APPENDIX C:
PROGRAMMER'S MANUAL
RSAP

Version 3.0.0

N C H R P
22-27

ROADSIDE SAFETY ANALYSIS PROGRAM (RSAP) UPDATE

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INTRODUCTION

This Manual is one of three reports which accompany this software, including a USER'S MANUAL and an ENGINEER'S MANUAL. This manual, the PROGRAMMER'S MANUAL, is intended for those that are maintaining or modifying the actual computer code for RSAPv3. Most typical changes and updates to RSAP can be accomplished using the many lookup tables and do not require any changes to the actual code. Instructions for making changes to the lookup tables are described in the ENGINEER'S MANUAL. When updating the program, the first and preferable choice is to try and make the change using the lookup tables and to change the underlying code only when absolutely necessary. This manual documents the program architecture, the data table specifications and the pseudo-code and provides the necessary background needed to understand the program structure.

The USER'S MANUAL is a reference for program users of all experience levels focusing on how to use the software and access its features. It includes several example problems that illustrate how data should be set up and entered and provides results that can be used to check a user's first runs. The ENGINEER'S MANUAL contains extensive explanations of the analysis methods, the supporting research and data used by the software, background information, explanation of existing software and literature and the potential implementation of this software. The ENGINEER'S MANUAL also contains instructions on how to maintain, modify and update the many lookup tables within RSAP so that the results of new research can be easily incorporated into the program.

BACKGROUND

RSAPv3 uses a conditional encroachment-collision-severity approach to determine the frequency, severity and societal cost of roadside crashes for each user-entered design alternative. These crash costs are then compared to the agency costs (i.e., construction and/or maintenance, etc.) of the proposed alternatives. An alternative which results in a reduction in crash costs greater than the agency costs of the improvement is considered a feasible project. The alternative with the highest benefit (i.e., reduction in crash costs) to agency costs ratio is the "best" alternative. An RSAPv3 analysis is composed of four major steps for assessing each alternative and is, therefore, structured into four modules:

- Encroachment Probability Module,
- Crash Prediction Module,
- Severity Prediction Module, and
- Benefit/Cost Analysis Module.

Each of these four modules are implemented as a code module in RSAPv3. Each code module will be discussed in the chapters and sections below.

OVERVIEW

The analysis technique used by RSAPv3 is based on a series of conditional probabilities. First, RSAPv3 predicts the number of encroachments that can be expected

on a given road segment as a function of the traffic and geometric characteristics of the roadway. Given an encroachment has occurred, the crash prediction module then assesses if the encroachment is likely to result in a crash, $P(Cr|Encr)$. If a crash is predicted, the severity prediction module estimates the severity of the crash, $P(Sev|Cr)$. The severity estimates of each crash are then calculated and transformed into units of dollars in order to compare the reduction in societal crash costs (i.e., benefits) to the direct cost of implementing the alternative (i.e., costs). The following conditional probability model is used for each alternative on each segment:

$$E(CC)_{N,M} = \text{ADT} \cdot L_N \cdot P(Encr) \cdot P(Cr|Encr) \cdot P(Sev|Cr) \cdot E(CC_s|Sev_s)$$

where:

$E(CC)_{N,M}$	=	Expected annual crash cost on segment N for alternative M,
AADT	=	Average Daily Traffic in vehicles/day,
L_N	=	Length of segment N in miles,
$P(Encr)$	=	The probability a vehicle will encroachment on the segment,
$P(Cr\|Encr)$	=	The probability a crash will occur on the segment given that an encroachment has occurred,
$P(Sev_s\|Cr)$	=	The probability that an crash of severity s occurs given that a crash has occurred and
$E(CC_s\|Sev_s)$	=	The expected crash cost of a crash of severity *s* in dollars.

The term ADT·L·P(Encr) yields the expected number of encroachments on a segment in units of encroachments/mi/year. ADT·P(Encr) can be further defined as:

$$ADT \cdot P(Encr) = f_{\underset{encr}{base}} \cdot \prod_{i=1}^{n} EAF_i$$

where the terms are as defined before and $f_{base\ encr}$ is the base encroachment rate in units of encroachments/mi/yr and EAF_i are encroachment adjustment factors. $f_{base\ encr}$ is tabulated on the "Encr Freq and Adj" worksheet in RSAPv3 as are the encroachment modification factors, EAF_i. These values are simple lookup tables where the appropriate adjustment or base encroachment is read from the tables given the geometric and traffic characteristics of the highway provided by the user.

The collision and severity conditional encroachments, $P(Cr|Encr) \cdot P(Sev_s|Cr)$, must be grouped together because each encroachment could have multiple events with different severities. $P(Cr|Encr) \cdot P(Sev_s|Cr)$ can be expanded to:

$$P(Cr|Encr)P(Sev_s|Cr) = \frac{1}{m}\sum_{k=1}^{l}\sum_{j=1}^{m} P(Trj_k \cap Haz_j|Encr)P(Sev_s|Trj_k \cap Haz_j)$$

Where $Trj_k \cap Haz_j$ is the probability that trajectory *k* will intersect hazard *j* and the summation is done over all hazards and all trajectories. RSAPv3 will typically process tens of thousands of trajectories for each segment to arrive at this summation. Each trajectory analyzed is compared to every hazard identified by the user for each alternative. Lastly the expected crash cost of a severity s crash, $E(CC_s|Sev_s)$, is multiplied by the result to convert the result to units of dollars. Combining all the terms yields:

$$E(CC)_{N,M} = L_N \cdot f_{\substack{base \\ encr}} \prod_{i=1}^{n} EAF_i \left[\frac{1}{m} \sum_{k=1}^{l} \sum_{j=1}^{m} P(Trj_k \cap Haz_j | Encr) P(Sev_s | Trj_k \cap Haz_j) \right] E(CC_S | Sev_s)$$

While the encroachment method is conceptually straight forward, estimating the three conditional probabilities at the heart of the method can be difficult and computationally demanding since tens of thousands of possible encroachments must be evaluated. Each of these conditional probabilities are based either on observed encroachment and crash data. Since the computations can be complicated, a computer program like RSAPv3 is the most convenient way to implement the encroachment-based approach in roadside safety analysis.

Each of these condition probabilities is implemented within RSAPv3 as a module. The results of the analysis (i.e., $E(CC)_{N,M}$) are used in the benefit/cost module to compare roadside design alternatives. Project specific data is collected from the user through a series of worksheets within the RSAPv3 user interface. This project specific data is used in conjunction with models based on research stored in other worksheets to preform calculations which are coded in RSAPv3.

Unlike earlier versions of RSAP, RSAPv3 does not use a Monte Carlo simulation method to calculate the probability of a collision given an encroachment. Instead, a deterministic method is used where a sample of real crash trajectories are compared to the roadside and used to perform the double summation in the equation above.

Documented below in four main chapters are the encroachment probability module, crash prediction module, severity prediction module, and the Benefit/Cost module as implemented in RSAPv3. Each chapter documents the program architechture and structure for each of the modules. This document mirrors the structure of the USER'S MANUAL and ENGINEER'S MANUAL to the extent possible. Each manual takes the same general form and references have been made to other manuals to avoid duplication across manuals.

ARCHITECHTURE

BACKGROUND

RSAPv3 is written as a series of Visual Basic for Applications (VBA) macros within Microsoft Excel. The Excel worksheets are used to provide a data entry location for the users as well as to provide project documentation and results to the user. The macros provide user control and input forms and perform the numerous analysis tasks in the background. RSAPv3 was written using VBA 7.0 running under Excel version 14.0 and Microsoft Windows NT 6.01 (i.e., Windows 7 Professional Service Pack 1). RSAPv3 is backwardly compatible with Excel 12 and has been tested with Windows NT, XP and 2007.

To access the VBA code, start any macro-enabled RSAP workbook or template. After the splash screen has disappeared and the RSAP Controls Dialog box has appeared select any cell in any worksheet and press ALT-F11. This starts the VBA editor which appears as another window. The RSAPv3 code is password protected so double clicking the RSAPv3 entry in the "Project" VBA workspace will prompt for a password. Once a

correct password has been entered, the project components are shown (note: the password up through RSAP 3.0.0. Beta Relese 120815 is “roadsafe”).

RSAP COMPONENTS

As is typical for VBA projects, there are three types of project components in RSAPv3 as follows:

- Microsoft Excel Objects
- Forms
- Modules

The Microsoft Excel Objects in RSAPv3 include the following 8 visible and 10 hidden worksheets (note: names in parenthesis are the worksheet names that are displayed in the workbook whereas the primary name is the internal name of the worksheet generally used in the code. Whether the worksheet is by default hidden is also indicated.):

- shAlternatives (Alternatives)
- shDefaults (Defaults) -- hidden
- shEncrAdj (Encr Freq and Adj)
- shPOCplots (POC Plots) – hidden
- shPOCscratch (POC Scratch) – hidden
- shPrgData (Program Data) – hidden
- shPrjInfo (Project Info)
- shProfile (Profile) – hidden
- shRdSegs (Road Segments)
- shRedirectionGridC (Redirection Cars) – hidden
- shRedirectionGridT (Redirection Trucks) – hidden
- shResults (Results)
- shSeverity (Severity)
- shTraffInfo (Traffic Info)
- shXsection (Cross-Section)
- TrajectoryGrid1 (TrajectoryGrid1) – hidden
- TrajectoryGrid2 (TrajectoryGrid2) – hidden
- TrajectoryGrid3 (TrajectoryGrid3) – hidden

The user interacts with RSAPv3 through the RSAP Controls Dialog box and the visible worksheets. The hidden worksheets contain a variety of default data, trajectory information and other data needed by RSAPv3 that the user should not normally need to see. These worksheets are hidden to prevent inadvertent changes in the default data and required program information.

The next type of components are Forms and RSAPv3 has the following forms defined:

- frmRSAPcontrols – this form is the primary means for the user to control the program flow.

- frmProgressBar – this form shows a progress bar during the analysis phase showing the percentage of completion as well as some trajectory selection messages.
- frmRSAPsplash – this form is a simple splash screen that appears and disappears when RSAPv3 is started.
- frmXsectionChoice – this is a minor selection input form for the selection of x-section data that is called by frmRSAPcontrols.

RSAPv3 is an event-driven piece of software meaning that the exact process flow is determined by the user through the choice and order of buttons that are selected. There is no overall "flow chart" of information flow since the user can move around the program in any order they wish with the exception that all input has to be complete before the "Run" button on frmRSAPcontrols is selected. This event-driven structure is enabled primarily by the frmRSAPcontrols form.

The last type of component in the RSAPv3 VBA project are code modules. There are nine RSAPv3 code modules:

- moduleAlternatives – contains code that supports the Alternatives worksheet.
- moduleEncroachments – contains code that calculates the base encroachment rate, applies adjustments and performs other tasks in support of the Road Segments worksheet.
- moduleMain – is the main program control for the analysis.
- modulePOCanalysis – contains code that performs the collision analysis.
- modulePOChaz – contains code that reads the hazard information and processes it in support of modulePOCanalysis.
- modulePOCtraj – contains code that selects, grades and processes trajectories in support of modulePOCanalysis.
- moduleResults – contains code that organizes and processes the results and creates the information on the Results worksheet.
- moduleTools – contains a variety of code that acts in support of RSAPv3 but is not associated with any particular worksheet or form.
- moduleXsection – contains code that supports the X-Section worksheet.

CONVENTIONS

Each of these worksheets, forms and code modules will be described in later portions of this manual. The following convention has generally been used throughout the RSAPv3 code:

- "sh" designates an MS Excel worksheet,
- "frm" designates a VBA form,
- "btn" designates a command button,
- "lbl" designates a label form,
- "module" designates a VBA code module,
- "txt" designates a text box form,
- "rbtn" designates a radio-button form and

- "txt" designates a text box.

Subroutine and method names generally start with one of the fore-going designations to help clarify the type of object that is being instantiated.

RSAP uses several worksheet cell styles to inform the user about where input can and cannot be placed. RSAP uses the following styles which can be found in Excel under the Home>Cell Styles group:

- Input – this style indicates cells where the user must enter information. This is the project specific information so there are no default values. This cell style has a yellow highlighted background to indicate user input is expected. This style is also by default unprotected.
- Input2 – this style indicates cells where the user may provide input but where RSAP will provide a default value. The cells are high-lighted rose and are unprotected.
- Heading1, Heading2, Heading3, Heading4, Normal 2—these four styles are used to format the RSAP worksheets with a variety of font sizes and font types. They user cannot change these cells as they are protected.

RSAP generally uses standard Excel format for number with one important exception. A custom style "0+##.00;##+##.##;0+00.##" has been added to display Station number in the traditional highway engineering format (i.e., the location 345.67 feet from the start of the project is Station 3+45.67). This is only a display format meaning the number is entered into the cell as 345.67 but will be displayed as 3+45.67. All cells that indicate station input have validation rules attached such that if the "+" sign or any other non-numeric character is typed an error will be displayed.

Most cells that accept user input (i.e., cell styles "Input" and "Input2") have validation rules attached to prevent invalid data from being entered. For example, if a positive numeric value is needed a validation rule requires the cell field to be input as such. The many validation rules are not described herein but they can easily be identified by selecting cell of interest, going to Data>Data Validation>Data Validation and examining the rule appropriate for that particular cell.

PROGRAM INITIATION

RSAPv3 is started whenever an RSAP macro-enabled worksheet or template is started in MS Excel and involves three subroutines found in moduleTools:

- AutoOpen
- StartRSAP
- ProcessPrioritySet

The subroutine moduleTools.AutoOpen() automatically starts when an RSAP workbook is opened. This subroutine does the following:

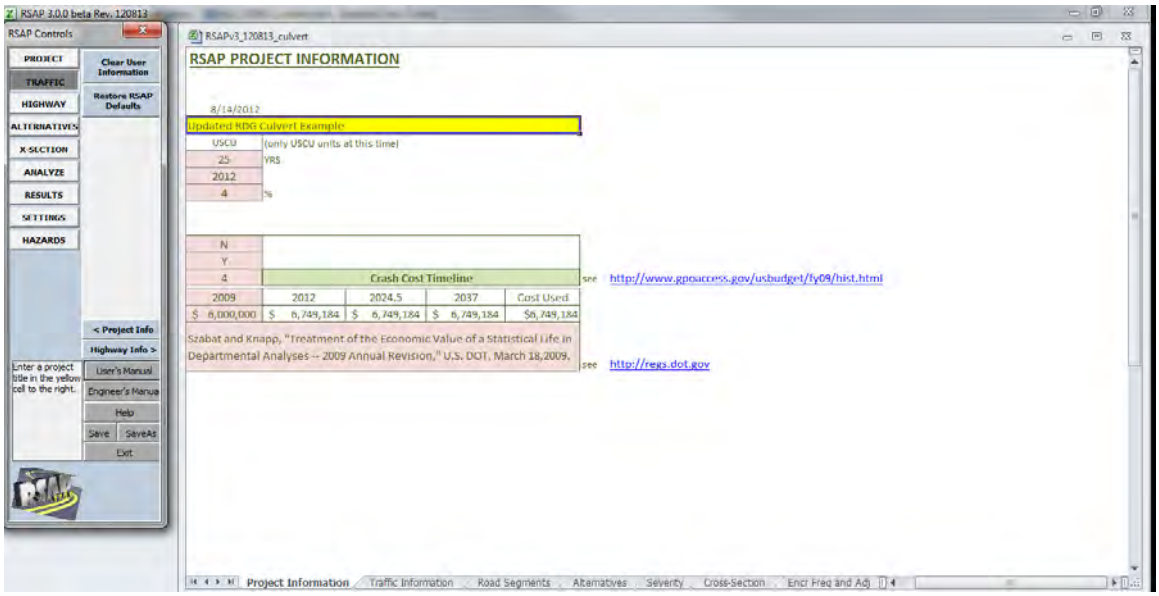
- *Unload any open forms so they do not conflict with the new instance of RSAPv3.*

- *Hide the standard excel ribbons interface and set up the standard RSAPv3 view.*
- *frmRSAPsplash displays the opening splash screen for 5 seconds*
- *moduleTools.StartRSAP starts the RSAP program.*

The subroutine moduleTools.Start RSAP actually starts the RSAP run as follows:

- *Sets up the application display to the RSAP default style*
- *ProcessPrioritySet(High) ‘ set the process priority to high so RSAP fall into the background processes.*
- *Load frmRSAPcontrols ‘ this starts the RSAP Control Dialog box*
- *Select shPrjInfo as the starting place for input*

When moduleTools.StartRSAP completes the application screen should look like Figure 1. If, for any reason, the RSAP controls dialog disappears, RSAPv3 can be re-started manually with the keystroke CTRL+s which is a keystroke macro that simply re-runs moduleTools.StartRSAP. No information on the worksheets is lost when selecting CTRL+S but any settings in the RSAP Controls Dialog box are re-set to their default values.



PROJECT INPUT AND CONTROL

RSAP CONTROLS DIALOG BOX

The RSAP controls dialog box is shown in Figure 2 and is initiated using the Show method executed from modulesTools.StartRSAP(). The RSAP controls dialog

box is defined in the object frmRSAPcontrols which is a standard VBA User Form. The main portion of the form a multipage form (i.e. mpControls) with a label in the lower left (i.e., lnlNextStepHint) and six command button forms (i.e., btn UserMan, btnEngMan, btnRSAPhep, btnSave, btnSaveAs, and btnExit). Figure 2 also shows the tab and button bindings indicating which subroutine or method is executed when the button or tab is pushed. frmRSAPcontrols has no input variables, constants or public variables other than the standard VBA User Form properties.

Pressing the tabs executes the frmRSAPcontrols.mpControls_Change() method which activates the appropriate worksheet, indicated on the left side of Figure 2 and sets the value of frmRSAPcontrols.mpControls.value. Each of the tabs will be discussed in detail below. The buttons that appear in the "context sensitive" area of Figure 2 are determined by the value of frmRSAPcontrols.mpControls.value.

The six command buttons at the bottom of the RSAP Controls Dialog shown in Figure 2 are always visible and available to the user. Pressing the buttons activates the method indicated in Figure 2. For example, pressing the "User's Manual" button executes the frmRSAPcontrols.btnUserMan_Click() method which opens a window with the User's Manual in it. These six buttons are briefly described below:

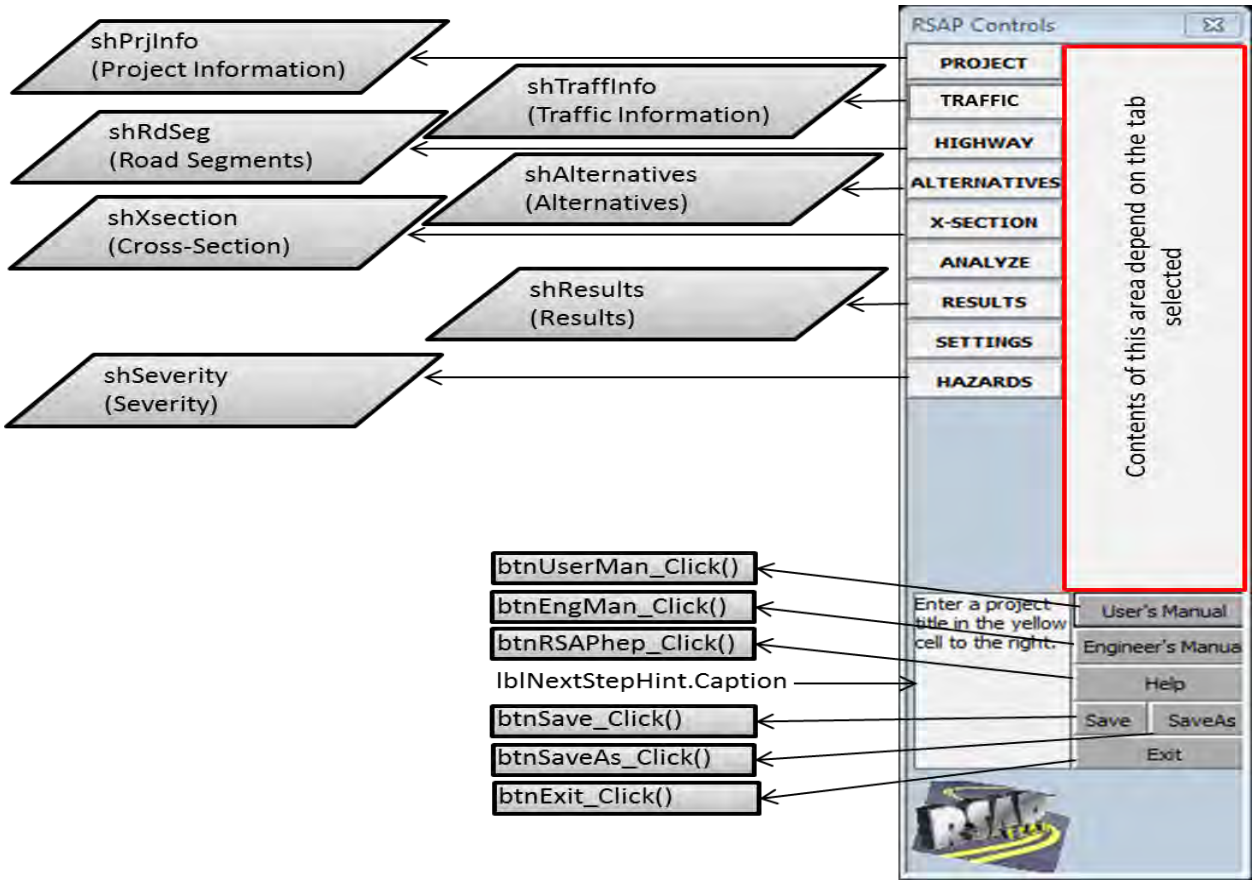


Figure 2. RSAP Controls Dialog -- tab and button bindings.

btnUserMan_Click()

This button displays a PDF copy of the User's Manual. RSAP first looks for the User's Manual file (i.e., RSAPv3userManual.pdf) in C:\Program Files\RSAPv3. If it does not find the file there it looks in the RSAP home directory stored in the "Program Information" worksheet in cell B24. If the file is not found in either of these places RSAP attempts to load the file from the Internet at http://rsap.roadsafellc.com/RSAPv3userManual.pdf. If even this fails an error message is displayed. Regardless of the file location, the file is displayed using the ActiveWorkbook.FollowHyperlink method; both local files and internet files are displayed using the same method.

btnEngMan_Click()

This button displays a PDF copy of the Engineer's Manual and the code is identical to the btnUserMan_Click() subroutine except the Engineer's Manual (i.e., the file name is RSAPv3EngineersManual.pdf).

btnRSAPhelp_Click()

This button opens the RSAP help file. The help file is a Microsoft Compile HTML help file (i.e., the file extension is .chm). The file RSAP.chm is distributed with RSAPv3 and is usually located in the C:\Program Files\RSAPv3 subdirectory. RSAP first looks for the file in the location specified in the public variable moduleTools.helpfile. If it does not find the file there it looks in the RSAP home directory stored in the "Program Information" worksheet in cell B24. If the help file is not found in either of these locations an error message is displayed and the Windows default help screen appears.

btnSave_Click()

This button saves the workbook using the existing workbook name property using the ActiveWorkbook.SaveAs method when the filename property is set to the current workbook name property.

btnSaveAs_Click()

This button prompts the user for a file name to save the current workbook. RSAP can be started from either a macro enabled template (i.e., an xltm file) or a macro-enabled workbook (i.e., an xlsm file). RSAP will not allow the user to save a project as a template, only as a macro-enabled workbook. This prevents unintentional overwriting of the source blank workbook template.

The method starts by setting the current workbook name property to the temporary variable "currentName." The Application.GetSaveAsFilename method is called which brings up a standard Windows file browser where the user indicates the desired filename and directory. If the filename returned by the GetSaveAsFilename method is valid the file is saved.

btnExit_Click()

This button simply issues the Application.Quit method and thereby indirectly executes the workbook_BeforeClose method of Excel. In RSAP the BeforeClose method

simply returns the ribbon interface back to its normal Excel settings so that when the user opens a non-RSAP workbook the interface will appear as the standard Excel interface.

lblNextStepHint.Caption

The last always-visible feature of the RSAP Controls Dialog shown in Figure 2 is the NextStepHint label. This area on the RSAP Controls Dialog is used to provide hints to the user about the next appropriate input step. This is accomplished by RSAP setting a text string equal to the lblNextStepHint.Caption property of frmRSAPcontrols. Many different subroutines and functions write into this text box depending on the context. The user cannot enter data in this locations; it is only for RSAP to write out text hints.

The lblNextStepHint label form can be hidden using the "Verbose Mode Off" button in the Settings tabs as will be described later. The label is hidden by setting the form property lblNextStepHint.Visible to FALSE.

PROJECT INFORMATION WORKSHEET

The "Project Information" worksheet is used to collect basic project information from the user like a project name, the design life, rate of return, construction year, etc. as shown in Figure 3. (Note: Figure 3, like other screen shots of the worksheet in this manual, shows the worksheets with the row and column labels on. This is not the normal RSAP default but they are shown that way in this manual to aid in referring to the cell locations in the text). The only required information is the project name in cell B5, indicated in yellow in Figure 3. The rose colored cells may be changed by the user but contain RSAP default values.

Selecting the "Project" tab in the RSAP Controls Dialog or selecting the "Program Information" worksheet tab will set the frmRSAPcontrols.mpControls.Value property to "0" , display the context sensitive buttons as shown in Figure 4 and activate the Project Information worksheet (i.e., shPrjInfo).

The Project Information view of RSAP Controls shown in Figure 4 includes five command buttons which will be described below. The user can either select button on the RSAP control form or select a "yellow" or "rose" user input cell on the worksheet in order to enter information.

Activate Method

Selecting the "Project" tab on the RSAP Dialog Controls or the "Project Information" tab in the Excel worksheet tabs instantiates the shPrjInfo.Worksheet_Activate() method. In the case of shPrjInfo, RSAP simply checks to see if there is any input in cell B5 (i.e., the project name). This is the only required information on the "Project Information" worksheet although there are a number of other default values that can be changed. If shPrjInfo.Range("B5") value is not blank, the "Traffic Info >" button is set to visible indicating that it is appropriate to move on to the next worksheet. If shPrjInfoRange("B5").Value="" (i.e., is equal to blank) the "Traffic Info >" remains hidden.

Lastly, shPrjInfo is selected and control is returned to frmRSAPcontrols.

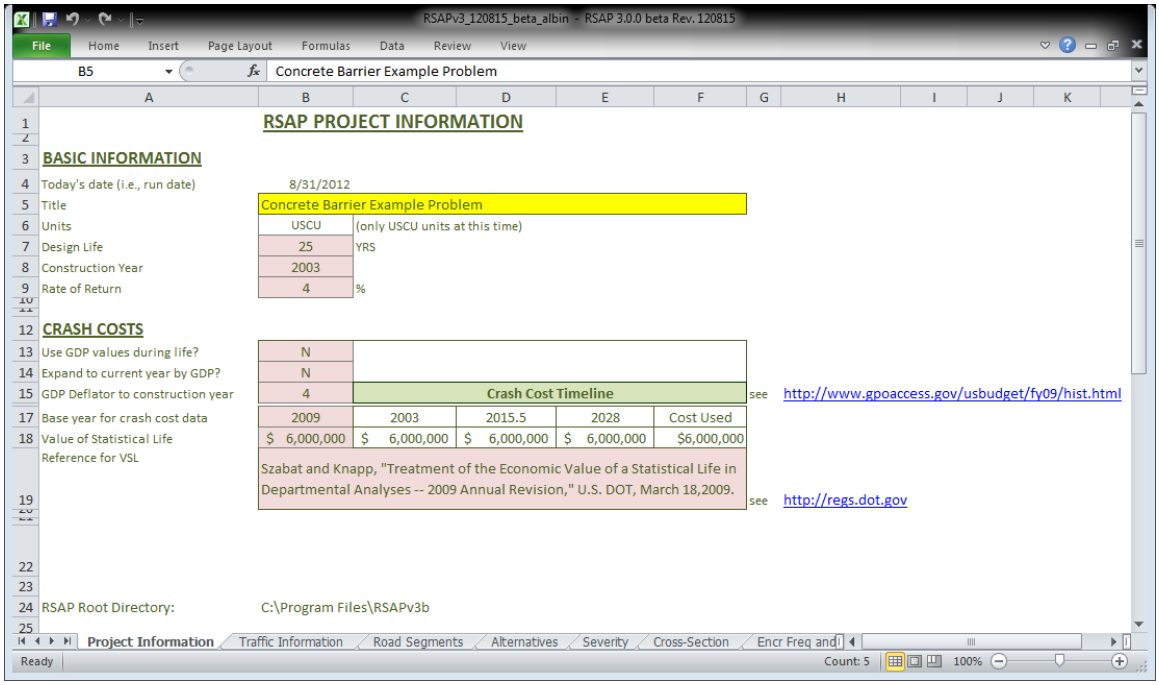


Figure 3. Project Information Worksheet.

Change() Method

Whenever a value on the Project Information worksheet is changed this method is activated. It simply checks to see if shPrjInfo.Range("B5") has a value. If it does, the "Traffic Info >" button is made visible. If there is no value, the "Traffic Info >"""" button is hidden.

btnNewPrj_Click()

The purpose of this method is to allow a user to clear any data from the worksheet and start a new fresh project. The method is executed by pressing the "Start a New Project" button shown in Figure 4. The method first notifies the user that all user entered information in the workbook will be removed and the RSAP defaults restored using a standard vbYesNo message box. If the user responds "No" the method exits. If the user responds "Yes", the following steps take place:

Notify user all data will be deleted in a Msgbox and ask if they want to proceed
If user_response= YES then
Turn off event processing
Turn off screen updating
Unprotect all user input sheets.
Clear the content of user input cells of each worksheet.
Restore the RSAP defaults by copying the appropriate ranges from shDefaults to the appropriate user input worksheet.
Select shPrjInfo.
Move the cursor to cell B5.

Reprotect all the user input sheets.
Re-enable event processing.
Re-enable screen updating
Set the Next button visibility to FALSE
End if

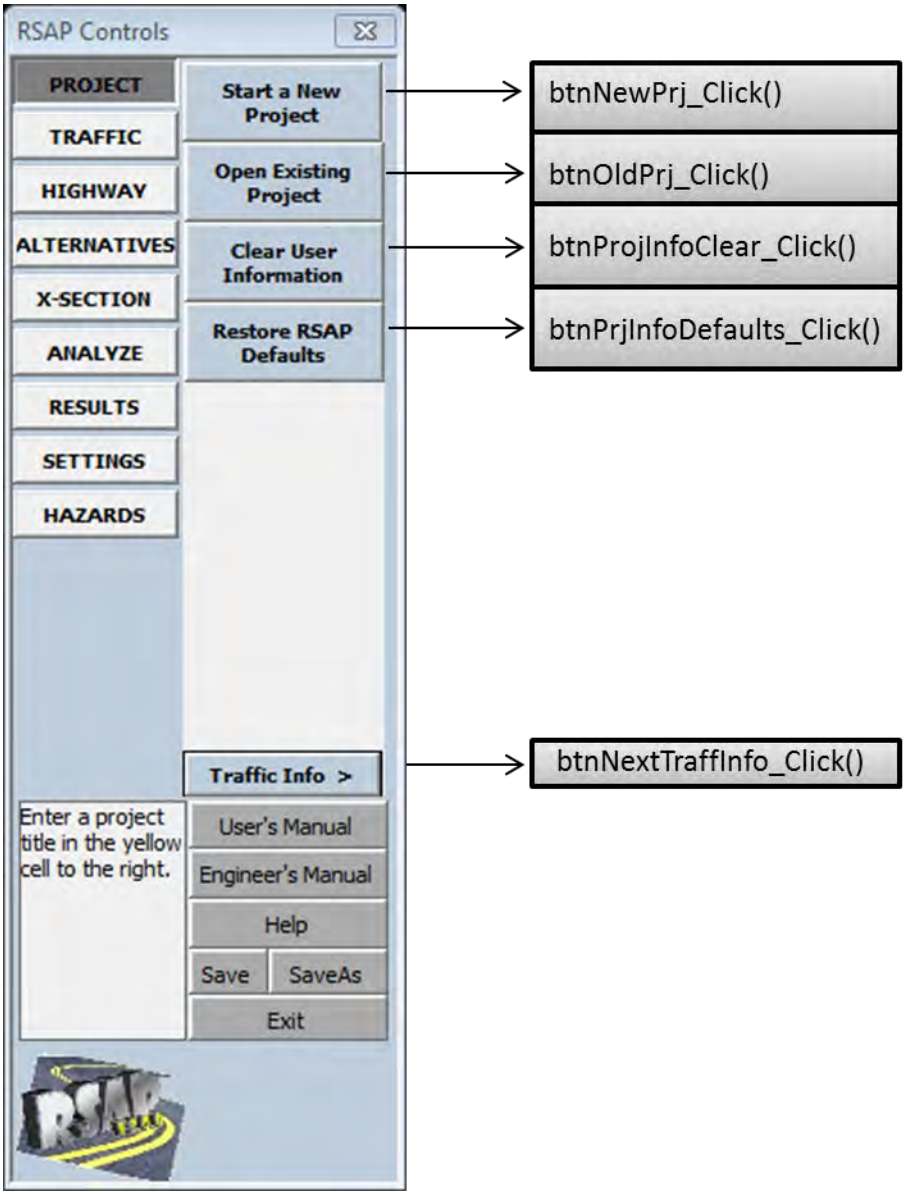


Figure 4. RSAP Controls Dialog -- Project Information.

btnOldPrj_Click()

This method is executed by pressing the "Open Existing Project" button shown in Figure 4. The purpose of this method is to allow the user to read in an already existing RSAP project file. Only the input data is read in and not the results. Once the data has

been read in it can be either changed or analyzed using the usual procedures. The procedure is as follows:

Notify user all data will be deleted in a Msgbox and ask if they want to proceed
If user_response= YES then
Disable events
Disable alerts
Disable screen updating
Unprotect all user input sheets
Go through each sheet and clear all user entered data
Go through each sheet and restore all RSAP defaults
Open the existing file with Workbooks.Open
If filename<>FALSE then 'file name is valid and exists
For all user input worksheets
Copy user input cells from old worksheet
PasteVavles user input cells into active worksheet
moduleEncroachments.sortRoadChars 'Sort the road characteristics
moduleEncroacments.segChars 'segment the project
btnEncr_Click() ' estimate the number of encroachments
shPrjInfo.Select ' go back to the Project Information worksheet
Re-protect all user sheets
Re-enable events
Re-enable screen updating
Re-enable alerts.
End if

btnProjInfoClear()

This method is executed by pressing the "Clear User Information" button shown in Figure 4. Unlike btnNewPrj_Click() which clears all user input in the workbook, this method only clears information on the Project Information worksheet.

Show Msgbox asking if the user really wants to clear the information
If user_choice = no then
Exit
Else
Unprotect shPrjInfo
shProjInfo.Range("B5").ClearContents
frmRSAPcontrols.btnNextTraffInfo.Visible=false
Protect shPrjInfo
End if

btnPrjInfoDefaults()

The purpose of this method is to allow a user to restore the RSAP default information to the "rose" colored cells (i.e., style "Input2")on the "Project Information" worksheet. Any information that has been changed in these cells will be overwritten.

Show Msgbox vbYesNo asking if the user really wants to clear the information and restore the RSAP defaults.
If user_choice = YES then
Unprotect shPrjInfo
shProjInfo.Range(""B5:I5").ClearContents
frmRSAPcontrols.btnNextTraffInfo.Visible=false
Protect shPrjInfo
End if

btnNextTraffInfo_Click()

The "Traffic Info>" button advances the control to the "Traffic Information" worksheet. The button will not appear until there is user input in cell B5 of the "Project Information" worksheet. Selecting the button execute this method which simply selects the "Traffic Information" worksheet (i.e., shTraffInfo), selects cell C3 in that worksheet and set the value of frmRSAPcontrols.mpControls.value=1.

TRAFFIC INFORMATION WORKSHEET

The "Traffic Information" worksheet is used to collect information from the user about the traffic volume, traffic mix and vehicle properties as shown in Figure 5. The rose colored cells may be changed by the user but contain RSAP default values.

Selecting the "Traffic" tab in the RSAP Controls Dialog or selecting the "Traffic Information" worksheet tab will set the frmRSAPcontrols.mpControls.Value property to "1" , display the context sensitive buttons as shown in Figure 5and activate the Traffic Information worksheet (i.e., shTraffInfo).

The Traffic Information view of RSAP Controls shown in Figure 6. Figure 4 includes four command buttons which will be described below. The user can either select buttons on the RSAP control form or select a "yellow" or "rose" user input cell on the worksheet in order to enter information.

The worksheet itself contains the following formulae in the protected cells indicated:

Cell	**Formula**
C6	=$C$3*(1+C$4/100)^('Project Information'!$B$7/2)
C7	=$C$3*(1+C$4/100)^('Project Information'!$B$7)
C8	=IF($C$5="Construction",C3,IF($C$5="End of Life",$C$7,$C$6)
C26	=Sum(C13:C16)

The formula in cell C6 calculates the projected AADT for the midlife using the AADT supplied in Cell C3, the traffic growth supplied in Cell C4 and half the project life previously supplied on the Project Information worksheet in cell B7. The formula in cell C7 is identical except the whole project life is used to calculate the AADT at the end of the project life. The AADT used in the benefit-cost calculations is shown in cell C8 based on the user's choice in cell C5. The formula in cell C26 simply sums the percent of traffic for each vehicle type. A validation rule is applied such that if the value is not equal to exactly 100.00 the cell is colored red. The user is not permitted to proceed until the sum is 100.00.

Activate Method

Selecting the "Traffic" tab on the RSAP Dialog Controls or the "Traffic Information" tab in the Excel worksheet tabs instantiates the shTraffInfo.Worksheet_Activate() method. In the case of shTraffInfo, RSAP simply checks to see if there is any input in user cells and either displays the "Highway Info" button if there is or leaves it blank if there is not.

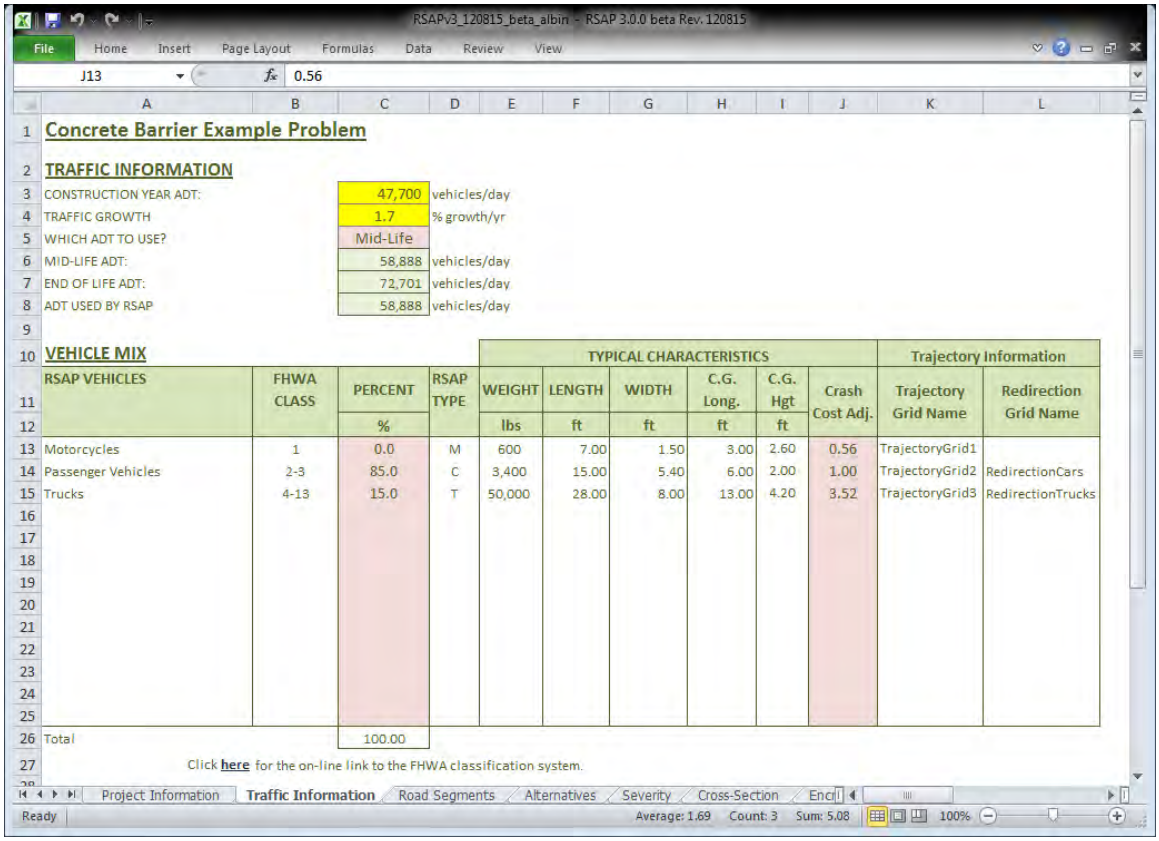


Figure 5. Traffic Information Worksheet.

Change() Method

Whenever a value on the Traffic Information worksheet is changed this method is activated. It simply checks to see if shTraffInfo.Range("C3:C4") has a value using moduleTools.RangeIsMT subroutine. If C3C4 has values, the "Highway Info >" button is made visible. If there is no value, the "Highway Info >" button is hidden.

btnClearTraffInfo_Click()

Selecting the "Clear User Information" on this form executes this method which is active only on the "Traffic Information" worksheet. The user is asked if the really want to delete all the traffic information, if they respond YES then all the yellow INPUT cells are cleared of their content. The "Highway Info >" next button is hidden unless all the yellow INPUT cells have values.

