	0.073	0.038	0.088

Table 37. Proportions of crashes by severity and type for crossroad ramp terminals and intersections. (Continued)

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	3ST	4ST	3SG	4SG
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric	numeric	numeric
CPT1	CPT2	CPT3	CPT4	CPT5	CPT6	CPT7	CPT8	CPT9
1	Fixed object	SV	U	FI	0.048	0.033	0.050	0.026
2	Animal	SV	U	FI	0.017	0.008	0.012	0.002
3	Pedestrian	SV	U	FI	0.011	0.009	0.008	0.013
4	Bicyclist	SV	U	FI	0.010	0.010	0.014	0.013
5	Parked car	SV	U	FI	0.003	0.002	0.001	0.002
6	Overturn	SV	U	FI	0.012	0.008	0.011	0.005
7	Other single-vehicle	SV	U	FI	0.043	0.074	0.021	0.043
8	Rear-End	MV	U	FI	0.355	0.234	0.557	0.471
9	Head-On	MV	U	FI	0.003	0.007	0.006	0.011
10	Angle	MV	U	FI	0.375	0.483	0.241	0.300
11	Sideswipe, same direction	MV	U	FI	0.039	0.041	0.026	0.041
12	Sideswipe, opposite direction	MV	U	FI	0.006	0.007	0.003	0.005
13	Other multiple-vehicle	MV	U	FI	0.078	0.084	0.050	0.068

Table 38. Proportions of crashes by severity and type for arterial crossroad roadway segments.

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	1-Lane Undivided	2-Lane Undivided	3-Lane Undivided	2-Lane Divided	3-Lane Divided
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric	numeric	numeric	numeric
CPC1	**CPC2**	**CPC3**	**CPC4**	**CPC5**	**CPC6**	**CPC7**	**CPC8**	**CPC9**	**CPC10**
1	Fixed object	SV	R	TOT	0.330	0.005	0.005	0.005	0.005
2	Animal	SV	R	TOT	0.377	0.061	0.061	0.120	0.120
3	Pedestrian	SV	R	TOT	0.001	0.004	0.004	0.004	0.004
4	Bicyclist	SV	R	TOT	0.000	0.000	0.000	0.001	0.001
5	Parked car	SV	R	TOT	0.000	0.000	0.000	0.001	0.001
6	Overturn	SV	R	TOT	0.023	0.004	0.004	0.005	0.005
7	Other single-vehicle	SV	R	TOT	0.043	0.161	0.161	0.296	0.296
8	Rear-End	MV	R	TOT	0.096	0.343	0.343	0.271	0.271
9	Head-On	MV	R	TOT	0.021	0.009	0.009	0.006	0.006
10	Angle	MV	R	TOT	0.021	0.185	0.185	0.089	0.089
11	Sideswipe, same direction	MV	R	TOT	0.014	0.039	0.039	0.043	0.043
12	Sideswipe, opposite direction	MV	R	TOT	0.026	0.011	0.011	0.005	0.005
13	Other multiple-vehicle	MV	R	TOT	0.048	0.178	0.178	0.154	0.154
1	Fixed object	SV	U	TOT	0.185	0.075	0.075	0.155	0.155
2	Animal	SV	U	TOT	0.173	0.003	0.003	0.129	0.129
3	Pedestrian	SV	U	TOT	0.002	0.019	0.019	0.001	0.001
4	Bicyclist	SV	U	TOT	0.000	0.013	0.013	0.000	0.000
5	Parked car	SV	U	TOT	0.000	0.013	0.013	0.000	0.000
6	Overturn	SV	U	TOT	0.007	0.010	0.010	0.013	0.013
7	Other single-vehicle	SV	U	TOT	0.031	0.004	0.004	0.043	0.043
8	Rear-End	MV	U	TOT	0.437	0.358	0.358	0.463	0.463
9	Head-On	MV	U	TOT	0.022	0.007	0.007	0.007	0.007
10	Angle	MV	U	TOT	0.046	0.359	0.359	0.056	0.056
11	Sideswipe, same direction	MV	U	TOT	0.027	0.102	0.102	0.075	0.075
12	Sideswipe, opposite direction	MV	U	TOT	0.023	0.012	0.012	0.015	0.015
13	Other multiple-vehicle	MV	U	TOT	0.047	0.025	0.025	0.043	0.043
1	Fixed object	SV	R	FI	0.330	0.005	0.005	0.005	0.005
2	Animal	SV	R	FI	0.377	0.061	0.061	0.120	0.120
3	Pedestrian	SV	R	FI	0.001	0.004	0.004	0.004	0.004
4	Bicyclist	SV	R	FI	0.000	0.000	0.000	0.001	0.001
5	Parked car	SV	R	FI	0.000	0.000	0.000	0.001	0.001
6	Overturn	SV	R	FI	0.023	0.004	0.004	0.005	0.005
7	Other single-vehicle	SV	R	FI	0.043	0.161	0.161	0.296	0.296
8	Rear-End	MV	R	FI	0.096	0.343	0.343	0.271	0.271
9	Head-On	MV	R	FI	0.021	0.009	0.009	0.006	0.006
10	Angle	MV	R	FI	0.021	0.185	0.185	0.089	0.089
11	Sideswipe, same direction	MV	R	FI	0.014	0.039	0.039	0.043	0.043
12	Sideswipe, opposite direction	MV	R	FI	0.026	0.011	0.011	0.005	0.005
13	Other multiple-vehicle	MV	R	FI	0.048	0.178	0.178	0.154	0.154

Table 38. Proportions of crashes by severity and type for arterial crossroad roadway segments. (Continued)

Crash No.	Crash Type	Number of Vehicles Involved	Area Type	Severity Level	1-Lane Undivided	2-Lane Undivided	3-Lane Undivided	2-Lane Divided	3-Lane Divided
		(SV, MV)	(R, U)	(TOT, FI)	numeric	numeric	numeric	numeric	numeric
CPC1	**CPC2**	**CPC3**	**CPC4**	**CPC5**	**CPC6**	**CPC7**	**CPC8**	**CPC9**	**CPC10**
1	Fixed object	SV	U	FI	0.185	0.075	0.075	0.155	0.155
2	Animal	SV	U	FI	0.173	0.003	0.003	0.129	0.129
3	Pedestrian	SV	U	FI	0.002	0.019	0.019	0.001	0.001
4	Bicyclist	SV	U	FI	0.000	0.013	0.013	0.000	0.000
5	Parked car	SV	U	FI	0.000	0.013	0.013	0.000	0.000
6	Overturn	SV	U	FI	0.007	0.010	0.010	0.013	0.013
7	Other single-vehicle	SV	U	FI	0.031	0.004	0.004	0.043	0.043
8	Rear-End	MV	U	FI	0.437	0.358	0.358	0.463	0.463
9	Head-On	MV	U	FI	0.022	0.007	0.007	0.007	0.007
10	Angle	MV	U	FI	0.046	0.359	0.359	0.056	0.056
11	Sideswipe, same direction	MV	U	FI	0.027	0.102	0.102	0.075	0.075
12	Sideswipe, opposite direction	MV	U	FI	0.023	0.012	0.012	0.015	0.015
13	Other multiple-vehicle	MV	U	FI	0.047	0.025	0.025	0.043	0.043

OUTPUT REPORTS

When the user clicks the Perform Calculations button on the Input-General worksheet, a number of output reports are generated within ISAT. ISAT automatically takes the user to the Output-General worksheet where output results are summarized in the following manner:

- Number of predicted crashes for entire interchange area.
- Number of predicted crashes by interchange element type.
- Number of predicted crashes by year.
- Number of predicted crashes by collision type.