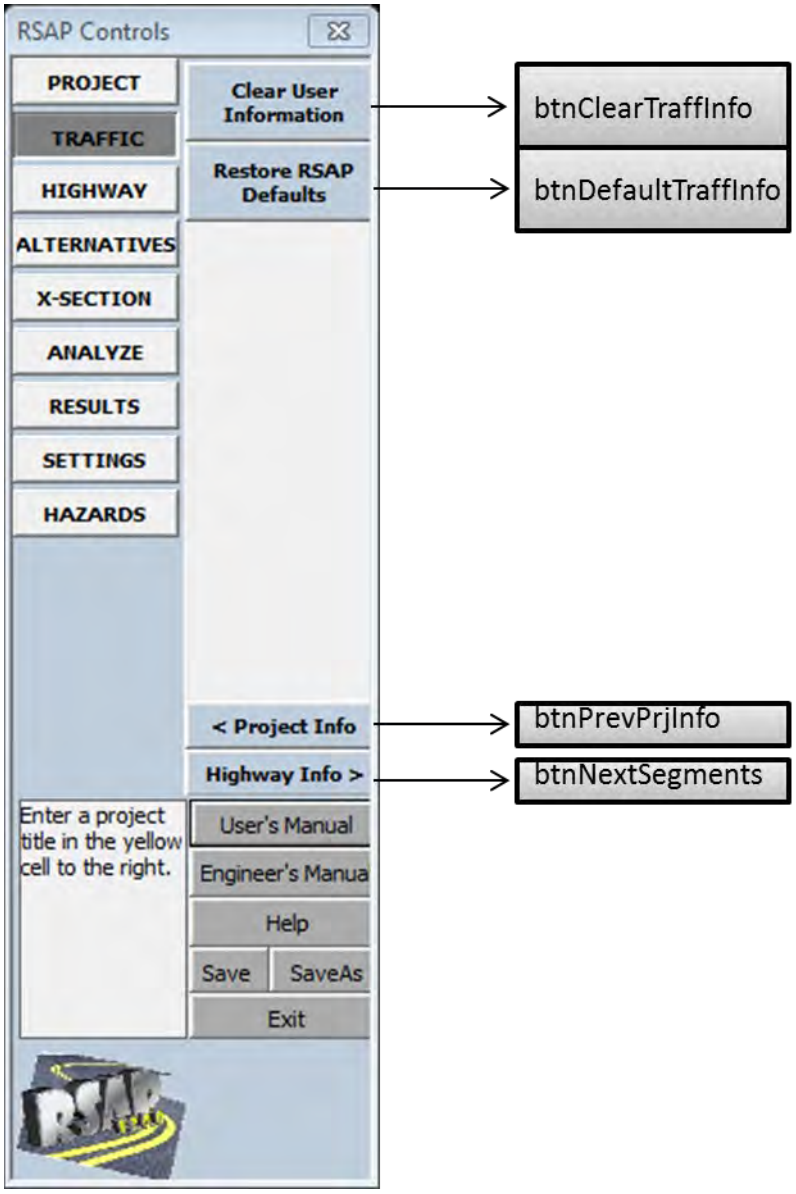


Figure 6. RSAP Controls Dialog -- Traffic Information.

btnDefaultTraffInfo_Click()

Selecting the “Restore RSAP Defaults” on this form executes this method which is active only on the “Traffic Information” worksheet (i.e., only information on the “Traffic Information” worksheet is deleted or overwritten). The user is asked if the really want to delete all the traffic information, if they respond YES then all the rose INPUT 2cells are cleared of their content and the appropriate default values are copied from shDefaults. The “Highway Info >” next button remains hidden unless all the yellow INPUT cells have values.

btnPrevProjInfo_Click()

The “<Project Info” button returns the control to the previous “Project Information” worksheet. Selecting the button executes this method which simply selects the “project Information” worksheet (i.e., shprojInfo)and sets the value of frmRSAPcontrols.mpControls.value=0.

btnNextSegments_Click()

The “Highway Info>” button advances the control to the “Road Segments” worksheet. The button will not appear until there is user input in all the yellow cells in the “Traffic Information” worksheet (i.e., style “Input”). Selecting the button executes this method which simply selects the “Road Segments” worksheet (i.e., shRdSegs), and set the value of frmRSAPcontrols.mpControls.value=2.

ROAD SEGMENTS WORKSHEET

The “Road Segments” worksheet is used to collect information from the user about the characteristics of the roadway as shown in Figure 7 and Figure 8. The rose colored cells may be changed by the user but initially contain RSAP default values; the yellow cells require user input.

Selecting the “Highway” tab in the RSAP Controls Dialog or selecting the “Road Segments” worksheet tab will set the frmRSAPcontrols.mpControls.Value property to 2 , display the context sensitive buttons as shown in Figure 9 activate the Road Segments worksheet (i.e., shRdSegs). The initial worksheet view will be similar to Figure 7.

The Road Segments view of RSAP Controls shown in Figure 9Figure 4 includes ten command buttons which will be described below. The user can either select buttons on the RSAP control form or select a “yellow” or “rose” user input cell on the worksheet in order to enter information. The Road Segments worksheet has two input areas. The first is the Whole Roadway Characteristics area at the top of the worksheet (i.e., shRdSegs.Range(E3:E8) and the second is the User Entered Characteristics area in shRdSegs.Range(A98:D587). The user is taken to the User Entered Characteristics area when the “Enter Highway Characteristics” button is selected.

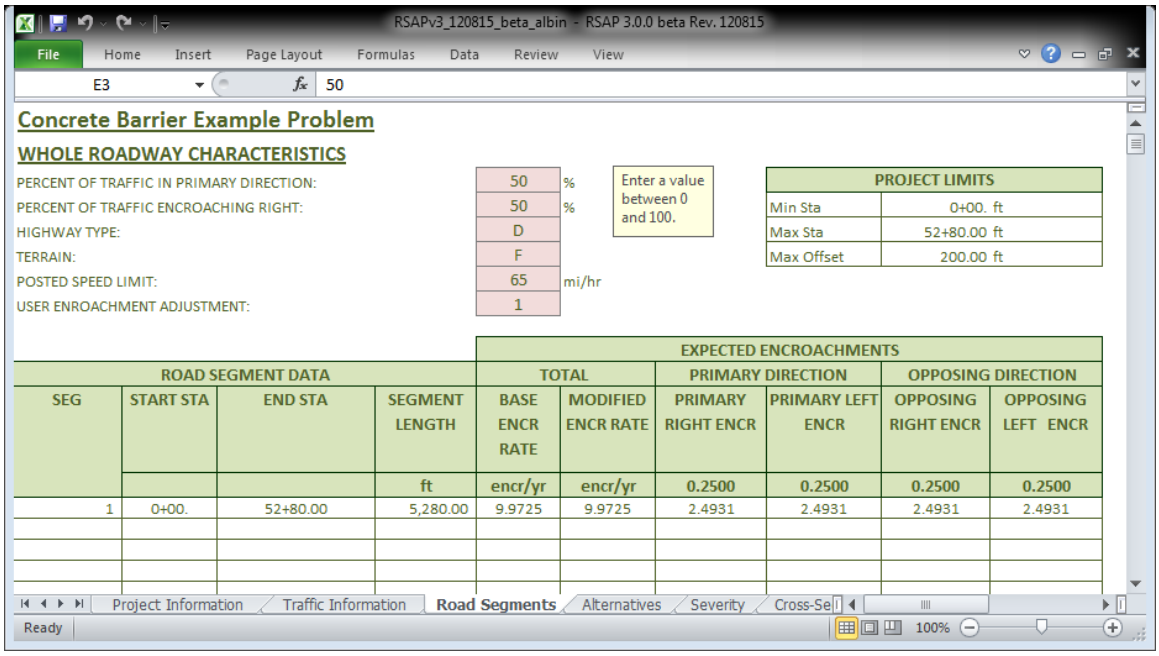


Figure 7. Road Segments Worksheet – Whole Roadway Characteristics Input Area.

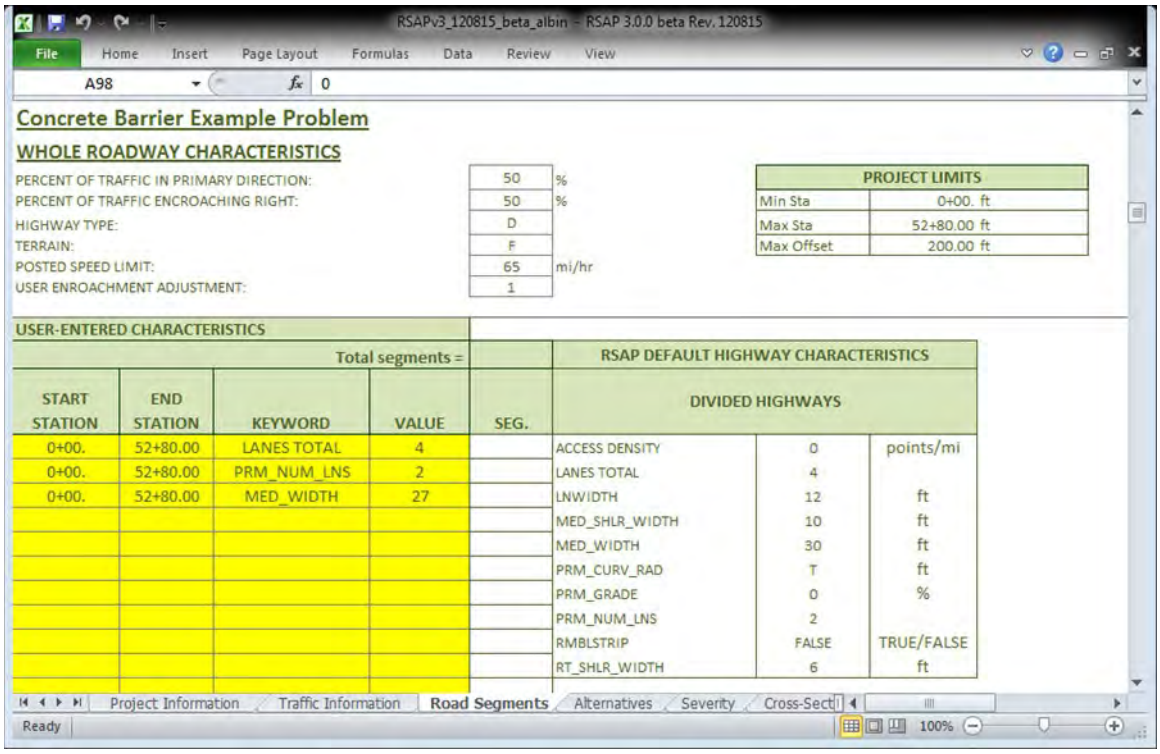


Figure 8. Road Segments Worksheet – User Entered Characteristics Input Area.

The Expected Encroachments Table has a variety of formulae coded into the worksheet as described below. The descriptions below apply to rows 14 through 33 where ROW would be replaced by the particular row number.

Column	Formula
A	=IF(D64>[ROW-13],[ROW-13],"")
F	=IF(D[ROW]="","",SUM(G[ROW]:J[ROW]))
G	=IF(D[ROW]="","",E14*G13*PRODUCT(B[40+ROW]:D[40+ROW], H[40+ROW]:N[40+ROW])
H	=IF(D[ROW]="","",E14*H13*PRODUCT(B[40+ROW]:D[40+ROW], H[40+ROW]:N[40+ROW])
I	=IF(D[ROW]="","",E14*I13*PRODUCT(E[40+ROW]:N[40+ROW])
J	=IF(D[ROW]="","",E14*J13*PRODUCT(E[40+ROW]:N[40+ROW])

The formula in column A simply writes the appropriate segment number starting with segment 1 in ROW=14 based on the total number of segments as listed in cell D64. The formulae in columns G through J calculate the adjusted number of expected encroachments for each encroachment type (i.e., PR, PL, OR and OL). The adjustments are multiplied together in the PRODUCT statement and then multiplied by the total encroachments in column E and multiplied by the proportion attributable to the particular encroachment from ROW 13. The column F formula sums up the total number of encroachments based on the estimates for the four types of encroachments listed in columns G through J provided that the segment number in column D is not blank.

Activate Method

Selecting the "Highway" tab on the RSAP Dialog Controls or the "Road Segments" tab in the Excel worksheet tabs instantiates the shRdSegs.Activate() method. In the case of shRdSegs, RSAP sets frmRSAPcontrols.mpControls.value=2 to shift to the appropriate control form, makes the default buttons visible (i.e., the view shown in Figure 9) and then changes the styles of range E3:E8 to "Input2" in order to accept user input and sets the styles of range A98:D587" to "Normal2" to prevent user input.

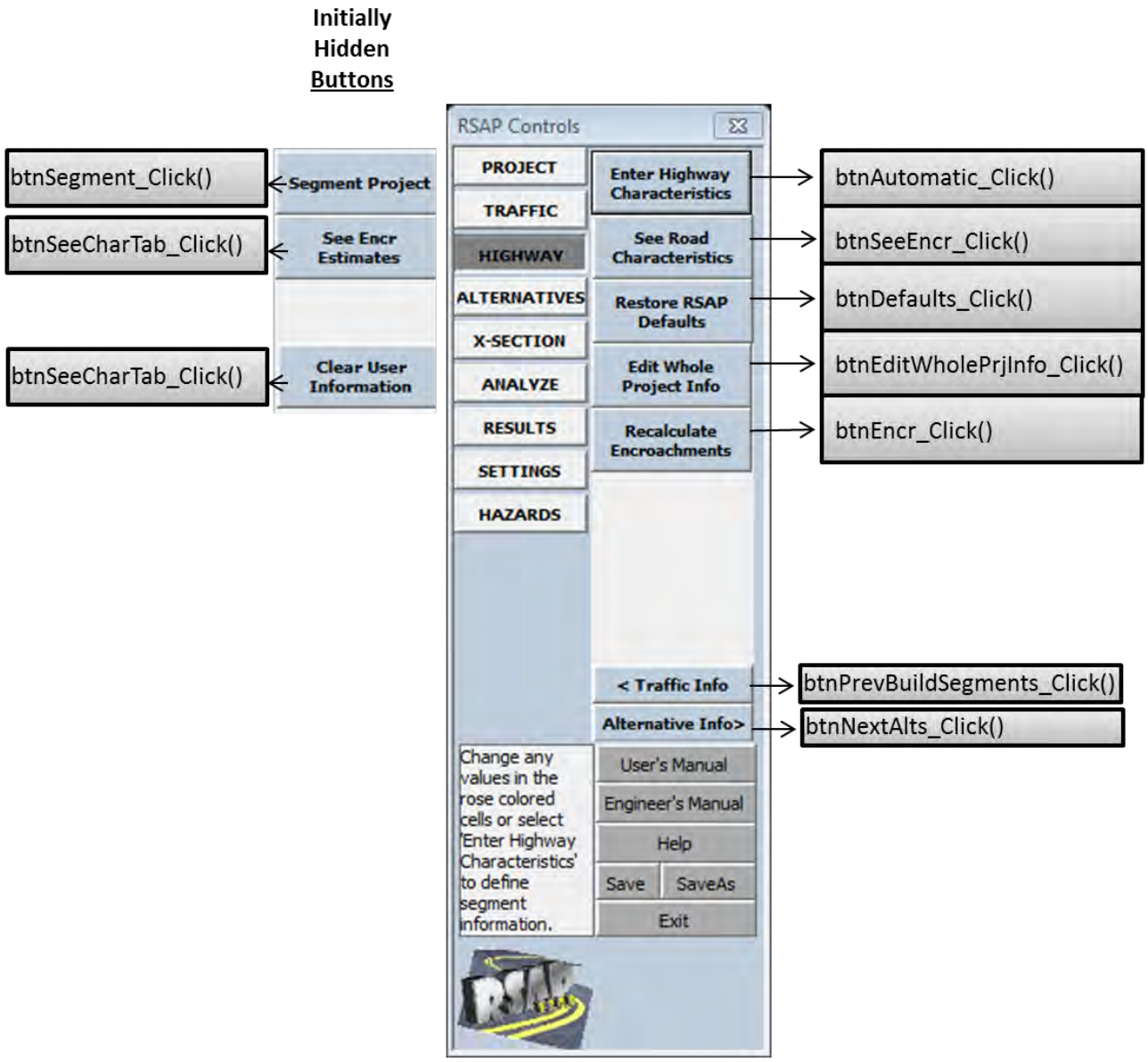


Figure 9. RSAP Controls Dialog – Highway.

Change() Method

Whenever a value on the Road Segments worksheet is changed this method is activated. If there is input in all of the input cells (i.e., A98:d588, E3:E5, G71:V90 and B71:c71) then the "Alternative Info >" button is made visible. If any of these ranges are completely blank, the button is hidden.

This method also checks cell E5 to determine the highway type (i.e., divided, undivided or one-way). A case statement is used to hide or make visible the appropriate columns of the Road Characteristics Table (i.e., range A63:P90) and the Encroachment Adjustments Table (i.e., range A38:M61).

The change method also checks to make sure that 100 percent of the volume is in the primary direction for one-way roadways by checking cells E5 and E3.

btnAutomatic_Click()

This macro shifts the view to the data entry area for road characteristics in shRdSegs.Range(A98:D587). The style for the data entry area is set to "Input" to allow for user input. The "Segment" and "Clear" buttons are made visible and the "Recalculate Encroachments," "Edit Whole Project Info" and "Defaults" buttons are hidden. The view is split showing the Whole Project Characteristics on the top and the user data entry area on the bottom. Control shifts to the user to allow for data entry and remains there until the user selects "Segment Project."

btnSeeEncr_Click()

This macro simply repositions the view of shRdSegs such that the Expected EncroachmentsTable (i.e., shRdSegs.Range(A11:J33)) is in view.

btnDefaults_Click()

This macro clears all information from the rose colored cells and copies the RSAP default values from shDefaults.

btnEditWholePrjInf_Click()

This macro sets up the view so that the Whole Project Information is visible and the styles are set to allow user input.

btnEncr_Click()

This button calls the macros that calculate the encroachments and adjustments on each segment of the roadway. The macro first checks to be sure there is appropriate data in the Road Characteristics Table. If there appears to be missing data the user is notified and the macro is exited. If there is sufficient data the macros moduleEncroachments.calcBaseEncr() and moduleEncroachment.adjustEncr() are called. These macros are described in the next chapter,Encroachment Module.

btnSegment_Click()

This button is initially hidden but is made visible when the "Enter Road Characteristics" button is pressed. The style of the input area (i.e., shRdSegs.Range(A98:B587)) is changed to "Normal 2" to prevent further use input and the Road Characteristics Table (i.e., shRdSegs.Range(B71:C90, G71:V90)) is cleared to prepare it for new data. The macro sortRoadChars() is then called to sort the characteristics into homogeneous segments and then segChars() macro is called to assign the segment characteristics to the Road Characteristics Table. Lastly, RSAP calls the btnEncr_Click() macro which calculates the base encroachment and applies the appropriate adjustments. Essentially, this button executes the encroachment module of RSAP as described in the next chapter. After the adjusted encroachments have been calculated the macro re-sets the buttons to the view shown in Figure 9.

btnSeeCharTable_Click()

This button simply shifts the view of shRdSegs such that the Roadway Characteristics Table is in view. The screen is split showing the Whole Project Information on the top and the Road Characteristics Table on the bottom.

btnClear_Click()

This button clears all the user-entered information on shRdSegs.

ALTERNATIVES WORKSHEET

The "Alternatives" worksheet is used to collect information from the user about the the various specific roadside alternatives that will be considered in the benefit-cost analysis. The alternative information is entered by the user on the Alternative worksheet (i.e., shAlternatives) as shown in Figure 10. There is no default information on the Alternatives worksheet and the user can define up to five different alternatives. The worksheet defaults to displaying alternative 1 when activated.

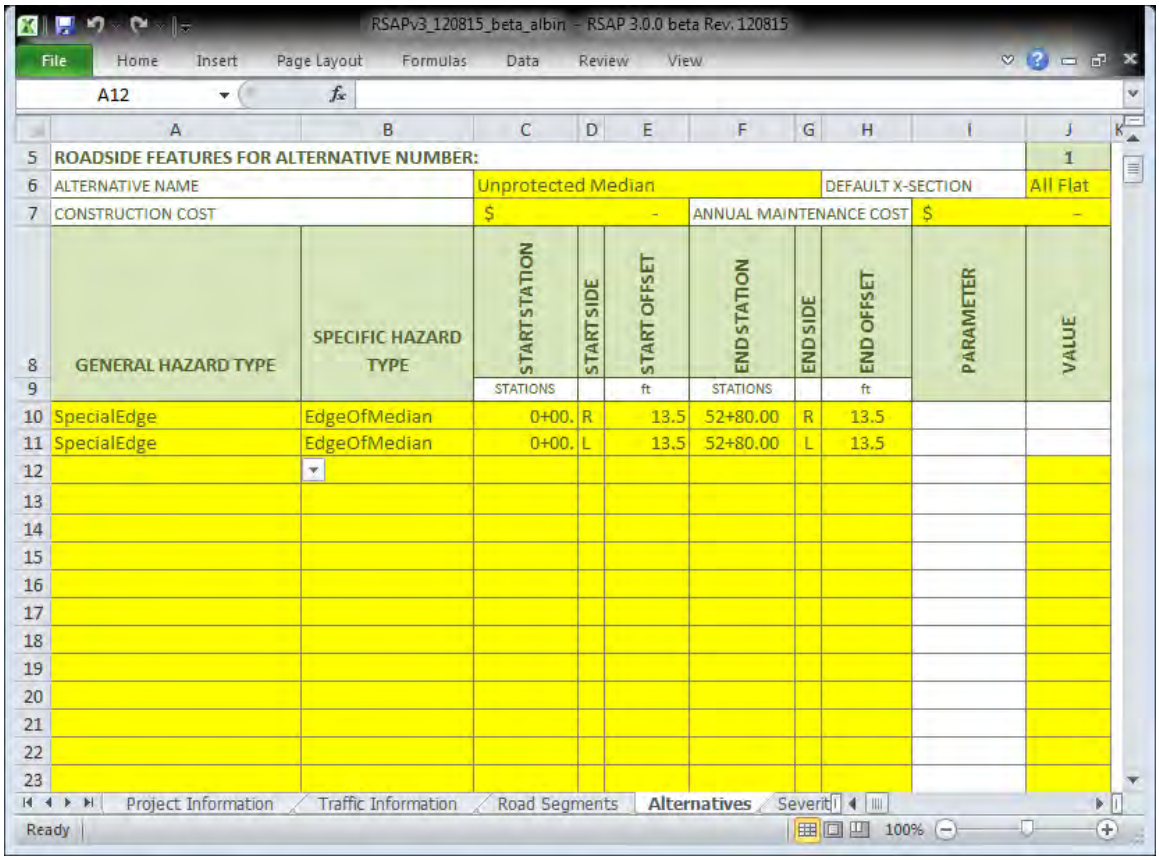


Figure 10. Alternatives Worksheet.

Selecting the "Alternatives" tab in the RSAP Controls Dialog or selecting the "Alternatives" worksheet tab will set the frmRSAPcontrols.mpControls.Value property to "3" , display the context sensitive buttons as shown in Figure 10and activate the Alternatives worksheet (i.e., shAlternatives).

The Alternatives view of RSAP Controls shown in Figure 11Figure 4 includes seven command buttons and two text-box displays which will be described below. The user can either select buttons on the RSAP control form or select a "yellow" user input cell on the worksheet in order to enter information.

Activate Method

Selecting the "Alternatives" tab on the RSAP Dialog Controls or the "Alternatives" tab in the Excel worksheet tabs instantiates the Alternatives.Worksheet_Activate() method. The value of mpControls is set to 3 and Alternative number 1 is pre-selected for input by executing the macro moduleAlternatives.EditAlt(1).

Change() Method

Whenever a value on the Alternatives worksheet is changed this method is activated. The shAlternatives.Change method performs a great deal of formatting for all rows greater than 9. First, event handling is disabled during the execution of the macro and then the following set of case statements are executed to accomplish the formatting:

Select Case Target.Column
Case 1, 12, 23, 34, 45 ' columns containing the hazard type value
Clear the eight columns to the left of the selected cell
Select Case Hazard Type
Case any longitudinal barrier hazard type
Set the style to of columns 4 to 6 to "Input"
Set the style of columns 7 and 8 to "Normal"
Clear any values from columns 7 and 8.
Print the label "width" in column 7
Set the style of column 8 to "Input2"
Case Special Edge
Set the style to of columns 4 to 6 to "Input"
Set the style of columns 7 and 8 to "Normal"
Clear any values from columns 7 and 8.
Print the label "NA" in column 7
Set the style of column 8 to "Input2"
Case PoleTreeSign
Set the style to of columns 4 to 6 to "Normal 2"
Set the value of columns 4 to 6 = "NA"
Set the style of columns 7 and 8 to "Normal"
Print the label "Dia." in column 7
Set the style of column 8 to "Input2"
Case TerminalEnds

Set the style to of columns 4 to 6 to "Normal 2"
Set the value of columns 4 to 6 = "NA"
Set the style of columns 7 and 8 to "Normal"
Print the label "Width" in column 7
Set the style of column 8 to "Input2"
Set the default value to 24"
End Case
End Select

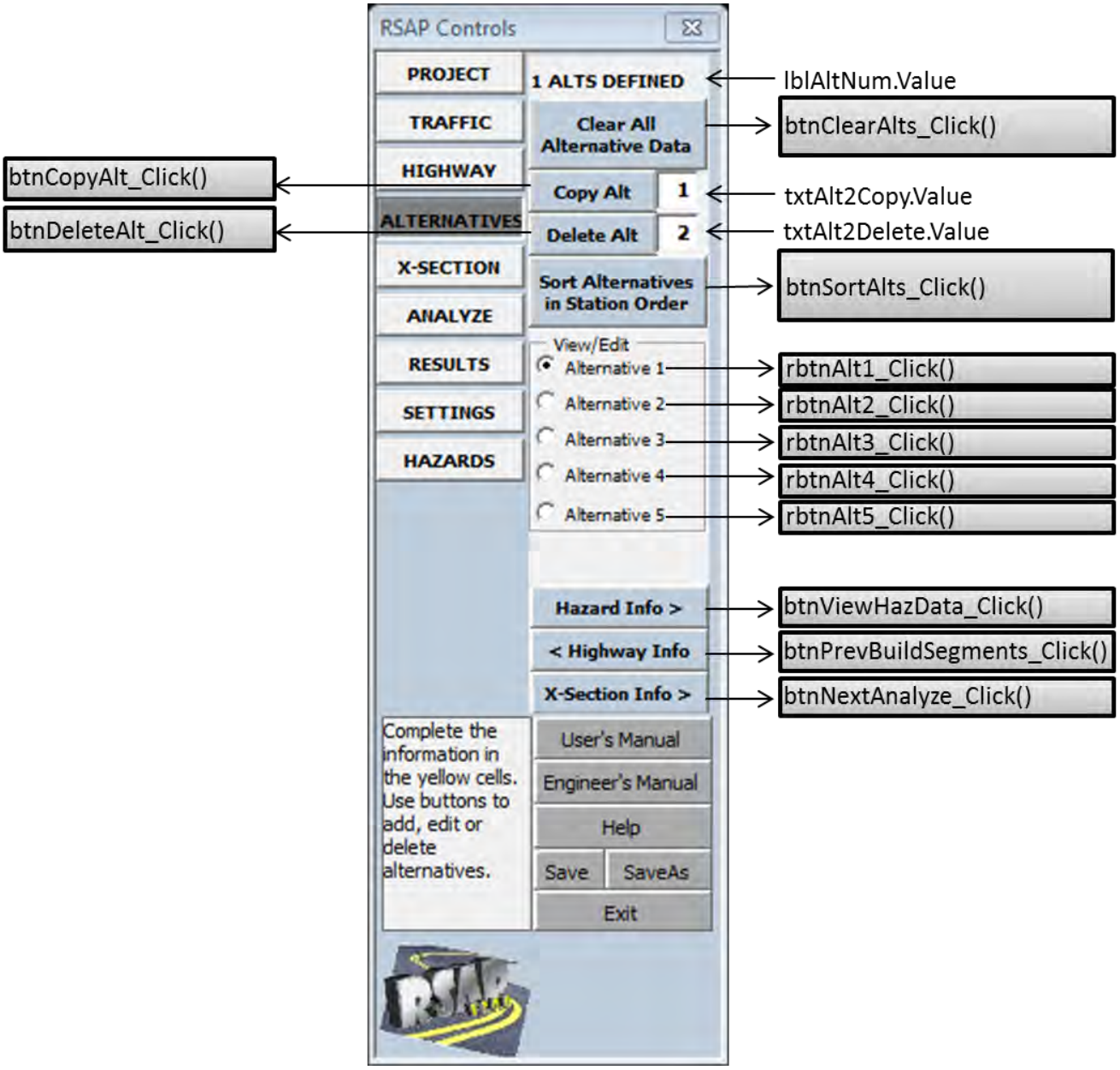


Figure 11. RSAP Controls Dialog -- Alternatives.

lblAltNum

This is a text box label that displays the number of alternatives that have been defined by the user. The initial default value is one. The number of alternatives must be an integer greater than zero and less than 6. The user cannot change this text box, RSAP changes the value based on the user choices described below.

btnClearAlts_Click()

This button clears all user entered information from the Alternatives worksheet.

txtAlt2Copy

The user can enter a number in this text box indicating the alternative they would like to copy. This text box works in conjunction with the "Copy Alt" button next to it. First, the user enters the integer value of the alternative they want to copy and then they press the "Copy Alt" button to affect that action. The new alternative is automatically added and the lblAltNum.value is incremented by one (i.e., if there are three alternatives and the user copies the 2nd alternative, the new copied alternative will be alternative 4).

btnCopyAlt_Click()

lblAlt2Delete

The user can enter a number in this text box indicating the alternative they would like to delete. This text box works in conjunction with the "Delete Alt" button next to it. First, the user enters the integer value of the alternative they want to delete and then they press the "Delete Alt" button to affect that action. The selected alternative is automatically removed and the lblAltNum.value is decreased by one (i.e., if there are three alternatives and the user deletes the 2nd alternative, the 3rd alternative will be become alternative 2).

btnSortAlts_Click()

This macro simply sorts the user entered information into station order. It is not necessary to press this button, it is only provided for the convenience of the user to organize the information.

rbtnAlt1_Click()

Five radio buttons are displayed in the a frame (i.e., Frame2) with the label "View/Edit." All five buttons work exactly the same so only the first (i.e., rbtnAlt1_Click()) is described here. Selecting the radio button shifts the view to display the user input area for the alternative selected, changed the cell style for that alternative to "Input" and changes the cell style for all other cells to "Normal 2." The user can then enter data in the yellow highlighted cells until they chose another button. This macro sets the rbtnAlt1.value=TRUE showing that the radio button has been selected and then calls the macro moduleAlternatives.EditAlt(1) which sets up the formating.

btnViewHazData_Click()

This button activates the Severity worksheet and shifts the view to the Severity worksheet (i.e., shSeverity). It also sets the mpControls value to 8 which displays the "Hazard" tab as shown in Figure 21. This button shifts control to the Severity tab of the RSAP Control Dialog.

btnPrevBuildSegments_Click()

This button returns the user to the Road Segments worksheet by activating shRdSegs and setting mpControls=2. The user is taken back to the previous input worksheet. Any information entered on the Alternatives worksheet is saved so the user can come back to where they left off.

btnNextAnalyze_Click()

This button advances the user to the X-Section worksheet by activating the "Cross-Section" worksheet (i.e., shXsection) and setting mpControls=4.

CROSS-SECTION WORKSHEET

The "Cross Section" worksheet is used to collect information from the user about the roadside and median cross sections for each of the alternatives defined on the Alternative worksheet as shown in Figure 12. The rose colored cells may be changed by the user but contain RSAP default values.

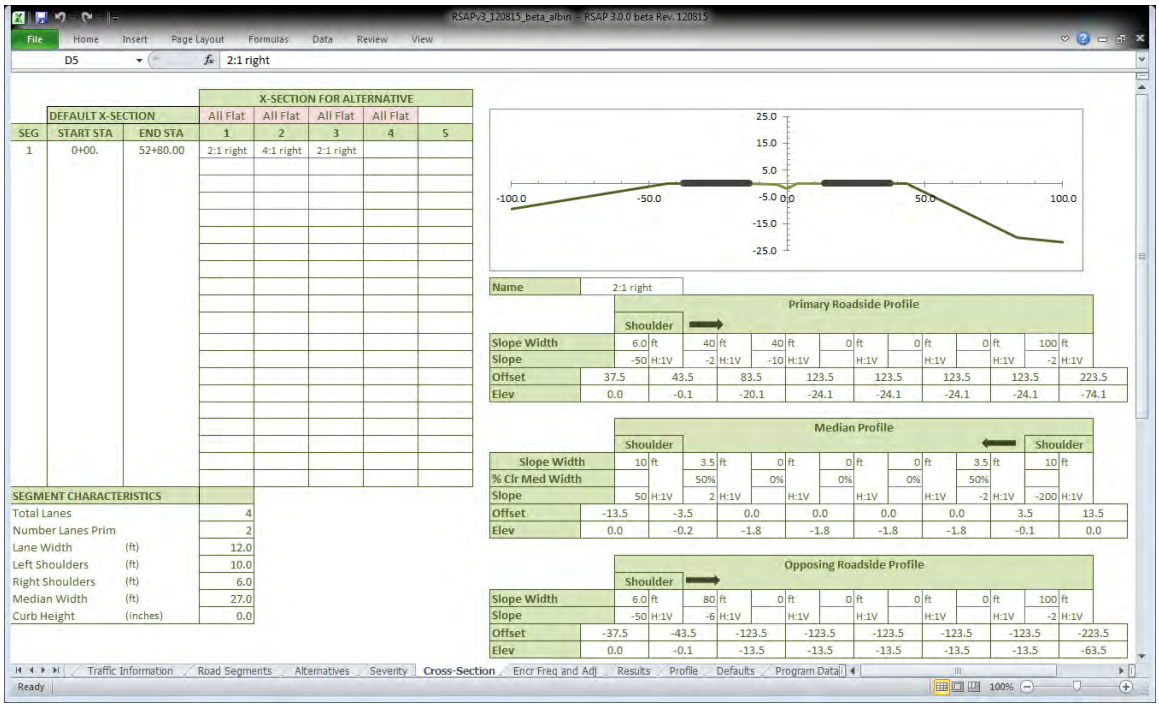


Figure 12. Cross-Section Worksheet.

Selecting the "X-Section" tab in the RSAP Controls Dialog or selecting the "Cross Section" worksheet tab will set the frmRSAPcontrols.mpControls.Value property to 4 , display the context sensitive buttons as shown in Figure 13and activate the Cross Section worksheet (i.e., shXsection). The mpControl method also calls the macro moduleXsection.buildXsectionListBox which creates the list shown in lbXsectionNames as discussed below.

The X-Section view of RSAP Controls shown in Figure 13 Figure 4 includes four command buttons and a selection-list dialog box which will be described below. The

user can either select buttons on the RSAP control form or select a “yellow” or “rose” user input cell on the worksheet in order to enter information.

Activate Method

Selecting the “X-Section” tab on the RSAP Dialog Controls or the “Cross-Section” tab in the Excel worksheet tabs instantiates the shXsection.Activate() method. The method first disables event handling, unprotects the sheet, sets mpControls=4 and hides columns AF:BR. The number of alternatives is read from shAlternatives.Range(“C3”).value, the highway type is read from shRdSegs.Range(“E5”).value and the number of segments is read from shRdSegs.Range(“D64”).value. These values are used in formatting the input area.

The input areas in D5:H24 and columns J:Z are first set to style “Normal 2” to prevent user input and any values are cleared. Next,

For i=1 to Number of Alternatives
The default value shown of shAlternatives for that Alternative is copied
The cell style is set to “Input 2” to allow for user input
Next Alternative
‘Show segment characteristics for segment 1 initially
Copy the data in shRdSegs row 71 to D26:D31

Once the formatting is complete, event handling is re-enabled, the sheet is re-protected and cell D5 is initially selected.

Change() Method

Whenever a value on the Cross-Section worksheet is changed the shXsection.Change method is activated. As usual event handling is disabled and the sheet is unprotected.

‘If the user selects a cells in the range D5:H24 do this
If 4>Target.Row<25 and the 3>Target.Column < 9 then
Copy segment information from shRdSegs
Write it into cells D26:D31
End if

Event handling is then re-enabled and the sheet is re-protected and controls is passed back to the user.

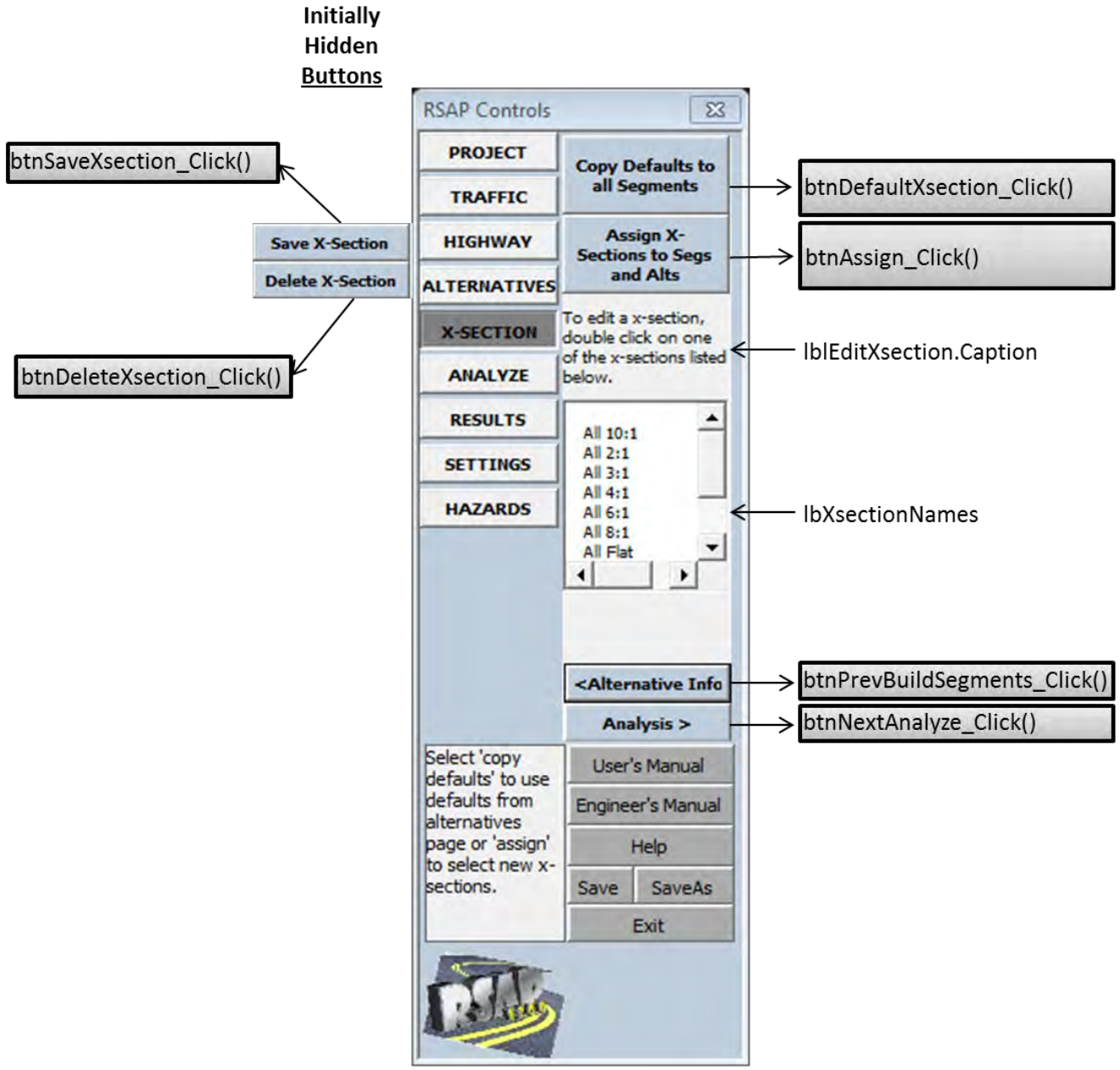


Figure 13. RSAP Controls Dialog – Cross-Section.

btnDefaultXsection_Click()

This macro copies the default cross-sections defined on the Alternative worksheet to all segments listed for that alternative. The individual segments for each alternative can be further modified by selecting the "Assign" button. The procedure is as follows:

Unprotect shXsection
Disable Event Processing

alts=Read the number of alternatives from shAlternatives.Range(C3)
hwyType= Read the highway type from shRdSegs.Range(E5)
segs=Read the number of segments from sRdSegs.Range(D64)
For iSegs=1 to segs
    For iAlt=1 to alts
        Copy the name in row3 for that alternative to every row in the column between 5 and segs+4
    Next iAlt
Next iSegs
Delete the validation rules in D5:H24
Set the style in D5:H24 to "Normal 2" to prevent user input
Protect shXsection
Enable event processing
Position the cursor at D5

btnSaveXsection_Click()

This button is initially hidden and is only revealed if the "Assign X-Sections to Segs and Alts" button is pressed. The purpose of the macro is to save a new or edited cross-section definition that the user has established in the detailed cross-section input area. When the user has entered all the information and is satisfied with the cross-section, this button is selected if the user wants to save the cross-section to use in RSAP. The macro proceeds as follows:

Ask the user for a name for the x-section
Select Case xSectionName
    Case ""
        Exit Sub
    Case frmRSAPcontrols.lbxsectionNames.value
        Loop through the name database and find the row associated with that name.
    Case Else
        Write the new name at the end of the database list in a new row
End Select
Unprotect shXsection
Disable event processing
Write all the information in the user input area into the database row for the named slope.
Call moduleXsection.buildXsectionListBox to re-build the list box view
Call moduleXsection.xsectionInList
Enable event processing
Position the cursor to D5
Protect shXsection

Hide btnSaveXsection
Hide btnDeleteXsection

btnDeleteXsection_Click()

This button is initially hidden and is only revealed if the "Assign X-Sections to Segs and Alts" button is pressed. The button removes a named cross-section from the RSAP database of cross-sections and re-builds the list box and validation menus. The procedure is as follows:

Ask user if they really want to delete the cross section
If YES then
Find the row in column 32 with a name that matches the selection
Unprotect shXsection
Disable event processing
Clear the row in column 32 where matching the cross-section name
Copy the next row to the last row
Paste the selection into the row just cleared
Call moduleXsection.buildXsectionListBox to re-build the list box
Call moduleXsection.xsectionInList to check that the name is valid
Enable event processing
Protect shXsection
Position the cursor in cell D5
Hide the Save and Delete buttons
End if

btnAssign_Click()

This macro allows the user to select different cross-sections for each segment and each alternative. Each cell in the input area (i.e., D5:H24) represents a different segment and alternative. The user can choose a cross-section for each cell. The macro proceeds as follows:

Unprotect shXsection
Disable Event Processing
alts=Read the number of alternatives from shAlternatives.Range(C3)
hwyType= Read the highway type from shRdSegs.Range(E5)
segs=Read the number of segments from sRdSegs.Range(D64)
Set the style of the detail cross-section input area to "normal 2" to prevent input
For iSeg=1 to segs
For iAlt=1 to alts
Set the style to "Input" to allow user input only in cells where a valid segment and alternative have been defined in shRdSegs and shAlternatives.
Next iAlt

Next iSeg
Delete the old validation rules in D5:H24
Create a new validation rule with drop-down menus pointing to the named range "SlopeNames"
Position the cursor in cell D5
Hide btnDeleteXsection
Hide btnSaveXsection
Enable event processing
Protect shXsection

When this macro finishes the user is in control via the worksheet interface. The validation rules have been re-set to what is currently in the slope name database. The user retains control until a button is pressed on the RSAP Controls Dialog.

lblEditXsection

This form component is a simple label with text identifying the list box below. The user cannot select or affect this label in any way.

lbXsectionNames_DblClick()

This form component is a list box that presents a list of cross-section names that have been saved in RSAPv3. The list box is actually built when the mpControl value is set to 5 by calling moduleXsection.buildXsectionListBox. which is discussed next.

Items in this listbox can be selected double clicking the name in the box. Double clicking initiates this macro. The procedure is as follows:

Unprotect shXsection
Disable Screen Updating
Disable Event Processing
Disable the validation rules in the input area (i.e., Range(D5:H24)
Set the style of the user input area D5:H24 to "Normal 2" to prevent input
Set the style of the Detailed Cross-Section Input area to "Input"
If the name selected <> blank then
    Call moduleXsection.writeXsectionInfo
Else
    Tell the user to select a cross-section
End if
Enable screen updating
Enable event processing
Make btnSaveXsection visible
Make btnDeleteXsection visible
Protect shXsection

When the macro finishes executing the user input area for detailed cross-section information is prepared with the appropriate cells being highlighted yellow indicating user input is needed. Control stays with the user on the worksheet until either the Save or Delete buttons are selected.

lbxXsectionNames_Change()

This macro simply repaints the list box whenever anything is changed such that the view is always current.

MODULEXSECTION

While the macros in this module are not a part of frmRSAPcontrols, they are discussed here because their only function is to support the control buttons on the X-Section tab of frmRSAPcontrols. The module consists of the following four macros:

buildXsectionListBox()

This macro is called whenever mpControls is set to 4 and …. . It builds the list that is displayed in the lbXsectionNames shown in Figure 13. The list is stored in a hidden portion of shXsection in column 32 starting in row 15.

Starting in row 15 of column 32
Look at each row until a blank cell is found
The cell above the blank is the last row
Name the range from row 14 to the last row in column 32 "SlopeNames"
Set the Rowsource of lbxsectionNames = SlopeNames
Sort the names in alphabetical order

The result of this macro is that the list of names in column 32 appear in the lbxsectionNames.

writeXsectionInfo()

This macro transfers the cross-section information from the user input area where new cross-sections can be defined and existing cross-section can be edited to the hidden database area of shXsection. The macro first looks to see if the name is already in use. If it is the new information is used to over-write the old data. If the name is not already in the list it is added and the new cross-section information is associated with the new name.

xsectionlnList()

This macro checks to ensure that the default cross-sections selected in the segment and alternative cells of shXsection are valid cross-section that are in the list in column 32. If a name is not found the user is notified and asked to pick a valid cross-section name from lbxXsectionNames. The macro will not allow the user to proceed until a valid name is selected.

ANALYZE

Unlike most of the tabs on the RSAP Controls Dialog, the "Analyze" tab is not associated with a particular worksheet. Instead, the buttons available on this form control

the execution of the analysis. The form has both a simple view and a more complicated view where analysis settings can be made as will be described shortly.

Selecting the "Analyze" tab in the RSAP Controls Dialog will set the frmRSAPcontrols.mpControls.Value property to "6" and display the context sensitive buttons as shown in X and Y .

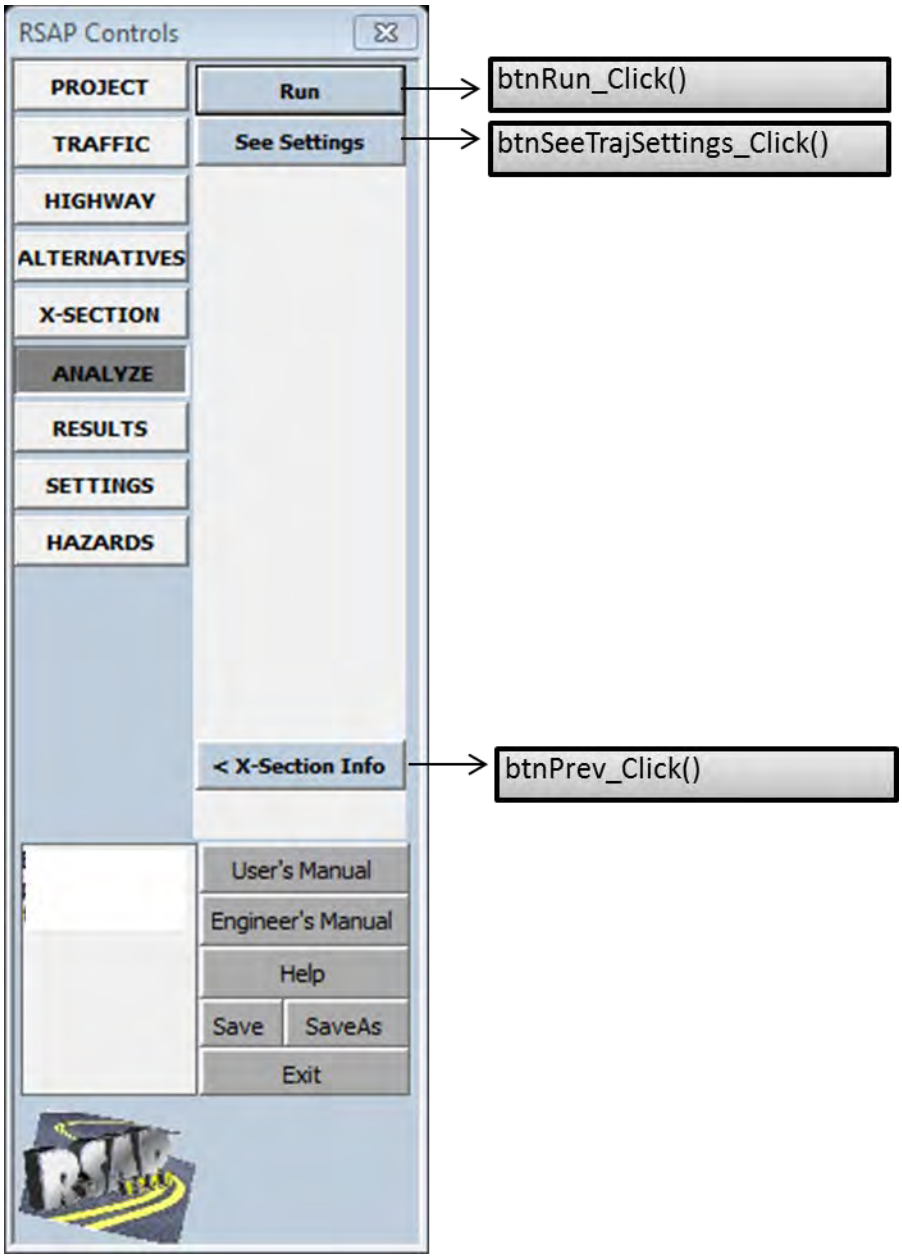


Figure 14. RSAP Controls Dialog – Analyze (Condensed View).

btnRun_Click()

The "Run" button initiates the RSAPv3 analysis phase. The macro proceeds as follows:

Screen updating is turned off
Display status bar is turned off
moduleXsection.finalXsectionWrite is called to write final roadside terrain data
shPOCscratch is unhidden and unprotected
shPOCplots is unhidden and unprotected
Load frmProgressBar
Start timer
Call ModuleMain.Main
End timer
Unload frmProgressBar
If user has not canceled the run then
    Activate the Results worksheet
    Set mpControls=6 to make the RSAP Controls Results Dialog visible
    Print the analysis time information on the Results worksheet
    Call moduleResults.FeatureResults
    Call moduleResults.SegResults
Else
    Set mpControls =5 'the Analyze tab
    Exit Sub
End if

The call to moduleMain.Main initiates the collision and severity modules of RSAP and are discussed in the Crash Prediction Module and Severity Module chapters. The calls to moduleResults.featureResults and moduleResults.segResults initiates the Benefit-Cost Module as discussed in the Benefit-Cost Module Chapter.

btnSeeTrajSettings_Click()

Selecting the "See Settings" button makes the full settings button panel visible as shown in Figure 23. The function and use of each of these settings buttons is described in detail in the Crash Prediction Module Chapter.

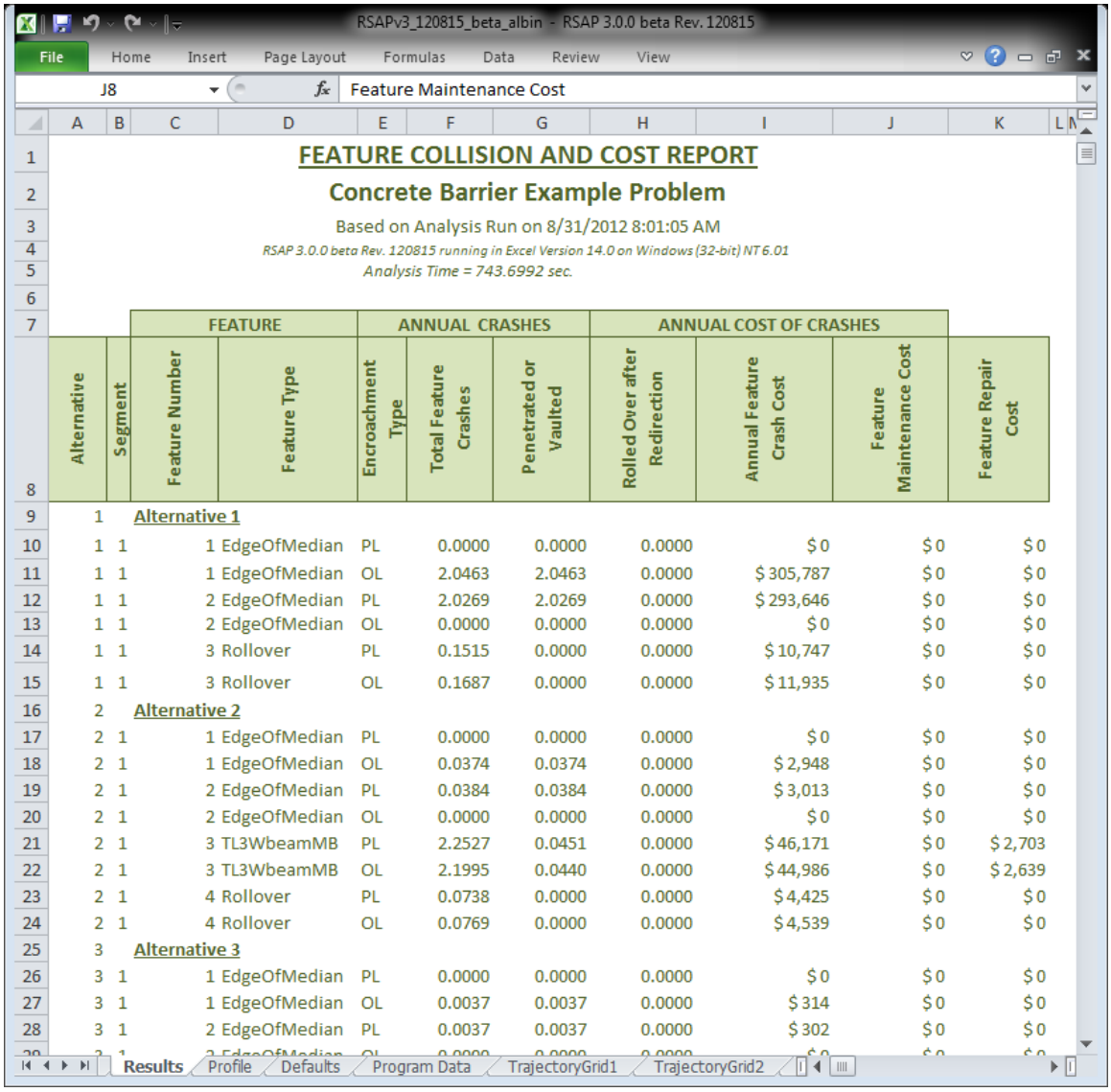
btnPrev_Click()

The "< X-Section Info" button sets the control back to the "Cross-Section" worksheet. Selecting the button executes this method which simply selects the "Cross-Section" worksheet (i.e., shXsection), and set the value of frmRSAPcontrols.mpControls.value=4.

RESULTS WORKSHEET

The "Results" worksheet is used to display the results of the analysis to the user and, in the background, perform the benefit-cost calculations. Selecting the "Results" tab in the RSAP Controls Dialog or selecting the "Results" worksheet tab will set the frmRSAPcontrols.mpControls.Value property to 6 , display the context sensitive buttons as shown in Figure 18 and activate the Results worksheet (i.e., shResults).

The Results view of RSAP Controls shown in Figure 18 includes four command buttons which will be described below. There is only one small user input area (i.e., Range(X5:X6)) where the user can change the project life or rate of return. RSAP uses the values entered previously on the Project Information worksheet as defaults but they are provided here as well in case the user desires to do some sensitivity analysis using just the life and rate of return.



FEATURE COLLISION AND COST REPORT

Concrete Barrier Example Problem

Based on Analysis Run on 8/31/2012 8:01:05 AM

RSAP 3.0.0 beta Rev. 120815 running in Excel Version 14.0 on Windows (32-bit) NT 6.01

Analysis Time = 743.6992 sec.

		FEATURE		ANNUAL CRASHES			ANNUAL COST OF CRASHES			
Alternative	Segment	Feature Number	Feature Type	Encroachment Type	Total Feature Crashes	Penetrated or Vaulted	Rolled Over after Redirection	Annual Feature Crash Cost	Feature Maintenance Cost	Feature Repair Cost
1		Alternative 1								
1	1	1	EdgeOfMedian	PL	0.0000	0.0000	0.0000	$0	$0	$0
1	1	1	EdgeOfMedian	OL	2.0463	2.0463	0.0000	$305,787	$0	$0
1	1	2	EdgeOfMedian	PL	2.0269	2.0269	0.0000	$293,646	$0	$0
1	1	2	EdgeOfMedian	OL	0.0000	0.0000	0.0000	$0	$0	$0
1	1	3	Rollover	PL	0.1515	0.0000	0.0000	$10,747	$0	$0
1	1	3	Rollover	OL	0.1687	0.0000	0.0000	$11,935	$0	$0
2		Alternative 2								
2	1	1	EdgeOfMedian	PL	0.0000	0.0000	0.0000	$0	$0	$0
2	1	1	EdgeOfMedian	OL	0.0374	0.0374	0.0000	$2,948	$0	$0
2	1	2	EdgeOfMedian	PL	0.0384	0.0384	0.0000	$3,013	$0	$0
2	1	2	EdgeOfMedian	OL	0.0000	0.0000	0.0000	$0	$0	$0
2	1	3	TL3WbeamMB	PL	2.2527	0.0451	0.0000	$46,171	$0	$2,703
2	1	3	TL3WbeamMB	OL	2.1995	0.0440	0.0000	$44,986	$0	$2,639
2	1	4	Rollover	PL	0.0738	0.0000	0.0000	$4,425	$0	$0
2	1	4	Rollover	OL	0.0769	0.0000	0.0000	$4,539	$0	$0
3		Alternative 3								
3	1	1	EdgeOfMedian	PL	0.0000	0.0000	0.0000	$0	$0	$0
3	1	1	EdgeOfMedian	OL	0.0037	0.0037	0.0000	$314	$0	$0
3	1	2	EdgeOfMedian	PL	0.0037	0.0037	0.0000	$302	$0	$0

Figure 15. Results Worksheet – Feature Report View.

The Results worksheet contains three reports. The Feature Report, shown in Figure 15, is the initial view shown. The Segment Report is shown in Figure 16 and the Benefit-Cost Report is shown in Figure 17. These reports are viewed by selecting the appropriate button in the RSAP Controls Dialog, shown in Figure 18, as will be described shortly.

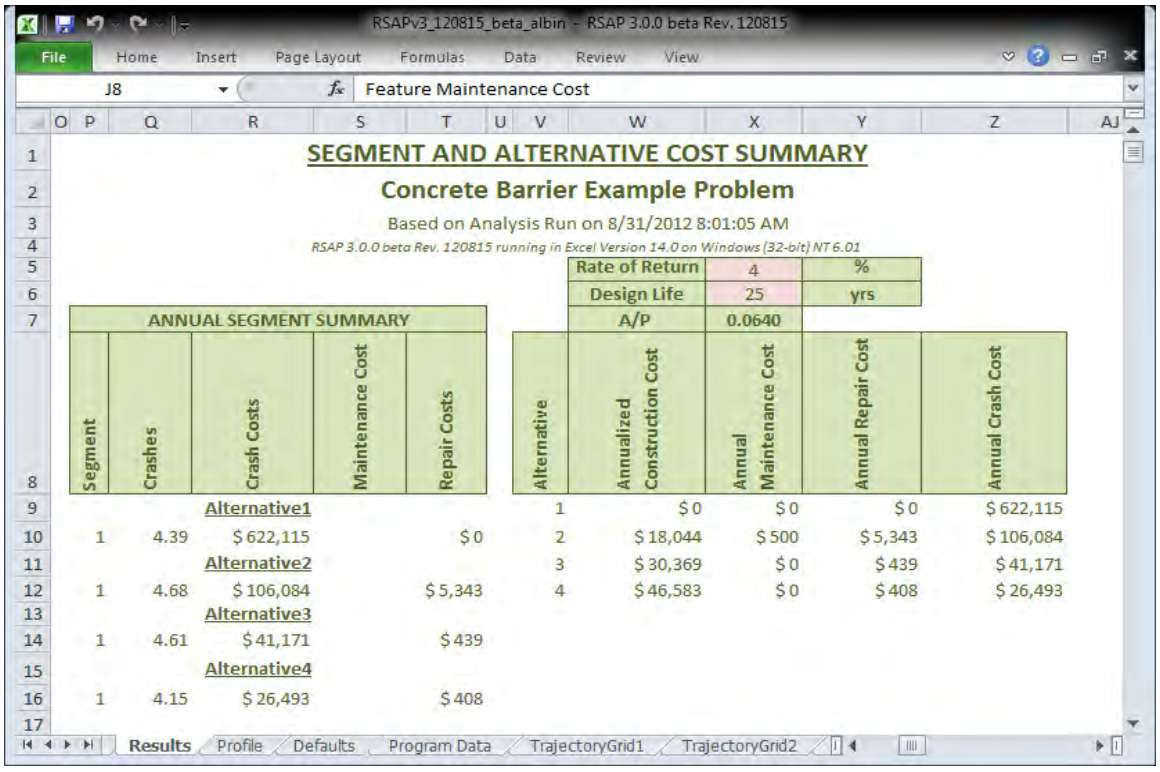


Figure 16. Results Worksheet – Segment Report View.

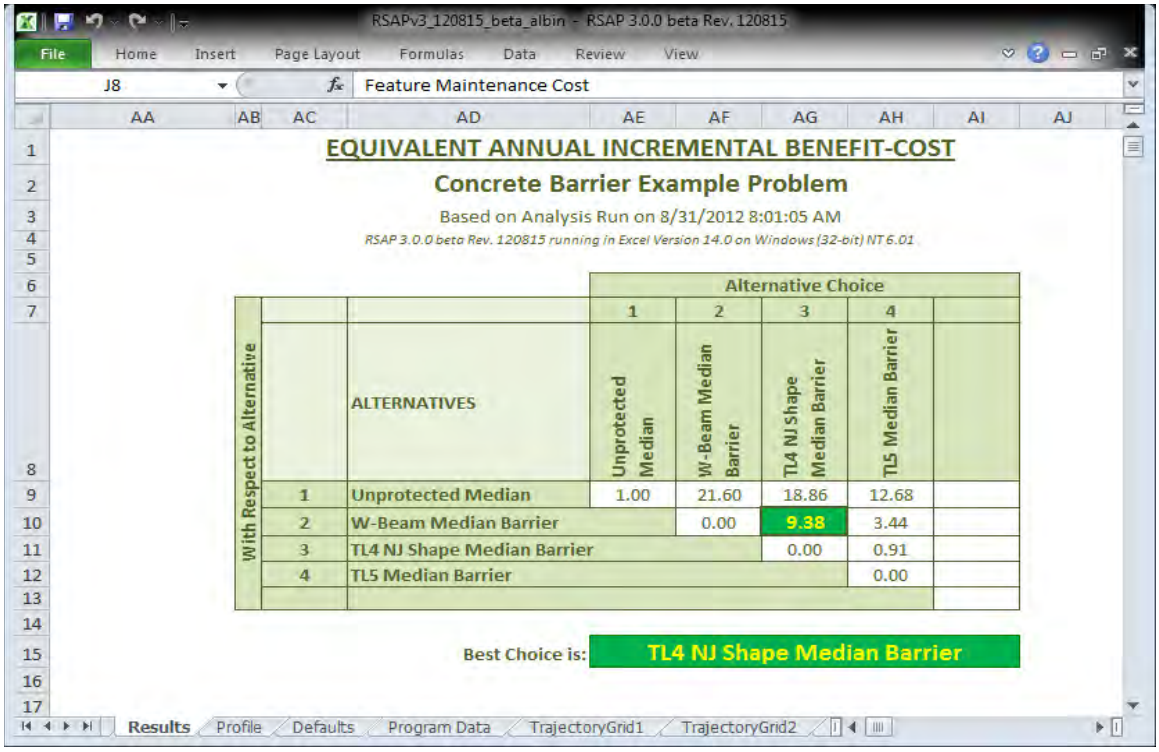


Figure 17. Results Worksheet – Benefit-Cost Report View.

The Results worksheet has several built-in formulae as discussed below. All the formulae are below row 8. ROW in the following list indicates the ROW number.

Column	Formula
J	=IF(B[ROW]="","",VLOOKUP(D[ROW] ,Severity!A4:H201,3,FALSE)
K	=IF(B[ROW]="","",VLOOKUP(D[ROW],Severity!A4:H201,4,FALSE,F[ROW]
W	=IF(V[ROW]="","",Alternatives!C7*X7)
X	=IF(V[ROW]="","",Alternatives!I7)

Cells in column J below row 8 include the formula shown above. The formula uses the VLOOKUP function to lookup the annual maintenance cost of each hazard in the Feature Report. The hazard annual maintenance cost is listed in column C of the Severity worksheet. Similarly, cells in column K below row 8 use the VLOOKUP formula to lookup the average repair cost for each feature and then multiply that value by the number of crashes with the feature shown in column F. In both cases, the lookup is only performed if the segment value in column B is not blank.

The formulae in columns W and X are part of the Segment Report. Both only display if the Alternative number shown in column V is not blank. Column W calculates the annualized construction cost by reading the total alternative construction cost from row 7 of the Alternatives worksheet and multiplying it by the rate of return value in cell X7. Similarly, column X reads the maintenance cost for each alternative from the Alternative worksheet.

The Benefit-Cost Report contains numerous formulae in the worksheet but discussion of these is deferred until the Benefit-Cost Module Chapter below.

Activate Method

Selecting the "Results" tab on the RSAP Dialog Controls or the "Results" tab in the Excel worksheet tabs instantiates the shResults.Activate() method. Columns A:K, L:AI and AL:AR are initially hidden in order to display the "Features Report" as the default. The value of mpControls is set to 6 which displays the buttons shown in Figure 18. The window is also scrolled to column A and row 1 for the initial view.

The macros that actually calculate the crash costs are executed after the crash prediction module is complete. The two macros moduleResults.featureResults and moduleResults.segResults are called at the end of the btnRun macro discussed in the Analysis section.

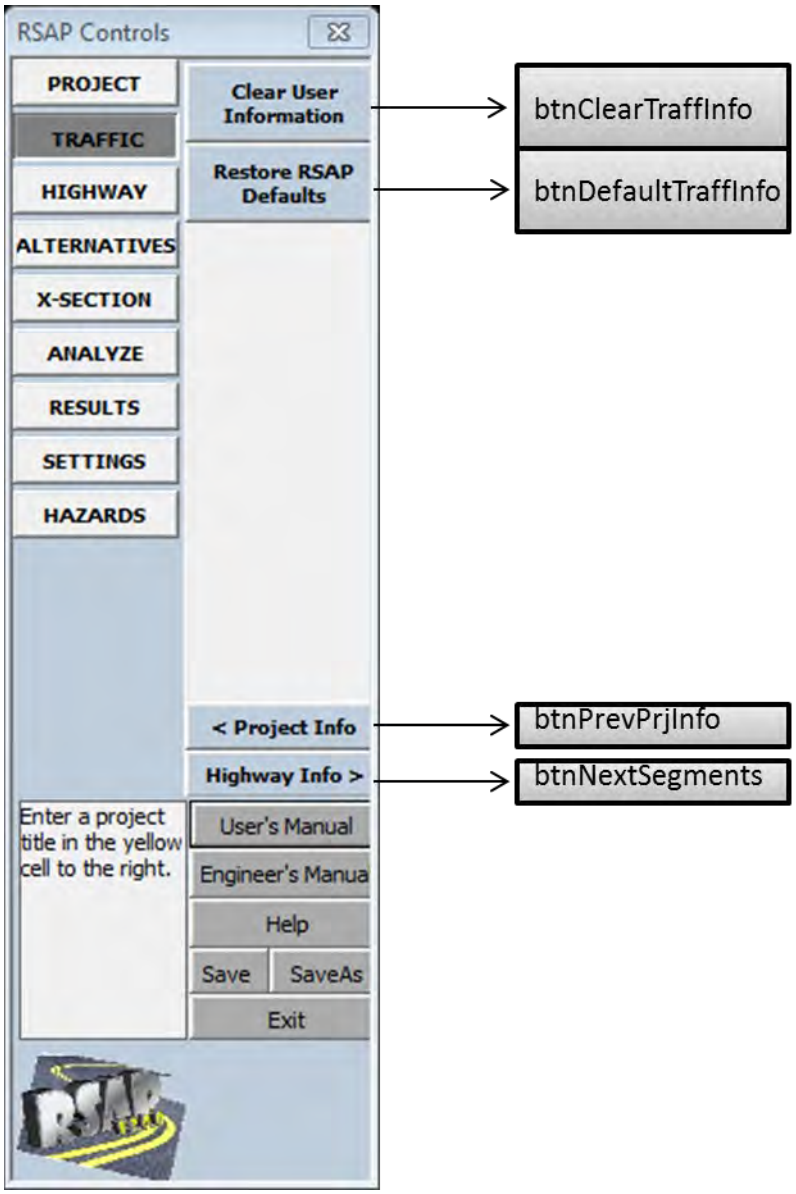


Figure 18. RSAP Controls Dialog -- Results.

Change() Method

Whenever a value on the Results worksheet is changed the shResults.Change method is activated. The method only looks for changes in cells X5 and X6 which contain the rate of return and design life values. If either of these are changed, the subroutine modulesResults.and segResults are re-run to recalculate the economic costs in the Segment Report.

btnSegReport_Click()

The Segment Report is contained in columns L:Z so this macro simply un-hides columns L:Z and hides columns A:K and AA:AI. The resulting view is shown in Figure 16.

btnBCReport_Click()

The Benefit-Cost Report and Table are contained in columns AA:AI so this macro makes those columns visible and hides columns A:K and L:Z. The resulting view is shown in Figure 17.

btnFeatureReport_Click()

The Feature Report is the default view shown on the Results worksheet and this button returns the view to that report. It simply makes columns A:K visible and hides columns L:AI. The resulting view is shown in Figure 15.

btnPrint_Click()

This macro first unprotects shResults and call the macro moduleResults.printReports which will be described in the Benefit-Cost Module Chapter.

SETTINGS

Unlike most of the tabs on the RSAP Controls Dialog, the Settings tab is not associated with a particular worksheet so whatever worksheet is active when the Setting tab is selected remains active and in view. The Settings tab provides some useful tools for the user to control the display and functionality of RSAP and has no impact on the analysis results.

Selecting the "Settings" tab in the RSAP Controls Dialog will set the frmRSAPcontrols.mpControls.Value property to "7" , display the context sensitive buttons as shown in Figure 19. The Settings view of RSAP Controls shown in Figure 19 includes three visible command buttons, one of which is a toggle, which will be described below.

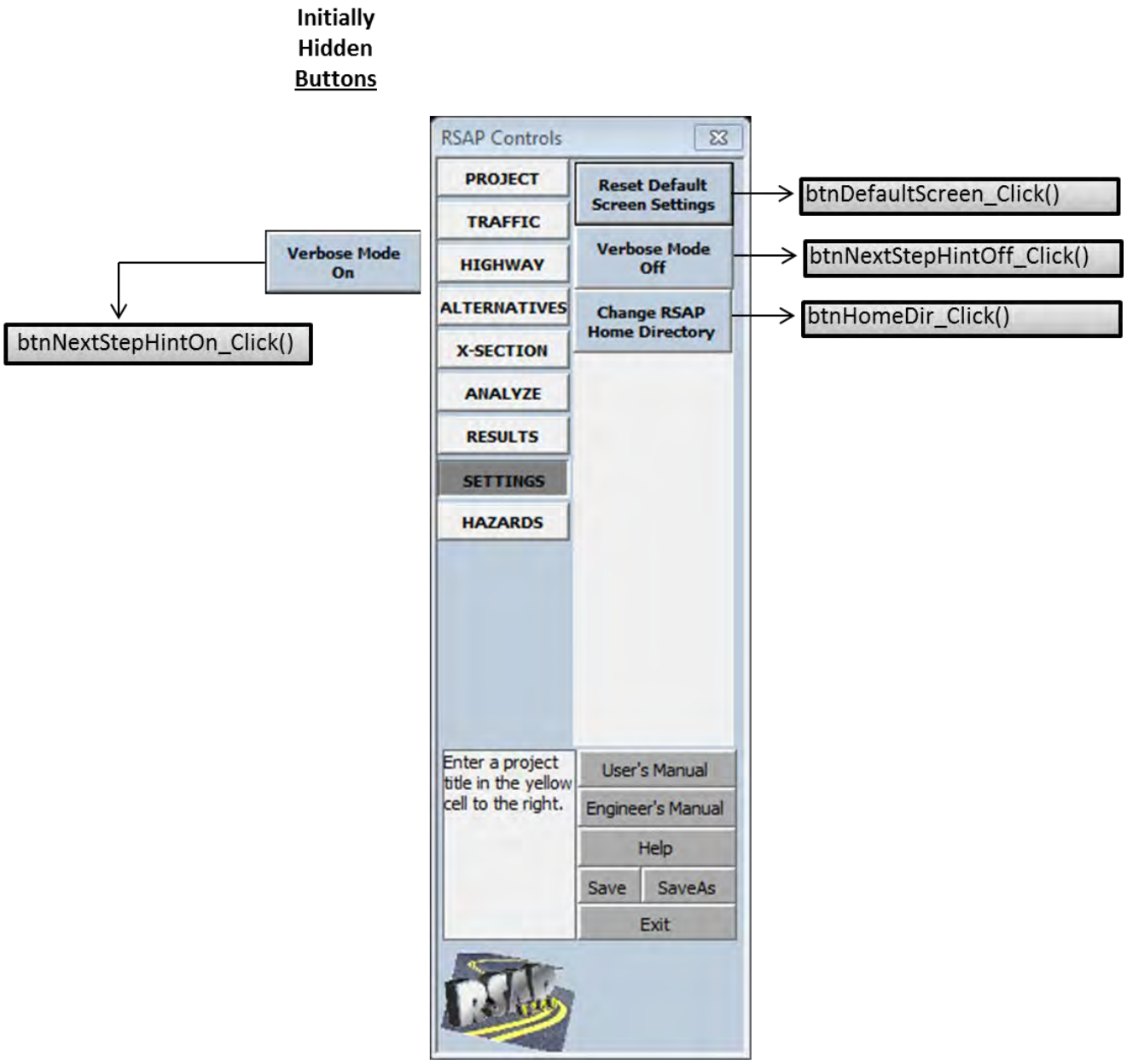


Figure 19. RSAP Controls Dialog -- Settings.

btnDefaultScreen_Click()

The Excel application window can be maximized, minimized, resized or moved while RSAP is active. The RSAP Controls Dialog can not be re-sized but it can be moved interactively anywhere on the desktop. Pressing the "Reset Default Screen Settings" button returns the display to its default RSAP configuration (i.e., see Figure 1) with the RSAP controls in the upper left of the application window and the worksheet view maximized within the application screen.

btnNextStepHintOff_Click()

Selecting the "Verbose Mode Off" on this form executes this method which hides the next step hint at the lower left of the RSAP Controls Dialog (i.e., lblNextStepHint). It also . Selecting this option also hides the message display area of the Progress Bar form that is shown while the analysis is running.

btnNextStepHintOn_Click()

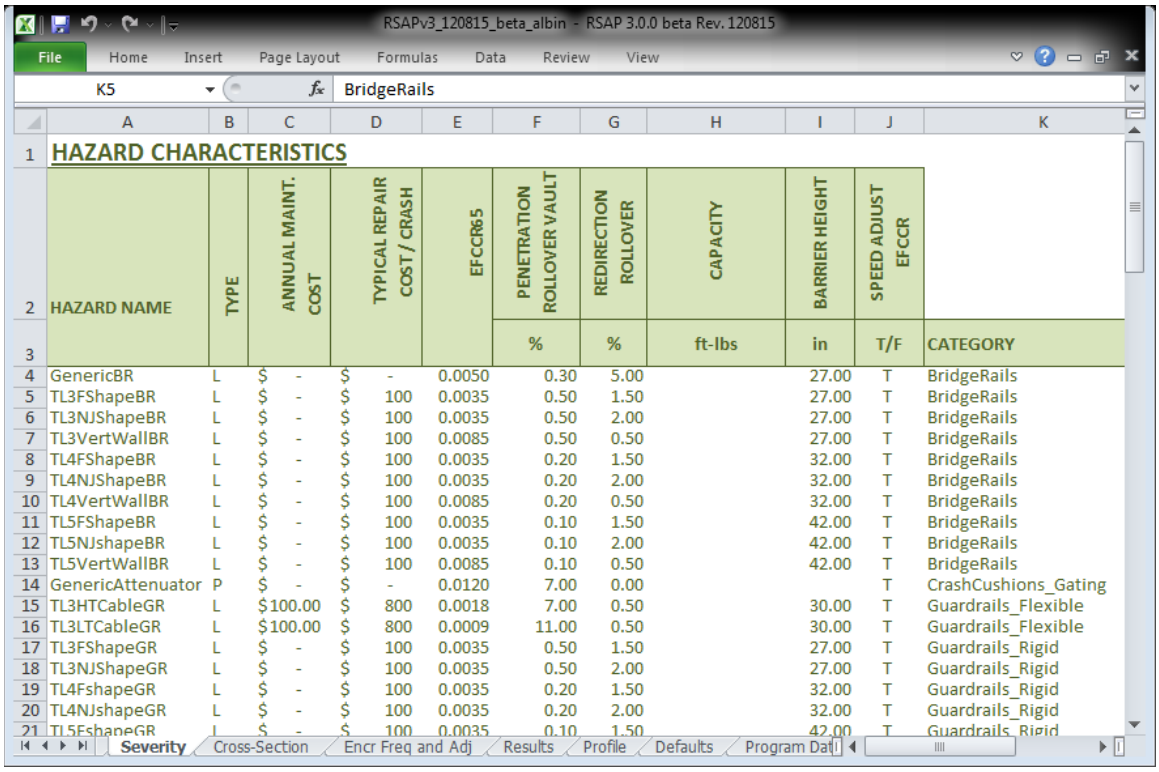
The verbose mode is actually a toggle so if "Verbose Mode Off" is selected it is replaced with the initially hidden button "Verbose Mode On" shown in Figure 19. Selecting this button turns the verbose mode back on by un-hiding the lblNextStepHint box and re-sizing the frmProgressBar such that the run-time messages appear.

btnHomeDir_Click()

The default condition for RSAP is to be installed in C:\Program Files\RSAPv3. Sometimes users do not have administrative privileges on their computers so they are not able to install RSAP in that location. Since RSAP is simply a macro-enabled Excel workbook it does not really need to be installed, the workbook can be copied to any location on the user's computer. The only disadvantage to putting an RSAP workbook in another location is that RSAP does not know the location of the User's Manual, Engineer's Manual and help file. Selecting the "Change RSAP Home Directory" brings up a directory selection browser. The user can select any subdirectory and the path to that subdirectory is saved in cell B24 of the "Project Information" worksheet. As described earlier, if the User's Manual, Engineer's Manual or help files cannot be found in C:\Program Files\RSAPv3 the directory listed in shPrjInfo.Range("B24").value is then searched.

HAZARDS WORKSHEET

The "Severity" worksheet, shown in Figure 20, is a database of all the hazards that can be used in RSAPv3. The "Severity" worksheet can be accessed either by selecting the "Hazard" tab on the RSAP Controls Dialog or selecting the "Severity" worksheet tab. The user is not allowed to make changes to the "Severity" worksheet but reviewing it can be useful.



RSAPv3_120815_beta_albin - RSAP 3.0.0 beta Rev. 120815

File Home Insert Page Layout Formulas Data Review View

K5 BridgeRails

HAZARD CHARACTERISTICS

HAZARD NAME	TYPE	ANNUAL MAINT. COST	TYPICAL REPAIR COST / CRASH	EFCCR65	PENETRATION ROLLOVER VAULT	REDIRECTION ROLLOVER	CAPACITY	BARRIER HEIGHT	SPEED ADJUST EFCCR	
					%	%	ft-lbs	in	T/F	CATEGORY
GenericBR	L	$ -	$ -	0.0050	0.30	5.00		27.00	T	BridgeRails
TL3FShapeBR	L	$ -	$ 100	0.0035	0.50	1.50		27.00	T	BridgeRails
TL3NJShapeBR	L	$ -	$ 100	0.0035	0.50	2.00		27.00	T	BridgeRails
TL3VertWallBR	L	$ -	$ 100	0.0085	0.50	0.50		27.00	T	BridgeRails
TL4FShapeBR	L	$ -	$ 100	0.0035	0.20	1.50		32.00	T	BridgeRails
TL4NJShapeBR	L	$ -	$ 100	0.0035	0.20	2.00		32.00	T	BridgeRails
TL4VertWallBR	L	$ -	$ 100	0.0085	0.20	0.50		32.00	T	BridgeRails
TL5FShapeBR	L	$ -	$ 100	0.0035	0.10	1.50		42.00	T	BridgeRails
TL5NJshapeBR	L	$ -	$ 100	0.0035	0.10	2.00		42.00	T	BridgeRails
TL5VertWallBR	L	$ -	$ 100	0.0085	0.10	0.50		42.00	T	BridgeRails
GenericAttenuator	P	$ -	$ -	0.0120	7.00	0.00			T	CrashCushions_Gating
TL3HTCableGR	L	$100.00	$ 800	0.0018	7.00	0.50		30.00	T	Guardrails_Flexible
TL3LTCableGR	L	$100.00	$ 800	0.0009	11.00	0.50		30.00	T	Guardrails_Flexible
TL3FShapeGR	L	$ -	$ 100	0.0035	0.50	1.50		27.00	T	Guardrails_Rigid
TL3NJShapeGR	L	$ -	$ 100	0.0035	0.50	2.00		27.00	T	Guardrails_Rigid
TL4FshapeGR	L	$ -	$ 100	0.0035	0.20	1.50		32.00	T	Guardrails_Rigid
TL4NJshapeGR	L	$ -	$ 100	0.0035	0.20	2.00		32.00	T	Guardrails_Rigid
TL5FshapeGR	L	$ -	$ 100	0.0035	0.10	1.50		42.00	T	Guardrails_Rigid

Severity | Cross-Section | Encr Freq and Adj | Results | Profile | Defaults | Program Dat

Figure 20. Seveity Worksheet.

Selecting the “Hazard” tab in the RSAP Controls Dialog or selecting the “Severity” worksheet tab will set the frmRSAPcontrols.mpControls.Value property to “8” , display the context sensitive buttons as shown in Figure 21 and activate the “Severity” worksheet (i.e., shSeverity).

Activate Method

Selecting the “Hazard” tab on the RSAP Dialog Controls or the “Severity” Excel worksheet tab instantiates the shSeverity.Worksheet_Activate() method. In the case of shSeverity, RSAP simply sets frmRSAPcontrols.mpControls.value=8 and positions the view at the row 1, column 1.

Five command buttons are available in the Hazards area as shown in Figure 21. There is also a hidden key-stroke macro, moduleTools.editSeverities, which can be used to edit the worksheet as described in the Engineer’s Manual. These macros will be described below.

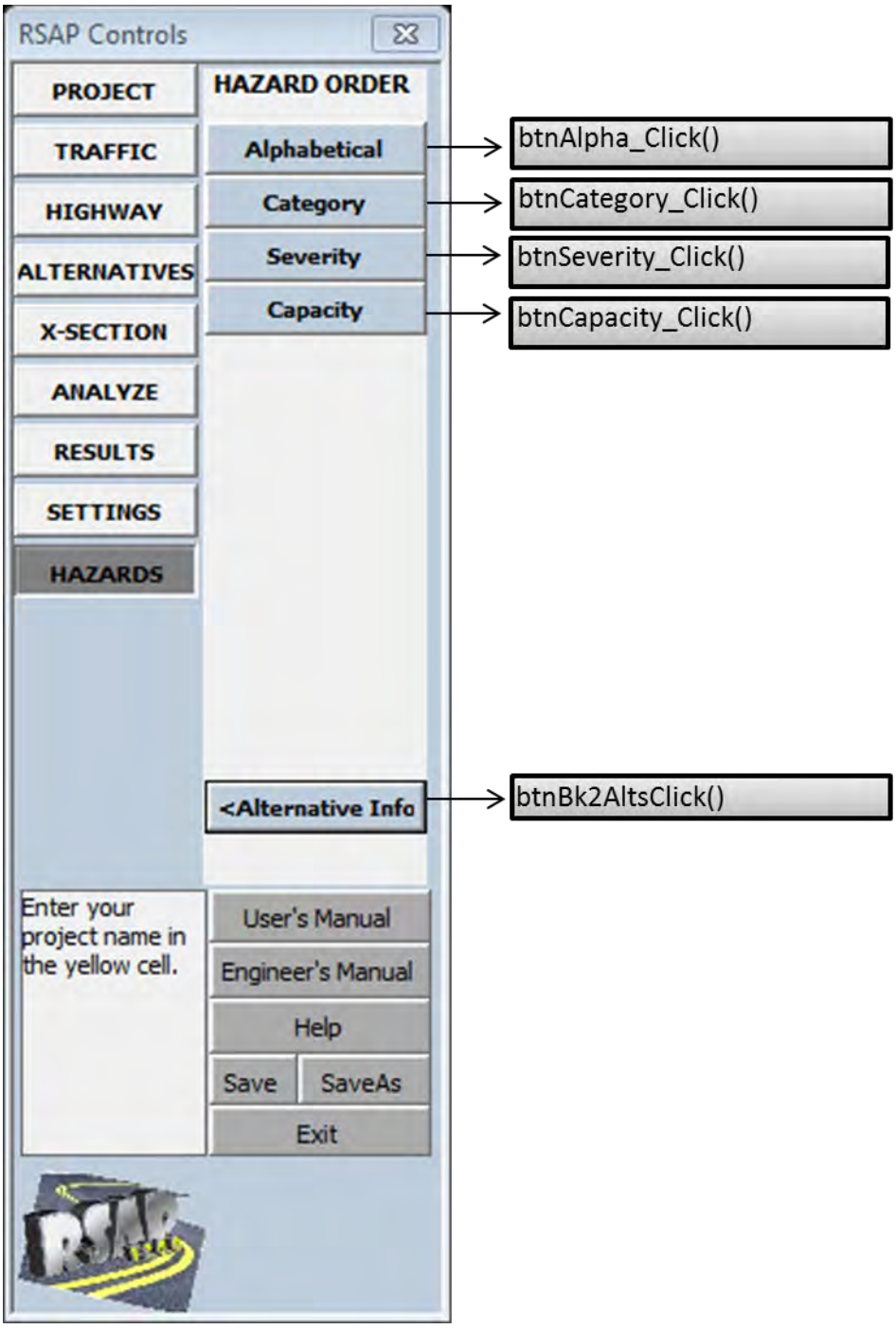


Figure 21. RSAP Controls Dialog -- Hazards.

btnAlpha_Click()

This button, like the following three buttons, simply rearranges the hazard data base shown in the "Severity" worksheet. In this case the hazards are arranged in alphabetical order by the hazard name listed in column A. The method uses the following VBA Excel sort method:

```
'first find the bottom row
Count = 4
Do Until shSeverity.Cells(Count, 1) = ""
   Count = Count + 1
Loop
botRow = Count - 1

'sort the list in alphabetical order to save on the severity worksheet
With shSeverity.Sort
   .SortFields.Clear
   .SortFields.Add Key:=Range(Cells(4, 1), Cells(botRow, 1)),
SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal
   .SortFields.Add Key:=Range(Cells(4, 9), Cells(botRow, 9)),
SortOn:=xlSortOnValues, Order:=xlAscending, DataOption:=xlSortNormal
   .SetRange Range(Cells(4, 1), Cells(botRow, 24))
   .Header = xlNo
   .MatchCase = False
   .Orientation = xlTopToBottom
   .SortMethod = xlPinYin
   .Apply
End With
```

btnCategory_Click()

This method works exactly like btnAlpha_Click() except the data is sorted by the hazard category in column 11 (i.e., column K) rather than 1.

btnSeverity_Click()

This method works exactly like btnAlpha_Click() except the data is sorted by the severity in terms of the $EFCCR_{65}$ in column 5 (i.e., column E) rather than 1.

btnCapacity_Click()

This method works exactly like btnAlpha_Click() except the data is sorted by the hazard capacity listed in in column 8 (i.e., column H) rather than 1.

btnBk2Alts_Click()

This button selects the “Alternatives” worksheet and sets the frmRSAPcontrols.mpControls.value = 3. This returns the view and control to the “Alternatives” worksheet.

modulesTools.editSeverities()

This is a hidden key-stroke macro meaning that it is not initiated from the RSAP Controls Dialog user interface and is not mentioned in the User’s Manual. Typical users will not need to edit the information on the “Severity” worksheet while it is visible it is

protected against user input. If the information in the hazard data base does need to be edited or updated, however, this macro can be used to do so.