Separate output worksheets are also generated for each type of interchange element (i.e., mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad segments). On these output reports the number of predicted crashes by collision type and severity level is summed across the individual components of the respective interchange elements, and results are provided for the individual components of the respective interchange elements.

Each of the output reports/worksheets is discussed in more detail below, using the output reports generated by the example that was illustrated throughout the user manual.

GENERAL OUTPUT REPORT

Five tables are included on the general output report (i.e., Output-General worksheet), titled:

- General interchange information.
- Number of predicted crashes for entire interchange area.
- Number of predicted crashes by interchange element type.
- Number of predicted crashes by year.
- Number of predicted crashes by collision type.

Tables 39 through 43 show the general output tables for the example.

Table 39 (General Interchange Information) reviews the input data from the Input-General worksheet. This table displays the project description, analyst, date, area type, and beginning and ending years of the analysis period. This example was of a rural diamond interchange, and the analysis period is from 2008 to 2017, inclusive. The table also displays whether crash data were incorporated into the calculations for the respective interchange elements. In this example, 5 years of crash data from 2001 to 2005 were considered in the calculations for each of the four interchange elements.

Table 39. General interchange information (General Output Report).

Project description:	Diamond Interchange Example 1			
Analyst:	MRI			
Date:	10/27/2006			
Area type:	Rural			
Beginning year of analysis period:	2008			
Ending year of analysis period:	2017			
	Mainline Freeway Segments	**Ramps**	**Crossroad Ramp Terminals and Intersections**	**Crossroad Segments**
Crash data available:	Y	Y	Y	Y
Beginning year of crash data:	2001	2001	2001	2001
Ending year of crash data:	2005	2005	2005	2005

Table 40 (Number of Predicted Crashes for Entire Interchange Area) shows the number of predicted crashes during the analysis period for the entire analysis area and shows the average number of predicted crashes per year during the analysis period. These numbers are provided for TOT, FI, and PDO severity levels. For instance in the example, 210.2 TOT crashes are predicted to occur during the ten year analysis period within the entire interchange area, and this translates to 21.0 TOT crashes per year.

Table 40. Number of predicted crashes for entire interchange area (General Output Report).

Number of Predicted Crashes During Analysis Period			**Average Number of Predicted Crashes per Year During Analysis Period**		
Total	FI	PDO	Total	FI	PDO
210.2	58.4	151.8	21.0	5.8	15.2

Table 41 (Number of predicted crashes by interchange element type) summarizes the crash predictions by interchange element types. This table shows the number of sites included in the analysis area for the four interchange elements. The table also shows the number of crashes by severity type that are expected to occur on each type of interchange element. Million vehicle-miles traveled (MVMT) are displayed for mainline freeway segments, ramps, and crossroad segments based upon the traffic volumes and lengths of these interchange elements. For crossroad ramp terminals and intersections, million entering vehicles (MEV) are displayed. The last column of the table displays the crash rates across each of the interchange elements, either based upon MVMT or MEV. The last row of the table shows totals for the entire interchange area. The crash rate in this last row is calculated using total crashes and total MVMT. In the example, 22 total sites are included in the analysis area (i.e., 10 mainline freeway segments, 4 ramps, 2 crossroad ramp terminals, and 6 crossroad segments). On the 10 mainline freeway segments, 109.9 TOT crashes, 29.0 FI crashes, and 80.9 PDO crashes are predicted to occur during the analysis period. The total MVMT across these 10 mainline freeway segments during the analysis period is 112.262. The average crash rate across the 10 mainline freeway segments is 0.979 TOT crashes/MVMT. The TOT number of crashes predicted to occur at the crossroad ramp terminals is 31.9 crashes. During the analysis period, it is calculated that 41.098 million vehicles will enter these two crossroad ramp terminals. This translates into an average crash rate

for the two crossroad ramp terminals of 0.776 TOT crashes/MEV for the analysis period. The average crash rate across the entire interchange area during the analysis period is 1.541 TOT crashes/MVMT.

Table 42 (Number of predicted crashes by year) displays predicted number of crashes for each year of the analysis period by severity level. Predicted crash totals for the entire analysis period are also summarized by severity level. In the example, 19.7 TOT crashes, 5.5 FI crashes, and 14.2 PDO crashes are predicted to occur during the first year of the analysis period (i.e., 2008). During 2009, 20.0 TOT crashes, 5.6 FI crashes, and 14.4 PDO crashes are predicted to occur, and so on.

Table 43 (Number of predicted crashes by collision type) shows the number and percentage of predicted crashes by collision type and severity level. Subtotals are also provided for all single-vehicle crashes and all multiple-vehicle crashes. In the example, 210.2 TOT crashes are predicted to occur within the analysis area during the 10 year analysis period. Of these 210.2 TOT crashes, 129.3 crashes (61.5 percent) are expected to involve single vehicles, and 80.9 crashes (38.5 percent) are expected to involve multiple vehicles. Of the single vehicle crashes, 46.8 crashes are expected to involve a vehicle striking a fixed object.

INDIVIDUAL OUTPUT REPORTS FOR INTERCHANGE ELEMENTS

ISAT also generates output reports for each of the four interchange elements (i.e., mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad segments). Each of these individual reports is formatted in a similar fashion with two tables. The first table shows the number and percentage of crashes by collision type across all sites of the respective interchange element. These numbers and percentages are provided by severity level. The second table provides the predicted number of crashes for the individual sites for the respective interchange element along with additional descriptive information.

Tables 44 and 45 show the output results for mainline freeway segments. Table 44 (Number of predicted crashes by collision type for all mainline freeway segments combined) shows that 109.9 TOT crashes, 29.0 FI crashes, and 80.9 PDO crashes are predicted to occur across all the mainline freeway segments included in the analysis area. These crashes are further categorized by the 13 collision types. Table 45 (Number of predicted crashes for individual mainline freeway segments) shows the segment number, segment description, direction of travel, beginning milepost, ending milepost, and segment length for each individual site. For each individual site, the number of predicted crashes during the analysis period is provided by severity level. The average daily traffic (ADT) for each site is given for the entire analysis period along with MVMT, crashes per mile per year, and crash rate per MVMT.

Table 41. Number of predicted crashes by interchange element type (General Output Report).

Interchange Element Type	Number of Sites	Number of Predicted Crashes During Analysis Period			MVMT	MEV	Crash Rate
		Total	FI	PDO			(per MVMT or MEV)
Mainline freeway segments	10	109.9	29.0	80.9	112.262		0.979
Ramps	4	13.6	2.7	10.9	4.218		3.233
Crossroad ramp terminals & ints	2	31.9	14.5	17.4		41.098	0.776
Crossroad segments	6	54.8	12.2	42.6	19.900		2.754
Total	22	210.2	58.4	151.8	136.380		1.541

Table 42. Number of predicted crashes by year (General Output Report).

	Total	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total Crashes	210.2	19.7	20.0	20.3	20.6	20.9	21.3	21.6	21.9	22.3	22.6
FI Crashes	58.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4
PDO Crashes	151.8	14.2	14.4	14.6	14.8	15.0	15.3	15.5	15.7	16.0	16.2

Table 43. Number of predicted crashes by collision type (General Output Report).