To execute the macro go to the "Severity" worksheet and use the key stroke CTRL+SHIFT+H. The macro is a toggle so the first time the key stroke is pressed the "Severity" worksheet is unprotected and the Excel ribbon interface is turned on. All the Excel interface features are turned on and the worksheet can be edited like any typical worksheet. The second time the CTRL+SHIFT+H key stroke is issued the ribbon interface is turned off, the sheet is re-protected and the internal hazard menus are sorted and rebuilt using the following code and RSAPv3 is re-started.

```
shSeverity.Select ' select the severity worksheet

'if the headings are on, turn them off and re-build the hazard menus
'otherwise turn them off and allow editing.
If ActiveWindow.DisplayHeadings=TRUE Then
        Start at row 4
        Count the rows until a blank cell is found
        The last non-blank cell is the bottomRow
        Sort the data fields in the worksheet by hazard category (i.e., column 11)
        Unprotect and make visible shPrgData
        Clear the old hazard menu definitions in Range("J3:T48")
        Copy the category names from shSeverity to shPrgData
        Rebuild the context sensitive menus by resizing the range names for each
                hazard category.
        Turn off display headings
        Turn off the formula bar
        Protect shSeverity
        Protect shPrgData
        Hide shPrgData
        Hide the Excel ribbons interface
        Re-start RSAP by calling moduleTools.StartRSAP
        Exit
Else
'turn on the ribbon interface and unprotect the worksheet to allow edits
        Turn on display headings
        Turn on the formula bar
        Unprotect shSeverity
        Unprotect shPrgData
        Unhide shPrgData
        Unhide the Excel ribbons interface
        Exit
```

End if

ENCROACHMENT MODULE

As discussed earlier, the number of encroachments that can be expected on a particular road section in a year is given by:

$$ADT \cdot L \cdot P(Encr) = L \cdot f_{\substack{base \\ encr}} \cdot \prod_{i=1}^{n} EAF_i$$

where the terms are as defined earlier. The encroachment module of RSAPv3 is executed when the user presses the "Segment Project" button on the "Highway" tab of the RSAP controls dialog shown earlier in Figure 9. The code for the encroachment module is contained in module.Encroachments which contains five subroutines and functions.

PROCEDURE

Estimating the number of encroachments is initiated in one of two ways by the user: either selecting the "Segment Project" button or the "Recalculate Encroachments" buttons on the RSAP controls dialog as shown in Figure 9. Selecting either button results in the following:

moduleEncroachments.calcBaseEncr
moduleEncrochments.adjustEncr

RSAP first calculates the expected number of encroachments using the base conditions (i.e., no adjustments) and then finds the appropriate adjustment factors. The details of each of these subroutines is discussed below.

adjust()

This function is a linear interpolation lookup function that takes the segment characteristic to find the appropriate adjustment value based on the characteristic value and the highway type.

Input Variables

The following five variables are passed to the subroutine:

- *inSheet* is …
- *startCell* is the top left cell in the adjustment factor lookup table being queried. The legal values of *startCell* in this version of RSAP are:
    - A5 or the base encroachment frequency,
    - E5 for the access density adjustment factor,
    - I5 for the rumble strip adjustment factor,
    - M5 for the multi-lane adjustment factor,
    - Q5 for the posted speed limit adjustment factor,
    - Y5 for the shoulder width adjustment factor,
    - AC5 for the terrain type adjustment factor,
    - AG5 for the grade adjustment factor and

    - AK5 for the horizontal curvature adjustment factor.
- *shift* corresponds to the number of columns to the left of the first column of the queried lookup table and represents the highway type. *Shift* can have one of the following values:
    - 1 for divided highways,
    - 2 for undivided highways and
    - 3 for one-way roadways.

      Any other value returns an error.
- *lookUpVal* is the value of the particular characteristic that is being adjusted. For example if the adjustment factor for Lane Width is being sought *lookUpVal* might be 12 feet.
- *debugFlag* is a Boolean indicator that will turn on debugging messages that may be useful to a programmer debugging the procedures.

Procedure

All the encroachment adjustment factors are located on shEncrAdj so the first step is to select that worksheet.

shEncrAdj.Range(startCell).select
Do Until lookUpVal >= selection and lookUpValue <= selection.off(next Row)
    Selection.offset(nextRow).select
Loop
If selection.value="" then notify user an adjustment could not be found
Else
    A=selection
    B=selection.offset(1,0)
    C=selection.offset(0,shft)
    D=selection.offset(1,shft)
    E=lookUpVal
    Adjustment=C+(D-C)(E-A)/B-A)*
End if
Return (Adjustment)

In setting up the lookup tables on shEncrAdj it is important to be sure that the first and last rows of the first column have values that are sized such that the input value is within the range. Using the Lane Width example, the smallest lane width in the table is 0 and the largest is 40. Obviously these are not reasonable values but they are used so that if a value of, say 8.9 is entered the value will not fall below the first value in the table. Likewise a maximum value should be identified such that there will never be an input value larger than that value. If a 14-ft lane is entered the value is still in the range of the table and the interpolation will work correctly.

adjustEncr()

After the base encroachment frequency has been determined in *calcBaseEncr()* it is modified by any appropriate adjustment factors based on the road characteristics written by *segChars* range A71:P90.

Program Variables

spdLim- the posted speed limit,

numLane – the total number of lanes,

p_grade – the grade in the primary direction,

p_hcurv – radius of horizontal curvature in the primary direction,

numLanePrim- number of lanes in the primary direction,

lnwidth – lane width,

access- access density,

rumble – Boolean value indicating presence/absence of edge-line rumble strips,

hwyType – character indicating the highway type:

- D for divided highways,
- U for undivided highways and
- O for one-way roads and ramps.

Terrain – character indicating the general terrain type:

- F for flat,
- R for rolling and
- M for mountainous.

Seg – segment number,

Procedure

adjustEncr() proceeds by reading in the highway characteristics from shRdSegs, performing some error checking appropriate to each characteristics and then looking up the appropriate adjustment factor on shEncrAdj using the adjust() function.

The subroutine has logic to account for the directionality of some of the adjustments. For example, the grade in the primary direction is used to find the adjustment in the opposing direction by taking the negative. If the primary grade is +2 percent then the opposing grade must be -2 percent. Similarly, if the total number of lanes are known and the number of lanes in the primary direction are known the number of lanes in the opposing direction can be calculated and the appropriate adjustment found.

```
shRdSegs.Range("A71").Select
Do Until Selection.value = ""
        seg = Selection.value
        'Work through the encroachments adjustments segment by segment.
        spdLim = Selection.offset(0, 4).value → column 5
```

```
numLane = Selection.offset(0, 6).value → column 7
p_grade = Selection.offset(0, 7).value → column 8
p_hcurv = Selection.offset(0, 8).value → column 9
'Protect against characters in the field
If LCase(p_hcurv) = "t" Then
        p_hcurv = 9999
End If
'Protect against large radii curves
 If Abs(p_hcurv > 9999) Then
        p_hcurv = (p_hcurv / Abs(p_hcurv)) * 9999
   End If
   numLanePrim = Selection.offset(0, 9).value → column 10
   'shldrWidth = Selection.Offset(0, 18).Value → column 19
   lnwidth = Selection.offset(0, 12).value → column 13
   access = Selection.offset(0, 13).value → column 14
   rumble = Selection.offset(0, 14).value → column 15
   hwyType = shRdSegs.Range("E5").value
   terrain = shRdSegs.Range("E6").value

   'check to be sure terrain value is legal
   If LCase(terrain) = "flat" Or LCase(terrain) = "f" Then
      terrain = "F"
   ElseIf LCase(terrain) = "mountainous"
      Or LCase(terrain) = "m" Then
         terrain = "M"
   ElseIf LCase(terrain) = "rolling" Or LCase(terrain) = "r" Then
          terrain = "R"
   Else  → invalid terrain, set terrain=”F”and notify user
   End If
    shRdSegs.Range("E6").value = terrain

    Col = 2
    ' Undivided highway data is offset 1
    ' Divided highway data is offset 2
    ' One-way highway data is offset 3
    ' All others return an error
    Select Case UCase(hwyType)
       Case "U"
          Col = 1
       Case "D"
```

```
        Col = 2
    Case "O"
        Col = 3
        If Not (shRdSegs.Range("E3").value) = 100 Then
        'make sure 100% of volume is in primary direction for one-way
        Userchoice → tell user RSAP is changine the primary vol to 100
            If userchoice = vbOK Then
                shRdSegs.Range("E3").value = 100
            Else
                Exit Sub
            End If
        End If
    Case Else
        MsgBox ("Error, illegal highway type")
        Exit Sub
    End Select

  'Primary Direction Grade Adjustment
  p_gradeAdj = adjust(shEncrAdj, "AG5", 1, p_grade, debugFlag)
  'Primary Direction Horizontal Curve Adjustment
  p_hcurvAdj = adjust(shEncrAdj, "AK5", 1, p_hcurv, debugFlag)
  'Speed Limit Adjustment
  spdLimAdj = adjust(shEncrAdj, "Q5", Col, spdLim, debugFlag)
  'Lane Width Adjustment
  lnWidthAdj = adjust(shEncrAdj, "U5", Col, lnwidth, debugFlag)

  If numLanePrim >= numLane And numLane > 1 Then
MsgBox ("Number of lanes in the primary direction on" & vbCrLf & _
            "segment " & CStr(seg) & "cannot be equal to or greater
            than the" & vbCrLf & _
        "total number of lanes.  Dividing lanes " & vbCrLf & _
        "equally between directions.")
    numLanePrim = numLane / 2
  End If
  'Number of Lanes Adjustment for primary direction
   p_numLaneAdj = adjust(shEncrAdj, "M5", Col, numLanePrim,
    debugFlag)

  ' find the adjustments for the opposing directions but only if
    not a one-way highway
```

```
If Not (hwyType = "O") Then
   'Number of Lanes Adjustment for opposing direction
  o_numLaneAdj = adjust(shEncrAdj, "M5", Col, (numLane –
   numLanePrim), debugFlag)
   'Opposing Direction Grade Adjustment
   o_gradeAdj = adjust(shEncrAdj, "AG5", 1, -p_grade, debugFlag)
   'Opposing Direction Horizontal Curve Adjustment
   o_hcurvAdj = adjust(shEncrAdj, "AK5", 1, -p_hcurv, debugFlag)
 Else
   o_numLaneAdj = 0#
   o_gradeAdj = 0#
   o_hcurvAdj = 0#
End If

'Shoulder Width Adjustment
 'shldrWidthAdj = adjust(shEncrAdj, "Y5", col, shldrWidth,
   debugFlag)

'Access Density Adjustment
 accessAdj = adjust(shEncrAdj, "E5", Col, access, debugFlag)

'Rumble Strip Adjustment
shEncrAdj.Select
Range("I5").Select
Do Until Selection.value = rumble
Selection.offset(1, 0).Select
   Loop
rumbleAdj = Selection.offset(0, Col)
If debugFlag = True Then
   MsgBox ("For " & CStr(rumble) & ", adjustment is = " &
CStr(rumbleAdj) & ".")
   End If

'Terrain Adjustment
shEncrAdj.Select
Range("AC5").Select
Do Until Selection.value = terrain
   Selection.offset(1, 0).Select
   Loop
terrainAdj = Selection.offset(0, 1)
```

```
            If debugFlag = True Then
               MsgBox ("For " & CStr(terrain) & ", adjustment is = " &
CStr(terrainAdj) & ".")
               End If

            'Write the adjustments back on shRdChar
            shRdSegs.Select
            shRdSegs.Unprotect (shPrgData.Range("B6").value)
            Range("A71").Select
            Selection.offset(seg - 1, 0).Select
            Selection.offset(-30, 1).value = p_gradeAdj
            Selection.offset(-30, 2).value = p_hcurvAdj
            Selection.offset(-30, 3).value = p_numLaneAdj
            Selection.offset(-30, 4).value = o_gradeAdj
            Selection.offset(-30, 5).value = o_hcurvAdj
            Selection.offset(-30, 6).value = o_numLaneAdj
            Selection.offset(-30, 7).value = spdLimAdj
            Selection.offset(-30, 8).value = lnWidthAdj
            'Selection.Offset(0, 30).Value = shldrWidthAdj
            Selection.offset(-30, 9).value = accessAdj
            Selection.offset(-30, 10).value = rumbleAdj
            Selection.offset(-30, 11).value = terrainAdj
            Selection.offset(-30, 12).value = shRdSegs.Range("E8").value
            'increment for the next row

            Selection.offset(1, 0).Select
      Loop
```

calcBaseEncr()

The road characteristics will have been previously written into shRdSegs.Range(A71:P90) by the *segChars* subroutine so this subroutine starts by selecting cell A71, the top-left cell of the road characteristics table.

Procedure

The procedure is to read in the start and end station for each segment, its ADT and the highway type and call the adjust() function to find the appropriate base encroachment frequency in the Base Encroachment Frequency lookup table on shEncrAdj.

```
shRdSegs.Range(A71).select
do until selection.value="" 'the segment number is in col A
      segment=selection.value
```

startSta=selection.offset(0,1).value
endStat=selecton.ofset(0,2).value
segmentLength=endSta-startSta
if segmentLength is blank or negative then
Display error message and exit
Else
ADT=selection.offset(0,3).value
hwyType=range(E5).value
Select Case hwyType
Case "U" → Col=1
Case "D" → Col=2
Case "O" → Col=3
Case Else
Invalid highway type → Exitt
End select
baseEncr=adjust(shEncrAdj, "A5", Col, ADT, FALSE)
'this calls the adjust function which looks up the appropriate base
'encroachment rate from the look up table on shEncrAdj
*baseEncr=baseEncr*segmentLength/5280*
'the lookup table value is in units of encr/mi/yr so this adjusts the
'rate based on the actual segment length.
Write baseEncr in column 5
End if
Loop ' proceed to the next segment until there are no segments left

segChars()

This subroutine is activated by pressing the "Segment project" button on the "Highway" tab of the RSAP controls dialog. Prior to calling this subroutine the style of the input area (i.e., shRdSegs.Range(A98:B587)) is changed to "Normal 2" to prevent further use input and the Road Characteristics Table (i.e., shRdSegs.Range(B71:C90, G71:V90)) is cleared to prepare it for new data. The macro sortRoadChars() is then called to sort the characteristics into homogeneous segments and then this macro is called.

sortRoadChars()

This subroutine is activated by pressing the "Segment project" button on the "Highway" tab of the RSAP controls dialog. Prior to calling this subroutine the style of the input area (i.e., shRdSegs.Range(A98:B587)) is changed to "Normal 2" to prevent further use input and the Road Characteristics Table (i.e., shRdSegs.Range(B71:C90, G71:V90)) is cleared to prepare it for new data.

Procedure

The purpose of the macro is to sort the characteristics of the roadway into order of increasing station number in the primary direction. The sort first sorts by start station

and then by end station. This sometimes takes several iterations until the list is contiguous (i.e., the end station of one segment is the same as the start station of the next). The macro will split over-lapping characteristic definitions and fill-in missing segments. If any row has a start station that is greater than the end station the row is deleted and the user is notified. Negative stations are allowed.

If shRdSegs.range(A98) is blank then
Notify the user there are not segment characteristics
Exit the sub
Else
Do Until the Begin Station value is blank
If End Station <= Begin Station then
Notify the user. Ask if this row should be deleted
If User says "NO" then
Exit Sub
Else
Copy the range from the next row to the last
Paste the copied range over the active row
Increment the row
End if
Loop
allOK=FALSE 'allOK is a flag indicating a problem has been found
CheckNo =0 'checkNo is an interation counter
maxChecks=10 'maxChecks is the maximum no. of iterations
Do While allOK=FALSE and CheckNo<maxChecks
Sort shRdSegs.Range(A98:D587) by Begin Station and End Station
If Begin and End stations of this row are the same as the next then
The characteristics are on the same segment
Else if Begin Stations are the same but the Ends are different then
Copy the longer segment and add a row
Set the End Station of the first row to the smaller value
Set the Begin station of the 2nd row to the end station of 1st
Else if 1st Begin Sta < the next and next End Sta > 1st Begin Sta
Split segment into two rows and adjust the begin and end
End if
Increment the row
Loop
'Check to be sure all segments are contiguous
allOK=TRUE
Do Until Begin Sta is blank

If current Begin Sta > current End Sta then
allOK=FALSE
End if
if current Begin Sta > next Begin Sta then
allOk=FALSE
end if
if current and next Begin Sta are same but Ends are not then
allOK=FALSE
End if
Increment row
Loop
Seg=1 'stating segment is 1
Do Until Begin Sta is blank or number of segments >20
If begin and end stations of current and next row are same then
Write seg into row E
Else
Seg=seg+1
End if

CRASH PREDICTION MODULE

INTRODUCTION

This macro computes the probability of a collision, given that a vehicle has encroached onto the roadside or median in order to accomplish the following portion of the main RSAP governing equation:

$$P(Cr|Encr) = \frac{1}{m}\sum_{k=1}^{l}\sum_{j=1}^{m} P(Trj_k \cap Haz_j|Encr)$$

This is accomplished by directly projecting encroachments from the reconstructed trajectory paths in the NCHRP 17-22 crash database onto the roadside or median and looking for intersections between the trajectories and hazard locations. This approach uses crash data directly to determine probability of impact and probable impact conditions (e.g., speed, angle, orientation, etc.) and is thus a deterministic method (i.e., given the same input it will always provide the same result). Each trajectory path in the database is examined point-by-point to determine if it intersects the location of a hazard. RSAP then computes the probability of impact based on the ratio of total number of impacts divided by total number of trajectory paths.

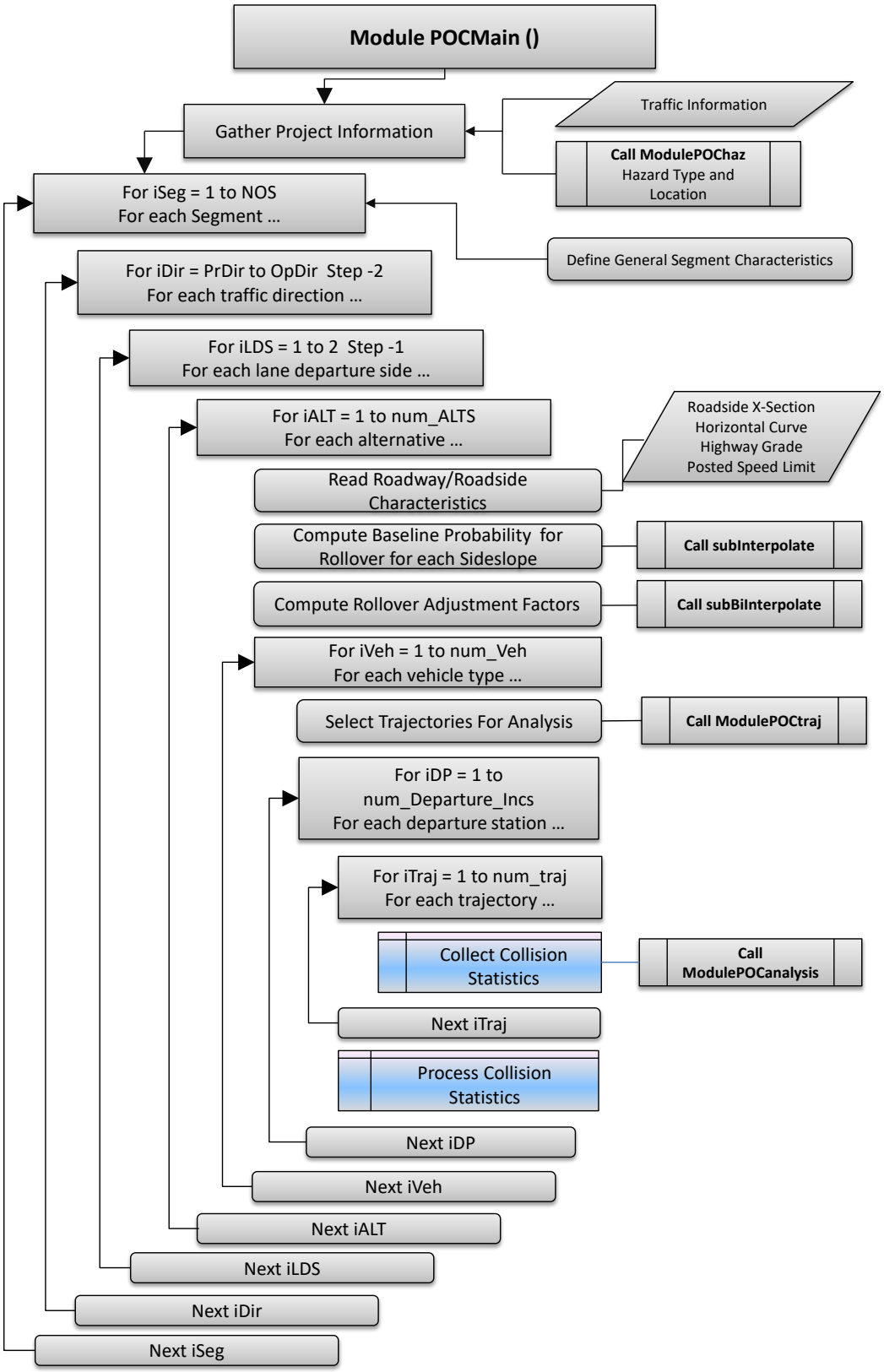
MODULE POCMAIN

ModulePOCmain is the Probability of Collision module and serves as the main program that controls the program flow for computing probability of collision. The probability of collision is determined by assessing each reconstructed trajectory path point-by-point for interaction with each roadside hazard and terrain feature. The flow chart for this program module is shown in Figure 22. The first step in the calculations is to read in basic project information including, roadway type, roadway characteristics and traffic data for each roadway segment.

The second step is to read in the roadside cross-section geometry and the type and location of each hazard to be analyzed for each set of alternatives. This task is performed in Module POChaz.

The third step is to select relevant trajectories from the crash reconstruction database in RSAPv3. This task is performed in Module POCtraj. The database is searched to identify crash cases that have roadway and roadside characteristics that most closely match those of the current analysis case (i.e., for current segment, roadside, and alternative), then the vehicle trajectories from that subset of crash cases are mapped onto the roadside and/or median.

The fourth step is to examine each trajectory for a possible interaction (i.e., collision) with a modeled hazard. This task is performed in Module POCanalysis. When examining a trajectory, there are many possible outcomes. For example, a trajectory may interact with a roadside barrier, then either stop in contact, penetrate, rollover the barrier or be redirected. The probability of each of these events is then calculated and the outcome of each of these events is evaluated. Continuing with the same example, if the vehicle penetrates the barrier, the trajectory is followed further to determine if it interacts with any other modeled hazards or results in rollover. If the trajectory is redirected, then redirection paths are evaluated for secondary collision events. After all of the possibilities have been exhausted, the selected trajectories are incremented forward a predetermined amount (default value is four feet) along the segment to continue the analysis. The following sections discuss the steps of the analysis process in more detail.


Module POCMain ()
Gather Project Information
Traffic Information
Call ModulePOChaz
Hazard Type and Location
For iSeg = 1 to NOS
For each Segment …
Define General Segment Characteristics
For iDir = PrDir to OpDir Step -2
For each traffic direction …
For iLDS = 1 to 2 Step -1
For each lane departure side …
For iALT = 1 to num_ALTS
For each alternative …
Roadside X-Section
Horizontal Curve
Highway Grade
Posted Speed Limit
Read Roadway/Roadside Characteristics
Compute Baseline Probability for Rollover for each Sideslope
Call subInterpolate
Compute Rollover Adjustment Factors
Call subBiInterpolate
For iVeh = 1 to num_Veh
For each vehicle type …
Select Trajectories For Analysis
Call ModulePOCtraj
For iDP = 1 to num_Departure_Incs
For each departure station …
For iTraj = 1 to num_traj
For each trajectory …
Collect Collision Statistics
Call ModulePOCanalysis
Next iTraj
Process Collision Statistics
Next iDP
Next iVeh
Next iALT
Next iLDS
Next iDir
Next iSeg

Input Variables

- **oNum_Hazards:** Number of hazards
- **oHzrd_Type:** Hazard type (line, area, point)
- **oHzrd_Name:** Hazard name (e.g., Strong Post Guardrail, Concrete Median Barrier, etc.)
- **oHzrd_EFCCR65:** EFCCR65 for hazard type
- **oHzrd_Prcnt_PRV:** Percent Penetration/Rollover/Vault for hazard
- **oHzrd_Prcnt_RR:** Percent redirection for hazard: including rollover after redirection
- **oHzrd_Capacity:** Energy capacity for hazard (ft-lb)
- **oHzrd_Height:** Barrier height (in)
- **oHzrd_Connection:** Identifies LON hazard attached to END TERMINAL
- **oHx:** Longitudinal coordinates of hazard (ft)
- **oHy:** Lateral coordinates of hazard (ft)
- **oPDG**: Vertical grade (percent)
- **oPDCR**: Horizontal curve radius in primary direction
- **oPSL**: Posted speed limit (mph)
- **DP_inc:** Increment of departure points along segment (ft)
- **SegStart:** Longitudinal start point of segment (ft)
- **SegEnd:** Longitudinal end point of segment (ft)
- **oMedianHW:** Median half-width (ft)
- **hwyType:** Highway type (divided, undivided or one-way)
- **NOS**: Total number of segments

Program Variables

- **Analysis**: Flag for conducting analysis for current roadside section
- **Col_EFCCRi**: Column position on worksheet "POC Scratch" for analysis output
- **count_pene:** Number of penetrations
- **count_RR:** Number of rollovers after redirection from a hazard
- **CSglob:** User defined X-section
    - **CSglob(*,1):** y-coordinate
    - **CSglob(*,2):** z-coordinate
    - **CSglob(*,3):** Relative slope
    - **CSglob(*,4):** Baseline probability of rollover as a function of slope
    - **CSglob(*,5):** Probability of rollover adjustment factor for Grade
    - **CSglob(*,6):** Probability of rollover adjustment factor for horizontal curve
- **CSloc:** User defined X-section (y,z) data in local coordinates
- **d0:** Distance from previous trajectory location to Hazard
- **decel:** Deceleration of trajectory path

- **EFCCR_RR:** Total of all EFCCRs for rollover after collision with hazard
- **EFCCR_tot:** Total of all EFCCRs for each hazard
- **EFCCRi:** Total of all EFCCRs for each trajectory computed for each segment
- **grid_inc:** x-increments for trajectories
- **HM:** Slope of line between hazard coordinates
- **Hy0:** Lateral coordinate of hazard at longitudinal coordinate *x*
- **Hy1:** Lateral coordinate of hazard at longitudinal coordinate *x+1*
- **impact_Count_NTS:** Non-traffic-side impacts on each hazard
- **impact_Count_tot:** Total count of all impacts on each hazard
- **impact_Count_TS:** Traffic-side impacts on each hazard
- **MaxL:** Maximum length of vehicle trajectory path
- **Max_num_traj**: Maximum number of possible trajectory paths for the analysis
- **MaxX:** Maximum x-coord value for vehicle trajectory
- **MinY:** Minimum y-coord value for vehicle trajectory
- **NCgrade**: Number of columns of data in the "Slope-Grade Adjustment" table
- **NChorcuv**: Number of columns of data in the "Slope-Horizontal Curvature (1/R) Adjustment" table
- **NCslope**: Number of columns of data in the "Rollover Probability" table
- **nopc:** Number of data points used in defining trajectory paths
- **NRgrade**: Number of rows of data in the "Slope-Grade Adjustment" table
- **NRhorcurv**: Number of rows of data in the "Slope-Horizontal Curvature (1/R) Adjustment" table
- **NRslope**: Number of rows of data in the "Rollover Probability" table
- **num_Departure_Incs:** Total number of departure points for a given segment
- **num_Dir:** Number of directions (e.g., Primary and/or Opposing) for each segment
- **num_LDS:** Number of lane departure sides (e.g., left and/or right) for each direction
- **num_pre:** Number of data columns preceding the trajectory path information in the trajectory databases
- **num_traj**: Number of trajectories evaluated at each increment for the current roadside segment
- **num_traj_seg**: Current trajectory path number being analyzed on segment
- **num_traj_tot**: Total number of trajectories evaluated for the current roadside segment
- **num_traj5:** Number of trajectory cases used in analysis
- **num_veh**: Total number of vehicle types for analysis
- **PHIgrade:** Table of Adjustment factors for rollover based on vertical grade

- **PHIhorcurv:** Table of Adjustment factors for rollover based on horizontal curvature
- **POC:** Probability of occurrence used as a weight factor for collision costs
- **PRslope:** Table of baseline probability for rollover
- **R:** Radius of point hazards
- **SegLength:** Length of segment
- **SegRow**: Row number for input of segment data on worksheet “Road Segements”
- **Shift**: For use in identifying column position on worksheet “Cross-Section” for input of roadside cross-section data
- **Row**: Row number for output to worksheet “POC Scratch”
- **TrajectoryGrid**: Name of trajectory-grid sheet for current vehicle type
- **trajx:** Vehicle trajectory path x-coord data (Trajectory Grid)
- **trajy:** Vehicle trajectory path y-coord data (Trajectory Grid)
- **v0:** Trajectory velocity data (Velocity Grid)
- **VehCharac:** Vehicle characteristics
- **X0**: Longitudinal coordinate of current encroachment location
- **Ymax**: Maximum lateral coordinate for roadside cross-section in local coordinate frame

Traffic Information

The traffic mix for the roadway segment and the vehicle characteristics (e.g., mass, dimensions, etc.) are read from the RSAPv3 worksheet "Traffic Information". Twelve columns of information are read from this sheet and are stored in the array variable called "VehCharac", where:

VehCharac(*,1): RSAP Vehicles Types by name (Motorcycles, Passenger Vehicles, Trucks)
VehCharac(*,2): FHWA Vehicle Class Designation
VehCharac(*,3): Percent of Traffic Mix
VehCharac(*,4): RSAP Vehicle Type Designator (M, C, or T)
VehCharac(*,5): Vehicle weight (lbs)
VehCharac(*,6): Vehicle length (ft)
VehCharac(*,7): Vehicle width (ft)
VehCharac(*,8): Longitudinal distance from front of vehicle to center of gravity (ft)
VehCharac(*,9): Vertical distance from ground to center of gravity (ft)
VehCharac(*,10): Crash cost adjustment factor
VehCharac(*,11): RSAP worksheet name containing trajectory information
VehCharac(*,12): RSAP worksheet name containing redirection trajectory information

Do Until *… {all traffic data has been read}*
If *{vehicle mix is not 0}* ***Then***
num_Veh = num_Veh + 1
For *j = 1* ***To*** *12*
VehCharac(num_Veh, j) = {data in column j}
Next *j*
End If
Loop

Define Hazard Information

Information about each of the hazards including hazard name, hazard type and geometric coordinates are read from the RSAPv3 worksheet called "Alternatives". The program calls "ModulePOChaz" to perform this task which returns the following information:

- Number of alternatives (Num_Alt)
- Number of hazards associated with each alternative (oNum_Hazards)
- Hazard Type (oHzrd_Type)
- Hazard name (oHzrd_Name)
- General Type of Hazard (oHzrd_GenType)
- The EFCCR65 for the hazard (oHzrd_EFCCR65)

- The percent penetration/rollover/vault for the hazard (oHzrd_Prcnt_PRV) derived from crash data
- The percent rollovers after redirection from the hazard (oHzrd_Prcnt_RR) derived from crash data
- The structural capacity of the hazard (oHzrd_Capacity) in units of ft-lb
- The height of the hazard (oHzrd_Height) for longitudinal barriers
- The longitudinal barrier that an end-terminal is attached to (oHzrd_Connection)
- The longitudinal coordinate of the nearest upstream point of the hazard (oHx)
- The lateral coordinate of the nearest upstream point of the hazard (oHy)
- The slope of the line defining line-hazards (HM)
- Radius of point hazards (R)

Lookup Tables for Probability of Terrain Rollover

The probability of rollover is computed in RSAPv3 based on sideslope, horizontal curve radius, and highway grade. The data which RSAPv3 uses for computing the probability of rollover were adopted from the NCHRP 17-11 study conducted by Bligh, Miaou and Mak [Bligh04] and from the *FHWA supplement to the Roadside Design Guide* [FHWA91]. More detail on the development of the rollover model is discussed in the ENGINEER'S MANUAL.

There are currently three lookup tables in RSAPv3 related to the probability of rollover on terrain slopes. These tables are listed on the "Encr Freq and Adj" worksheet under the headings "Rollover Prob.", "Slope-Grade Adjustment", and "Slope-Horizontal Curvature (1/R) Adjustment", as shown in Table 1, Table 2 and Table 3, respectively.

Table 1. Lookup Table for probability of rollover as a function of roadside slope.

	AO	AP
1	Rollover Prob.	
2		P(R|S)
3	Slope	50
4		
5	-0.5000	0.1852
6	-0.3333	0.1204
7	-0.2500	0.0682
8	-0.1667	0.0582
9	-0.1000	0.0503
10	0.0000	0.0361
11	0.2500	0.0582
12	0.3333	0.0899
13	0.5000	0.1323

Table 1 provides the baseline probability of rollover for straight, level roadways with speed limit of 50 mph and constant roadside slopes. The left column in the table is the roadside slope and the right column is the corresponding probability of rollover. The program reads this table by calling the subroutine "subRollInput".

Call *subRollInput(PRslope, NRslope, NCslope, "Rollover Prob.")*

The input to subroutine *subRollInput* is simply the name of the table heading under which the data is found in worksheet "Encr Freq and Adj". The subroutine then searches the table headings in worksheet "Encr Freq and Adj" for the name "Rollover Prob." It then determines how many columns of data are in the table (e.g., there are two columns of data in Table 1). The data in the table is read one row at a time until a blank row is found. The data that is read from the worksheet is stored in the variable array name "PRslope" which is passed back to the main program. The routine is programed this way to facilitate changes and updates to the probability of rollover data, which can be made directly to the worksheet without any modifications needed in the program. For example, not only can the values in the table be easily changed, but also the number of rows and columns of data can be easily expanded or reduced as well. It is important that that the names of these table headings are not changed, however, since the program uses these names to identify the appropriate table on the worksheet.

Table 2. Adjustment Factor Lookup Table for probability of rollover as a function of roadside slope and vertical grade.

	AQ	AR	AS	AT	AU	AV
1	Slope-Grade Adjustment					
2		Vertical Grade				
3	Slope	-6.00%	-3.00%	0.00%	3.00%	6.00%
4						
5	-0.5000	1.2965	1.2949	1.0000	0.6570	0.6179
6	-0.3333	1.2965	1.2949	1.0000	0.6570	0.6179
7	-0.2500	1.7830	1.5279	1.0000	1.0103	0.7991
8	-0.1667	1.5773	1.0859	1.0000	0.9570	0.7595
9	-0.1000	1.1491	1.0696	1.0000	0.7157	0.5447
10	0.0000	1.5042	1.1163	1.0000	0.7230	0.6316
11	0.2500	1.5042	1.1163	1.0000	0.7230	0.6316
12	0.3333	1.5042	1.1163	1.0000	0.7230	0.6316
13	0.5000	1.5042	1.1163	1.0000	0.7230	0.6316

Table 3. Adjustment Factor Lookup Table for probability of rollover as a function of roadside slope and horizontal curve radius.

	AW	AX	AY	AZ	BA	BB	BC
1	Slope-Horizontal Curvature (1/R) Adjustment						
2		-500	-637	-955	-1910	-100000	500
3	Slope	-0.002	-0.00157	-0.00105	-0.00052	-0.00001	0.002
4							
5	-0.5000	1.0623	1.0623	1.1445	1.2118	1.0000	1.0000
6	-0.3333	1.0623	1.0623	1.1445	1.2118	1.0000	1.0000
7	-0.2500	1.3519	1.3519	1.4457	1.2991	1.0000	1.0000
8	-0.1667	0.8471	0.8471	0.9450	1.0619	1.0000	1.0000
9	-0.1000	0.9583	0.9583	1.0636	1.0080	1.0000	1.0000
10	0.0000	1.2548	1.2548	1.1801	1.0831	1.0000	1.0000
11	0.2500	1.2548	1.2548	1.1801	1.0831	1.0000	1.0000
12	0.3333	1.2548	1.2548	1.1801	1.0831	1.0000	1.0000
13	0.5000	1.2548	1.2548	1.1801	1.0831	1.0000	1.0000

Call *subRollInput(PHIgrade, NRgrade, NCgrade, "Slope-Grade Adjustment")*
Call *subRollInput(PHIhorcurv, NRhorcurv, NChorcurv, "Slope-Horizontal Curvature (1/R) Adjustment")*

Segment Characteristics and Analysis Settings

This section of the program (1) reads in starting and ending coordinates for each segment in the project and (2) reads in various analysis settings from the RSAPV3 CONTROL FORM including, the distance between encroachment points along the roadway segment and the encroachment sides that are to be evaluated in the analysis, as illustrated in Figure 23.

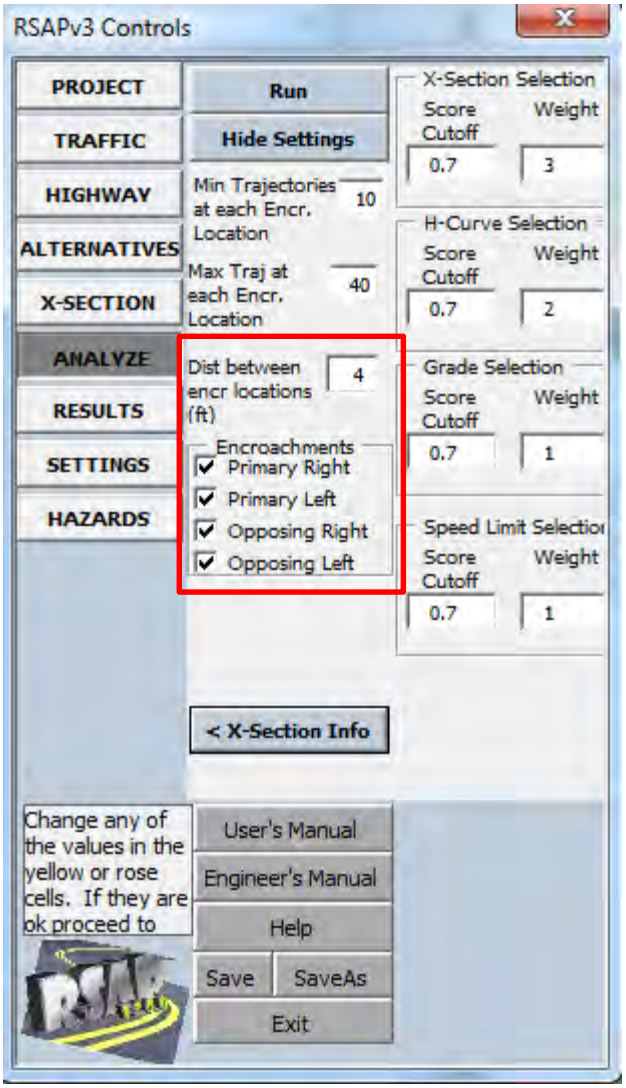


Figure 23. RSAP Controls Dialog – Analyze (Expanded View Showing Settings).

DP_inc = {distance between encroachment locations (ft) read from RSAPv3 Control Form}

***If** {no value is provided for DP_inc}*
***then** {a default value of 4 ft is used}*
NOS = {number of segments read from RSAPv3 worksheet "Road Segments"}
***For** iSeg = 1 **To** NOS*
SegStart = {Start station for segment from RSAPv3 worksheet "Road Segments"}
SegEnd = {End station for segment from RSAPv3 worksheet "Road Segments"}
SegLength = SegEnd - SegStart
' total length of segment
num_Departure_Incs = {Integer Value of (SegLength / DP_inc)}

The number of directions, the number of departure sides and the median width is determined based on Highway type. There are three roadway types in RSAPv3: (1) divided roadway, (2) undivided roadway and (3) one-way roadway, as illustrated in Figure 24, Figure 25, and Figure 26, respectively.

A divided highway, as shown in Figure 24, has two directions of traffic (Primary and Opposing), separated by a median, whose width is determined from the RSAPv3 worksheet named "Road Segments". For each direction of traffic there are two possible encroachment options (left-side encroachments and right-side encroachments). Right-side encroachments initiate from the edge-line of the right-most lane of traffic, with respect to

the direction of traffic, and encroach directly onto the roadside. Likewise, left-side encroachments initiate from the edge-line of the left-most lane of traffic, with respect to the direction of traffic, and encroach directly onto the median. The lateral offset for divided highways is measured with respect to the center-line of the median.

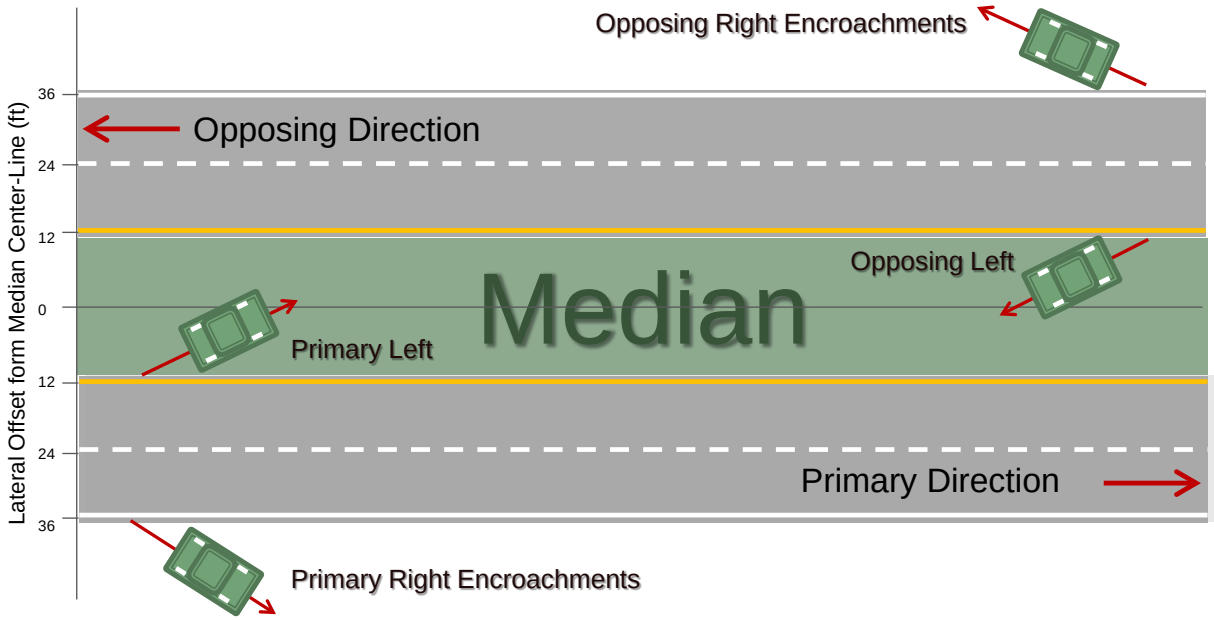


Figure 24. Illustration of encroachment locations for a divided roadway.

An undivided highway, as shown in Figure 25, also has two directions of traffic (Primary and Opposing); however, there is no separation distance between the opposing lanes (e.g., median width is zero). For each direction of traffic there are again two encroachment possibilities, left-side encroachments and right-side encroachments. Right-side encroachments initiate from the edge-line of the right-most lane of traffic, with respect to the direction of traffic, and encroach directly onto the roadside. Left-side encroachments initiate from the edge-line of the left-most lane of traffic, with respect to the direction of traffic, and encroach directly into the opposing traffic lanes. Thus, for undivided roadways the lateral extent of the vehicle trajectory must exceed the total width of all opposing lanes before it reaches the left roadside. The lateral offset for undivided highways is measured with respect to the center-line (yellow line) separating the two traffic directions. While left encroachments depart from the centerline of the highway there is no provision in RSAPv3 for examining the probability that the vehicle will strike a vehicle in the opposing direction.

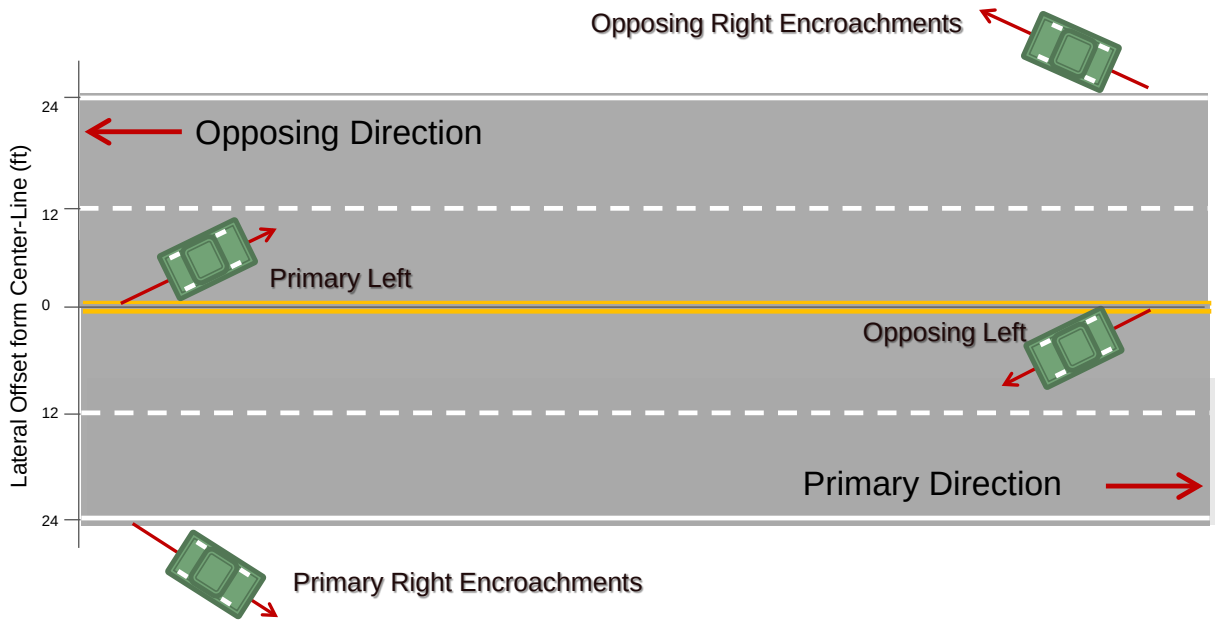


Figure 25. Illustration of encroachment locations for an undivided roadway.

A one-way roadway, as shown in Figure 26, has only one direction of traffic (i.e., primary) and two encroachment locations, left-side encroachments and right-side encroachments. Right-side encroachments initiate from the edge-line of the right-most lane of traffic and encroach directly onto the right-roadside. Left-side encroachments initiate from the edge-line of the left-most lane of traffic and encroach directly into the left-roadside. The lateral offset for one-way roads is measured with respect to the left edge-line of the roadway.

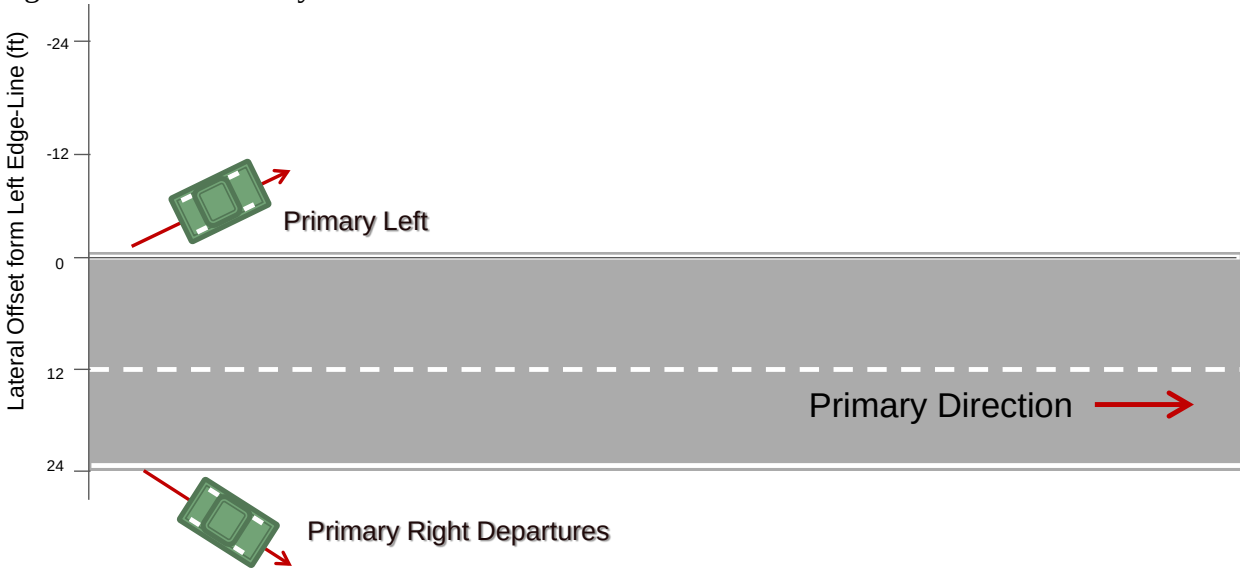


Figure 26. Illustration of encroachment locations for a one-way roadway.

The maximum number of roadside encroachments for each segment is defined in the program via the following procedure:

```
Divided Roadway
        For iSeg = 1 To NOS
            If {roadway type} = "D" Then
                    num_LDS = 2
                    num_Dir = 2
                    oMedianHW = shRdSegs.Cells(SegRow, "K").value / 2

Undivided Roadway
            ElseIf {roadway type} = "U" Then
                    num_LDS = 2
                    num_Dir = 2
                    oMedianHW = 0

One-Way Roadway
            Else
                    num_LDS = 2
                    num_Dir = 1
                    oMedianHW = 0
            End If
```

The next step in the analysis is to determine which encroachments (e.g., Primary-Right, Primary Left, etc.) to evaluate based on user-selection information from the RSAPv3 Control Form.

In some cases, only certain roadsides will be of interest in an analysis. For example, a highway engineer may want to know the best alternative for a median along a specific section of a divided highway where the roadside in both the primary and opposing directions are to remain unchanged. For each new roadway segment and traffic direction, the program will read from the RSAPv3 Control Form to determine which roadsides to analyze (refer to Figure 23**Error! Reference source not found.**). In the following lines of the program, iDir = 1 corresponds to the primary direction of traffic and iDir = -1 represents opposing traffic direction. Likewise, iLDS = 1 corresponds to right side encroachments and iLDS = -1 corresponds to left-side encroachments.

```
    For iSeg = 1 To NOS
      For iDir = 1 To 2 Step -2
        For iLDS = 1 To 2 Step -2
                    ⋮

            Primary-Right Encroachments
            If iDir = 1 And iLDS = 1 Then
```

If *{check-box for primary-right} = False* ***Then*** *{skip analysis}*

Primary-Left Encroachments
ElseIf *iDir = 1* ***And*** *iLDS = -1* ***Then***
If *{check-box for primary-left = False}* ***Then*** *{skip analysis}*

Opposing-Right Encroachments
ElseIf *iDir = -1* ***And*** *iLDS = 1* ***Then***
If {check-box for opposing-right} = False Then {skip analysis}

Opposing-Left Encroachments
ElseIf *iDir = -1* ***And*** *iLDS = -1* ***Then***
If *{check-box for opposing-left = False}* ***Then*** *{skip analysis}*
Else *… {Continue with analysis for the current encroachment side}*
End If

Define Roadway and Roadside Characteristics

For each alternative, the program (1) reads in specific roadway characteristics: posted speed limit, highway grade and horizontal curve radius, (2) reads in the roadside cross-section geometry corresponding to the roadside or median at the current encroachment location, (3) and then converts the cross-section coordinates from the global coordinate reference frame to a local coordinate system relative to the encroachment point. The information processed in this section of the program is used primarily for selecting trajectories for the analysis, which will be discussed in a later section.

Determine Posted Speed Limit, Roadway Grade and Horizontal Curve Radius

Three roadway characteristics, i.e., posted speed limit, roadway vertical grade, and horizontal curve radius, are read from worksheet “Road Segments.” These characteristics will be used later in the trajectory selection process. The values for vertical grade and horizontal curve radius are defined with respect to the primary direction of traffic and must be redefined to correspond to the current encroachment conditions. For example, a positive value for highway grade defined in the worksheet “Road Segments” corresponds to an “up-hill” grade for vehicles traveling in the primary traffic direction and, consequently, to a “down-hill” grade for vehicles traveling in the opposing traffic direction. So, when evaluating encroachments in the opposing traffic direction, the sign of the vertical grade from the worksheet must be reversed for the analysis.

Similarly, a positive value for horizontal curve radius as defined in worksheet “Road Segments” corresponds to a roadway curving to the right for traffic moving in the Primary traffic direction. Thus, when a vehicle traveling in the primary direction encroaches to the right, the road curves back toward the encroachment path as the vehicle advances. Such encroachments tend to remain relatively close to the roadway. On the other hand, when a vehicle traveling in the primary direction encroaches to the left, the roadway curves away from the encroachment path. These encroachments tend to extend farther and farther from the roadway as the trajectory advances. Similar situations exist

for vehicles traveling in the opposing direction. The following lines of code read in values for the roadway characteristics from the worksheet "Road Segments" and redefine them according to the current encroachment conditions.

oPSL = {posted speed limit read from worksheet "Road Segments"}
oPDG = {vertical grade} iDir*
oPDCR = {horizontal curve radius} iDir * iLDS*

Roadside Cross-Section Geometry for Use in Trajectory Selection

The trajectory cases in the crash reconstruction database are all normalized to correspond to primary-right departures. That is, the cross-section coordinates in the crash reconstruction database are based on a local reference frame relative to the departure point which starts at lateral offset y=0 and extends from that point with lateral coordinate values increasing monotonically.

An important criterion used in the selection of trajectories for the analysis is based on a point to point comparison of the roadside cross-section profile to those in the crash reconstruction database. Therefore, the roadside cross-section coordinates for the current encroachment location must be converted to the local reference frame of the crash cases in the database to enable a direct comparison of the cross-section profiles.

For example, consider a primary-left encroachment onto a median with cross-section defined by the coordinates listed in Figure 27. In order to compare the median cross-section to those in the database, the median cross-section profile must be transformed from global coordinates (e.g., as shown in the upper table in Figure 27) to the local coordinate reference frame (e.g., as shown in the lower table in Figure 27).

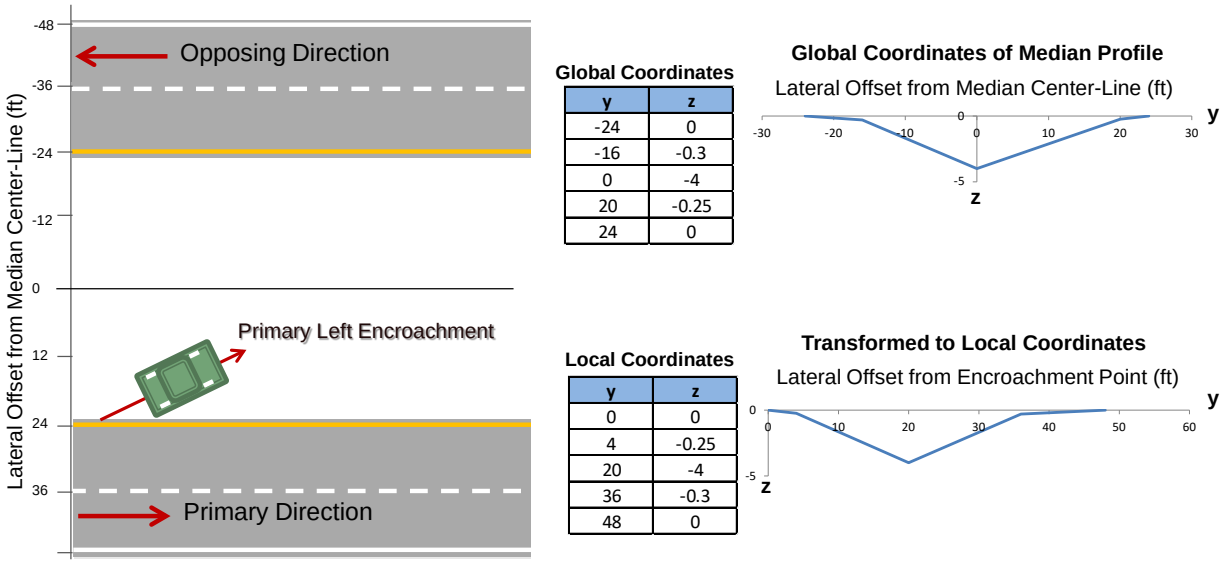


Figure 27. Illustration of transforming the median cross-section coordinates from the global reference frame to the local reference frame.

The following section of the program performs the task of reading the roadside cross-section coordinates corresponding to the current encroachment location and converting them from global coordinates to the local reference frame of the trajectory database.

```
For iSeg = 1 To NOS
  For iDir = 1 To 2 Step -2
    For iLDS = 1 To 2 Step -2
      For iAlt = 1 To num_Alts
            ⋮
```

The following lines of code define the location (i.e., starting row and column position) of the cross-section data on the RSAPv3 worksheet named “Profile” corresponding the current roadside encroachment location (e.g., PR, PL, OR, or OL) and reads in the cross-section coordinates.

```
        SegOffset = {row position on worksheet “Alternative”}
        AltOffset = {column offset on worksheet “Alternative” based on
alternative num}
        Shift = {column offset on worksheet “Alternative” based on encroachment
side}
        For i = 1 To 8
            If {data exists in cell (iSeg, Altoffset+shift+2(i-1))} <> "" Then
                iXsect = iXsect + 1 ‘ count number of x-section data points
                CSloc(iXsect, 1) =  {lateral coordinate of X-section}
                CSloc(iXsect, 2) = {vertical coordinate of X-section}
            End If
        Next i
```

The next step is to transform the cross-section coordinates from the global to local coordinates. This task is generally carried out via the coordinate transformation matrix; however, since the angle between the global and local reference frames will always be either 0 or 180 degrees, the task can also be achieved by simply resorting the data in descending order for Primary-Left and Opposing-Right encroachments (i.e., iDir * iLDS = -1). It is also necessary to resort the data for Primary-Right and Opposing-Left encroachments (i.e., iDir * iLDS = 1) in order to guard against data being input out of order and to eliminate any data with “null” values. For example, the worksheet provides the option of using up to eight data points to define a cross-section profile. In most cases, however, only a few data points will be necessary to completely define the roadside, in which case many of the data cells in the worksheet will have no data.

```
        If iDir * iLDS = 1 Then
            Call MatrixSort {and sort cross-section coordinates in ascending
            order with respect to local reference frame}
      If iDir * iLDS = -1 Then
```

Call MatrixSort {and sort cross-section coordinates in descending order with respect to local reference frame}

The next step is to determine starting lateral coordinate for roadside cross-section corresponding to the edge of the roadway at the point of encroachment. This point (CSy0, 0) represents the origin for the local coordinate system of the roadside cross-section.

```
oRoadWPR = {Primary road width read from worksheet "Road Segments"}
oRoadWOP = {Opposing road width read from worksheet "Road Segments"}
If hwyType = {Divided}
    If {Encroachment Side = Primary Right} Then
        CSy0 = (oMedianHW + oRoadWPR) * iDir
    If {Encroachment Side = Opposing Right} Then
        CSy0 = (oMedianHW + oRoadWOP) * iDir
    If {Encroachment Side = Primary or Opposing Left} Then
        CSy0 = (oMedianHW) * iDir *
ElseIf hwyType = {Undivided} Then
    If {Encroachment Isde = Primary or Opposing Right} Then
        CSy0 = oRoadWPR * iDir
    If {Encroachment Side = Primary Left} Then
        CSy0 = oRoadWOP * iDir
    If {Encroachment Side = Opposing Left} Then
        CSy0 = oRoadWPR * iDir
ElseIf hwyType = {One-Way} Then
    If {Encroachment Side = Primary Right} Then
        CSy0 = oRoadWPR * iDir
    If {Encroachment Side = Primary Left} Then
        CSy0 = 0
End If
```

The final steps are to translate the cross-section coordinates so that it starts at the local origin and to calculate the vertical slope between each cross-section break point. Note that the vertical slope CSloc(i,3) is only used for resampling the cross-section data in ModulePOCtraj so that a point-to-point comparison can be made with crash cases in the crash reconstruction database when selecting trajectories for the analysis.

```
For i = 1 To iXsect
    If CSloc(i, 1) <> "" Then
        CSloc(i, 1) = CSloc(i, 1) * iLDS * iDir - CSy0 * iDir
        ' --- compute slope values ---
```

```
                    If i = 1 Then
                        CSloc(1, 3) = 0
                    Else
                        CSloc(i, 3) = {vertical slope}
                    End If
                End If
            Next i
            ymax = {maximum lateral extent of the cross-section data}
```

Global Cross-Section Geometry and Corresponding Baseline Probability of Rollover

The following lines of code read in and process the complete cross-section profile of the current roadway segment and terrain alternative, including all roadsides, roadways and road shoulders; and then uses this information to determine the baseline probability of rollover corresponding as a function of slope, vertical grade and horizontal curve radius. This information is later used in the probability-of-collision analysis. In particular, each trajectory path is monitored at every increment during the analysis and its position is continuously cross-checked against the terrain profile to determine the probability of rollover.

Determine Cross-Section Coordinates and Slope

The first step of this task is to read in all roadside cross-section coordinates from the RSAPv3 worksheet named "Profiles" and store them in the array variable "CSglob".

```
            For i = 1 To 8 * 3  'eight columns of data for each possible roadside
(primary
                                roadside, opposing roadside and median)
                CSglob(countX, 1) = {y-coord of X-section}
                CSglob(countX, 2) = {z-coord of X-section}
            Next i
```

The next step is to sort all the coordinates in ascending order with respect to the lateral offset coordinate values in order to guard against data being input out of order and to eliminate any data with "null" values. The slope between each breakpoint is then computed and stored as part of the CSglob array for quick access during the analysis.

```
            Call ModulePOCtraj.MatrixSort(CSglob, countX, "ascend", 3, 1)
```

The "apparent" direction of the slope (i.e., up-hill or down-hill slope) is dependent on approach path of the vehicle. For example, Figure 28 shows a median cross-section with a vehicle encroaching from the left. In this scenario the vehicle would be going down-hill on the left slope and up-hill on the right slope; thus the slope of the terrain is effectively negative on the left and positive on the right for this encroachment condition. On the other hand, when a vehicle encroaches onto the median from the right side, the vehicle would be going down-hill on the right slope and up-hill on the left slope; in which case, the slope of the terrain would effectively be negative on the right and positive on the left.

(a) Left Encroachment

(b) Right Encroachment

Figure 28. Illustration of "apparent" sign of roadside slope relative to encroachment path of vehicle.

The next step is to define the lateral coordinate of the encroachment point (i.e., *y0*) for the current trajectory path in the global reference frame. Recall that for divided roadways the origin of the global coordinate system is the center of the median; for undivided roadways the global origin is at center of the yellow line(s) separating the opposing traffic lanes; and for one-way roadways the origin is at the left edge of the roadway. The following lines of code define the lateral coordinate of the encroachment point based on departure side (iLDS) and direction (iDir).

If *hwyType = {divided}* ***Then***
If *iLDS = 1* ***And*** *iDir = 1* ***Then*** *y0 = (oMedianHW + oRoadWPR) * iDir*
If *iLDS = 1* ***And*** *iDir = -1* ***Then*** *y0 = (oMedianHW + oRoadWOP) * iDir*
If *iLDS = -1* ***Then*** *y0 = (oMedianHW) * iDir*

ElseIf *hwyType = {undivided}* ***Or*** *hwyType = {one-way}* ***Then***
If *iLDS = 1* ***And*** *iDir = 1* ***Then*** *y0 = oRoadWPR * iDir*
If *iLDS = 1* ***And*** *iDir = -1* ***Then*** *y0 = oRoadWOP * iDir*
If *iLDS = -1* ***Then*** *y0 = 0*

```
End If
```

The following lines of code compute the slope between each breakpoint of the cross-section terrain and determine the sign of the slope based on its location relative to the encroachment point.

```
For i = 1 To (number of slope break points)
   'CSglob(i, 3) = 1
   If CSglob(i, 1) > y0 Then      ' negative slopes go downhill as y
increases
      CSglob(i, 3) = (CSglob(i, 2) - CSglob(i - 1, 2)) / _
                     (CSglob(i, 1) - CSglob(i - 1, 1))
   Else                           ' Negative slopes go downhill as y decreases.
      If i = 1 Then               ' Slope is equal to adjacent slope at extents _
                                     beyond the most negative defined point.
         CSglob(i, 3) = (CSglob(i, 2) - CSglob(i + 1, 2)) / _
                        (CSglob(i + 1, 1) - CSglob(i, 1))
      Else
         CSglob(i, 3) = (CSglob(i - 1, 2) - CSglob(i, 2)) / _
                        (CSglob(i, 1) - CSglob(i - 1, 1))
      End If
   End If
```

Baseline Probability and Adjustment Factors

The next step is to determine the baseline probability of rollover for each cross-section slope. This task is accomplished using linear interpolation of the "probability of rollover table", which was previously stored in array PRslope. The value of the baseline probability of rollover is then stored in the array CSglob(*,4).

```
Call subInterpolate()
```

The adjustment factors for the probability of rollover for vertical grade and horizontal curve radius is then determined using bi-linear interpolation of the "adjustment factor tables" (e.g., stored in arrays PHIgrade and PHIhorcurv, respectively). The values for the vertical grade adjustment factor and the horizontal curve adjustment factor are stored in array CSglob(*,5) and CSglob(*,6), respectively.

```
   Call subBiInterpolate()
   Call subBiInterpolate()
Next i
```

Select Trajectories for Analysis

The next step in the analysis is to select trajectories that are representative of the vehicle type and roadway/roadside characteristics. The probability of collision given that

a vehicle has encroached onto the roadside or median is determined by directly projecting encroachment trajectories from reconstructed crash cases onto the roadside or median and evaluating their probability of collision with each roadside hazard. Three databases of trajectories are stored on RSAPv3 worksheets “TrajectoryGrid1”, “TrajecotryGrid2” and TrajectoryGrid3, for motorcycle trajectories, passenger vehicle trajectories and truck trajectories, respectively. Currently, all three trajectory databases are identical, which assumes that encroachment paths for all vehicle types are of similar form. This of course is not likely true, but at the present time, there is insufficient data for the development of accurate trajectory paths for motorcycles and trucks; when such data becomes available, however, the trajectory database worksheets can be readily updated.

The trajectory data currently included in RSAPv3 corresponds to trajectories taken from the NCHRP 17-22 crash reconstruction database and are based on reconstructed crashes involving passenger vehicles. The database is composed of 787 of the 890 crash cases collected from the FHWA rollover study, NCHRP Project 17-11 and NCHRP Project 17-22.[Bligh04; Mak10] Since each trajectory case in the 22-27 database is linked directly to its corresponding crash conditions and roadway and roadside characteristics, it is a simple process to filter the trajectory data directly and select only the trajectory cases with roadway and roadside characteristics similar to those for the given project case. This eliminates the need to have multiple layers of trajectory tables corresponding to numerous roadway and roadside conditions.

Select Trajectory Path Database

The name of the worksheet containing the database of trajectories for each vehicle type is read from column 11 on the “Traffic Information” worksheet in RSAPv3.

For *iVeh = 1* ***To*** *{number of vehicle types in analysis}*
TrajectoryGrid = {name of trajectory worksheet}

Select Relevant Trajectory Paths for the Analysis

RSAPv3 searches the trajectory database to identify relevant cases based on *similarity* to the given road-segment characteristics; that is, the program selects all trajectory cases that have characteristics which fall within a specified range of those defined for a given segment of roadway. Refer to the ENGINEER’S MANUAL for more information regarding trajectory selection methodology.

The program calls ModulePOCtraj to gather trajectory information which will be used in the analysis, such as number of trajectory cases (num_traj), coordinates of the trajectory path (trajx and trajy), the number of data columns preceding the trajectory path information (num_pre), the longitudinal increments of the path data (grid-inc), the minimum and maximum lateral extents of each trajectory path (MinY and MaxY) and the maximum length of each trajectory path (MaxL).

Call *ModulePOCtraj.TrajectorySelect()*

Initialize Variables for Collision-Statistics

During the analysis various types of data relevant to the probability of collision are collected. These data include number of traffic-side impacts on each hazard, number

of non-traffic side impacts on each hazard, total number of all impacts on each hazard, total crash cost (EFCCR) for collisions with each hazard, total crash cost associated with rollovers after redirection with each hazard, number of rollovers after redirection and number of penetrations of each hazard. These data are stored until the current roadside encroachment location has been analyzed for the full length of the segment for the current vehicle type; the variables are then re-initialized for the next vehicle type and for each encroachment-side location. The following lines of code are used to initialize the variables for collision statistics:

```
For K = 1 To {total number of hazards including rollovers}
        impact_Count_TS(K) = 0
        impact_Count_NTS(K) = 0
        impact_Count_tot(K) = 0
        EFCCR_tot(K) = 0
        EFCCR_RR(K) = 0
        count_RR(K) = 0
        count_pene_RSAP(K) = 0
 Next K
impact_total = 0
```

Search Selected Trajectory Paths for impact with Hazard(s) and Compute POC

The cost of collision is then determined based on the impact conditions, hazard severity and probability of the collision event. The program calls ModulePOCanalysis to perform the collision-analysis task, where each trajectory is individually examined for possible collisions with hazards; the collision statistics are computed and stored in the appropriate data collectors; and these data are then returned to the main program (i.e., ModulePOCmain) for processing. The programming details of the Probability-of-Collision analysis module will be presented in a subsequent section of this Manual.

The first step in this task is to determine the longitudinal coordinate of the encroachment point. When the encroachments are being evaluated for the primary traffic direction, the analysis starts at the beginning of the segment and evaluates each preselected trajectory path for collisions; then increments forward along the segment by a predefined increment length (i.e., DP_inc) and again evaluates each trajectory path for collisions; this process continues until the end of the segment is reached.

```
For iSeg = 1 To NOS
  For iDir = 1 To 2 Step -2
    For iLDS = 1 To 2 Step -2
      For iAlt = 1 To num_Alts
            ⋮
        For iDP = 0 To num_Departure_Incs
          If iDir = 1 Then
            x0 = iDP * DP_inc * iDir + SegStart
            ' start at beginning of segment for  primary direction
```

```
Else
   x0 = iDP * DP_inc * iDir + SegEnd   ' start at end of segment for
                                       ‘ opposing direction
End If

For itraj = 1 To {number of trajectories}
   WF = 1
   num_traj_seg = num_traj_seg + 1
   nopc = {number of path coordinate points}
   '  ---  initialize EFCCR for this trajectory
  EFCCRi(num_traj_seg, 1) = 0
   ' --- Record Vehicle Type (M, C, or T) for this segment
   EFCCRi(num_traj_seg, 2) = VehCharac(iVeh, 4)
   ' --- Record Alternative number for the segment
   EFCCRi(num_traj_seg, 3) = iAlt

   Call ModulePOCanalysis.sub_Impact_Search()

Next itraj
```

Some additional variables are defined in this section of the program, including POC, num_traj_seg, and EFCCRi. The variable POC represents the probability of collision and is applied as a weight factor to the crash cost of each collision. As an example, refer to the sequence of possible crash events illustrated in Figure 29. At the beginning of each trajectory path (Point A) the probability of occurrence is 1.0. In other words, each trajectory case is an encroachment event, so there is a 100 percent chance of an encroachment during the first increment of each trajectory path. As the encroachment continues, the likelihood of rollover increases. So, the probability of a collision at Point B is dependent on the vehicle getting to Point B without rolling over first. The crash cost of an impact at Point B is computed based on impact conditions and the severity rating of the hazard. Then the average expected cost of the collision is determined by multiplying the baseline crash cost by its probability of occurrence (POC). Likewise, for the encroachment to result in a second collision at Point E a sequence of three specific events must happen: (1) the vehicle must get to Point B without rolling over, (2) the vehicle must penetrate or vault the line hazard (Point D), and (3) the vehicle must then get to Point E without rolling over or stopping first. Thus the probability of collision for each possible collision in the sequence of events continuously reduces with each collision. So even though the severity rating for the hazard at Point E may be very high, the average crash-cost on the hazard will be reduced according to the likelihood of the sequence A-B-D-E occurring.

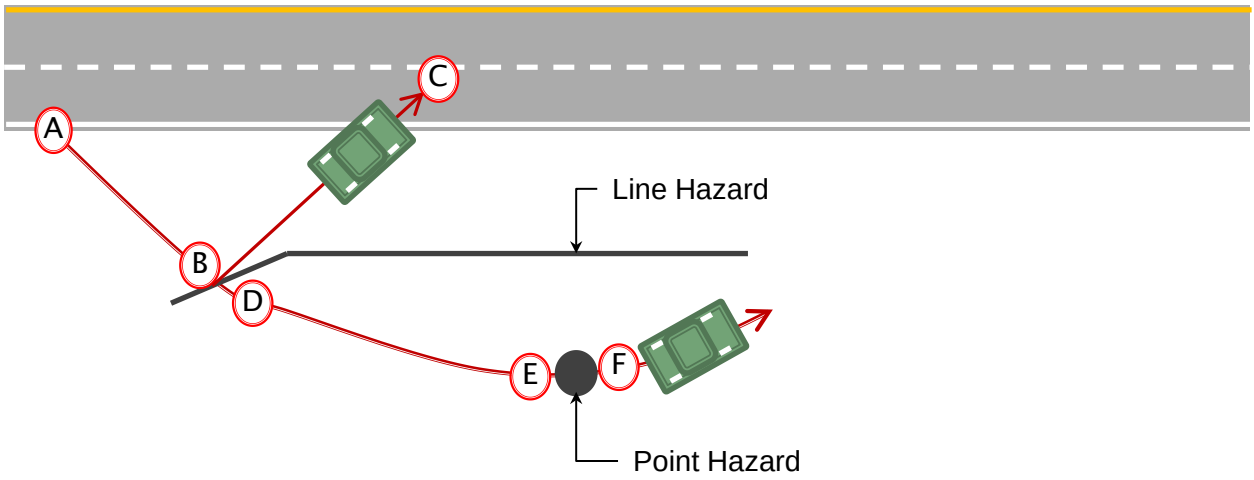


Figure 29. Illustration of a possible sequence of crash events for a given trajectory scenario

The variables *num_traj_seg* and *EFCCRi* are used to compute percentile costs for each segment, where *num_traj_seg* is a running count of the total number of trajectories being evaluated for each segment, and *EFCCRi* is an array variable that stores the individual crash cost of each trajectory path.

Calculate and Write Average Crash Costs to Worksheet

The following lines of code compute the average crash costs associated with each hazard at the end of each segment analysis, as well as other collision statistics. For example, the average crash cost on a particular hazard is computed as the total crash cost of all collision on that hazard divided by the total number of encroachments. These values are written to the "POC Scratch" worksheet and are later used for generating the "Feature Report", "Segment Report", and "B/C Report" on the "Results" worksheet in RSAPv3. An example of the output to the "POC Scratch" worksheet is shown in Table 4.

```
For iSeg = 1 To NOS
  For iDir = 1 To 2 Step -2
    For iLDS = 1 To 2 Step -2
      For iAlt = 1 To num_Alts
        For iVeh = 1 To num_veh
          For iDP = 0 To num_Departure_Incs
            ⋮
          If iDP = num_Departure_Incs Then
            For K = 1 To oNum_Hazards(iAlt) + 1
              shPOCscratch.Cells(Row, "A").value = iSeg
              shPOCscratch.Cells(Row, "B").value = iAlt
              If iDir = 1 Then
                shPOCscratch.Cells(Row, "C").value = "P"
              Else
```

```
      shPOCscratch.Cells(Row, "C").value = "O"
   End If

   If iLDS = 1 Then
      shPOCscratch.Cells(Row, "D").value = "R"
   Else
      shPOCscratch.Cells(Row, "D").value = "L"
   End If
   shPOCscratch.Cells(Row, "E").value = VehCharac(iVeh, 4)

   shPOCscratch.Cells(Row, "F").value = num_traj_tot
   shPOCscratch.Cells(Row, "G").value = oHzrd_Name(iAlt, K)
   shPOCscratch.Cells(Row, "H").value = K ' hazard number
   shPOCscratch.Cells(Row, "I").value = EFCCR_tot(K)
   shPOCscratch.Cells(Row, "J").value = impact_Count_TS(K)
   shPOCscratch.Cells(Row, "K").value = impact_Count_NTS(K)
   If impact_Count_tot(K) <> 0 Then
      shPOCscratch.Cells(Row, "L").value = EFCCR_tot(K) / _
                                           impact_Count_tot(K)
   End If
   shPOCscratch.Cells(Row, "M").value = impact_Count_tot(K) /
_
                                           num_traj_tot
   shPOCscratch.Cells(Row, "N").value = EFCCR_tot(K) /
num_traj_tot

   If K <= oNum_Hazards(iAlt) Then
      shPOCscratch.Cells(Row, "P").value = count_pene(K)

      ' rollover-after-redirection from hazard k statistics
      If count_RR(K) <> 0 Then
         shPOCscratch.Cells(Row, "Q").value = count_RR(K)
         shPOCscratch.Cells(Row, "R").value = EFCCR_RR(K)
         shPOCscratch.Cells(Row, "S").value = EFCCR_RR(K) / _
                                              count_RR(K)
         shPOCscratch.Cells(Row, "T").value = count_RR(K) / _
                                              num_traj_tot
         shPOCscratch.Cells(Row, "U").value = EFCCR_RR(K) / _
                                              num_traj_tot
      End If
```

```
                    End If
                Row = Row + 1
            Next K      ' next hazard
        End If
    Next iDP            ' next departure point/station
Next iVeh           ' next vehicle type
Next iAlt           ' next roadside alternative
Next iLDS           ' next encroachment side
Next iDir           ' next traffic direction
Next iSeg           ' next segment

End Sub
```

Table 4. Example Output to POC Scratch worksheet

SCRATCH SHEET FOR COLLISION PROBABILITY AND COST

Encroachment Location						Hazard		Statistics												
									Collisions					# of Penetrations		Rollover after Redirection				
SEG	ALT	DIR	SIDE	Veh Type	Num of Encroach	Name	Num.	EFCCR	TS	NTS	EFCCR/C	C/E	EFCCR/E	capacity	RSAP	# of rollovers	EFCCR	EFCCR/C	C/E	EFCCR/E
1	1	P	R	T	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	P	R	C	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	P	L	T	40	EdgeOfMedian	1	1.33781	17.4979	0.0000	0.0765	0.43745	0.03345	0.0000	17.4979					
1	1	P	L	C	40	EdgeOfMedian	1	1.11484	17.4979	0.0000	0.0637	0.43745	0.02787	0.0000	17.4979					
1	1	O	R	T	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	O	R	C	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	O	L	T	40	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	O	L	C	40	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	P	R	T	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.0000000	0.0000	0.0000					
1	1	P	R	C	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	P	L	T	40	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.0000000	0.0000	0.0000					
1	1	P	L	C	40	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	O	R	T	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	O	R	C	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	1	O	L	T	40	EdgeOfMedian	2	1.33781	17.4979	0.0000	0.0765	0.43745	0.03345	0.0000	17.4979					
1	1	O	L	C	40	EdgeOfMedian	2	1.11484	17.4979	0.0000	0.0637	0.43745	0.02787	0.0000	17.4979					
1	1	P	R	T	10	Rollover	3	0.00000	0.0000	0.0000		0.00000	0.00000							
1	1	P	R	C	10	Rollover	3	0.00000	0.0000	0.0000		0.00000	0.00000							
1	1	P	L	T	40	Rollover	3	0.00945	0.7805	0.0000	0.0121	0.01951	0.00024							
1	1	P	L	C	40	Rollover	3	0.00788	0.7805	0.0000	0.0101	0.01951	0.00020							
1	1	O	R	T	10	Rollover	3	0.00000	0.0000	0.0000		0.00000	0.00000							
1	1	O	R	C	10	Rollover	3	0.00000	0.0000	0.0000		0.00000	0.00000							
1	1	O	L	T	40	Rollover	3	0.00945	0.7805	0.0000	0.0121	0.01951	0.00024							
1	1	O	L	C	40	Rollover	3	0.00788	0.7805	0.0000	0.0101	0.01951	0.00020							
1	2	P	R	T	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	P	R	C	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	P	L	T	40	EdgeOfMedian	1	1.29183	15.7967	0.0000	0.0818	0.39492	0.03230	0.0000	15.7967					
1	2	P	L	C	40	EdgeOfMedian	1	0.01131	0.1433	0.0000	0.0789	0.00358	0.00028	0.0000	0.1433					
1	2	O	R	T	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.0000000	0.0000	0.0000					
1	2	O	R	C	10	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	O	L	T	40	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	O	L	C	40	EdgeOfMedian	1	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	P	R	T	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	P	R	C	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.0000000	0.0000	0.0000					
1	2	P	L	T	40	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	P	L	C	40	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	O	R	T	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	O	R	C	10	EdgeOfMedian	2	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					
1	2	O	L	T	40	EdgeOfMedian	2	1.29183	15.7967	0.0000	0.0818	0.39492	0.0322958	0.0000	15.7967					
1	2	O	L	C	40	EdgeOfMedian	2	0.01131	0.1433	0.0000	0.0789	0.00358	0.00028	0.0000	0.1433					
1	2	P	R	T	10	TL3ESbapeGR	3	0.00000	0.0000	0.0000		0.00000	0.00000	0.0000	0.0000					

MODULEPOCHAZ

This module is called by ModulePOCmain to gather information about each hazard and then processes the hazard data so that it can be readily accessed during the analysis. The program (1) reads hazard information from worksheet “Alternatives”, such as hazard type and location; (2) searches for the hazard type on worksheet “Severity” to gather data necessary for the analysis, such as severity, capacity, repair cost, etc.; (3) defines the longitudinal barrier associated with each end-terminal; and (4) stores the data in arrays for ready-access during the analysis. The flow chart for this program module is shown in Figure 30.