Collision Type	Number and Percentage of Predicted Crashes by Collision Type					
	Total		FI		PDO	
	No.	%	No.	%	No.	%
All collision types	**210.2**	**100.0%**	**58.4**	**100.0%**	**151.8**	**100.0%**
Single vehicle	*129.3*	*61.5%*	*32.9*	*56.3%*	*96.4*	*63.5%*
Fixed object	46.8	22.3%	11.7	20.0%	35.1	23.1%
Animal	34.7	16.5%	8.2	14.1%	26.5	17.5%
Pedestrian	0.2	0.1%	0.1	0.1%	0.1	0.1%
Bicyclist	0.2	0.1%	0.1	0.1%	0.1	0.1%
Parked car	1.0	0.5%	0.3	0.5%	0.7	0.5%
Noncollision	26.7	12.7%	6.9	11.8%	19.8	13.1%
Other single-vehicle	19.7	9.4%	5.6	9.6%	14.0	9.2%
Multiple vehicle	*80.9*	*38.5%*	*25.5*	*43.7%*	*55.4*	*36.5%*
Rear-end	33.8	16.1%	9.6	16.4%	24.2	16.0%
Head-on	2.3	1.1%	0.6	1.1%	1.6	1.1%
Angle	18.1	8.6%	7.6	13.0%	10.5	6.9%
Sideswipe, same direction	12.3	5.8%	3.6	6.1%	8.7	5.7%
Sideswipe, opposite direction	2.3	1.1%	0.6	1.1%	1.7	1.1%
Other multiple-vehicle	12.1	5.8%	3.5	6.0%	8.6	5.6%

Table 44. Number of predicted crashes by collision type for all mainline freeway segments combined.

Collision type	Number and Percentage of Predicted Crashes by Collision Type					
	Total		FI		PDO	
	No.	%	No.	%	No.	%
All collision types	**109.9**	**100.0%**	**29.0**	**100.0%**	**80.9**	**100.0%**
Single vehicle	*74.2*	*67.5%*	*19.4*	*66.8%*	*54.8*	*67.8%*
Fixed object	23.6	21.5%	6.3	21.7%	17.3	21.4%
Animal	13.7	12.5%	3.5	11.9%	10.3	12.7%
Pedestrian	0.1	0.1%	0.0	0.1%	0.0	0.1%
Bicyclist	0.0	0.0%	0.0	0.0%	0.0	0.0%
Parked car	0.8	0.7%	0.2	0.7%	0.6	0.8%
Noncollision	23.5	21.4%	6.1	20.9%	17.5	21.6%
Other single-vehicle	12.4	11.3%	3.3	11.5%	9.1	11.3%
Multiple vehicle	*35.7*	*32.5%*	*9.6*	*33.2%*	*26.1*	*32.2%*
Rear-end	17.8	16.2%	4.8	16.6%	13.0	16.1%
Head-on	0.7	0.6%	0.2	0.6%	0.5	0.6%
Angle	1.7	1.5%	0.5	1.6%	1.2	1.5%
Sideswipe, same direction	8.6	7.8%	2.3	8.0%	6.3	7.8%
Sideswipe, opposite direction	0.4	0.4%	0.1	0.4%	0.3	0.4%
Other multiple-vehicle	6.4	5.9%	1.7	6.0%	4.7	5.8%

Table 45. Number of predicted crashes for individual mainline freeway segments.

Segment Number	Segment Description	Direction of Travel	Beginning MP	Ending MP	Segment Length km (mi)	Number of Predicted Crashes During Analysis Period: Total	FI	PDO	ADT (veh/day)	Max ADT for SPF Exceeded	MVMT	Crashes per Mile per Year	Crash Rate per MVMT	Incorrect Collision Distribution
Total					**6.300**	**109.9**	**29.0**	**80.9**	**4,882**		**112.262**	**1.744**	**0.979**	
1	EB Upstream Segment (MF1)	EB	0.000	1.000	1.61 (1.000)	14.9	3.7	11.2	4,741		17.304	1.489	0.861	
2	EB Segment Adjacent to Decel Lane (MF2)	EB	1.000	1.300	0.48 (0.300)	6.5	1.9	4.6	4,741		5.191	2.157	1.247	
3	EB Between Ramps (MF3)	EB	1.300	1.850	0.89 (0.550)	10.5	3.1	7.4	4,148		8.328	1.908	1.260	
4	EB Segment Adjacent to Accel Lane (MF4)	EB	1.850	2.150	0.48 (0.300)	6.6	1.5	5.1	5,334		5.840	2.200	1.130	
5	EB Downstream Segment (MF5)	EB	2.150	3.150	1.61 (1.000)	16.3	4.1	12.2	5,334		19.467	1.634	0.840	
6	WB Upstream Segment (MF6)	WB	3.150	2.150	1.61 (1.000)	16.3	4.1	12.2	5,334		19.467	1.634	0.840	
7	WB Segment Adjacent to Decel Lane (MF7)	WB	2.150	1.850	0.48 (0.300)	7.2	2.1	5.1	5,334		5.840	2.404	1.235	
8	WB Betweem Ramps (MF8)	WB	1.850	1.300	0.89 (0.550)	10.5	3.1	7.4	4,148		8.328	1.908	1.260	
9	WB Segment Adjacent to Accel Lane (MF9)	WB	1.300	1.000	0.48 (0.300)	6.1	1.6	4.6	4,741		5.191	2.040	1.179	
10	WB Downstream Segment (MF10)	WB	1.000	0.000	1.61 (1.000)	14.9	3.7	11.2	4,741		17.304	1.489	0.861	

As illustrated in table 45, several columns are provided to serve as warnings to users when interpreting the output. One warning is associated with the ADT of a given site. As indicated earlier, SPFs are used in predicting the number of crashes at a given site. Each SPF was calibrated/calculated using data from actual sites. The maximum ADT used in calibrating/calculating each SPF is one of the parameters included on the SPF worksheets. With a slight tolerance (i.e., 130 percent), if the ADT at a given site for any year in the analysis period exceeds the maximum ADT used to calibrate the SPF, which is used in predicting crashes for the respective site, this is indicted to the user by showing a “YES” in the respective row under the column headed “Max ADT for SPF exceeded”. A “YES” is also provided in the first row of the table under the same column. These “YES” values serve as a warning to the user to view the predictions for the given site with caution. Because the ADT for the given site is beyond the limits for which the SPF was calibrated, there is less certainty associated with the predictions for the given site. A second warning is associated with the crash distributions. For a given group of crash types (i.e., 13 crash types) and subtype, the sum of the proportions should equal 1.00. If the sum of the proportions does not equal exactly 1.00, erroneous results will be calculated for the collision types. A “YES” value in the respective row under the column headed “Incorrect collision distribution” indicates that crash distributions used in the calculations for the given site were incorrect (i.e., did not sum to 1.00), and the user should adjust the respective crash distributions and re-run the analysis. Finally, the top row of this second table provides totals across all mainline freeway segment sites included in the analysis area.

Turning to the example, Segment No. 1 [EB Upstream Segment (MF1)] is 1.61 km (1.00 mi) in length. It is predicted that 14.9 TOT crashes, 3.7 FI crashes, and 11.2 PDO crashes will occur on this segment during the analysis period. The average ADT for this site during the 10 year analysis period is 4,741 veh/day. The total vehicle-miles traveled across this segment is calculated to be 17.304 MVMT. The average number of crashes per mile per year for this site is predicted to be 0.925 TOT crashes/km/yr (1.489 TOT crashes/mi/yr), and the crash rate is 0.861 TOT crashes/MVMT. No warnings are indicated for this site associated with the yearly ADTs exceeding the max ADT used to calibrate the respective SPF, nor for incorrect collision distributions. Results for the other individual segments can be interpreted in the same manner. As a reminder, the crash estimates for mainline freeway segments within interchange areas include crashes along the mainline freeway lanes, adjacent speed-change lanes (i.e., deceleration and acceleration lanes), and adjacent roadsides. These estimates are adjusted to account for acceleration lane lengths as input by the user. Crash estimates for mainline freeway segments outside interchange areas include crashes along the mainline freeway lanes and adjacent roadsides.

Tables 46 and 47 show the output results for ramps. The output results are displayed very similarly to those for mainline freeway segments with the following exception; there is no column for crashes per mile per year. In the example, there are 4 ramps included in the analysis area. The total length of these ramps is 2.09 km (1.300 mi). It is predicted that 13.6 TOT crashes, 2.7 FI crashes, and 10.9 PDO crashes will occur on these ramps during the analysis period. The average ADT across all of the ramps is 889 veh/day. The total vehicle-distance traveled across these four ramps is calculated to be 6.788 million vehicle kilometers traveled (4.218 MVMT), and the crash rate is 3.233 TOT crashes/MVMT. No warnings are indicated for any of the ramp sites associated with the yearly ADTs exceeding the max ADT used to calibrate the respective SPFs, nor for incorrect collision distributions.

Table 46. Number of predicted crashes by collision type for all ramps combined.

Collision Type	Number and Percentage of Predicted Crashes by Collision Type					
	Total		FI		PDO	
	No.	%	No.	%	No.	%
All collision types	13.6	100.0%	2.7	100.0%	10.9	100.0%
Single vehicle	*6.3*	*46.5%*	*1.2*	*43.0%*	*5.2*	*47.4%*
Fixed object	3.5	26.0%	0.7	24.2%	2.9	26.5%
Animal	0.1	0.5%	0.0	0.5%	0.1	0.5%
Pedestrian	0.0	0.0%	0.0	0.0%	0.0	0.0%
Bicyclist	0.0	0.0%	0.0	0.0%	0.0	0.0%
Parked car	0.0	0.0%	0.0	0.0%	0.0	0.0%
Noncollision	1.1	7.7%	0.2	6.8%	0.9	7.9%
Other single-vehicle	1.7	12.3%	0.3	11.5%	1.4	12.5%
Multiple vehicle	*7.3*	*53.5%*	*1.6*	*57.0%*	*5.7*	*52.6%*
Rear-end	5.3	38.8%	1.2	42.4%	4.1	37.9%
Head-on	0.0	0.1%	0.0	0.2%	0.0	0.1%
Angle	0.2	1.7%	0.0	1.7%	0.2	1.7%
Sideswipe, same direction	1.0	7.2%	0.2	7.3%	0.8	7.2%
Sideswipe, opposite direction	0.1	0.4%	0.0	0.5%	0.0	0.4%
Other multiple-vehicle	0.7	5.1%	0.1	5.0%	0.6	5.2%

Table 47. Number of predicted crashes for individual ramps.

Ramp Number	Ramp Description	Ramp Length	Number of Predicted Crashes During Analysis Period				Max ADT for SPF Exceeded	MVMT	Crash rate per MVMT	Incorrect collision distribution
		km (mi)	Total	FI	PDO	ADT				
Total		**2.09 (1.300)**	**13.6**	**2.7**	**10.9**	**889**		**4.218**	**3.233**	
1	EB Off-Ramp (R1)	0.480 (0.300)	4.2	0.8	3.4	593		0.649	6.495	
2	EB On-Ramp (R2)	0.563 (0.350)	2.5	0.3	2.1	1,185		1.514	1.625	
3	WB Off-Ramp (R3)	0.480 (0.300)	5.8	1.5	4.3	1,185		1.298	4.436	
4	WB On-Ramp (R4)	0.563 (0.350)	1.2	0.1	1.1	593		0.757	1.591	

Tables 48 and 49 show the output results for crossroad ramp terminals and intersections. The primary difference associated with these output results is that rather than reporting MVMT, exposure is represented by million entering vehicles (MEV). In the example, 2 crossroad ramp terminals are included in the analysis area. Focusing on the South Ramp Terminal (RT1), 13.4 TOT crashes, 6.2 FI crashes, and 7.1 PDO crashes are predicted to occur at this ramp terminal during the analysis period. A total of 19.467 million vehicles are expected to enter this ramp terminal during the analysis period, and it is predicted that 1.337 TOT crashes/yr will occur with a crash rate of 0.687 TOT crashes/MEV. No warnings are indicated for the site associated with the yearly ADTs exceeding the max ADT used to calibrate the respective SPF, nor for incorrect collision distributions.

Tables 50 and 51 show the output results for arterial crossroad segments. These output results are displayed exactly the same way as results for mainline freeway segments and would be interpreted in the same manner.

Table 48. Number of predicted crashes by collision type for all crossroad ramp terminals and intersections combined.

Collision Type	Number and Percentage of Predicted Crashes by Collision Type					
	Total		FI		PDO	
	No.	%	No.	%	No.	%
All collision types	31.9	*100.0%*	14.5	*100.0%*	17.4	*100.0%*
Single vehicle	*6.3*	19.9%	*2.9*	19.9%	*3.5*	19.9%
Fixed object	1.6	4.9%	0.7	4.9%	0.9	4.9%
Animal	0.3	0.9%	0.1	0.9%	0.2	0.9%
Pedestrian	0.1	0.3%	0.0	0.3%	0.1	0.3%
Bicyclist	0.2	0.5%	0.1	0.5%	0.1	0.5%
Parked car	0.2	0.6%	0.1	0.6%	0.1	0.6%
Noncollision	0.9	2.7%	0.4	2.7%	0.5	2.7%
Other single-vehicle	3.2	10.0%	1.4	10.0%	1.7	10.0%
Multiple vehicle	*25.5*	*80.1%*	*11.6*	*80.1%*	*14.0*	*80.1%*
Rear-end	5.4	16.9%	2.4	16.9%	2.9	16.9%
Head-on	0.4	1.4%	0.2	1.4%	0.2	1.4%
Angle	15.1	47.2%	6.8	47.2%	8.2	47.2%
Sideswipe, same direction	1.9	6.0%	0.9	6.0%	1.0	6.0%
Sideswipe, opposite direction	0.4	1.3%	0.2	1.3%	0.2	1.3%
Other multiple-vehicle	2.3	7.3%	1.1	7.3%	1.3	7.3%

Table 49. Number of predicted crashes for individual crossroad ramp terminals and intersections.

Terminal Number	Terminal Description	Number of Predicted Crashes During Analysis Period			Max ADT for SPF Exceeded	MEV	Crashes per Year	Crash Rate per MEV	Incorrect Collision Distribution
		Total	FI	PDO					
Total		31.9	14.5	17.4		41.098	3.190	0.776	
1	South Ramp Terminal (RT1)	13.4	6.2	7.1		19.467	1.337	0.687	
2	North Ramp Terminal (RT2)	18.5	8.2	10.3		21.631	1.852	0.856	

Table 50. Number of predicted crashes by collision type for all arterial crossroad roadway segments combined.