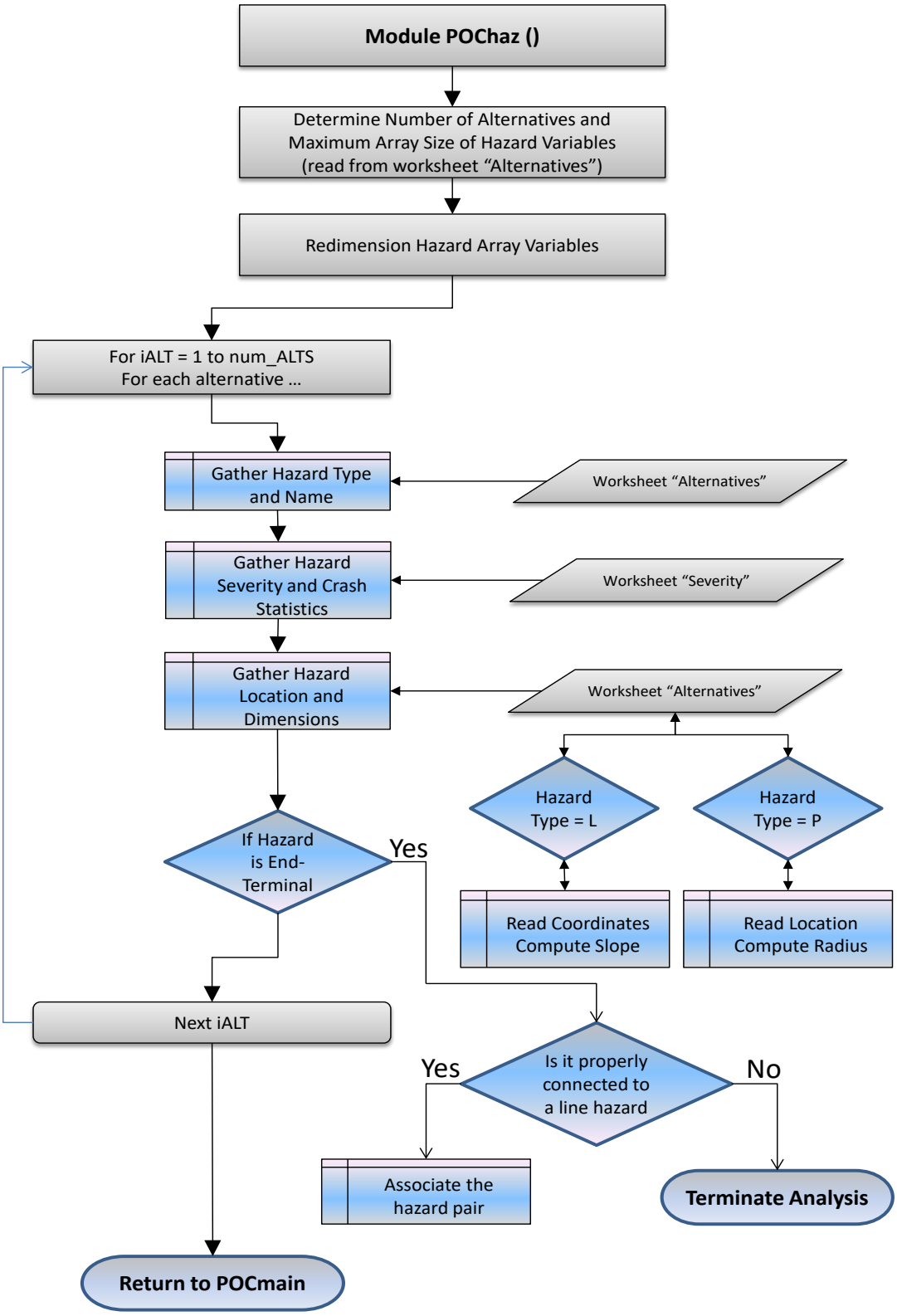


Figure 30. Flow chart for ModulePOChaz.

Program Variables

- max_num_haz: maximum number of hazards for any alternative
- num_ALTS: number of alternatives in the analysis
- HM: slope of line segment connecting hazard ends
- HazRow: Current row number with hazard information on worksheet "Alternatives"
- AltOffset: Current column number with hazard information on worksheet "Alternatives"
- R: Radius of Point hazards (inches)
- oHx:
- oHy:
- oHzrd_Capacity:
- **oHzrd_Connection**: Identifies LON hazard attached to END TERMINAL
- oHzrd_EFCCR45:
- oHzrd_Height:
- oHzrd_GenType:
- oHzrd_Prcnt_PRV:
- oHzrd_Prcnt_RR:
- oHzrd_Type:
- oNum_Hazards:

Procedure

The number of alternatives is read directly from the RSAPv3 worksheet "Alternatives" and the maximum array size for the hazard variables is based on the maximum number of hazards for any alternative case. The total number of hazards also includes the area hazard "rollover" which is automatically added to the hazard list for each alternative case. This increases the number of columns in the array size by one.

num_ALTS = (read number of alternatives from Alternatives worksheet)
max_num_haz = (number of hazards in the alternative with the most hazards)

***ReDim** oNum_Hazards(num_ALTS)*
***ReDim** oHzrd_Type(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_Name(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_GenType(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_EFCCR45(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_Prcnt_PRV(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_Prcnt_RR(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_Capacity(num_ALTS, max_num_haz + 1)*
***ReDim** oHzrd_Height(num_ALTS, max_num_haz + 1)*

```
ReDim oHzrd_Connection(num_ALTS, max_num_haz + 1)
ReDim oHx(num_ALTS, max_num_haz + 1, 2)
ReDim oHy(num_ALTS, max_num_haz + 1, 3)
ReDim HM(num_ALTS, max_num_haz + 1)
ReDim R(num_ALTS, max_num_haz + 1)
```

The hazard information on worksheet “Alternatives” is then read for each alternative case. The first step is to determine which side (i.e., left or right) of the baseline the hazard is located (i.e., “Start Side” and “End Side” on worksheet “Alternatives”).

```
HazRow = 10 ' starting row for hazard data on worksheet "Alternatives"
For iAlt = 1 To {number of alternatives}
  AltOffset = iAlt * 11
  oNum_Hazards(iAlt) = {read number of hazards from worksheet
“Alternatives”}
  For K = 1 To oNum_Hazards(iAlt) + 1
    ' find out which side of the baseline the hazard is on
    If (“Start Side”)  = "L" Then
      sideStart = -1
    Else
      sideStart = 1
    End If

    If (“End Side”) = "L" Then
      sideEnd = -1
    Else
      sideEnd = 1
    End If
```

The next step is to determine the type and name of each hazard in each alternative. This information is read directly from the worksheet “Alternatives” except for rollover hazards, which are defined explicitly in the program.

```
    If K > oNum_Hazards(iAlt) Then
          oHzrd_Name(iAlt, K) = "Rollover"
    Else
         oHzrd_GenType(iAlt, K) = {read general hazard type}
          oHzrd_Name(iAlt, K) = {read hazard name}
    End If
```

The repair cost, severity, penetration-rollover-vault statistics, redirection-after-rollover statistics, capacity, height, and category are then read from the worksheet

"Severity. RSAPv3 searches each row of the "Severity" worksheet until it finds the corresponding hazard, then reads the pertinent information.

```
m = 4  ' Starting row with data in the "Severity" worksheet
Do Until shSeverity.Cells(m, 1).value = oHzrd_Name(iAlt, K)
        m = m + 1
Loop

oHzrd_Type(iAlt, K) = {read hazard type}
oHzrd_EFCCR65(iAlt, K) = {read hazard severity EFCCR65}
oHzrd_Prcnt_PRV(iAlt, K) = {read percent of PRV}
oHzrd_Prcnt_RR(iAlt, K) = {read percent rollover after redirection}
oHzrd_Capacity(iAlt, K) = {read hazard capacity}
oHzrd_Height(iAlt, K) = {read hazard height}
```

The next step is to determine the location of the hazard. If the hazard is a line hazard then the program reads the start- and end-coordinates of the hazard from worksheet "Alternatives"; computes the slope between the two points; and reads in the width of the hazard from worksheet "Alternatives". A sketch of a line hazard with dimensions is illustrated in Figure 31.

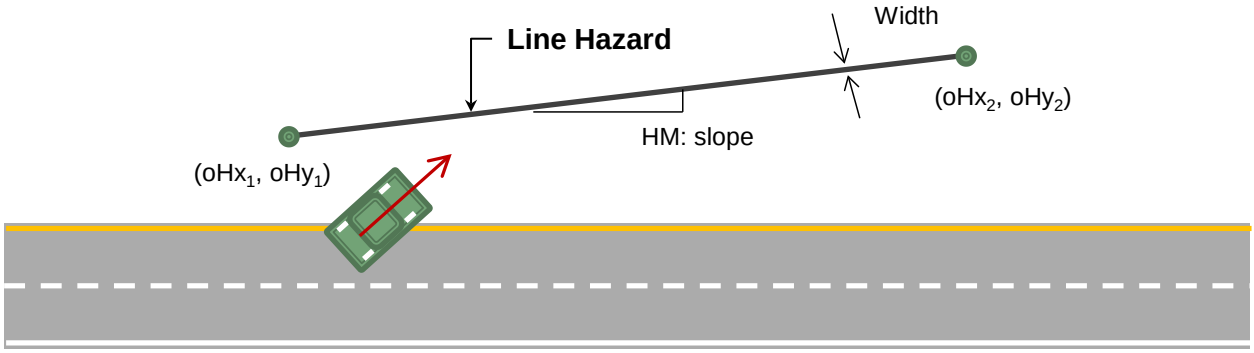


Figure 31. Sketch of line-hazard dimensions.

```
If oHzrd_Type(iAlt, K) = "L" Then
   oHx(iAlt, K, 1) = {read longitudinal coordinate, oHx1}
   oHy(iAlt, K, 1) = {read lateral coordinate, oHy1}* sideStart

   oHx(iAlt, K, 2) = {read longitudinal coordinate, oHx2}
   oHy(iAlt, K, 2) = {read lateral coordinate, oHy2} * sideEnd

   oHy(iAlt, K, 3) = {read hazard width} / 12 ' convert to feet from inches

'          --- Compute slopes of piecewise linear segment defining hazard ---
```

If oHx(iAlt, K, 2) = oHx(iAlt, K, 1) Then
oHx(iAlt, K, 2) = oHx(iAlt, K, 2) + 0.1 ‘ guard against undefined slopes
End If
HM(iAlt, K) = (oHy$_2$ – oHy$_1$) / (oHx$_2$ - oHx$_1$)

Point hazards are defined by a point and radius. The coordinates of the center of the hazard and the hazard diameter are read from the worksheet “Alternatives”.

ElseIf oHzrd_Type(iAlt, K) = "P" Then
oHx(iAlt, K, 1) = {longitudinal coordinate of hazard center point}
*oHy(iAlt, K, 1) = {lateral coordinate of hazard center point} * sideStart*
R(iAlt, K) = ({Diameter} / 2) /12 ' converted from inches to feet
End If
oHzrd_Connection(iAlt, K) = 0
Next K

After all the hazards have been defined, the final task is then to associate terminal-ends to their mating longitudinal barriers (e.g., guardrail). The program goes back and looks for hazards named “end-terminal”. It then searches the end coordinates of all line hazards to find the one that is coincident with the location of the end-terminal. The end-terminal and the line hazard are then associated by setting oHzrd_Connection (iAlt,K) = j, where iALT is the alternative containing the hazard pair, K is the hazard number for the end-terminal, and j is the hazard number for the line-hazard. If a mate cannot be found RSAPv3 will terminate the analysis; then place the cursor on the “alternative” worksheet in the data cell corresponding to the end-terminal; and show a pop-up window with the message, “Guardrail terminal not connected to guardrail”. The coordinates will have to be corrected on the “Alternative” sheet and the analysis restarted.

For K = 1 To oNum_Hazards(iAlt)
If oHzrd_GenType(iAlt, K) = "TerminalEnds" Then
oHzrd_Connection(iAlt, K) = 0 ‘ initialize association to 0
For j = 1 To oNum_Hazards(iAlt)
If oHzrd_Type(iAlt, j) = "L" Then
If {oHx$_1$ of end-terminal = oHx$_1$ or oHx$_2$ of line-hazard} _
And _
{oHy$_1$ of end-terminal = oHy$_1$ or oHy$_2$ of line-hazard} _
Then
oHzrd_Connection(iAlt, K) = j

```
                    End If
                End If
            Next j
            If oHzrd_Connection(iAlt, K) = 0 Then
                shAlternatives.Select
                Cells(HazRow + (K - 1), AltOffset - 8).Select
                MsgBox ("Guardrail terminal not connected to
Guardrail")
                End
            End If
        End If
    Next K
Next iAlt
End Sub
```

MODULEPOCTRAJ

This module is called by ModulePOCmain to select trajectories from the crash reconstruction database (trajectory database) to be used in the analysis. The primary function of this module is search the database to identify relevant cases based on *similarity* to the given road-segment characteristics; that is, the program selects all trajectory cases that have characteristics which fall within a specified range of those defined for the given project. The selection methodology involves examining and scoring each individual trajectory case based on a quantitative comparison of the four critical roadway characteristics (i.e., Roadside cross-section profile, Horizontal curve radius, Highway vertical grade, and Posted speed limit) to those in the current project section. The individual scores for each of the four criteria are then combined into a single representative composite score for the trajectory case. After all trajectories have been assigned a score, RSAPv3 then selects the trajectories with the highest scores for use in the analysis. Figure 32 shows the flow chart for this program module. The following sections discus the various programming tasks. Additional information on the methodology for trajectory selection is provided in the ENGINEER'S MANUAL.

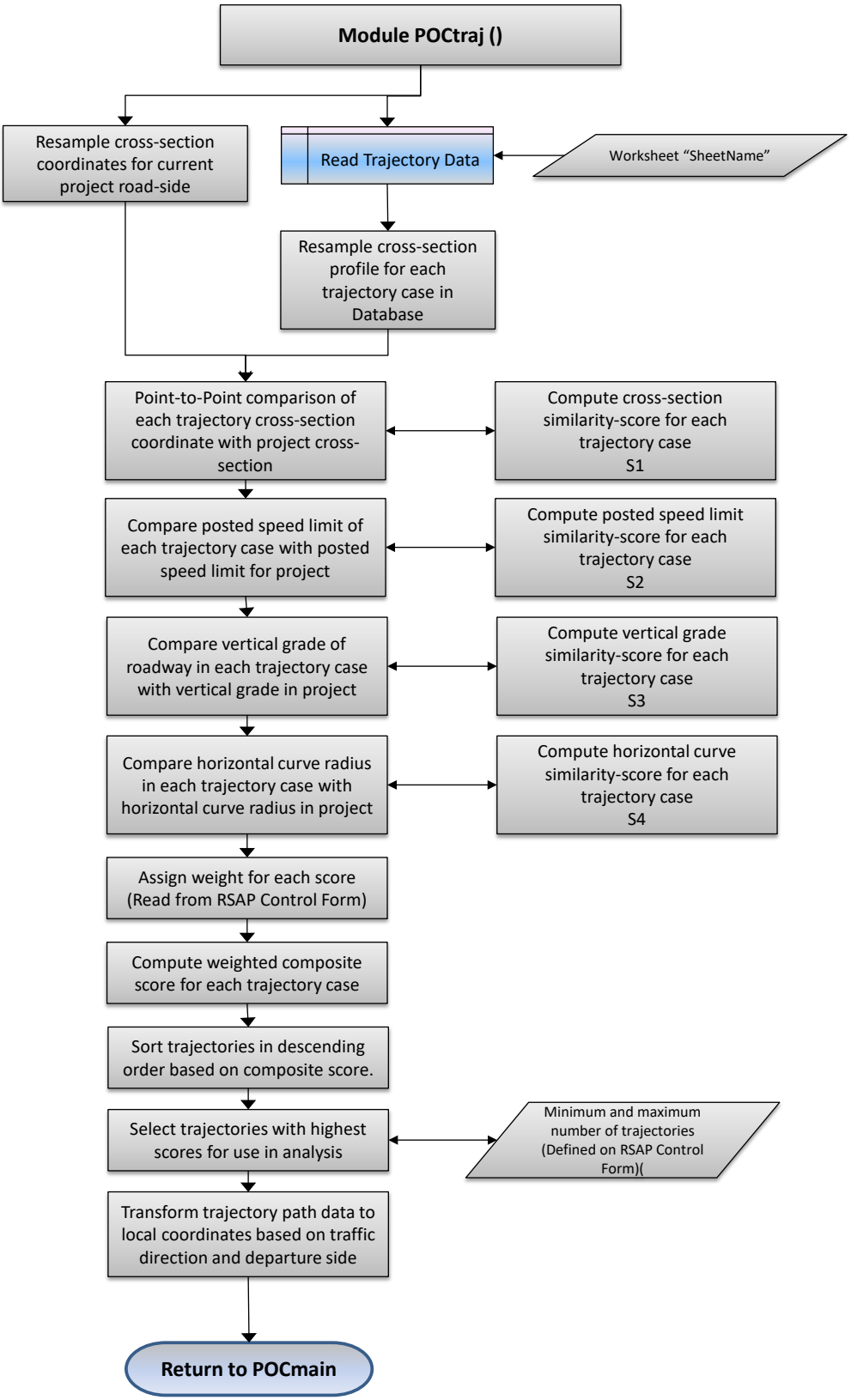


Figure 32. Flow chart for Module POCtraj.

Input Variables

The following are a list of variables passed from Module POCMain.

- ***CSloc***: roadside cross-section profile in local coordinates
- ***iALT***: alternative number
- ***iDirection***: traffic direction (i.e., 1= primary, -1 = opposing)
- ***iLDS***: encroachment side (1 = right, -1 = left)
- ***iSeg***: segment number
- ***iVeh***: vehicle type number
- ***grid_inc***: longitudinal increments of trajectory path
- ***oPDCR***: horizontal curve radius
- ***oPDG***: roadway vertical grade
- ***oPSL***: posted speed limit
- ***SheetName***: name of the worksheet containing the database of reconstructed trajectories
- ***num_veh***: total number of vehicle types
- ***ymaxp***: maximum extent of cross-section profile in local coordinates

Program Variables

The following are a list of variables defined in the Module.

- ***TrajectoryData***: variable array that stores the entire trajectory database to facilitate quick access to the data
- ***delta_y***: lateral increment for resampling cross-section profiles
- ***myrow***: first row with data on the trajectory grid worksheets
- ***num_pre***: Number of data columns preceding the trajectory path information in the trajectory databases
- ***num_traj***: total number of trajectories selected for the analysis
- ***SumErrSq***: sum of the errors squared for comparing roadside cross-section profiles
- ***TrajScore***:
- ***trajx***:
- ***trajy***:
- ***traj_select***:
- ***y***: lateral coordinate of resampled cross-section profile of project road segment
- ***z***: vertical coordinate of resampled cross-section profile of project road segment
- ***yt***: lateral coordinates of cross-section profile from trajectory database
- ***zt***: vertical coordinates of cross-section profile from trajectory database
- ***st***: slopes of cross-section profile from trajectory database
- ***yy***: lateral coordinate of resampled cross-section profile from trajectory database

- ***zz***: vertical coordinate of resampled cross-section profile from trajectory database
-

Read all Data from Trajectory Grid Worksheet

The number of rows of data in the trajectory database is determined and the variable array traj_select is re-dimensioned. The name of the trajectory database is passed in from Module POCMain as *SheetName*. The program then reads in the complete trajectory database and stores it in the array variable *TrajectoryData* to facilitate quick access to the data.

```
Count = 0
Do Until {a blank row is found, indicating the end of data}
    Count = Count + 1
Loop
ReDim traj_select(Count)

TrajectoryData = Sheets(SheetName).Range(Cells(4, "A").Address, Cells(Count
+ 3, num_pre(iVeh) + 300).Address).value
```

Compute Roadside Cross-Section Profile Score

In order to perform a point-to-point comparison of the similarity of a given roadside cross-section to those from the trajectory database, the lateral coordinates must be sampled at the same increments. The program first resamples the cross-section coordinates for the project segment at lateral increments of *delta_y* using linear interpolation.

```
delta_y = 1 'ft
y(0) = CSloc(1, 1)
z(0) = CSloc(1, 2)
i = 2

For j = 1 To ymaxp / delta_y
    y(j) = y(j - 1) + delta_y
    If y(j) > CSloc(i, 1) Then ' if y>y0 then a slope change occurs between
these two
                                positions
        z(j) = CSloc(i + 1, 3) * (y(j) - CSloc(i, 1)) + CSloc(i, 2)
        i = i + 1
    Else
        z(j) = CSloc(i, 3) * delta_y + z(j - 1)
    End If
    zmaxp = Application.Max(zmaxp, Abs(z(j)))
Next j
```

The program then reads in the cross-section profile for each case in the trajectory database and computes the slope between break-points. Note that there are eight (y, z) coordinate pairs defining each cross-section profile case in the database. The lateral coordinates start at column 29 (“AC”) and the vertical coordinates start at column 37 (“AK”).

```
num_traj(iVeh) = 0
N = 1
For i = 1 To Count
    iXsect = 1
    yt(0) = 0
    zt(0) = 0
    Do While TrajectoryData(i, 29 + iXsect) <> "" And iXsect < 8
        yt(iXsect) = TrajectoryData(i, 28 + iXsect)    'y-coord of X-section
        zt(iXsect) = TrajectoryData(i, 36 + iXsect)    'z-coord of X-section
        ymaxt = yt(iXsect)
        If iXsect <> 0 Then
            ' -- check and correct infinite slopes
            delta_yt = (yt(iXsect) - yt(iXsect - 1))
            If delta_yt < 0.01 Then
                delta_yt = 0.01
            End If
            ' -- compute slope
            st(iXsect) = (zt(iXsect) - zt(iXsect - 1)) / delta_yt
        End If
        iXsect = iXsect + 1
    Loop
```

The next step is to resample each of these cross-section profiles at increments of *delta_y* using linear interpolation and then perform a point-to-point comparison of each cross-section to the project’s cross-section profile by summing the square of the errors at each point.

```
For i = 1 To Count
    ⋮
    yy(0) = yt(0)
    zz(0) = zt(0)
    SumErrSq = 0    ' initialize the "sum of the errors squared" value

    ii = 1
    st(iXsect) = 0
```

```
' set lateral extent beyond known data to a very large number (to make
sure yy(j)
can never be greater than this value)
yt(iXsect) = 1000000#

For j = 1 To ymaxp / delta_y
    yy(j) = yy(j - 1) + delta_y
    ' if y>y0 then a slope change occurs between these two positions
    If yy(j) > yt(ii) Then
        zz(j) = st(ii + 1) * (yy(j) - yt(ii)) + zt(ii)
        ii = ii + 1
    Else
        zz(j) = st(ii) * delta_y + zz(j - 1)
    End If

    SumErrSq = (z(j) - zz(j)) ^ 2 + SumErrSq
Next j
```

The roadside cross-section for each crash case in the trajectory database is compared directly to that of roadway being analyzed and is given a score which represents its degree of similarity. The similarity score, *S1score,* is calculated based on the square root of the sum of the residual errors squared divided by the total width of the roadside cross-section, as defined below

```
For i = 1 To Count
    ⋮
S1score  = 1-(SumErrSq ^ 0.5) / ymaxp
```

Compute Post Speed Limit Score

The posted speed limit for each case in the trajectory database is then compared with the posted speed limit of the current road segment and a similarity score is determined based on the following relationship:

```
For i = 1 To Count
    ⋮
    If {no speed limit was reported for a given case in the trajectory
database} Then
        TrajectoryData(i, 7) = 55 'Set value to 55 mph
    End If
    S2score = 1 - Abs(oPSL - TrajectoryData(i, 7)) / 50
```

The above calculation for *S2score* basically deducts 0.1 point from the score for every 5 mph difference between the posted speed limit of the segment and the value in the i^{th} trajectory case from the database.

Compute Vertical Grade Score

The scoring criteria for vertical grade is based on the assumption that slight differences in vertical grade would have less influence on trajectory characteristics for cases of flat and uphill grades than it would for downhill grades. Accordingly, the vertical grade for each crash case in the database is compared to the value for each segment using the following relationships:

```
For i = 1 To Count
        ⋮
    If {no vertical grade was reported for a given case in the database} Then
        TrajectoryData(i, 21) = 0       ' set grade to "flat"
    End If

    If oPDG >= -2 Then
        S3score = -0.02392 * Abs(TrajectoryData(i, 21) - oPDG) ^ 2
                  - 0.0257 * Abs(TrajectoryData(i, 21) - oPDG) + 1
    ElseIf oPDG >= -10 And oPDG < -2 Then
        S3score = -0.2 * Abs(TrajectoryData(i, 21) - oPDG) + 1
    Else
        S3score = -0.1 * Abs(TrajectoryData(i, 21) - oPDG) + 1
    End If
```

Compute Horizontal Curve Score

The criteria for the similarity score for horizontal curve radii, *S4score*, is based on the absolute difference between the reciprocal of the curve radius of each segment in the project (i.e., *curvature*) and the reciprocal of the curve radius for i^{th} trajectory from database. This value is then multiplied by a factor of 1,079 which converts the score to the same scoring scale used in the previous scoring criteria.

Horizontal curves are defined by curve radius and by the relative direction of the curve (e.g., positive curves to right and negative to left relative to the direction of travel). Accordingly, the horizontal curve radius for each crash case in the database is compared to the value for each segment using the following relationships:

```
For i = 1 To Count
        ⋮

    If {no value for horizontal curve was reported for a given case in the
database} _
    Or If {a value of 0 was mistakenly entered} Then
```

```
        TrajectoryData(i, 16) = 100000          ' set to straight
    End If
```

If departure is to the right then the curvature relative to the vehicle departure is positive

```
    If TrajectoryData(i, 28) = "R" Then
        curvature = 1 / TrajectoryData(i, 16)
        oPDcurvature = 1 / oPDCR
```

If departure is to the left then the curvature relative to the vehicle departure is negative

```
    Else
        curvature = -1 / TrajectoryData(i, 16)
        oPDcurvature = 1 / oPDCR
    End If

    S4score = 1 - 1079 * (Abs(curvature - oPDcurvature))
```

The one exception is if both the oPDCR and the curve for the trajectory case are "tangent" (i.e., |>10,000|), then the score is set to 1.0.

```
    If Abs(oPDcurvature) <= (1 / 10000) And Abs(curvature) <= (1 / 10000)
Then
        S4score = 1
    End If
```

Compute Composite Score for Each Case in the Database

The individual scores for each of the four criteria presented above are then combined into a single representative composite score for the trajectory case, where the composite score is a weighted average of the four individual scores. In some cases, the similarity scores might be very high for certain characteristics and low for others. In these cases the weighted average score may result in a relatively high value. To reduce the likelihood of such a trajectory case being selected for the analysis, a "cutoff" value is set for each characteristic score. When an individual score falls below the cutoff value then its value is reduced by half in order to sufficiently lower the composite score and minimize its chance for selection. The cutoff values for each characteristic are defined on the RSAPv3 Control Form, as shown in Figure 33. The default value is 0.7.

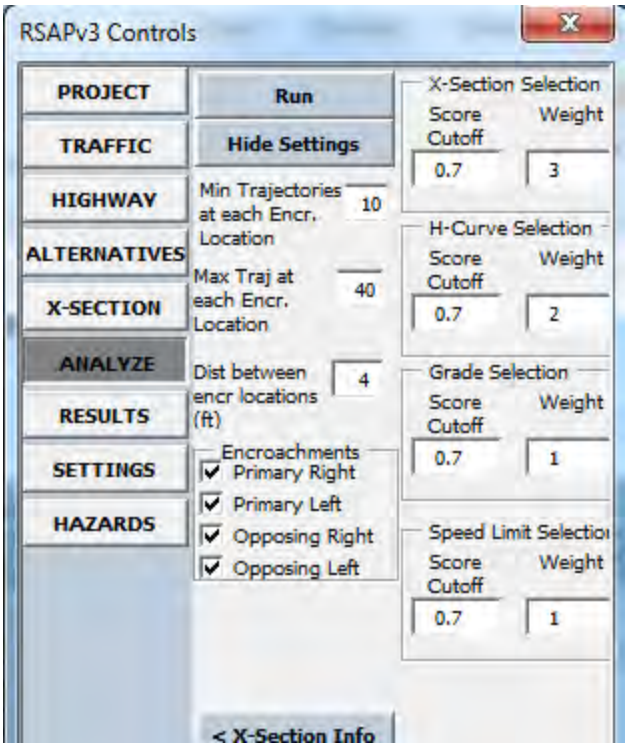


Figure 33. RSAPv3 Controls Dialog -- Default Analysis Settings.

The following lines of code read the cutoff values from the RSAPv3 Control Form.

```
For i = 1 To Count
        ⋮
    S1cutoff = CDbl(frmRSAPcontrols.{Read cutoff value for x-section score}
    S2cutoff = …{Read cutoff value for posted speed limit score}
    S3cutoff = …{Read cutoff value for vertical grade score}
    S4cutoff = …{Read cutoff value for Horizontal Curve score}

    If S1score < S1cutoff Then
        S1score = S1score / 2
    End If
    If S2score < S2cutoff Then
        S2score = S2score / 2
    End If
    If S3score < S3cutoff Then
        S3score = S3score / 2
    End If
    If S4score < S4cutoff Then
        S4score = S4score / 2
    End If
```

The weight assigned to each of the characteristic scores is also defined on the RSAPv3 Control Form shown in Figure 33. It was determined that the roadside cross-section has a greater influence on the vehicle's trajectory path than the other roadway and roadside characteristics and was therefore assigned a higher weight in the calculation of the composite score. Likewise, the horizontal alignment of the roadway was also considered to have a significant effect on trajectory path and was assigned a relatively higher weight as well. The default value of the weight assigned to each criterion is listed below. Refer to the ENGINEER'S MANUAL for further discussion regarding these values.

- $W_1 = 3$, (weight assigned to roadside cross-section)
- $W_2 = 2$, (weight assigned to horizontal curvature)
- $W_3 = 1$, (weight assigned to vertical grade)
- $W_4 = 1$, (weight assigned to posted speed)

The following lines of code read the weight values from the RSAPv3 Control Form; compute the composite score for the i^{th} trajectory case; and store the score values in the array *Trajscore*.

```
    WS1 = CDbl(frmRSAPcontrols.{Read weight for cross-section slope
profile}
    WS2 = …{Read weight for posted speed}
    WS3 = …{Read weight for vertical grade}
    WS4 = …{Read weight for horizontal curve radius}

    Trajscore(i, 1) = i
    Trajscore(i, 2) = (WS1 * S1score + WS2 * S2score + WS3 * S3score _
                    + WS4 * S4score) / (WS1 + WS2 + WS3 + WS4)
    Trajscore(i, 3) = S1score
    Trajscore(i, 4) = S2score
    Trajscore(i, 5) = S3score
    Trajscore(i, 6) = S4score
Next i
```

Select Trajectories for the Analysis

Once the individual scores for each of the four criteria have been computed and combined into a single representative composite score for the trajectory case, RSAPv3 then sorts the trajectory cases in descending order based on their composite score and selects the trajectory cases with the highest scores for use in the analysis. RSAPv3 selects only those trajectories that have a composite score of 0.93 or higher or until the minimum number of desired trajectory cases are obtained. The minimum number of trajectories is defined on the RSAPv3 Control Form shown in Figure 33 and the default value is 10.

For some road segments with very common roadside characteristics, there may be a relatively large number of trajectory cases with a score higher than 0.93– particularly as

more and more cases are added to the database. Although the accuracy of the analysis is expected to increase as the number of "applicable" trajectories increases, the time for completing the analysis will also increase. It is assumed that a maximum of forty trajectories will provide sufficient accuracy with acceptable analysis time; however, the maximum number of trajectory cases is defined on the RSAPv3 Control Form, where it can be readily changed. The following lines of code (1) sort the composite scores in descending order, (2) selects the trajectories cases with the highest scores for use in the analysis, (3) determines the lowest composite score and the average composite score of the selected trajectory cases.

Call *MatrixSort({sort trajectory scores in descending order})*

sumTrajscore = 0 ' initialize sum of trajectories scores

Do While *{number of selected cases} < {min number}* ***Or*** *{composite score} > 0.93_*
And *{number of selected cases} < Application.Max({min number}, {max number})*
    num_traj(iVeh) = num_traj(iVeh) + 1 ' increase count of selected trajectory cases
    sumTrajscore = sumTrajscore + {current trajectory score}
Loop
minTrajscore = {minimum value of selected trajectory scores}
avgTrajscore = sumTrajscore / num_traj(iVeh)

Redefine the Selected Trajectory Cases Based on Traffic Direction and Departure Side

As discussed earlier, the trajectory paths in the trajectory database have all been normalized to a local reference frame with positive path coordinates (e.g., consistent with primary-right encroachments). The trajectory path data must be transformed to the global coordinate frame for application in the analysis. The following lines of code re-dimension the trajectory path variables and transform the trajectory path coordinates from local to global coordinates for each trajectory case selected for the analysis.

ReDim *trajx(num_veh, num_traj(iVeh), num_pre(iVeh) + 300)*
ReDim *trajy(num_veh, num_traj(iVeh), num_pre(iVeh) + 300)*
ReDim *MaxL(num_veh, num_traj(iVeh))*
ReDim *MinY(num_veh, num_traj(iVeh))*
ReDim *MaxY(num_veh, num_traj(iVeh))*

For *i = 1* ***To*** *{total number of selected trajectories}*
    MinY(iVeh, i) = 1000000#
    MaxY(iVeh, i) = -1000000#

For *j = 1* ***To*** *num_pre(iVeh) + 300*

The longitudinal path coordinates are not explicitly defined in the database; instead, the lateral trajectory path coordinates are defined at specified longitudinal increments equal to *grid_x*. The following line of code determines the x-coordinate of the of trajectory path based on the increment value, *grid_x* and the number of data columns preceding the trajectory path coordinates (i.e, *num_pre*). The value of *trajx* starts at zero when *j = num_pre*.

*trajx(iVeh, i, j) = (j - 1 - num_pre(iVeh)) * grid_inc(iVeh) * iDirection*

The next lines of code read in and define the trajectory coordinates. The lateral coordinate data is preceded by various other trajectory data, which are read from the trajectory database and stored in the variable array *traj_y*. The lateral coordinates are then transformed from local to global reference frame (i.e., they are multiplied by *iDirection* and *iLDS*).

If *j <= num_pre(iVeh)* ***Then***
trajy(iVeh, i, j) = {read crash cases data preceding path _ coordinates}
ElseIf *TrajectoryData(Trajscore(i, 1), j) = "" **Then***
trajy(iVeh, i, j) = "" 'Blank cells remain blank
Else
*trajy(iVeh, i, j) = {read coordinate data} * iDirection * iLDS*

The minimum and maximum lateral extents of the trajectory paths are also computed for use later in the analysis in deciding if a trajectory path will be assessed for collision with each hazard. For example, if the hazard lies outside the extent of the trajectory path, then the path is not checked for collision with the hazard. The maximum length of the path is also computed for use in the determining the probability of rollover.

MinY(iVeh, i) = {check if current path coordinate is less than the previous minimum value and keep the lesser of the two}
MaxY(iVeh, i) = {check if current path coordinate is greater than the previous maximum value and keep the greater of the two}
If *j = num_pre(iVeh) + 1* ***Then***
MaxL(iVeh, i) = trajy(iVeh, i, j)
Else

MaxL(iVeh, i) = {compute maximum length of trajectory path}

End If

End If

***Next** j*

***Next** i*

MODULEPOCANALYSIS

This module is called by ModulePOCMain to compute the probability of impact for a given trajectory case and to compute the associated crash costs. The basic procedure is to (1) map the trajectory path onto the roadside or median; (2) examine the trajectory point-by-point for collision with each hazard; (3) if collision occurs compute collision cost (i.e., call subTrajectory_Statistics), check for penetration (call subPenetrate), and check for redirection (call subRedirect); (4) return cost statistics back to Module POCMain.

Input Variables

The following are a list of variables passed from Module POCMain.

- **i**:trajectory path number
- **iALT**: alternative number
- **iDirection**: traffic direction (i.e., 1 = primary, -1 = opposing)
- **iDP**: departure point
- **iLDS**: encroachment side (1 = right, -1 = left)
- **iSeg:** segment number
- **iVeh**: vehicle type number
- **grid_inc**: longitudinal increments of trajectory path
- **oHzrd_Name**: Name of hazard
- **oHzrd_GenType**:
- **oHzrd_Type**:
- **oHzrd_EFCCR65**:
- **oHzrd_Prcnt_PRV**:
- **oHzrd_Prcnt_RR**:
- **oHzrd_Capacity**:
- **oHzrd_Height**:
- **oHzrd_Connection**:Identifies LON hazard attached to END TERMINAL
- **oPDCR**: horizontal curve radius
- **oPDG**: roadway vertical grade
- **oPSL**: posted speed limit
- **SheetName**: name of the worksheet containing the database of reconstructed trajectories

- **num_veh**: total number of vehicle types
- **ymaxp**: maximum extent of cross-section profile in local coordinates

Program Variables

The following are a list of variables defined in the Module.

- **POC**: probability of collision

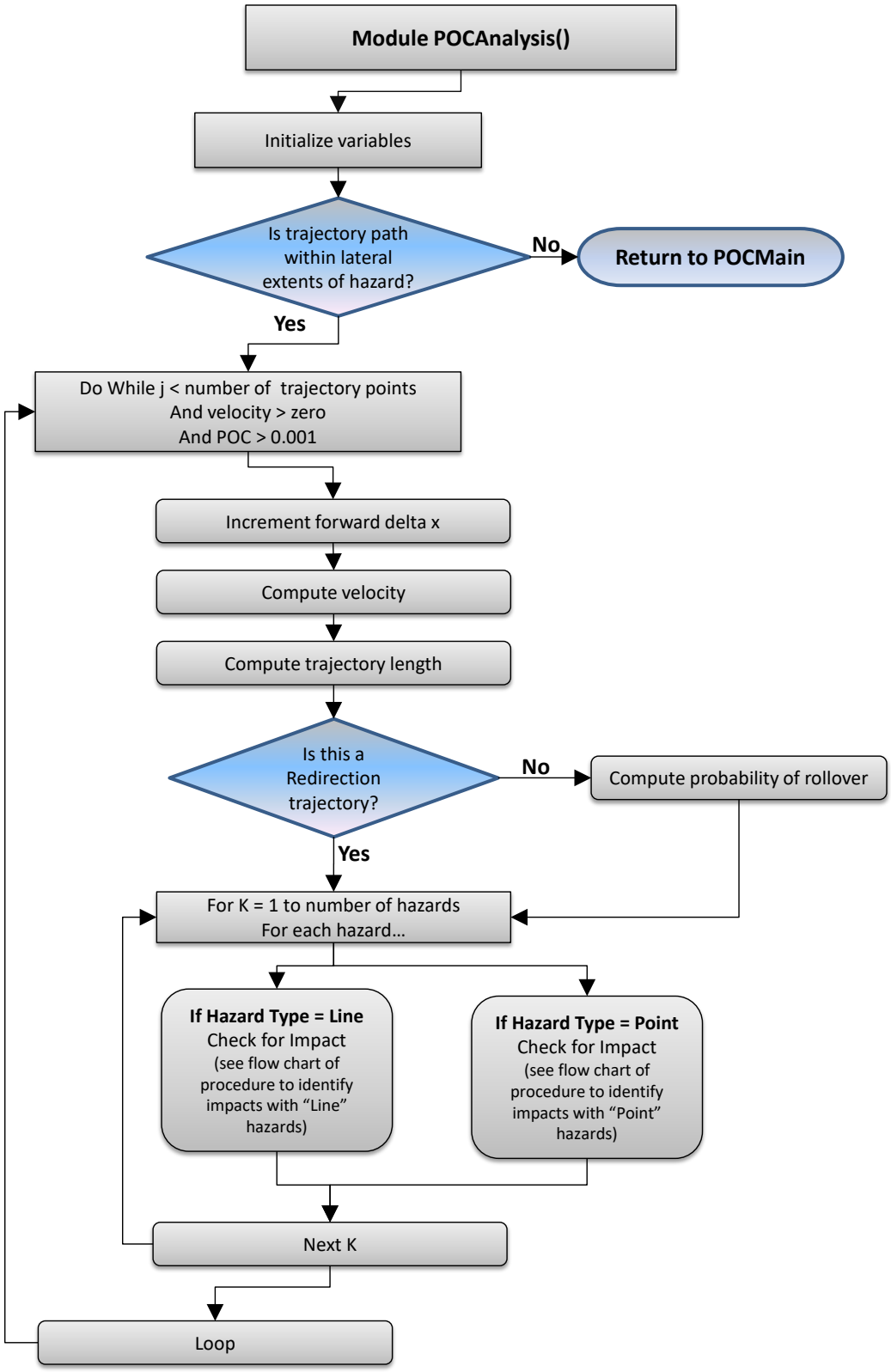


Figure 34. Flow Chart for Module POCanalysis.

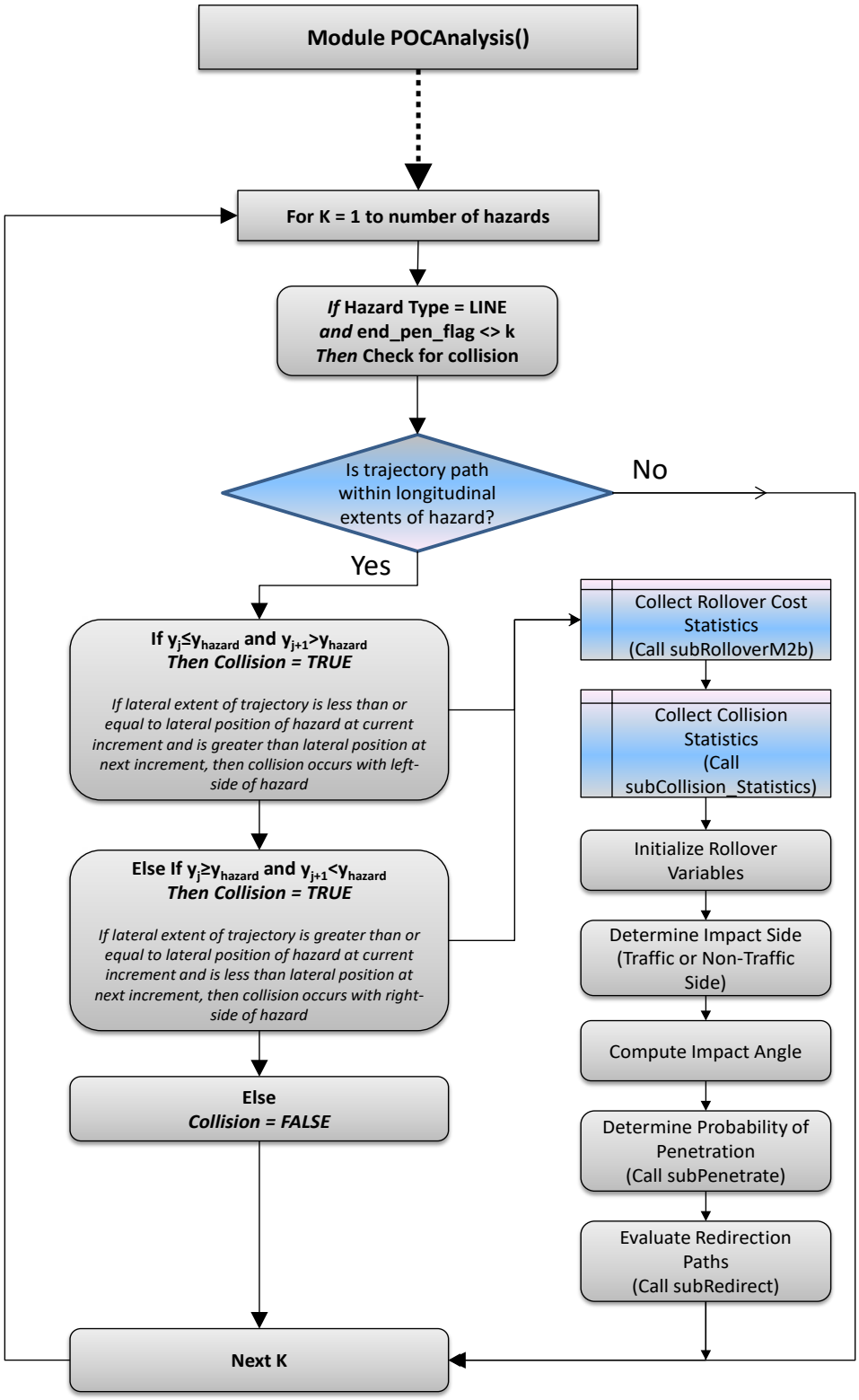


Figure 35. Flow chart for detecting collisions with line hazards in Module POCanalysis.