Collision Type	Number and Percentage of Predicted Crashes by Collision Type					
	Total		FI		PDO	
	No.	%	No.	%	No.	%
All collision types	54.8	100.0%	12.2	100.0%	42.6	100.0%
Single vehicle	*42.4*	*77.4%*	*9.5*	*77.4%*	*32.9*	*77.4%*
Fixed object	18.1	33.0%	4.0	33.0%	14.0	33.0%
Animal	20.7	37.7%	4.6	37.7%	16.0	37.7%
Pedestrian	0.1	0.1%	0.0	0.1%	0.0	0.1%
Bicyclist	0.0	0.0%	0.0	0.0%	0.0	0.0%
Parked car	0.0	0.0%	0.0	0.0%	0.0	0.0%
Noncollision	1.3	2.3%	0.3	2.3%	1.0	2.3%
Other single-vehicle	2.4	4.3%	0.5	4.3%	1.8	4.3%
Multiple vehicle	*12.4*	*22.6%*	*2.8*	*22.6%*	*9.6*	*22.6%*
Rear-end	5.3	9.6%	1.2	9.6%	4.1	9.6%
Head-on	1.2	2.1%	0.3	2.1%	0.9	2.1%
Angle	1.2	2.1%	0.3	2.1%	0.9	2.1%
Sideswipe, same direction	0.8	1.4%	0.2	1.4%	0.6	1.4%
Sideswipe, opposite direction	1.4	2.6%	0.3	2.6%	1.1	2.6%
Other multiple-vehicle	2.6	4.8%	0.6	4.8%	2.0	4.8%

Table 51. Number of predicted crashes for Individual arterial crossroad roadway segments.

Segment Number	Segment Description	Direction of Travel	Beginning MP	Ending MP	Segment Length km (mi)	Number of Predicted Crashes During Analysis Period Total	FI	PDO	ADT (veh/day)	Max ADT for SPF Exceeded	MVMT	Crashes per Mile per Year	Crash Rate per MVMT	Incorrect Collision Distribution
Total					**3.864 (2.400)**	**54.8**	**12.2**	**42.6**	**2,272**		**19.900**	**2.283**	**2.754**	
1	NB Upstream Segment (RS1)	NB	0.000	0.500	0.805 (0.500)	11.7	2.6	9.1	2,370		4.326	2.340	2.705	
2	NB Between Ramp Terminals (RS2)	NB	0.500	0.700	0.32 (0.200)	4.0	0.9	3.1	1,778		1.298	1.998	3.079	
3	NB Downstream Segment (RS3)	NB	0.700	1.200	0.805 (0.500)	11.7	2.6	9.1	2,370		4.326	2.340	2.705	
4	SB Upstream Segment (RS4)	SB	1.200	0.700	0.805 (0.500)	11.7	2.6	9.1	2,370		4.326	2.340	2.705	
5	SB Between Ramp Terminals (RS5)	SB	0.700	0.500	0.32 (0.200)	4.0	0.9	3.1	1,778		1.298	1.998	3.079	
6	SB Downstream Segment (RS6)	SB	0.500	0.000	0.805 (0.500)	11.7	2.6	9.1	2,370		4.326	2.340	2.705	

APPLICATIONS OF ISAT

ISAT was developed for a wide range of applications. This section highlights several interchange analysis applications for which ISAT can be used, including:

- Application 1—Estimating the safety performance of an existing interchange.
- Application 2—Predicting the safety performance of design alternatives for a new interchange.
- Application 3—Predicting the safety performance of design alternatives for an existing interchange.

This section also explains how ISAT can be applied to several common interchange types.

TYPES OF ANALYSIS APPLICATIONS

Application 1—Estimating the Safety Performance of an Existing Interchange

The first, and most basic, application of ISAT is to estimate the safety performance of an existing interchange. This is done by applying Steps 1 through 8 as described in the Basis Analysis Procedures section of this manual. Estimating the safety performance of an existing interchange can be useful for determining the need and priority for reconstruction of the interchange. In some instances, agencies simply do not have crash data to conduct a safety assessment of an existing interchange. In these instances ISAT provides the means to do so based upon its predictive capabilities. In situations where agencies have crash data available for an existing interchange, the crash data can be combined with the safety experience of similar types of interchanges through state-of-the-art statistical techniques to develop a more accurate safety assessment for the interchange.

Application 1 can be useful to highway agencies in their safety management of interchanges. By applying this application to a number of existing interchanges, highway agencies can identify sites with sufficient crashes (actual or estimated) to provide an opportunity for safety improvement. In this way agencies can better determine the priorities for interchange reconstruction projects in their jurisdiction.

Application 2—Predicting the Safety Performance of Design Alternatives for a New Interchange

Prior to ISAT, no tools were available to design engineers to assess the safety performance of design alternatives for a new interchange. Design alternatives for interchange projects have typically been compared on the basis of cost and traffic operational measures. ISAT fills this void and provides the capability to include safety as one of the primary measures when comparing design alternatives for a new interchange.

ISAT was developed to include those geometric, traffic control, and traffic volume components most critical to the overall safety of an interchange, as determined through valid statistical models. By controlling certain components and varying others, engineers can assess the safety consequences of different design alternatives. With ISAT, design engineers now have the capability to assess the safety performance of different design alternatives which can be useful in selecting the final design for a new interchange.

Application 3—Predicting the Safety Performance of Design Alternatives for an Existing Interchange

This application is very similar to Application 2, except that this application focuses on design alternatives for an *existing* interchange rather than a *new* interchange. ISAT provides the capability to include safety as one of the primary measures when comparing design alternatives for an existing interchange. ISAT was developed to include those geometric, traffic control, and traffic volume components most critical to the overall safety of an interchange. By controlling certain components, and varying others, engineers can assess the safety consequences of different design alternatives. With this being an application for an existing interchange, ISAT also provides the capability to compare the predicted safety performance of proposed design alternatives to the safety performance of the existing interchange design (i.e., the no-build scenario).

APPLICATION OF ISAT TO SPECIFIC INTERCHANGE CONFIGURATIONS

This section explains how ISAT can be applied to four common interchange types: full diamond, partial cloverleaf, full cloverleaf, and directional. Figures 5 through 8 illustrate these interchange types. These examples provide sufficient information to guide the user in applying the tool to other, less standard, interchange configurations.

In applying ISAT to any interchange, study area boundaries must be established at each mainline freeway leg and each arterial crossroad leg. These study area boundaries should be far enough from the ramps that the entire interchange influence area on the mainline freeway is included within the study area boundaries. If the safety performance of an existing and proposed interchange design is being compared, or if several proposed design alternatives for the interchange are being compared, the same study area boundaries must be used for all design alternatives, and the study area must be large enough to include all of the alternatives.

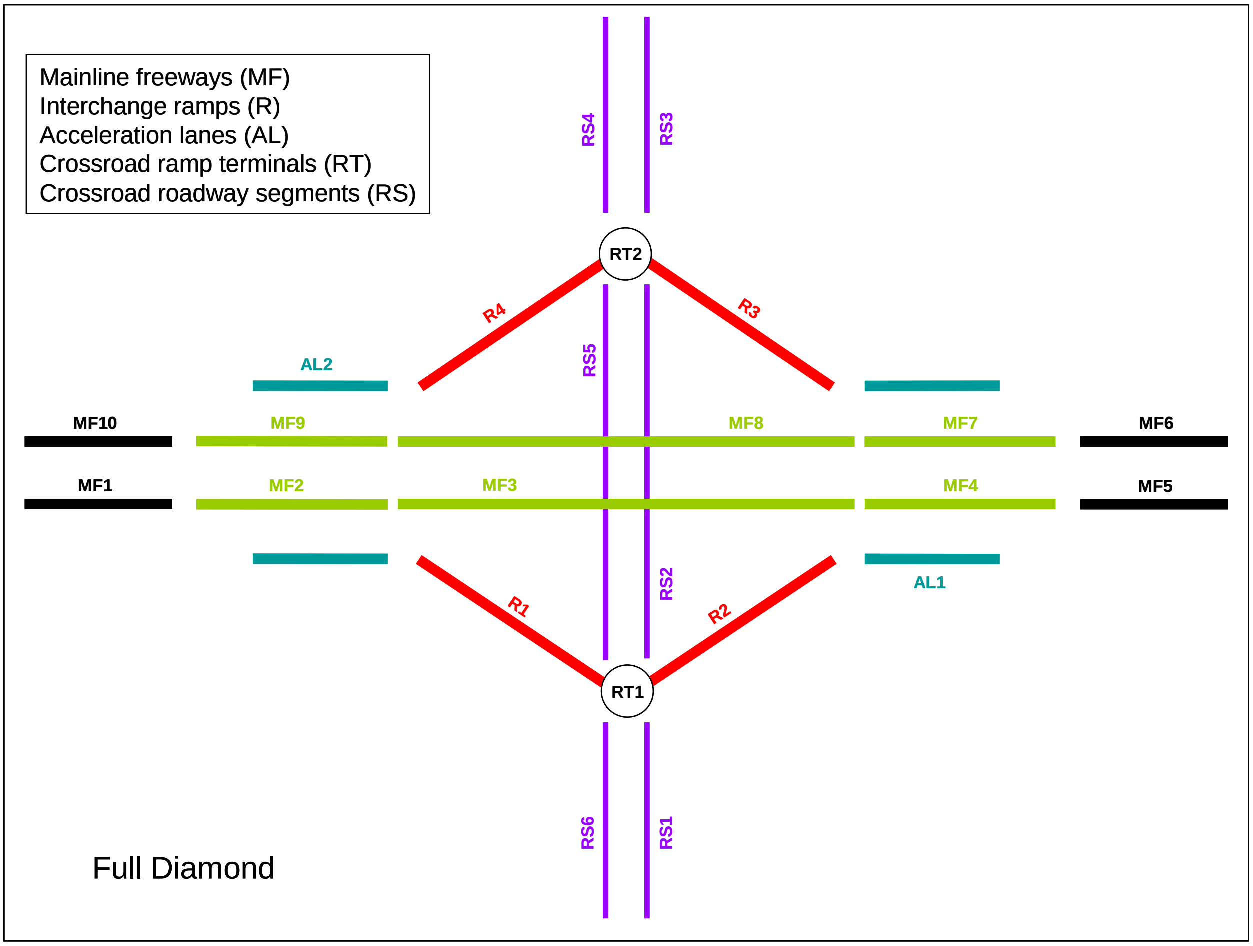


Figure 5. Sample application of ISAT to a full diamond interchange.

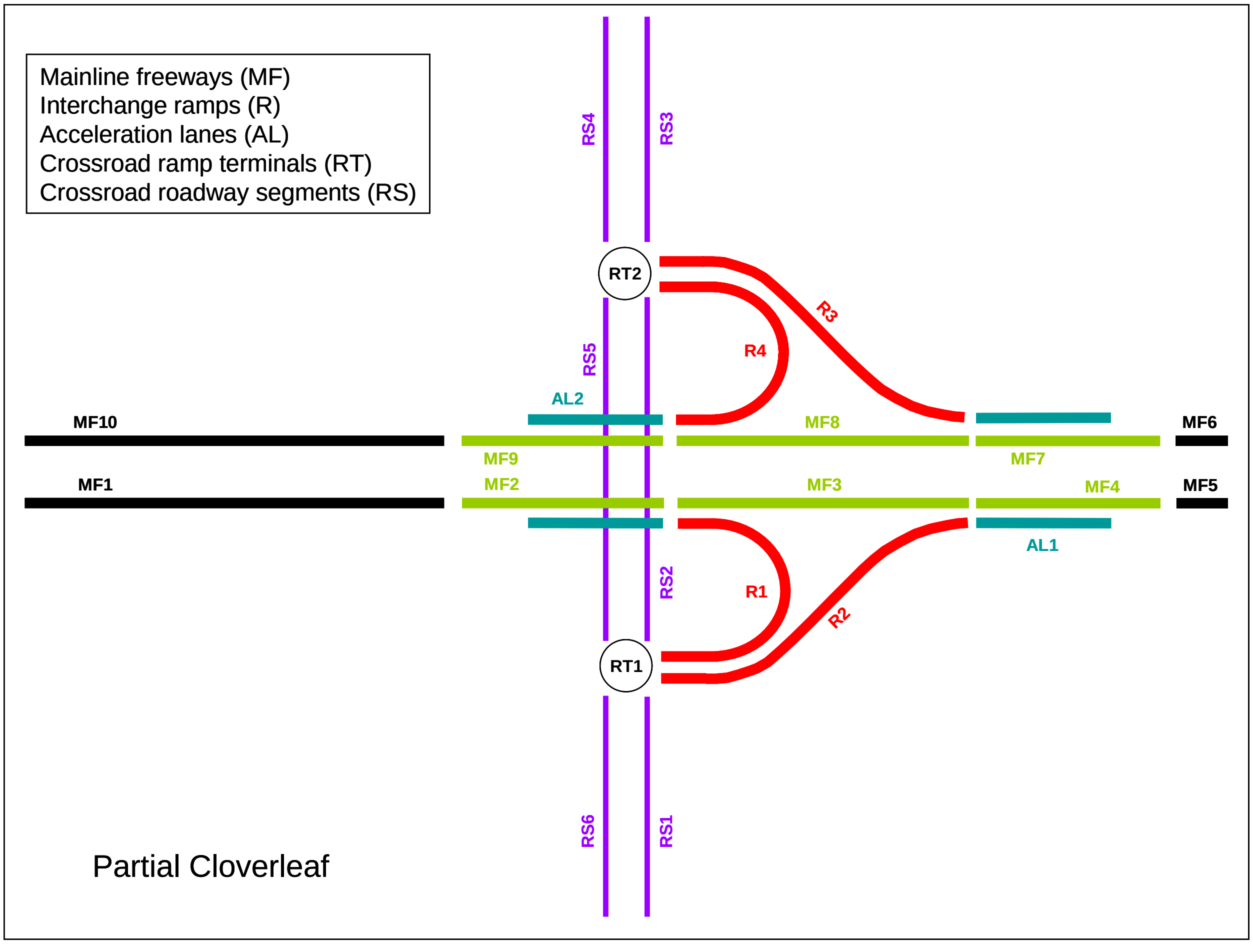


Figure 6. Sample application of ISAT to a partial cloverleaf interchange.