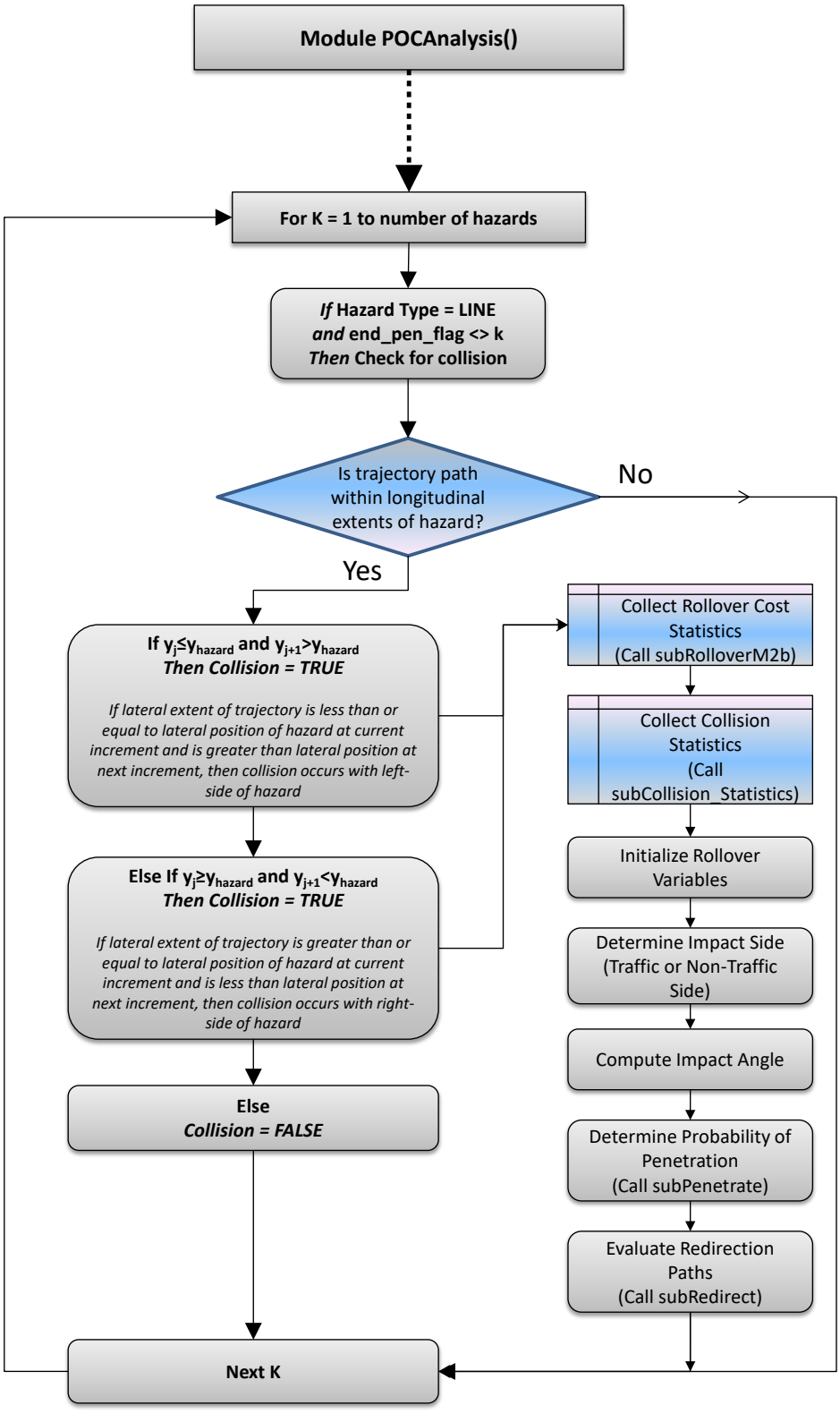


Figure 36. Flow chart for detecting collisions with point hazards in Module POCanalysis.

Initialize Variables

Several variables are initialized at the beginning of this analysis procedure:

end_pen_flag = 0
VE = V0
v = V0
decel = decel0
For *K = 1* ***To*** *{total number of hazards for current alternative}*
    d0(K) = {distance from current path position to first hazard coord.}
Next *K*

The variable *end_pen_flag* is initialized to zero, which indicates that the path is not a redirection path and that terrain rollovers should be considered (i.e., rollovers after redirection are handled separately). The variables *VE* and *v* are defined as the initial velocity; the variable *decel* is defined as the average deceleration of the trajectory path. The variables *v* and *decel* may change during the analysis, depending on various factors, and therefore must be renamed at the start of the analysis to prevent any changes from being passed back to the parent module.

Determine if Trajectory Path Falls Within Extents of the Hazard

The next step in the analysis is to determine if a hazard is located within the lateral extents of the trajectory path. If it is not, then it will not be checked for impact with the hazard. If the hazard is located outside the extents of the trajectory path, then a flag is set, *logic_1(k) = "false"*, which tells the program that it can skip the collision analysis for hazard *k*. If the hazard is located within the extents of the trajectory path then the program sets *logic_1(k) = "true"*, which tells the program that it must check that trajectory for impact with hazard *k*. It also sets another flag, *logic_2 = "true"*, which tells the program that at least one hazard is located within the extents of the trajectory path. The probability of roadside rollovers is checked for all cases unless it is a redirection-trajectory.

max_extent = {maximum lateral extent of trajectory path}
min_extent = {minimum lateral extent of trajectory path}

For *K = 1* ***To*** *{total number of hazards for current alternative}*
  If *{hazard type} = {Point}* ***Then***
    If *oHy(iAlt, K, 1) < min_extent* ***Or*** *oHy(iAlt, K, 1) > max_extent* ***Then***
      Logic_1(K) = "false"
    Else
      Logic_1(K) = "true"
      logic_2 = "true"
    End If
  ElseIf *{hazard type} = {Line}* ***Then***

If *{both ends of the hazard are less than the minimum lateral extents of trajectory}* _

Or _

{if both ends of the hazard exceed the maximum lateral extents of trajectory} _

Or _

{if hazard is Opposing median edge ***And*** *encroachment is from Primary Direction}* _

Or_

{if hazard is Primary median edge ***And*** *encroachment is from Opposing Direction}* _

Then

logic_1(K) = "false"

Else

logic_1(K) = "true"

logic_2 = "true"

End If

End If

Next *K*

Evaluate Trajectory Path

This section of the module checks for impacts when the following three conditions are met: (1) the hazard is within the lateral extents of the trajectory path or terrain rollover is possible, (2) the velocity is greater than zero, and (3) the probability of occurrence is greater than 0.1%.

The program examines each point of the trajectory path starting at x_0, which is the current encroachment location being evaluated for all the trajectory paths as illustrated in Figure 37.

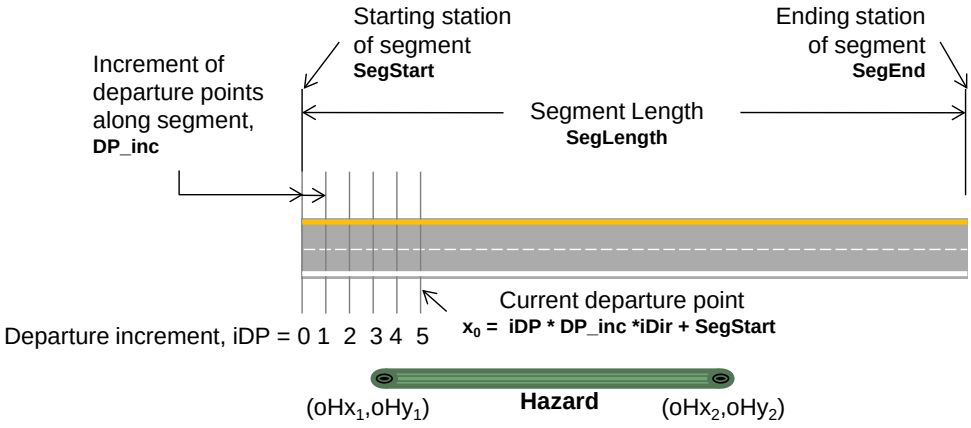


Figure 37. Illustration of roadway segment showing definition of x_0.

The following lines of code perform the following tasks: (1) define the current x-coordinate relative to the departure point x_0, (2) define the longitudinal increment of the trajectory path, and (3) computes the velocity based on initial velocity, deceleration and distance traveled.

```
j = 1
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
    j = j + 1
    x = trajx(iVeh, i, j + num_pre) + x0 ' x-coordinate
    If j = 1 Then
        dx = trajx(iVeh, i, j + num_pre)
    Else
        dx = trajx(iVeh, i, j + num_pre) - trajx(iVeh, i, j + num_pre - 1)
    End If
```

If the lateral coordinate at x is blank, then the end of path is reached and the velocity is zero; otherwise, compute velocity.

```
If traj(iVeh, i, j + num_pre) <> "" Then
    Lj = {√(y_j − y_(j−1))^2 − dx^2}      ' length of current increment
    TL = TL + Lj   'cummulative length of path
```

Deceleration is pre-defined for each trajectory case in Trajectory database. In some of those cases, however, the deceleration is considered to be unreasonably low, particularly for the case of long trajectory paths. It is assumed that if a person is not braking before the vehicle leaves the roadway, then braking should initiate as soon as the driver is aware of the situation. The original value for deceleration (from the trajectory database) is used to compute velocity until the encroachment reaches a critical distance. At that point, if the deceleration is less than the 20th percentile deceleration value of 6.4 ft/s^2, then the velocity from that point on is computed using 20th percentile value. The critical length is the distance that the vehicle travels during typical perception-reaction time, *t*, of one second.

```
    t = 1    'perception-reaction time
    If TL > -decel / 2 * t ^ 2 + V0 * t Then decel = Application.Max(decel,
6.4)

    ' prevent overflow in max length calculation below
    If decel = 0 Then decel = 0.001
```

The maximum length of the trajectory path, *MaxL*, was computed earlier; however, its value will decrease if the value for deceleration is increased and must be recomputed (note: this variable is used for computing probability of rollover in a later task).

*MaxL = Application.Min(MaxL0, (VE ^ 2 / decel) * (1 / 2))*

If the velocity is less than zero for the current increment, then set the velocity to zero.

If** (V0 ^ 2 - 2 * decel * TL) > 0 **Then
*v = (V0 ^ 2 - 2 * decel * TL) ^ 0.5*
Else
v = 0 ' deceleration was increased and path ended prior to reaching the
' end of original path definition.
End If
Else
v = 0 ' velocity set to zero at end of path definition
End If

Compute Rollover Statistics and Check for Rollover

Before checking the path for impact with roadside features, the program first computes the probability of rollover at the current path increment, unless the current trajectory is a redirection event. The probability of rollover for a given trajectory path is modeled in RSAPv3 using the following relationship, which is based on the *average* probability of rollover as the vehicle traverses multiple sideslopes along its trajectory path:

$$P(R) = \frac{1}{L_{tot}} \sum_{i}^{N} P(R|slope)_i * \phi_{S_i,G} * \phi_{S_i,HC} * L_i$$

Where:

$P(R) = Probability\ of\ rollover\ for\ the\ trajectory$
$P(R|slope)_i = Probability\ of\ rollover\ based\ on\ the\ sideslope\ at\ increment\ i$
$\phi_{S_i,G} = Adjustment\ factor\ for\ vertical\ grade\ and\ sideslope\ at\ increment\ i$
$\phi_{S_i,HC} = Adjustment\ factor\ for\ hor.\ curve\ radius\ and\ sideslope\ at\ increment\ i$
$L_i = Length\ of\ current\ increment$
$L_{tot} = Total\ length\ of\ the\ trajectory\ path$
$N = Total\ number\ of\ increments\ along\ trajectory\ path\ during\ analysis$

The program calls subroutine *subRolloverM2a* to update the values in the rollover equation at each increment. If the current increment is the last increment of the trajectory path, then the program calls subroutine *subrolloverM2b* to compute the probability of rollover and the associated crash cost. The subroutines are presented in a later section of this Manual and the details of the rollover model are provided in the ENGINEER'S MANUAL.

***Do While** j < nopc **And** logic_2 = "true" **And** v <> 0 **And** POC > 0.001*
⋮

```
If redir_flag <> 1 Then
    N = N + 1       ' number of increments in rollover count
   Call subRolloverM2a()
```

If the current increment is the end of trajectory and probability of occurrence is greater than 0.1% then compute probability of rollover.

```
        If j = nopc Or traj(iVeh, i, j + num_pre + 1) = "" Or v = 0 And POC > 0.001
        Then
          Call subRolloverM2b()
```

When a rollover event has been determined, the statistical variables must be re-initialized.

```
          SumV2 = 0
          V2avg = 0
          N = 0
       End If
    End If
```

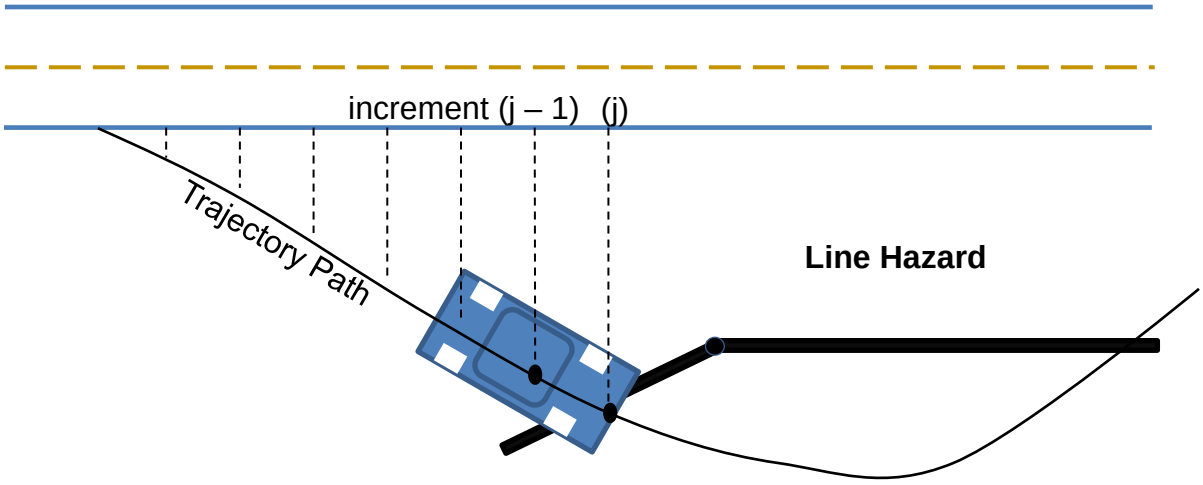
Check for Collision with Hazards

At each increment of the trajectory, the coordinates of the path are checked to determine if they have encountered any of the hazards. If, however, it was predetermined that the hazard is not located within the extents of the trajectory path then the evaluation for that hazard is skipped.

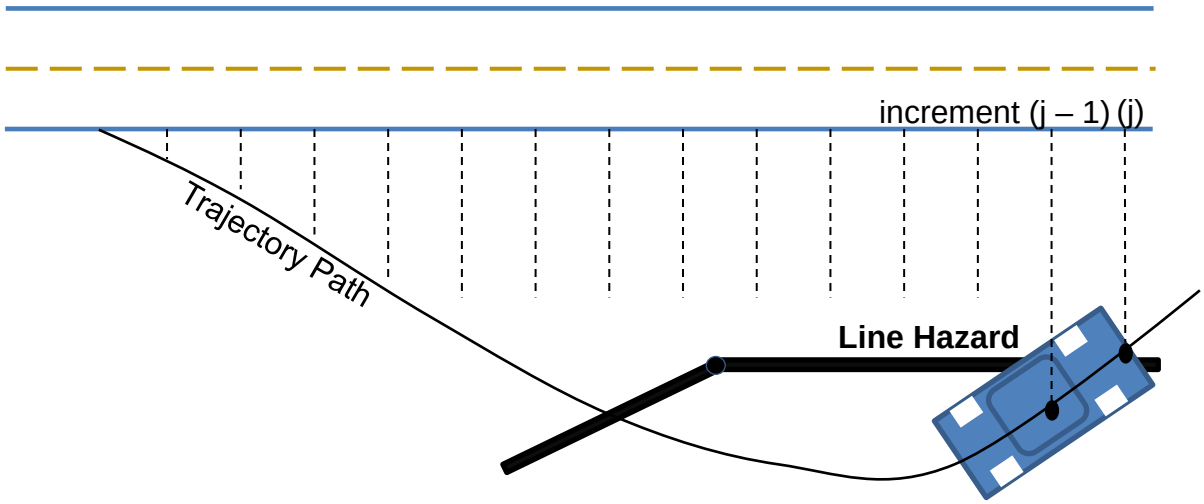
```
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
        ⋮
  If {y_j} <> "" Then

      If logic_1(K) = "true" Then
```

Line Hazards

The basic procedure for identifying impact with “line” hazards is to compare the lateral coordinate of the trajectory at the current and previous increment with the corresponding lateral coordinates of the hazard. If the trajectory path at the previous increment (j-1) is on the left-side of the hazard and the path at the current increment (j) is on the right-side of the hazard, then the hazard was struck from the left side, as illustrated in Figure 38(a). Likewise, if the trajectory path at the previous increment (j-1) is on the right-side of the hazard and the path at the current increment (j) is on the left-side of the hazard, then the hazard was struck from the right side, as illustrated in Figure 38(b).



a) Impact on left-side of hazard



b) Impact on right-side of hazard

Figure 38. Illustration. Trajectory path (a) crossing hazard from left side and (b) crossing hazard from right side.

The following lines of code check for impacts with line hazards unless it is connected to an end-terminal that has already been struck. Recall that when an end-terminal is struck, the *end_pen_flag* value is set to the hazard-number corresponding to the line hazard which is attached to the end-terminal.

```
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
  If {yj} <> "" Then
    For K = 1 To {total number of hazards for the current alternative}
      If logic_1(K) = "true" Then
            ⋮
        If oHzrd_Type(iAlt, K) = "L" And end_pen_flag <> K Then




          If iDir = 1 Then
            loc_check1 = x + dx
            loc_check2 = x
          Else
            loc_check1 = x
            loc_check2 = x + dx
          End If
```

There are cases when the longitudinal length of a hazard (e.g., line hazard perpendicular to roadway) is less than the longitudinal increment of the trajectory (e.g., 1 ft). To avoid passing over such hazards, the path position at a x+dx is checked to see if it has passed the upstream end of the hazard and the path position at x is checked to see if it has passed the down-stream end of the hazard. If TRUE, then check for collision.

```
          If loc_check1 >= oHx(iAlt, K, 1) And loc_check2 <= oHx(iAlt, K, 2)
  Then
```

The first step of this task is to compute the lateral coordinate value of the line hazard at *x* and at *x+1*. The collision flag is set to *Collision = "checking"*. When a collision has been determined this flag will then be set to "true", in which case rollover statistics will be computed prior to the analysis of the collision.

```
            Hy0 = HM(iAlt, K) * (x - oHx(iAlt, K, 1)) + oHy(iAlt, K, 1)
            Hy1 = HM(iAlt, K) * ((x + dx) - oHx(iAlt, K, 1)) + oHy(iAlt, K, 1)
            Collision = "checking"        ' initialize collision flag
```

The criteria for collision on the left side of the barrier is defined as follows: *If lateral trajectory at previous point is less than lateral position of hazard and the lateral trajectory at the current point is greater than lateral position of hazard and if there is no*

rollover or end of trajectory path, then path crossed barrier from left side. The width of the barrier is accounted for when determining the hazard location.

```
BHW = {barrier width} / 2
If {yj} <= Hy0 - BHW _
And {yj} <= Application.Max{oHy1, oHy2} - BHW _
And {yj+1} > Hy1 - BHW _
And {yj+1} > Application.Min{oHy1, oHy2}  - BHW Then
        CSRL = "left"   ' collision side "left" used for determining
                                ‘sign of angle for redirection trajectories
        Collision = "true"
```

The criteria for collision on the right side of the barrier is defined as follows: *If lateral trajectory at previous point is greater than lateral position of hazard and the lateral trajectory at the current point is less than the lateral position of hazard and if there is no rollover or end of trajectory path, then path crossed barrier from right side.*

```
ElseIf {yj} >= Hy0 + BHW _
And {yj} >= Application.Min{oHy1, oHy2} + BHW _
And {yj+1} < Hy1 + BHW _
And {yj+1} < Application.Max{oHy1, oHy2} + BHW Then
   CSRL = "right"     ' collision side "right" used for determining
                                ‘sign of angle for redirection trajectories
        Collision = "true"
End If
```

If a collision has occurred on either side of the hazard, then (1) compute probability and associated costs of a rollover occurring prior to the collision with the hazard, (2) compute crash statistics and associated costs for collision with the hazard, (3) determine probability of PRV, (4) evaluate redirection trajectories for secondary collisions and (5) continue evaluating current path (post penetration) for secondary collisions.

(1) Compute Rollover Statistics and Cost

If the trajectory is not a redirection trajectory then the program calls subroutine *subRolloverM2b* to calculate rollover statistics. The subroutines are presented in a later section of this Manual and the details of the rollover model are provided in the ENGINEER’S MANUAL.

```
If Collision = "true" Then
   If redir_flag <> 1 Then
      Call subRolloverM2b()
      'Initialize Rollover Variables
      SumV2 = 0
      V2avg = 0
```

N = 0
End If

(2) Compute Crash Statistics for Collision with Hazard

The program first determines which side of the hazard was struck, which is stored in the variable *CS*.

y = traj(iVeh, i, j + num_pre) + y0 ' lateral impact location
Call *sub_CS(oHy(iAlt, K, 1), oHy(iAlt, K, 2), iDir, CS, y0, y)*

A median edge line is considered to be a hazard only when a vehicle is crossing into opposing lanes of traffic. So, if the hazard is not a median edge and the vehicle is not crossing from the non-traffic side, then it is considered a collision and the subroutine subCollision_Statistics is called to compute the crash-cost statistics. The subroutines are presented in a later section of this Manual and the details of computing crash statistics are presented in the ENGINEER'S MANUAL.

If Not *(oHzrd_Name(iAlt, K) = "EdgeOfMedian"* ***And*** *CS = "NTS")*
Call subCollision_Statistics()

The initial velocity for subsequent redirection trajectories is equal to the current velocity. The angle of impact relative to the barrier is also computed for use in computing impact severity and redirection paths.

vR0 = v ' impact velocity stored for use in evaluating
'redirection paths in subRedirect

Impact angle with respect to roadway:

If *dx = 0* ***Then***
Theta_traj = Atn{y_1 / x_1}
Else
Theta_traj = Atn{(y_j - y_{j-1}) / dx}
End If

Angle of hazard with respect to roadway:

Theta_Haz = Atn(HM(iAlt, K))

Impact angle with respect to hazard:

Theta = Theta_traj - Theta_Haz ' Impact angle w.r.t. barrier

(3) Determine Probability of Penetration, Rollover Barrier and Vault

The subroutine *subPenetrate* is called to compute the probability of penetration due to exceeding structural capacity of the barrier, rolling over the barrier, and vaulting the barrier. Along with the crash statistics (e.g., probability of penetration, probability of redirection, etc.), the subroutine also passes back the updated velocity which is reduced

according to the amount of energy expended in penetrating the barrier. The subroutines are presented in a later section of this Manual and the details of determining penetration are presented in the ENGINEER'S MANUAL.

```
Call subPenetrate()
V0 = v
TL = 0      ' trajectory length is reset to correspond to the new
v0
```

(4) Evaluate Redirection Paths for Secondary Collisions

When a collision occurs with a line hazard there is generally a probability of redirection (some exceptions would be a tree-line hazard or a water hazard). For longitudinal barriers in particular the probability of redirection is dependent upon the type of vehicle and whether or not the vehicle penetrated the barrier. Impacts with motorcycles are not evaluated for redirection since it is likely that the passengers would have been ejected upon impact.

Penetration is determined using a combination of crash statistics and the mechanics of the impact event which are discussed in detail in the ENGINEER'S MANUAL. If the probability of redirection is greater 1 percent and the vehicle type is not a motorcycle, then the program calls subroutine subRedirect to evaluate redirection paths for secondary collisions. Recall that the probability of redirection was determined in step (3) from subroutine *subPenetrate.* The subroutines are presented in a later section of this Manual. Since the following lines of code conclude the analysis for the line hazard, all the preceding program *loops* and *nested If statements* associated with the analysis of the line hazard are presented in gray font for convenience.

```
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
  If {yj} <> "" Then
    For K = 1 To {total number of hazards for the current alternative}
      If logic_1(K) = "true" Then
        If oHzrd_Type(iAlt, K) = "L" And end_pen_flag <> K Then
          If loc_check1 >= oHx(iAlt, K, 1) And loc_check2 <= oHx(iAlt, K, 2)
Then
            If Collision = "true" Then
              If Not (oHzrd_Name(iAlt, K) = "EdgeOfMedian" And CS =
              "NTS")

              ⋮

                If POR > 0.01 And {vehicle type} <> "M" Then
                  Call subRedirect()
                End If
              End If
            End If
```

End If
End If

Move to the next hazard and continue evaluating current path for collisions.

⋮

***Next** K*

Point Hazards

To determine if a vehicle following a given trajectory path will encounter a "Point" hazard, the program increases the effective radius of the hazard to account for the "swath" of the vehicle. The effective radius of the hazard is then defined as $R = r_h + w/2$, where r_h is the radius of the hazard and *w* is the width of vehicle, as illustrated in Figure 39. The vehicle swath is read from the RSAPv3 worksheet named "Traffic Information".

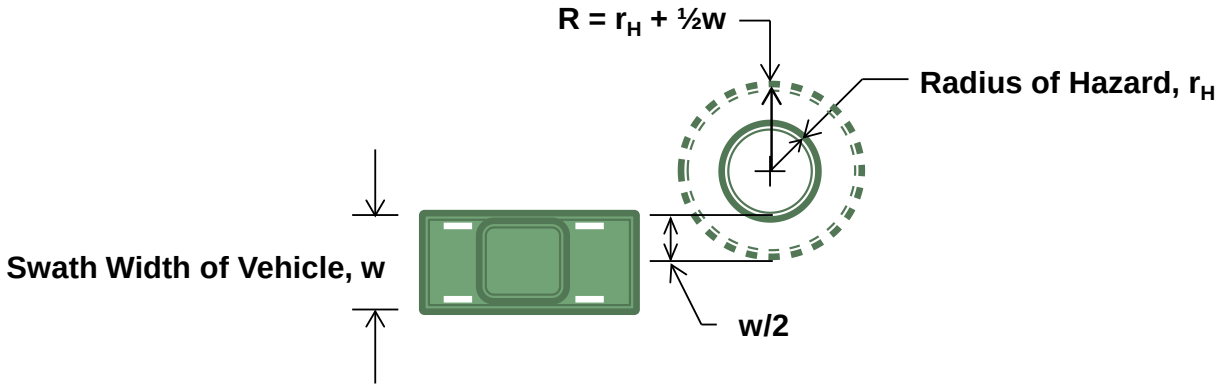


Figure 39. Illustration. Defining the effective radius, R, of a "Point" hazard.

The basic procedure for identifying impact with "Point" hazards is to compute the distance, *d* from the path at the current increment, *j*, to the center-point of the hazard and compare it to the effective radius of the hazard, *R*. If the distance to the hazard is less than *R* then the path is inside the boundaries of the hazard and impact has occurred, as illustrated in Figure 40. It is possible that the path may fall inside the radius of the hazard at several consecutive increments along the path, as illustrated in Figure 6. To avoid counting these as subsequent impacts, the program checks to see if the path was inside the hazard at the previous increment (*j*-1). If so, the current increment (*j*) is not considered a collision.

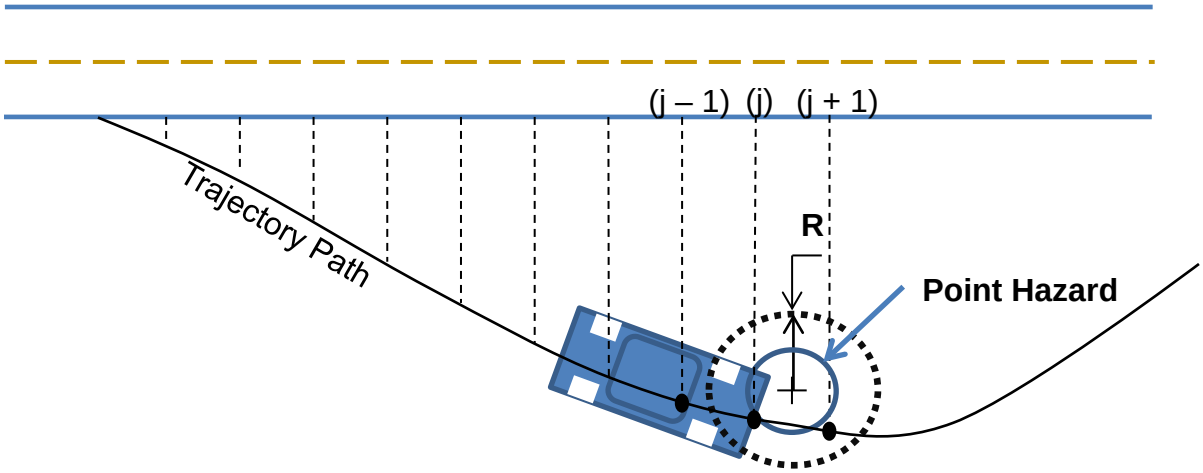


Figure 40. Illustration. Trajectory path crossing a point hazard.

The following lines of code check for impacts with point hazards. The first step of this task is to compute the lateral coordinate value of the line hazard at *x* and at *x+1*.

```
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
  If {yj} <> "" Then
    For K = 1 To {total number of hazards for the current alternative}
      If logic_1(K) = "true" Then
            ⋮
       If oHzrd_Type(iAlt, K) = "P" Then
         Hy0 = oHy(iAlt, K, 1)
```

The program only looks for collisions when the longitudinal coordinate of the path is within the effective radius of the hazard (i.e., radius of hazard plus swath width of vehicle). It then computes the lateral coordinate of the trajectory path (based on the current increment of the path and the encroachment point) and the distance from the current path location to the center of the hazard.

```
If x >= {oHx1} – {effective radius of hazard} _
And x <= {oHx1} + {effective radius of hazard} _
And yj <> "" Then
   yp = traj(iVeh, i, j + num_pre) + y0
   D = ((x - oHx(iAlt, K, 1)) ^ 2 + (yp - Hy0) ^ 2) ^ (0.5)
```

The criterion for impact is then: *If current trajectory point (D) is found to be within the effective radius of the hazard and the previous trajectory point (d0) was outside this radius then impact occurred*. Otherwise impact has not occurred or the impact occurred during a previous increment and has already been accounted for.

```
If D <= {effective radius of hazard} _
And d0(K) > {effective radius of hazard} Then
```

If a collision has occurred and the current path is not a redirection path, then (1) compute probability and associated costs of a rollover occurring prior to the collision with the hazard, (2) compute crash statistics and associated costs for collision with the hazard, (3) determine probability of penetration, and (4) continue evaluating current path (post penetration) for secondary collisions.

(1) Compute Rollover Statistics and Cost

If the trajectory is not a redirection trajectory then the program calls subroutine *subRolloverM2b* to calculate rollover statistics.

```
If redir_flag <> 1 Then
   Call subRolloverM2b()
   'Initialize Rollover Variables
   SumV2 = 0
   V2avg = 0
   N = 0
End If
```

(2) Compute Crash Statistics for Collision with Hazard

All collisions with point hazards are considered traffic-side impacts, so the program sets:

```
CS = "TS"
```

The subroutine subCollision_Statistics is called to compute the crash-cost statistics.

```
Call subCollision_Statistics()
```

(3) Determine Probability of Penetration

The subroutine *subPenetrate* is called to compute the probability of penetration due to exceeding structural capacity of the hazard.

```
Call subPenetrate()
```

If the hazard is an end-treatment for a LON barrier then set *end_pen_flag* value to the hazard number corresponding to the mating LON barrier and ignore subsequent impacts on that barrier.

```
If oHzrd_GenType(iAlt, K) = "TerminalEnds" Then
   end_pen_flag = oHzrd_Connection(iAlt, K)
End If
```

Along with the crash statistics (e.g., probability of penetration), the subroutine *subPenetrate* also passes back the updated velocity, which is reduced according to the amount of energy expended in penetrating the hazard. The initial velocity for post-

penetration is re-initialized along with the value for the trajectory length (*TL*) used in computing the probability of rollover.

```
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
  If {yj} <> "" Then
    For K = 1 To {total number of hazards for the current alternative}
      If logic_1(K) = "true" Then
        If oHzrd_Type(iAlt, K) = "P" Then
          If x >= {oHx1} – {effective radius of hazard} _
          And x <= {oHx1} + {effective radius of hazard} _
          And yj <> "" Then
            If D <= {effective radius of hazard} _
            And d0(K) > {effective radius of hazard} Then
                    ⋮
              V0 = v        ' v0 is reset corresponding to change in velocity
                            ‘after penetration
              TL = 0      ' trajectory length is reset to correspond to the new v0
            End If
```

Reset distance d0 for next increment.

```
            d0(K) = D       ' redefine distance from previous trajectory point to
hazard
          End If
        End If
      End If
```

Move to the next hazard and continue evaluating current path for collisions.

```
    Next K
```

If the velocity of the current increment is zero (e.g., due to kinetic energy expended during a penetration or redirection) or the trajectory path has ended then set *j = nopc* which will end the analysis for the current increment.

```
Do While j < nopc And logic_2 = "true" And v <> 0 And POC > 0.001
  If {yj} <> "" Then
      ⋮
  ElseIf v = 0 Or {yj}= "" Then
    j = nopc
  End If
 Loop
End Sub
```

SubCollision_Statistics

This subroutine is called by ModulePOCAnalysis, and the subroutines subPenetrate and subRolloverMB2 to compute crash-cost statistics variables. The program passes impact conditions, vehicle characteristics and hazard severity information into the subroutine; these data are used to compute the crash costs for the current impact which are added to the cumulative cost of impacts on the hazard. The details of the development of this procedure are provided in the ENGINEER'S MANUAL.

Input Variables

The following are a list of variables passed from the parent modules and subroutines.

- **cost_adj**: cost adjustment factor for current vehicle type
- **CS**: collision side
- **iALT**: current alternative
- **num_traj_seg**: cumulative number of trajectories for this segment
- **oHzrd_EFCCR65**:
- **POC**: probability of collision
- **v**: impact velocity
- **veh_type**: vehicle type

Program Variables

The following are a list of variables defined in the subroutine.

- **EFCCR**: Equivalent Fatal Crash Cost Ratio (e.g., normalized crash cost)
- **EFCCRi**(num_traj_seg,1): total cumulative EFCCR the current trajectory
- **EFCCRi**(num_traj_seg,2): vehicle type
- **EFCCRi**(num_traj_seg,3): alternative
- **EFCCR_tot**: total cumulative EFCCR for this hazard
- **Impact_Count_tot**: cumulative number of impacts on current hazard
- **Impact_Count_NTS**: cumulative number of impacts on non-traffic side of hazard current hazard
- **Impact_Count_TS**: cumulative number of impacts on traffic side of hazard current hazard

Procedure

Compute EFCCR for current collision based on vehicle type, hazard severity, and impact conditions.

*EFCCR = VehCharac10 * (oHzrd_EFCCR65 / 274625) * (v * 60 / 88) ^ 3*

The *EFCCR* value is a normalized crash cost defined as the ratio of the crash cost divided by the cost of a fatal crash. The *EFCCR* is weighted based on the probability of the collision occurring (i.e., *POC*). The value for POC is determined in subPenetrate and

subRollover based on probability of penetration and rollover, respectively. The cumulative crash cost for the current hazard and the total number of impacts on the hazard are then computed. This information is later used to compute the average crash-cost for impacts with the hazard.

*EFCCR_tot = EFCCR_tot + EFCCR * POC*
impact_Count_tot = impact_Count_tot + POC

The following information is not used in computing crash costs, but is computed here and later written to the RSAPv3 "POC scratch" worksheet for information purposes only.

If** CS = "TS" **Then
    impact_Count_TS = impact_Count_TS + POC
Else
    impact_Count_NTS = impact_Count_NTS + POC
End If
End Sub

SubPenetrate

This subroutine is called by ModulePOCAnalysis to determine the probability of penetration of a hazard during collision. The basic procedure is to (1) determine probability of penetration due to structural failure or vaulting of hazard, (2) determine probability of penetration due to rolling over the barrier (i.e., analysis for trucks only), (3) determine probability of rollover after redirection and compute crash statistics for the rollover event, (4) determine probability of redirection and (5) pass this information back to parent module. The details of the development of this procedure are provided in the ENGINEER'S MANUAL.

Input Variables

The following are a list of variables passed from the parent module.

- **iALT**: current alternative
- **EFCCRi**: total cumulative EFCCR the current trajectory
- **EFCCR_RR**: cumulative EFCCR for rollover-after-redirection for current hazard
- **K**: hazard number
- **num_traj_seg**: cumulative number of trajectories for this segment
- **oHzrd_Capacity**: hazard capacity
- **oHzrd_EFCCR65**: hazard severity (Effective Fatal Crash Cost Ratio for impact speed of 65 mph)
- **oNum_Hazards**: number of hazards in current alternative
- **oHzrd_Height**: height of hazard
- **oHzrd_Prcnt_RR**: percent of rollover after redirection from crash statistics
- **oHzrd_Type**: hazard type

- **POC**: probability of occurrence for this trajectory increment (e.g. probability of collision)
- **Theta0**: impact angle
- **v**: impact velocity
- **VehCharac(*,1)**: RSAPv3 vehicle name
- **VehCharac(*,2)**: FHWA vehicle class
- **VehCharac(*,3)**: percent of traffic mix
- **VehCharac(*,4)**: RSAPv3 vehicle type (M, C, T)
- **VehCharac(*,5)**: vehicle weight
- **VehCharac(*,6)**: vehicle length
- **VehCharac(*,7)**: vehicle width
- **VehCharac(*,8)**: distance from cg to front of vehicle
- **VehCharac(*,9)**: cg height
- **VehCharac(*,10)**: crash cost adjustment factor

Program Variables

The following are a list of variables defined in the Module.

- **POR**: effective probability of redirection given collision conditions and probability of collision event
- **PORV**: effective probability of truck rolling over hazard given collision conditions and probability of collision event
- **POC**: probability of collision and/or occurrence of current trajectory path
- **PRB**: probability of rolling over hazard given current impact conditions (ignoring probability of penetration)
- **PRR**: probability of rollover after redirection given current impact conditions (ignoring probability of penetration and rolling over the barrier)
- **KE**: kinetic energy of vehicle
- **KK**: hazard number set for rollovers
- **Capacity**: barrier capacity in units of energy
- **ISeverity**: impact severity
- **m**: vehicle mass
- **Count_pene_RSAP**: number of penetrations on current hazard
- **V0rv**: modified post-impact velocity die to loss of energy during redirection and rollover)
- **WRR**: probability of rollover after redirection (considering probability of penetration, and rolling over the hazard)
- **WRV**: probability of rolling over barrier given current impact conditions (considering probability of penetration)

- **WR**: probability of redirection (considering probability of penetration, rollover barrier and rolling over after redirection)
- **WP**: probability of penetration given current impact conditions

Procedure

Probability of Penetration due to Structural Failure or Vaulting

The program uses two different approaches for determining penetration:

Criterion A

If impact severity is greater than the structural capacity of the barrier and the structural capacity is greater than or equal to zero, then the probability of penetration is determined based on a combination of impact mechanics and a pseudo-probabilistic model, where the probability of penetration up to capacity is based on crash statistics (i.e., PRV from RSAPv3 "severity" worksheet) and increases toward 100% as impact severity values increase beyond hazard capacity. In this case, it is assumed that the probability of penetration can be described by the hyperbolic tangent function defined below. More details on the development of the hyperbolic-tangent probability model are presented in the ENGINEER'S MANUAL.

$$P(Penetration|collision) = \frac{(1-PRV)}{2} * \tanh\left[5\left(\frac{IS}{Capacity} - 1.5\right)\right] + \frac{(1+PRV)}{2}$$

```
Theta = Abs(Theta0)                          ' impact angle
Capacity = {hazard capacity} * Convert       '(ft-lb) energy
m = {vehicle weight} / 32.2 'lb-ft/s2        ' vehicle mass
KE = (1 / 2) * m * v ^ 2                     ' kinetic energy
ISeverity = (1 / 2) * m * (v * Sin(Theta)) ^ 2  ' Impact Severity
If capacity >= 0 And ISeverity > capacity Then
        s = oHzrd_Prcnt_PRV(iAlt, K) / 100  ' s = PRV
        B = 5
        shift = 1.5
        If s < 1 And capacity > 0 Then
                WP = (1 - s) / 2 * Application.Tanh((ISeverity / capacity - shift) _
                * B) + (1 - s) / 2 + s ' Percent penetration
        Else
                WP = s
        End If
        '       --- modified velocity due to loss of energy during penetration
        vp = ((2 / m) * (ke - capacity)) ^ 0.5
```

Criterion B

Else, (i.e., *If the impact severity is less than the structural capacity of the barrier or if the structural capacity of the barrier is zero or unknown),* the probability of penetration is defined solely based on crash statistics (i.e., PRV) and this value is used to

"weight" the crash cost of any subsequent impacts. This value is provided on the Severity worksheet in RSAPv3.

Else

WP = oHzrd_Prcnt_PRV(iAlt, K) / 100
' --- Energy loss is assumed to be 30% for PRV penetrations
*DeltaE = ke * 0.3*
*vp = ((2 / m) * (ke - DeltaE)) ^ 0.5*

End If

Probability of Penetration due to Rolling Over Barrier (Trucks Only)

If the vehicle does not penetrate the barrier upon impact, the next possibility is rolling over the barrier as the vehicle is trying to redirect. The probability of rolling over the barrier is only considered in the analysis of truck trajectories and only when the center-of-gravity of the truck is higher than the top of the barrier. An additional criterion is used for only considering longitudinal barriers with heights ranging from 2.0 ft to 7.5 ft height. The program calls the subroutine *subRolloverBarrier* to compute the rollover-ratio parameter, which is used to determine the probability of the truck rolling over the barrier. The equations in subroutine *subRolloverBarrier* are presented in the ENGINEER'S MANUAL. The probability of rolling over the barrier is then computed using the hyperbolic tangent model, as shown in Figure 41.

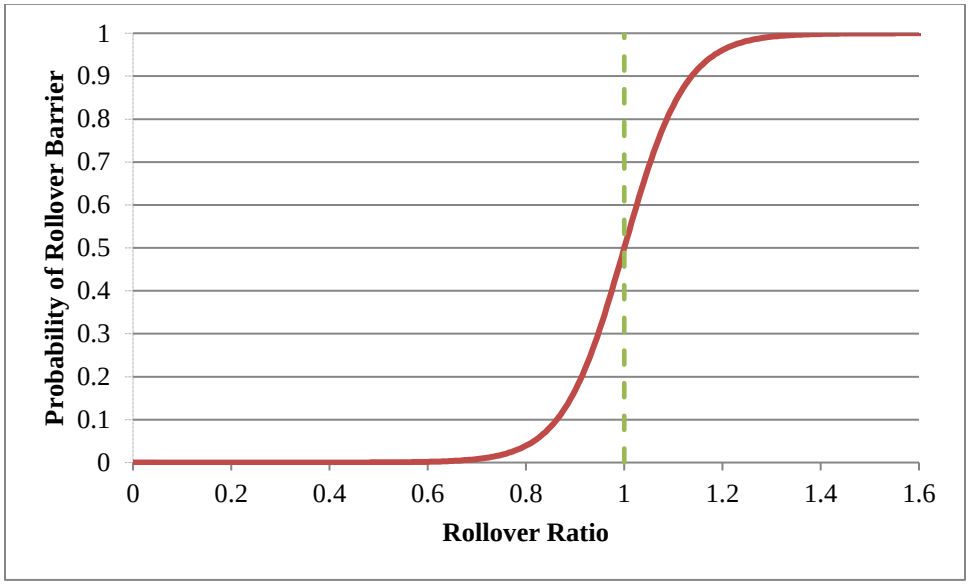


Figure 41. Probability model for trucks rolling over longitudinal barriers.

If *{vehicle type} = {truck} _*
And *{hazard type} = {line} _*
And *{vehicle c.g.} > {hazard height} _*
And *{hazard height} > 2.0 _*
And *{hazard height} < 7.5 _*
And *v > 0* ***Then***

```
Call subRolloverBarrier()
s = 0
B = 8
shift = 1.4
PRB = (1 - s) / 2 * Application.Tanh((ratio - shift) * B) + (1 - s) / 2 + s
' Compute change in velocity due to loss of energy during impact
' … change in energy during redirection along barrier
   DeltaKERed = ke * Sin(Abs(Theta))
   If ke - DeltaKERed - PEroll > 0 Then
      v0rv = ((2 / m) * (ke - DeltaKERed - PEroll)) ^ 0.5
   Else
      v0rv = 0
   End If
Else
   PRB = 0
End If
```

The probability of rolling over the barrier is dependent on whether or not the vehicle penetrated the barrier upon impact.

```
WRV = PRB * (1 - WP)
```

Probability of Rollover After Redirection

If the vehicle doesn't penetrate the barrier and doesn't roll over the barrier during redirection, the next possibility is that the vehicle rolls over as it is redirecting from the barrier. Redirection is not considered for Point hazards or for motorcycles. The probability of passenger vehicles rolling over after redirection is determined solely from crash statistics; whereas, the probability of trucks rolling over after redirection is determined based on impact conditions, vehicle characteristics and barrier height. An additional criterion is implemented which only considers rollover if the height of the hazard is within the range of 2.25 to 7.5 ft.

```
WRR = 0
If {hazard type} = {line} And v > 0 Then
```

It was determined from review of full-scale crash tests that the typical loss of kinetic energy could be approximated by multiplying the impact energy by the sine of the impact angle.

```
   DeltaKE = KE * Sin(Abs(Theta))        ' reduction in energy during
redirection
   Vr = ((2 / m) * (KE - DeltaKE)) ^ 0.5  ' redirection velocity
```

The following lines of code compute the probability of rollover after redirection for trucks.

If *{vehicle type} = {truck} _*
And *{hazard height} >= 2.25 _*
And *{hazard height} < 7.5 _*
Then

The program calls the subroutine subRolloverTafficSide to compute the rollover-ratio parameter, which is used to determine the probability of the truck rolling over the barrier. The probability of rolling over the barrier is then computed using the same hyperbolic tangent model that was shown in Figure 41.

Call *subRolloverTrafficSide()*
s = 0
B = 8
shift = 1
*PRR = (1 - s) / 2 * App.Tanh((ratio - shift) * B) + (1 - s) / 2 + s*

The probability of rolling over after redirection is dependent on whether or not the vehicle penetrated the barrier upon impact or rolled over the barrier during redirection.

*WRR = PRR * (1 - WP - WRV)*

Trucks tend to only roll a quarter-turn onto their side, whereas' passenger vehicles tend to roll multiple quarter-turns. The severity of rollovers for trucks is, therefore, likely to be less than severity of rollovers for passenger vehicles; however, the baseline severity (EFCCR65) for rollovers is currently the same value for all rollover events. The variable, *scalePOC,* was defined here to scale the severity for truck rollovers if/when data warrant it. The scale factor is applied to the EFCCR65 value as it is passed to subCollision_Statistics for use in computing rollover-cost statistics.

scalePOC = 1 '
KK = {set hazard type to rollovers}
Call *subCollision_Statistics(…, oHzrd_EFCCR65(iAlt, KK) * scalePOC,…)*

The following lines of code compute the probability of rollover after redirection for passenger vehicles.

ElseIf *VehCharac(iVeh, 4) = "C"* ***Then***
KK = {set hazard type to rollovers}

The probability of rollover after redirection is taken as the lesser value between:

- One minus the percent of rollover-after-redirection provided on the RSAPv3 “Severity” worksheet and
- the probability that penetration did not occur.

For example, if it was determined that the probability of penetrating the barrier was 0.99 and the percent of rollovers after redirection provided on the RSAPv3 "Severity" worksheet was 0.04, then *WRR* would be taken as (1 - 0.99) = 0.01.

```
                WRR = App.Min(1 - WP - WRV, oHzrd_Prcnt_RR(iAlt, K) / 100)
                Call subCollision_Statistics()
        End If
    End If
```

Probability of Redirection

If the vehicle does not penetrate the barrier, and does not roll over the barrier during redirection, and does not rollover after redirection, then final possibility is that the vehicle exited from the hazard and its exit trajectory will have to be evaluated for possible secondary collisions. As mentioned previously, redirection is not considered for Point hazards or for motorcycles.

```
If {vehicle type} = {motorcycle} Then
    WR = 0
Else
    WR = 1 - (WP + WRV + WRR)
End If
```

Compute Effective Probability Statistics and Pass Back to Parent Module

The final step of this subroutine is to compute the effective probability of redirection and penetration, which will be passed back to ModulePOCanalysis for use in evaluating secondary collisions. For example, the effective probability of redirection is computed as the probability of redirection given the current collision conditions times the probability of the impact occurring.

Probability of Redirection

*POR = WR * POC*

Probability of Rollover after Redirection

*PORV = WRV * POC*

Probability of Penetration

*POC = WP*POC*

count_pene_PRVcapacity(K) = {cumulative capacity penetrations for hazard K}

count_pene_rollvault(K) = {cumulative penetrations of hazard K from rollover-vault}

SubRedirect

This subroutine is called by ModulePOCAnalysis to determine redirection paths to be evaluated for subsequent impacts after redirection from the current hazard. The redirection path is influenced by many factors including, impact angle, impact speed,

vehicle type, barrier type (i.e., rigid, semi-rigid, flexible, etc.), vehicle damage (e.g., wheel assembly damage), vehicle-to-barrier interaction (e.g., snagging), and driver reaction, to name a few. In the context of an RSAPv3 analysis, however, only three factors are considered: impact angle, barrier type and vehicle type. The influence of each of these factors is discussed in more detail in the ENGINEER'S MANUAL.

The basic procedure is to (1) Determine the redirection speed, (2) Select redirection paths (path coordinates relative to barrier's local reference frame), (3) convert path coordinates to the global reference frame and (4) send each selected path to ModulePOCanalysis to evaluate for secondary collisions.

Input Variables

The following are a list of variables passed from the parent module and used in this subroutine.

- **CSRL**: collision side of barrier (right or left)
- **K**: hazard number
- **iALT**: current alternative
- **iVeh**: current vehicle number
- **iDir**: current traffic direction
- **oHzrd_GenType**: general type of hazard (e.g., bridge rail, Guardrails_Rigid, etc)
- **POR**: probability of redirection
- **Theta**: impact angle
- **Theta_Haz**: angle of hazard relative to roadway
- **v**: impact velocity
- **VehCharac(*,1)**: RSAPv3 vehicle name
- **VehCharac(*,2)**: FHWA vehicle class
- **VehCharac(*,3)**: percent of traffic mix
- **VehCharac(*,4)**: RSAPv3 vehicle type (M, C, T)
- **VehCharac(*,5)**: vehicle weight
- **VehCharac(*,6)**: vehicle length
- **VehCharac(*,7)**: vehicle width
- **VehCharac(*,8)**: distance from cg to front of vehicle
- **VehCharac(*,9)**: cg height
- **VehCharac(*,10)**: crash cost adjustment factor
- **x**: x-coordinate of initial redirection point
- **y**: y-coordinate of initial redirection point
- **grid_inc**: longitudinal increment of original trajectory path
- **Max_L**: maximum length of original trajectory path

Program Variables
The following are a list of variables defined in the Module.

- **Grid_incR**:
- **Max_Traj_xR**:
- **nopcR**:
- **num_preR**:
- **POC**: probability of occurrence for this trajectory path

Pass-Through Variables
The following are a list of variables that are not directly used in this subroutine but are required in the probability of collision analysis of the redirection paths (i.e., call of ModulePOCanalysis).

- **CountCSg**: number of cross-section coordinates in CSglob
- **count_pene_RSAP**:
- **count_RR**:
- **CS**: collision side (e.g. traffic side, non-traffic side)
- **CSglob**: coordinates of global terrain cross-section
- **d0**: distance to hazard coordinate
- **EFCCRi**: total cumulative EFCCR the current trajectory
- **EFCCR_RR**: cumulative EFCCR for rollover-after-redirection for current hazard
- **EFCCR_tot**: cumulative EFCCR for the current hazard
- **iDP**: departure point
- **iLDS**: lane departure side
- **impact_Count_NTS**:
- **impact_Count_tot**:
- **impact_Count_TS**:
- **oNum_Hazards**: number of hazards in current alternative
- **oHzrd_Capacity**: hazard capacity
- **oHzrd_Connection**: Identifies LON hazard attached to END TERMINAL
- **oHzrd_EFCCR65**: hazard severity (Effective Fatal Crash Cost Ratio for impact speed of 65 mph)
- **oHzrd_Height**: height of hazard (ft)
- **oHzrd_Name**: hazard name (e.g., TL3FShapeBR)
- **oHzrd_Prcnt_PRVR**: percent of penetration/vault from crash statistics
- **oHzrd_Prcnt_RR**: percent of rollover after redirection from crash statistics
- **oHzrd_Type**: hazard type
- **oHx**: longitudinal coordinate of hazard with respect to global reference frame
- **oHy**: lateral coordinate of hazard with respect to global reference frame

- **HM**: slope of hazard with respect to global reference frame
- **num_traj_seg**: cumulative number of trajectories for this segment
- **R**: radius of hazard

Procedure
First, the new array variables which will be defined in these calculations are dimensioned.

```
Dim xR(13, 100, 500)
Dim yR(13, 100, 500)
Dim thetaR(2)
Dim d0R()
ReDim d0R(total number of hazards, including rollover)
```

Redirection Speed
When vehicles impact against longitudinal barriers, some of the kinetic energy is expended through various mechanisms. The result is a reduced velocity of the vehicle as it redirects from the barrier system.

It is not possible to accurately calculate the exact reduction in kinetic energy of the vehicle without conducting a detailed analysis of the crash event (e.g., finite element analysis). It was determined from review of full-scale crash tests that the typical loss of kinetic energy could be approximated by multiplying the impact energy by the sine of the impact angle.

```
m = {vehicle weight} / 32.2 'lb-ft/s2 ' vehicle mass
KE = (1 / 2) * m * v ^ 2                ' kinetic energy computed from impact
velocity
DeltaKE = KE * Sin(Abs(Theta))    ' change in energy during redirection from
hazard

vR0 = ((2 / m) * (KE - DeltaKE)) ^ 0.5      ' redirection velocity
```

Select Redirection Paths
Determine Name of Worksheet with Redirection Trajectories
The redirection trajectory paths are selected based on vehicle type and barrier type and are obtained directly from the predefined paths on the RSAPv3 worksheets.

```
redirection = {worksheet containing redirection trajectories, based on vehicle
type}
```

The direction of the local x-coordinate for the redirection trajectories is initialized to be in the same direction as the impact trajectory.

```
grid_incR = Sheets(redirection).Cells(2, "E").value * (grid_inc / Abs(grid_inc))
Max_Traj_xR = 300                       ' Max trajectory length on Redirection
Grid
```

nopcR = Max_Traj_xR / Abs(grid_incR) - 1 ' number of path coordinates (nopc)
num_preR = 3 ' number of data columns preceding path coordinates

Compute the sign of the slope for the redirection paths, where negative slopes change the sign of lateral coordinates. For example:

- negative slope:
  - traffic-side impact on right-side of road (CSRL="left" side of hazard)
  - non-traffic-side impact on left-side of road (CSRL="left" side of hazard)
- positive slope:
  - non-traffic-side impact on right-side of road (CSRL="right" side of hazard)
  - traffic-side impact on left-side of road (CSRL="right" side of hazard)

Where CSRL is an acronym for “Collision-Side-Right-or-Left”.

If** CSRL = "left" **Then
SignY = -1
Else
SignY = 1
End If

If the impact angle is greater than 90 degrees, then the x-coordinate of the redirection path in the local reference frame (i.e., relative to the hazard) changes sign.

If** Abs(Theta) > 90 * 3.14159 / 180 **Then
SignX = -1
Else
SignX = 1
End If

Determine total number of redirection paths to be used in analysis

MyrowR = 4 ' first row with path data
***Do Until** {there are no more rows of data}*
***If** {hazard general type} = "BridgeRails" _*
***Or** {hazard general type} = "Guardrails_Rigid" _*
Or** {hazard general type} = "MedianBarriers_Rigid" **Then
BarrierType = "Rigid"
Else
BarrierType = "Non-Rigid"
End If

If the hazard type on the current row in the redirection trajectory database is equal to *BarrierType*, then it will be included in the analysis.

```
        If {barrier type in database}   = BarrierType Then
                trajR_tot = trajR_tot + 1 ' cumulative count of trajectories
        End If
        MyrowR = MyrowR + 1 ' next redirection trajectory
    Loop
```

Read redirection path coordinates from RSAPv3 worksheet

```
    MyrowR = 4              ' first row with path data
    Do Until {there are no more rows of data}
        If {hazard general type} = "BridgeRails"  _
        Or {hazard general type} = "Guardrails_Rigid" _
        Or {hazard general type} = "MedianBarriers_Rigid" Then
          BarrierType = "Rigid"
        Else
          BarrierType = "Non-Rigid"
        End If
```

If the hazard type on the current row in the redirection trajectory database is equal to *BarrierType*, then include its trajectory path in the analysis.

```
        If {barrier type in database}   = BarrierType Then
```

A constant deceleration of 12 ft/s^2 is assumed for all the redirection paths.

```
        decelR = 12     ' (ft/s2)
```

Initialize the minimum and maximum extents of the redirection trajectory paths. Recall that these parameters are used in ModulePOCanalysis to determine if a hazard is within reach of the path; if not, the path is not evaluated.)

```
        MinY = 1000000#
        MaxY = -1000000#
```

Initialize starting coordinates of redirection path.

```
        x0 = x
        y0 = y
```

Read in the redirection path coordinates for the currently selected row of data and correct for local path direction relative to the hazard's local reference frame.

```
        For j = 1 To {total number of path coordinates}
          xL = {x-coordinate value} * SignX
          yL = {y-coordinate value} * SignY
```

Transform from Local to Global Reference Frame

The local x-coordinate direction of each trajectory is co-linear with the line of the hazard. The following lines of code transforms the coordinates from the local reference frame to the global coordinate system for the analysis.

```
xR(iVeh, i, j) = xL * Cos(-Theta_Haz) + yL * Sin(-Theta_Haz)
yR(iVeh, i, j) = -xL * Sin(-Theta_Haz) + yL * Cos(-Theta_Haz)
```

Determine minimum and maximum extent of redirection paths, and determine the maximum length of the path.

```
If yR(iVeh, i, j) < MinY Then
   MinY = yR(iVeh, i, j)
End If
If yR(iVeh, i, j) > MaxY Then
   MaxY = yR(iVeh, i, j)
End If
If j = 1 Then
   MaxL = (yR(iVeh, i, j) ^ 2 + xR(iVeh, i, j) ^ 2) ^ 0.5
Else
   MaxL = MaxL + {((yR_j - yR_j-1))^2  + (xR_j - xR_j-1))^2 ) ^ 0.5}
End If
Next j
```

Each selected trajectory path is assigned equal probability of occurrence. Thus, the probability of occurrence (i.e., POC) for a given trajectory path is computed as: *the probability that a redirection event occurred (i.e., POR) times the probability that the current path will occur (i.e., 1/number of paths)*

```
POC = POR * (1 / trajR_tot)
```

Set redirection-flag to 1 to indicate that this is a redirection path. This flag is used in ModulePOCanalysis to determine if various collision events will be considered (e.g., rollovers are not considered for redirection trajectories since they were already accounted for in subroutine subPenetrate).

```
redir_flag = 1
```

Call ModulePOCanalysis to Evaluate Path for Secondary Collisions.

The program calls ModulePOCanalysis to perform the collision-analysis task, where each trajectory is individually examined for possible collisions with hazards; the collision statistics are computed and stored in the appropriate data collectors; and these data are then returned to the main program (i.e., ModulePOCmain) for processing. The programming details of ModulePOCMain were presented earlier.

```
   Call sub_Impact_Search()
End If
```

Move to next trajectory case in the database and repeat analysis procedure.

```
        MyrowR = MyrowR + 1 ' next redirection trajectory
    Loop
End Sub
```

SubRolloverM2a

This module is called by ModulePOCanalysis to update the variables in the rollover algorithm at each increment of the trajectory path. The probability of rollover at each increment is a function of the incremental length of the trajectory, L_i. The general procedure is as follows: At each increment, the program (1) determines the probability of rollover for the current increment (i.e., $P(R|slope)_i * \phi_{S_i,G} * \phi_{S_i,HC}$, (2) updates the effective probability of rollover for the trajectory path and (3) updates the average velocity cubed at each increment for use later in subroutine SubRoloverM2b for computing rollover costs. The flow chart for this program module is shown in Figure 42.

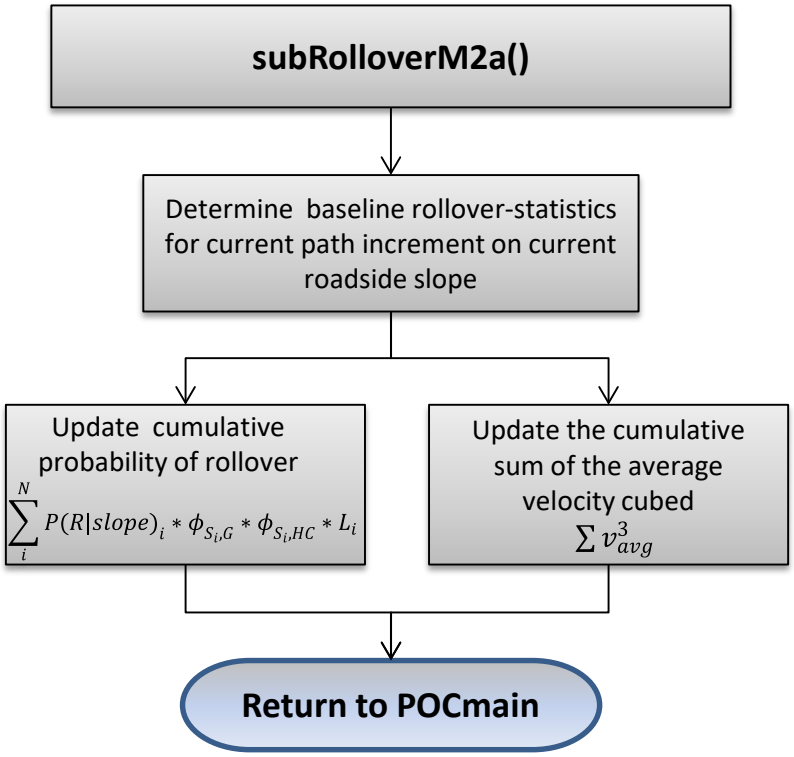


Figure 42. Flow chart for subroutine subrolloverM2a.

Input Variables
The following are a list of variables passed from the parent module and used in this subroutine.

- CountCSg: number of coordinates in global cross-section profile
- CSglob(*,1): y-coordinate value of global cross-section profile
- CSglob(*,2): z-coordinate value of global cross-section profile
- CSglob(*,3): slope of global cross-section
- CSglob(*,4): baseline probability of rollover
- CSglob(*,5): vertical-grade adjustment factor for rollover
- CSglob(*,6): horizontal-curve-radius adjustment factor for rollover

Program Variables
The following are a list of variables defined in the subroutine.

- Lj: length of trajectory increment
- POR: probability of rollover
- SumPRslopexL: cummulative sum of P(R|CSslope)*Lj
- SumV3:cumulative sum of cubed-velocities
- V3avg: average cubed-velocity

Procedure
Initialize probability of rollover to a value of zero.

```
POR = 0    ' initialize Probability to 0
```

The baseline probability of rollover (POR) is determined by associating the location of the current increment with the probability of rollover statistics in the array variable CSglob.

```
i = 1
Do While POR = 0 And i <= CountCSg
   If y < CSglob(i, 1) Then POR = CSglob(i, 4) * CSglob(i, 5) * CSglob(i, 6)
      i = i + 1
  Loop
```

The next step is to update the effective probability of rollover for the trajectory path, which is computed as the cumulative sum of the probability of rollover at each increment.

```
SumPRslopexL = SumPRslopexL + POR * Lj
```

The following lines of code update the average cubed-velocity at each increment for use in later in subroutine SubRoloverM2b for computing rollover costs.

```
SumV3 = SumV3 + v ^ 3
V3avg = SumV3/ N
```

End Sub

SubRolloverM2b

This subroutine is called by ModulePOCanalysis to compute the probability of rollover and associated rollover-crash costs. When a collision is detected in ModulePOCanalysis, the probability of occurrence must be determined in order to compute the statistical cost of the collision event. The probability of occurrence (POC) is dependent on the complete history of trajectory path up to the current path coordinate, including impact with previous hazards and the probability of rollover occurring prior to impact with the current hazard. For example, if a trajectory path first intersects one hazard and then another, then the probability of the second impact occurring is dependent on the vehicle getting to the first hazard without rolling over, penetrating the first hazard, not rolling over after the penetration, and not reaching zero velocity prior to collision with the second hazard.

This section of the program computes the probability of the trajectory resulting in a rollover before reaching the hazard. The basic procedure is to (1) compute the probability of a rollover based on trajectory path length since the last collision event, roadway/roadside conditions and probability of getting to the current path location, (2) compute the expected crash cost for the rollover event based on the average velocity cubed and probability of occurrence, and (3) return relevant statistical information to ModulePOCanalysis. The flow chart for this program module is shown in Figure 43.

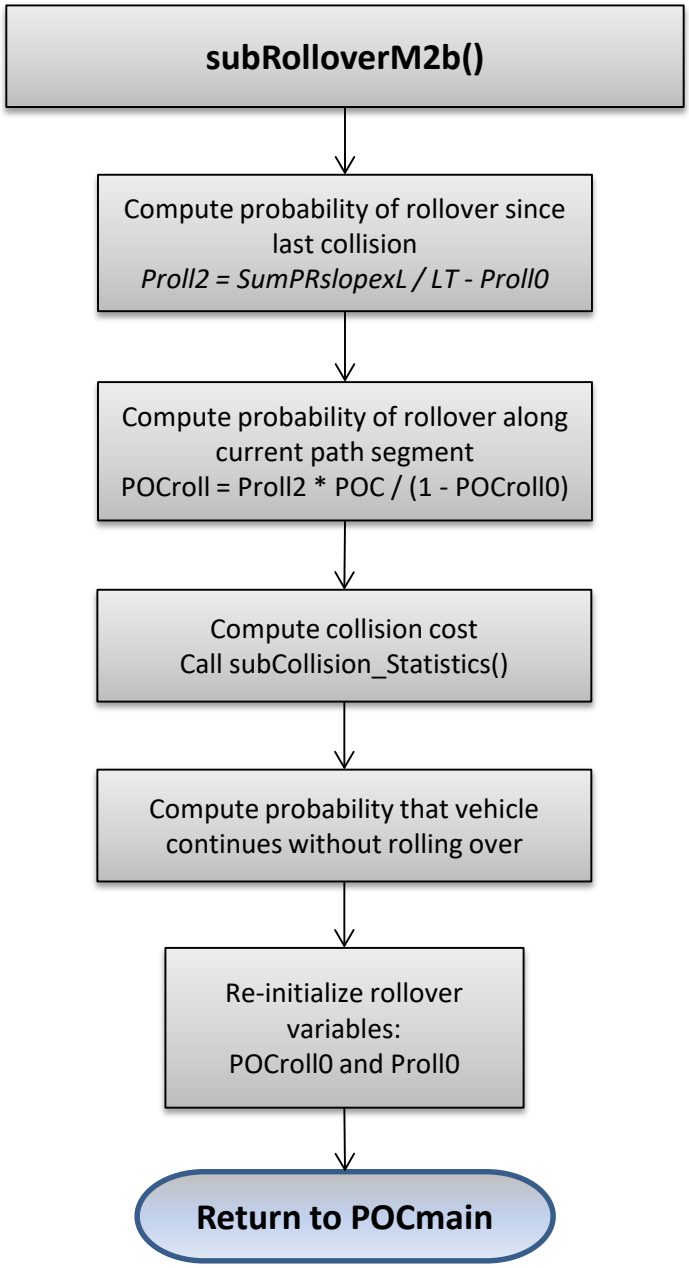


Figure 43. Flow chart for subroutine subRolloverM2b.

Input Variables

The following are a list of variables passed from the parent module and used in this subroutine.

- **CS**: collision side (i.e., traffic or non-traffic side)
- **Haznum**: total number of defined hazards
- **LT**: total length of trajectory path computed from Trajectory Grid in ModulePOCtraj
- **POCroll0**: Effective probability of rollover at time of previous collision event

- **POC**: probability of occurrence
- **SumPRslopexL**: cummulative sum of P(R|CSslope)*Lj
- **Proll0**: Probability of rollover before previous event (e.g., if no prior collision occurred for this trajectory path, then Proll0 = 0
- **V3avg**: average cubed-velocity

Program Variables

The following are a list of variables defined in the subroutine.

- **K**: hazard number
- **POCroll**: Effective probability of rollover used in crash cost calculations (i.e., probability of rollover given roadside and impact conditions times the probability of the trajectory getting to this point)
- **Proll2**: Probability of rollover since previous event
- **Vavg**: Effective average velocity used in crash cost calculations

Procedure

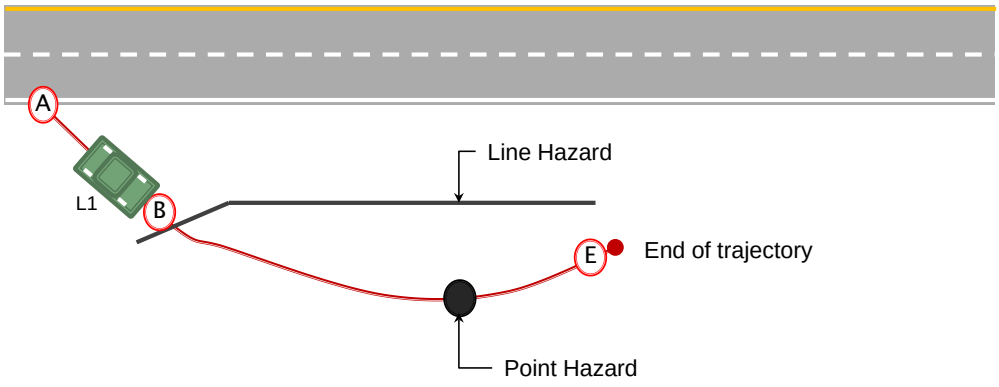
The first step is to compute the probability of a rollover since the last collision event based on roadway/roadside conditions (i.e., *Proll2*). The following line of the code calculates *Proll2* as the total probability for rollover from the point of encroachment to the current trajectory position minus the probability of rollover from the point of encroachment to the previous collision event.

Proll2 = SumPRslopexL / LT - Proll0

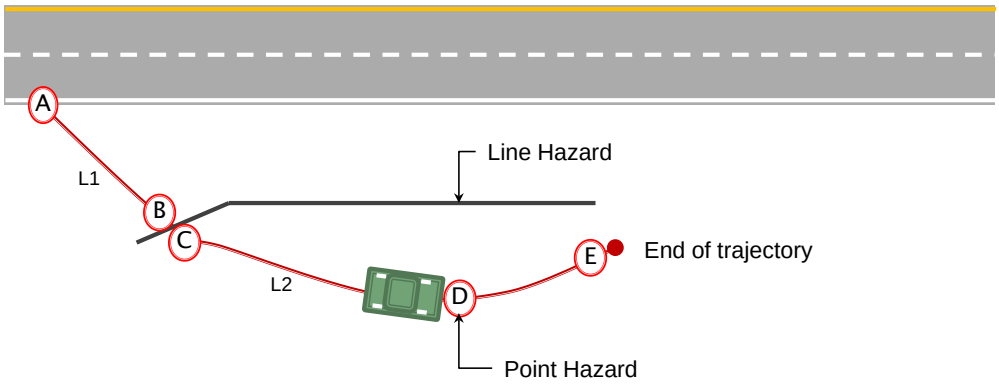
For example, Figure 44 illustrates a trajectory path intersecting two hazards. In Figure 44a, the vehicle is about to impact the first hazard at Point B. In this case,

$$SumPRslopexL = \sum_{i}^{N} P(R|slope)_i * \phi_{S_i,G} * \phi_{S_i,HC} * L_i$$

Where *SumPRslopexL* is the sum of the probabilities for rollover at each increment of the path from Point A to Point B, *LT* is the maximum length of the path (i.e., length from Point A to Point E) and *Proll0* is zero (i.e., there were no events prior to the encroachment at Point A). In Figure 44b, SumPRslopexL is the sum of the probability for rollover at each increment of the path from Point A to Point D, *LT* is the maximum length of the path (i.e., length from Point A to Point E) and *Proll0* is the sum of the probability for rollover at each increment of the path from Point A to Point B.



(a) Impact with first hazard



(b) Impact with second hazard

The next step is to compute the "effective probability for rollover" along the current path segment. The "effective probability for rollover" is defined as the probability of rollover given the various roadway and roadside conditions (i.e., *Proll2*) times the probability that the vehicle penetrated the previous hazard.

$$POCroll = Proll2 * POC / (1 - POCroll0)$$

The term *POC/(1-POCroll0)* in the equation above represents the probability that the vehicle penetrated the previous hazard, where POC can be defined as:

$$POC = POC_0 * PenHaz_0$$

Where POC_0 is the probability of collision with the previous hazard, $PenHaz_0$ is the probability of penetrating the hazard, and *POC* is the resulting probability of the vehicle getting to the current increment. The term $POCroll0 = 1 - POC_0$, thus:

$$\frac{POC}{1 - POCroll0} = \frac{POC_0 * PenHaz_0}{1 - (1 - POC_0)} = PenHaz_0$$

The next step is to compute the average crash-cost for a rollover along the current segment of the trajectory path. The crash cost is based on the velocity cubed (v^3) at the time of rollover. Recall that in subRolloverM2a the velocity cubed was computed at each increment along the path and stored in variable *V3avg*. This value could be used directly in the calculation of EFCCR; however, the subroutine SubCollision_Statistics, which is used to compute crash-cost statistics, requires velocity as input. The representative velocity for computing the crash-costs is then computed as:

```
vavg = (V3avg) ^ (1 / 3)
```

The program then calls the subroutine subCollision_Statistics.

```
K = Haznum + 1   ' sets the array position to rollover hazard
CS = "TS"        ' set Colloision Side to CS for counting the number of rollovers

Call subCollision_Statistics()
```

The probability that the vehicle continues on without rolling over is then computed and returned to ModulePOCanalysis.

```
POC = (POC - POCroll)
```

The variables POCroll0 and Proll0 are computed and saved for subsequent rollover calculations.

```
POCroll0 = 1 - POC
Proll0 = SumPRslopexL / LT
End Sub
```

SEVERITY MODULE

The severity module is interwoven with the crash prediction module since the severity of each crash predicted must be estimated. The severity module is represented by the following term in the RSAP governing equation:

$$P(Sev_s|Trj_k \cap Haz_j)$$

There are actually relatively few severity calculations within RSAP since the database of EFCCR values serves as a measure of the severity of each likely crash. As described in the last chapter, when a collision is detected in the crash prediction module the EFFCR corresponding to the hazard struck and the speed of the vehicle is obtained from the Severity worksheet. All the EFCCR values for each hazard interacted with along the vehicle's trajectory are summed and this summation is the EFCCR for that particular trajectory.

Background for developing and adding EFCCR values to the Severity worksheet database are described in the Engineer's Manual.

BENEFIT-COST MODULE

When conducting a benefit-cost analysis a benefit-cost ratio (B/C) for each feasible alternative with benefits in the numerator and agency costs in the denominator. Project benefits, in this case, are defined as a reduction in crash costs. Project costs include the design, construction, and maintenance costs associated with the improvement as well as repairs required due to crashes predicted on the segment.

RSAPv3 determines the crash costs of each user entered roadside design alternative as described in the previous chapters. The results of the final module are converted to a monetary unit of measure for direct comparison with project costs. The B/C ratio, therefore, is unitless. The benefit-cost ratio (BCR) is defined as follows:

$$BCR_{i/j}=\frac{CC_i - CC_j}{DC_j - DC_i}$$

Where:
$BCR_{i/j}$= Incremental BCR of alternative j with respect to Alternative i
CC_i , CC_j = Annualized crash cost for Alternatives i and j
DC_i , DC_j = Annualized direct cost for Alternatives i and j

For each alternative, an average annual crash cost is calculated by summing the expected crash costs for the predicted crashes. Theses crash costs are then normalized to an annual basis. Any direct costs, as defined by the user (i.e., initial installation and annual maintenance) are also normalized using the project life and the discount rate to an annualized basis and the BCR is calculated.

The macros that execute the benefit-cost module are contained in moduleResults. The actual benefit-cost calculations are done as worksheet functions on the Results worksheet.

PROCEDURE

featureResults()

This macro is executed automatically when the Results worksheet is activated and also when the “Feature Report” button is selected as shown in Figure 18. The purpose of the macro is to process the crash prediction and severity information stored on the hidden shPOCscrach worksheet and display it as a summarized report of the collisions with each roadside feature (i.e., hazard) defined in the alternatives. The procedure is as follows:

Start At row 10
Search Column A until the value is blank
myRow=The row before the blank column is the last row
Sort range A10:myRow21) by :
Column 2: Alternative number
Column 1: Segment number
Column 8: Hazard number
Column 4: Traffic side

Column 5: Vehicle type

Print the run date, time, Excel version and RSAP version in the Feature Report
Select shPOCscratch.Range(B11) → the alternative column
'Set up initial values
Row=9
Totalcrash=0
Prvcrash=0
Redirectrollcrash=0
Vsl=shPrjInfo.Range(F18).value → value of statistical life
Clear shResults.Range(A9:I5000)
Do Until alternative is blank
'Read the row of data from shPOCscratch
Alt=selection.offset(0,0) 'the alternative number
Seg=selection.offset(0,-1) 'the segment number
Haz=selection.offset(0,6) 'the hazard number
Hazname=selection.offset(0,5) 'the hazard name
Vehicle=selection.offset(0,3) 'the vehicle type
numEncr=selection.offset(0,4) 'number of encroachments
encrType=selection.offset(0,1) & selection.offset(0,2)

'read the number of expected encroachments for each encr type
Select Case encrType
Case "PR"
Encr=shRdSegs.cells(13+seg,"G")
Case "PL"
Encr=shRdSegs.cells(13+seg,"H")
Case "OR"
Encr=shRdSegs.cells(13+seg,"I")
Case "OR"
Encr=shRdSegs.cells(13+seg,"J")
Case Else → Error message
End Select

'Find the vehicle cost adjustment and traffic mix
I=14
Do Until shTraffInfo.cells(I,4).value=""
If shTraffInfo(cells(I,4).value=vehicle then 'look for a match
vehicleMix=shTraffInfo.cells(I,3)
Exit Do
End If

```
                I=I+1
        Loop

        'Read in the number of events for the row
        Num_crashes=selection.offset(0,8)+selection.offset(0,9)     'crashes
        Num_prv=selecton.offset(0,14)                               'penetrations, rolls, vaults
        Num_reroll=selection.offset(0,15)                           'redirection rollovers

        If numEncr>0 then
                'Estimate the total number of crashes and the crash cost
                If Num_crashes is not 0 or blank then
                        Totalcrash=(Num_crashes*encr/NumEncr)*vehicleMix
                        Crashcost=vsl*selection.offset(0,12)*encr)*vehicleMix
                Else
                        Totalcrash=0
                        Crashcost=0
                End if
                'Estimate the Penetration-Rollover-Vault crashes
                If Num_prv is not 0 or blank then
                        Prv_crash=(Num_prv*encr/NumEncr)*vehicleMix
                Else
                        Prv_crash=0
                End if

                'Estimate the Redirection Rollover crashes
                If Num_reroll is not 0 or blank then
                        redirectionrollcrash=(Num_reroll*encr/NumEncr)*vehicleMix
                                +redirectionrollcrash
                                Crashcost=(vsl*selecton.offset(0,19)*encr)*vehicleMix
                                        +Crashcost
                Else
                        redirectionrollcrash=0
                End if
        End if
```

segResults()

This macro calculates the segment cost information by summing portions of the feature report by segment and alternative. This macro is activated when the "Segment Report" button is selected and results in a view similar to that shown earlier in Figure 16.

printReports()

This macro prints the three reports shown on the Results worksheet using the worksheet PrintOut and PageSetUp methods. The resulting printouts are identical to what is displayed in the three reports on the Results worksheet. The procedure is as follows:

Enable the Excel Ribbon Toolbar
Top Row is 9
Do Until the cell ROW column C is blank
Bottom Row =Row
Set featurerange= shResults.range(cells(1,"B"),cells(BottomRow,"J")
With shResults
Make all columns visible
Clear PrintArea
'Print Feature Report
PageSetUp.PrintArea=featurerange
PrintOut to print with1 copy and Preview=TRUE
Print Segment Report
PageSetUp.PrintArea=N1:AA43
PrintOut to print with1 copy and Preview=TRUE
Print Benefit-Cost Report
PageSetUp.PrintArea=AB1:AH15
PrintOut to print with1 copy and Preview=TRUE
End With
Turn off Excel Ribbon Toolbar

DEVELOPMENT AND MAINTENANCE TOOLS

RSAPv3 contains a variety of macros that are used as development and maintenance tools. These macros are not normally needed by the user but are useful when adding lookup tables, debugging and other software maintenance tasks.

Auto_Open()

This macro was previously discussed and described in the Project Input and Control Chapter to which the reader should refer. This macro unloads any currently running forms to avoid conflicts, hides the Excel toolbars, loads the splash screen for 5 seconds and then unloads it. The macro then calls the macro StartRSAP which starts the RSAP execution.

editSeverities()

This macro is a toggle macro that is turned on and off by selecting the key stroke CTRL+SHIFT+H. The first toggle stops the execution of RSAP and puts Excel into a conventional editing model. The second toggle removed the standard Excel ribbons, re-protects the worksheet and restarts RSAP. The second toggle also rebuilds the hazard menusm on shPrgData. The procedure is as follows:

Select the Severity Worksheet
Detect the mode by whether the display headings are on or off
If ActiveWindow.DisplayHeadings = True Then → turn off edit mode and re-start
Count number of rows in shSeverity
botRow = Count - 1
Sort the hazard data into hazard category order
Copy hazard names to the Program Data worksheet
Reset the data range names on shPrgData using ActiveWorkbook.Names
Set the display back to usual RSAP mode

```
shSeverity.Select
ActiveWindow.DisplayHeadings = False
Application.DisplayFormulaBar = False
shSeverity.Protect (shPrgData.Range("B6").value)
shPrgData.Protect (shPrgData.Range("B6").value)
shPrgData.Visible = xlVeryHidden
Application.ExecuteExcel4Macro
        "SHOW.TOOLBAR(""Ribbon"",false)"
```

Re-start RSAP with → StartRSAP
Else
Unload frmRSAPcontrols → stops execution of RSAP
Restore usual Excel display settings

```
ActiveWindow.DisplayHeadings = True
Application.DisplayFormulaBar = True
shSeverity.Unprotect (shPrgData.Range("B6").value)
Application.ExecuteExcel4Macro
        "SHOW.TOOLBAR(""Ribbon"",true)"
```

End If

EditSheet()

This macro is very similar to editSeverities, the only difference being that the hazard validation binding for the menus are not rebuilt. The macro simply turns the Excel edit mode on and off. This macro is also a toggle where the key stroke CTRL+SHIFT+E is used. The first toggle returns the control to the usual Excel functionality and the second toggle puts the system back into RSAP mode and restarts

RSAP. The marco works on whatever worksheet is active at the time the toggle is selected. The procedure is as follows:

Select the ActiveWorksheet
Detect the mode by whether the display headings are on or off
If ActiveWindow.DisplayHeadings = True Then → turn off edit mode and re-start
Set the display back to usual RSAP mode
shSeverity.Select
ActiveWindow.DisplayHeadings = False
Application.DisplayFormulaBar = False
ActuveWorksheet.Protect (shPrgData.Range("B6").value)
Application.ExecuteExcel4Macro
"SHOW.TOOLBAR(""Ribbon"",false)"
Re-start RSAP with → StartRSAP
Else
Unload frmRSAPcontrols → stops execution of RSAP
Restore usual Excel display settings
ActiveWindow.DisplayHeadings = True
Application.DisplayFormulaBar = True
ActiveWorksheet.Unprotect (shPrgData.Range("B6").value)
Application.ExecuteExcel4Macro
"SHOW.TOOLBAR(""Ribbon"",true)"
End If

killSplash()

This macro, which is called from the Auto_Open() macro, simply unloads the splash screen form after it has been displayed for 5 seconds.

RangeisMT()

This macro tests a range to determine if there are any values in the range. The variable testRange is passed to the macro and tested for blank values using the range method "Find". The procedure is:

Set test=testRange.find("", LookIn:=xlValues)
If test is nothing then
RangeisMT=FALSE
Else
RangeisMT=TRUE
End if

This function is used in several subroutines to test if there is data in the specified range.

showRowsCols()

This is a useful macro for debugging. The macro is a toggle much like editSeverity() and editSheet(). The macro turns on all Excel toolbar functions, makes all sheets visible and makes the row and column labels visible.

StartRSAP()

This macro was previously discussed and described in the Project Input and Control Chapter to which the reader should refer. This macro is called by the Auto_Open() macro but can also be executed using the key stroke CTRL+S. This is the macro that actually starts RSAP.

CONCLUSIONS

The preceding chapters and sections have described the architecture of RSAPv3, it event-control structure and user input facilities. The algorithms used for the analysis were presented with pseudo-code and flow charts. This manual should provide all that is necessary for a programmer needing to modify, update or otherwise revise RSAPv3.

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