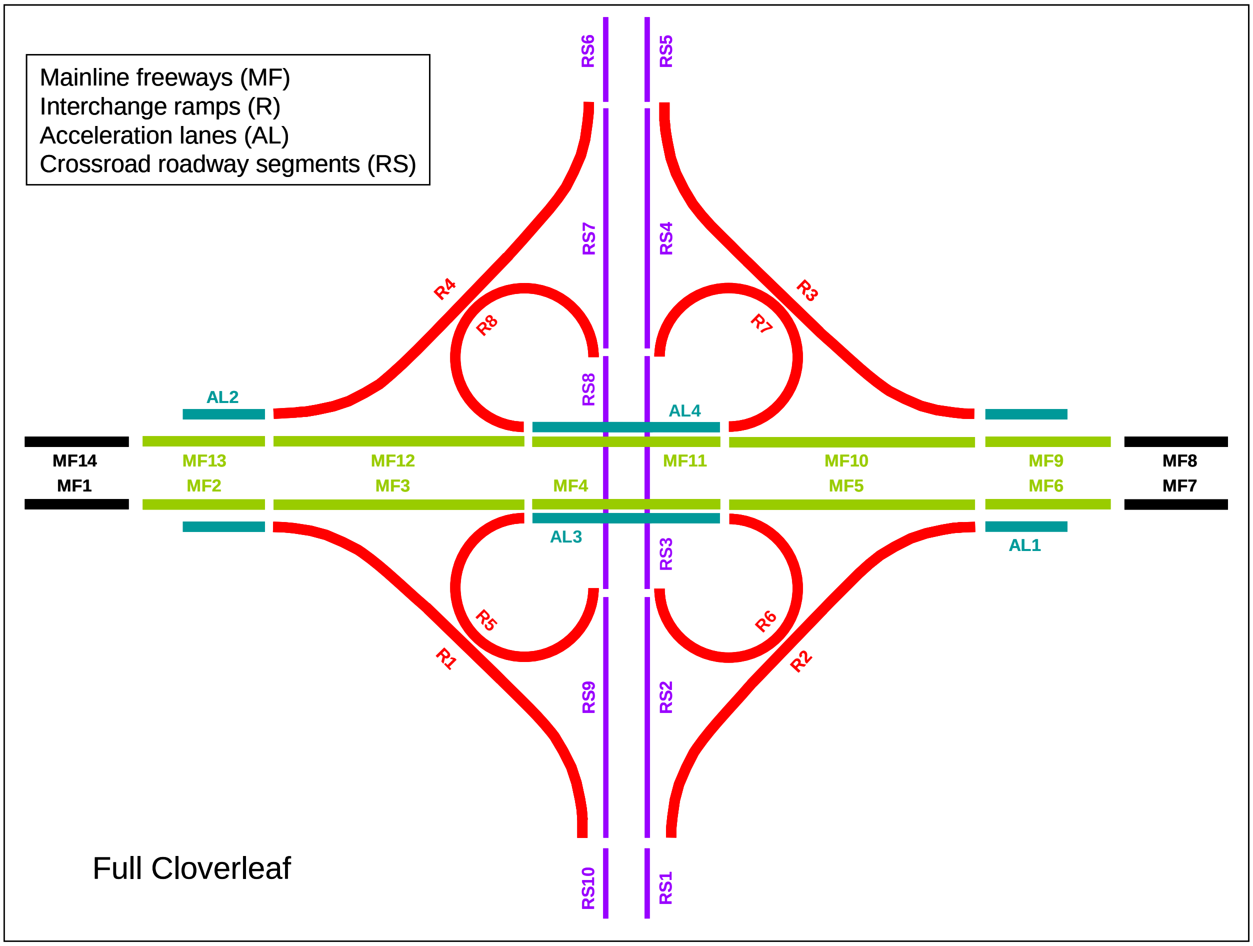


Figure 7. Sample application of ISAT to a full cloverleaf interchange.

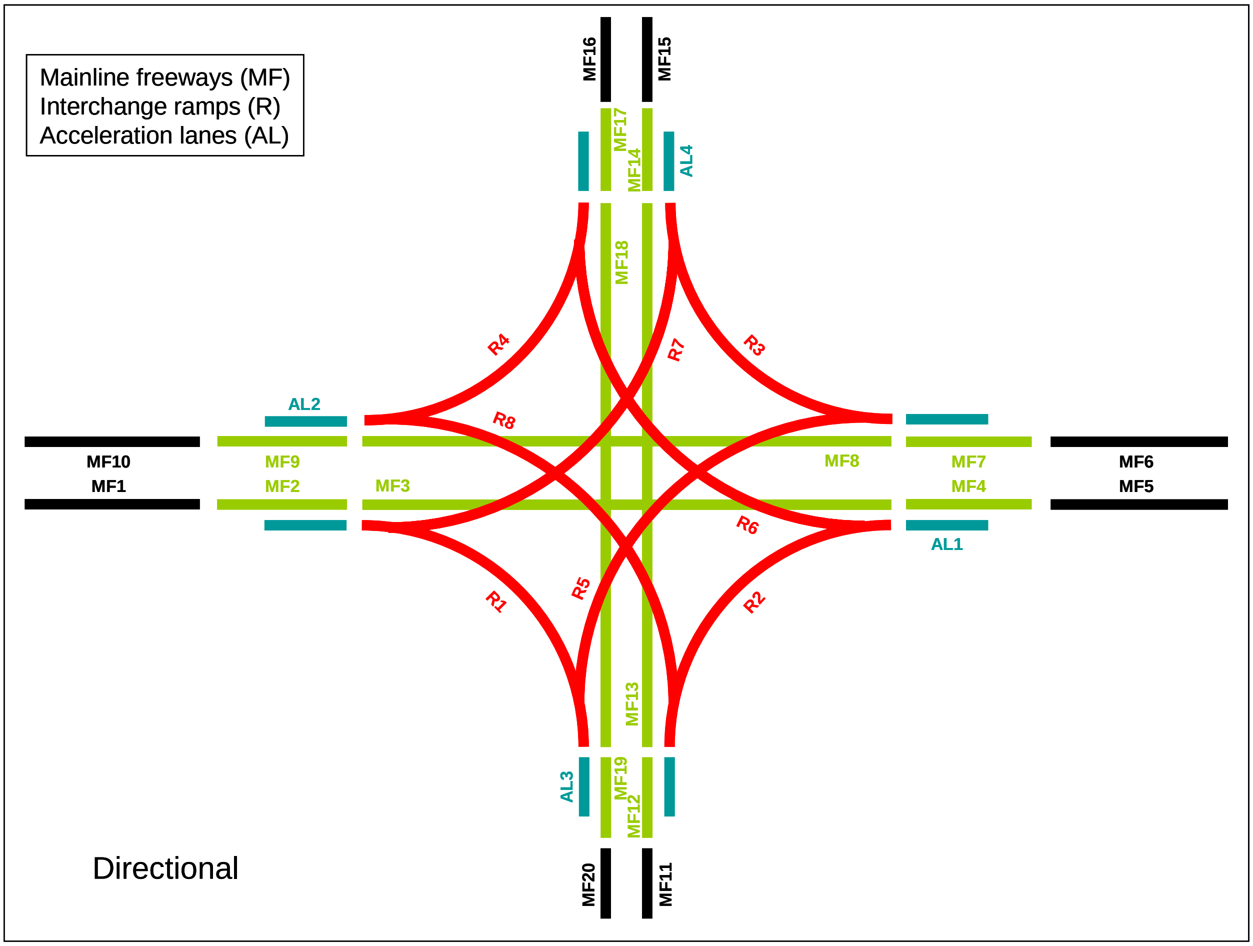


Figure 8. Sample application of ISAT to a directional interchange.

Full Diamond Interchange

The full diamond interchange in figure 5 would be subdivided for analysis purposes as follows:

- Mainline freeway segments MF1, MF5, MF6, and MF10 are located outside the interchange influence area.
- Mainline freeway segments MF2, MF3, MF4, MF7, MF8, and MF9 are located within the interchange influence area. (Note: there are segment breaks at the off- and on-ramp gore areas because the traffic volumes change at those points.)
- Diamond off-ramps R1 and R3 have no acceleration lanes adjacent to the associated mainline freeway segments.
- Diamond on-ramps R2 and R4 have acceleration lanes (i.e., AL1 and AL2) adjacent to the associated mainline freeway segments.
- Crossroad ramp terminals RT1 and RT2 are treated as four-leg intersections.
- Crossroad segments RS1, RS2, RS3, RS4, RS5, and RS6 break at the ramp terminals because the traffic volumes change at those points.

Partial Cloverleaf Interchange

The partial cloverleaf interchange in figure 6 would be subdivided for analysis purposes as follows:

- Mainline freeway segments MF1, MF5, MF6, and MF10 are located outside the interchange influence area.
- Mainline freeway segments MF2, MF3, MF4, MF7, MF8, and MF9 are located within the interchange influence area. (Note: there are segment breaks at the off- and on-ramp gore areas because the traffic volumes change at those points.)
- Parclo loop off-ramp R1 has no acceleration lane adjacent to the associated mainline freeway segment.
- Diamond on-ramp R2 has an acceleration lane (i.e., AL1) adjacent to the associated mainline freeway segment.
- Diamond off-ramp R3 has no acceleration lane adjacent to the associated mainline freeway segment.
- Parclo loop on-ramp R4 has an acceleration lane (i.e., AL2) adjacent to the associated mainline freeway segment.
- Crossroad ramp terminals RT1 and RT2 are treated as three-leg intersections.
- Crossroad segments RS1, RS2, RS3, RS4, RS5, and RS6 break at the ramp terminals because the traffic volumes change at those points.

Full Cloverleaf Interchange

Full cloverleaf interchanges can, at present, be represented only imperfectly in ISAT. Research to develop additional safety prediction models so that ISAT can address full cloverleaf interchanges completely is needed. The full cloverleaf interchange in figure 7 would be subdivided for analysis purposes as follows:

- Mainline freeway segments MF1, MF7, MF8, and MF14 are located outside the interchange influence area.
- Mainline freeway segments MF2, MF3, MF4, MF5, MF6, MF9, MF10, MF11, MF12, and MF13 are located within the interchange influence area. (Note: there are segment breaks at the off- and on-ramp gore areas because the traffic volumes change at those points.)
- Outer-connection off-ramps R1 and R3 have no acceleration lanes adjacent to the associated mainline freeway segments. (Note: ISAT contains no existing models for cloverleaf outer-connection ramps; until more research is completed, it is recommended that cloverleaf outer-connection off-ramps be classified as diamond off-ramps. Furthermore, ISAT does not address acceleration lanes on arterial roadways, so unless the crossroad is also a mainline freeway, acceleration lanes should not be specified for ramps R1 and R3.)
- Outer-connection on-ramps R2 and R4 have acceleration lanes (i.e., AL1 and AL2) adjacent to the associated mainline freeway segments. (Note: ISAT contains no existing models for cloverleaf outer-connection ramps; until more research is completed, it is recommended that cloverleaf outer-connection on-ramps be classified as diamond on-ramps)
- Free-flow loop on-ramps R5 and R7 have acceleration lanes (i.e., AL3 and AL5) adjacent to the associated mainline freeway segments. [Note: ISAT has no explicit safety prediction

models for freeway weaving areas, so the weaving areas between the loop ramps on the mainline freeway (R5/R6 and R7/R8) can only be treated as acceleration lanes at present.]
- Free-flow loop off-ramps R6 and R8 have no acceleration lanes adjacent to the associated mainline freeway segments. [Note: ISAT has no explicit safety prediction models for arterial weaving areas or arterial acceleration lanes, so the weaving areas between the loop ramps on the mainline freeway (R6/R7 and R8/R5) cannot be evaluated at present.]
- Crossroad segments RS1, RS2, RS3, RS4, RS5, RS6, RS7, RS8, RS9, and RS10 break at the ramp terminals because the traffic volumes change at those points.

A full cloverleaf interchange has no crossroad ramp terminals. It should also be noted that ISAT, at present, has no capability to estimate the safety performance of any collector-distributor roads that may be present in cloverleaf interchanges.

Directional Interchange

The directional freeway-to-freeway interchange in figure 8 would be subdivided for analysis purposes as follows:

- Mainline freeway segments MF1, MF5, MF6, and MF10 are located outside the interchange influence area on one freeway, and mainline freeway segments MF11, MF15, MF16, and MF20 are located outside the interchange influence area on the other freeway.
- Mainline freeway segments MF2, MF3, MF4, MF7, MF8, and MF9 are located within the interchange influence area on one freeway, and mainline freeway segments MF12, MF13, MF14, MF17, MF18, and MF19 are located within the interchange influence area on the other freeway. (Note: there are segment breaks at the off- and on-ramp gore areas because the traffic volumes change at those points.)
- Direct connection ramps R1, R2, R3, and R4 have acceleration lanes (i.e., AL1, AL2, AL3, and AL4) adjacent to the associated mainline freeway segments.
- Semidirect connection ramps R5, R6, R7, and R8 join other ramps and, therefore, do not have acceleration lanes on the mainline freeways.

A directional freeway-to-freeway interchange has no crossroad ramp terminals or crossroad segments.

Extended Roadway Networks Near Interchanges

Some users may wish to apply ISAT to estimate the safety performance for extended roadway networks near interchanges. For example, ISAT can be applied to evaluate two or more interchanges in sequence along a freeway or arterial roadway networks that connect interchanges to one another or to nearby development. To evaluate two or more interchanges in sequence along a freeway, all of the mainline freeway segments, ramps, crossroad ramp terminals and intersections, and crossroad segments for the interchanges should be included in the ISAT input data. In addition, the entire mainline freeway between the interchanges should be included in one or more mainline freeway segments in the ISAT input data.

The arterial roadway network surrounding a freeway that connects the interchanges to one another or to nearby development can be evaluated with ISAT. Additional arterial crossroad roadway segments and intersections on the network of interest can be included in the ISAT input data, together with the data for the interchanges themselves. Data for all intersections on arterial roadways in the network should be included in the ISAT input data for crossroad ramp terminals, and data for arterial roadway segments in the network should be included in the ISAT input data for crossroad segments.

The number of interchanges and the extent of the network considered is constrained only by the limit of 50 mainline freeway segments, 50 ramps, 50 crossroad ramp terminals and intersections, and 50 crossroad segments in the ISAT software.

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