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FEDERAL RAILROAD ADMINISTRATION
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IMPROVEMENTS EVALUATION USING GRADEDEC.NET
VOLUME 2

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MODULE 7 CAPITAL PROGRAMMING

7.1 Introduction

7.1.1 What is Capital Programming?

Capital programming refers to multi-year planning and a series of phased investments for grade crossing improvements in a region or corridor.

When working with a small number of crossings, it may be reasonable to assume that the improvements to the corridor will be executed all at once. The alternative case, which is to be compared with the base case in the investment analysis, will have all the improvements made to all the crossings in the base year (i.e., in year 1 of the analysis all improvements will be operational in the alternative case). However, for corridors with many crossings the budget and schedule for improvements may span a number of years.

Moreover, when examining improvements over a 20 year time horizon, budgets and priorities may dictate phased improvements at a crossing. For instance, a Phase I investment in year 2 may upgrade a crossing from lights to gates while a Phase II investment in year 14 may grade separate the crossing. Note also that regardless of budget considerations, a phased deployment may be the most cost-beneficial: A grade separation may payoff only after highway traffic and rail service at the crossing have grown significantly.

Large, multi-year corridor improvements require identifying not only the improvements, but also the timing of the improvements.

In a corridor with capital programming the alternative case may have the crossing with the base case device for several years, the Phase I improvement device for several years, then the Phase II improvement for the remaining years. Potentially, there may be improvements in each year of the analysis.

7.2 Creating a Capital Program

We will create a capital program for the corridor in Case Study 2. The first step is to modify the settings for the corridor on the “**Settings**” page.

In the “**Settings**” page with Corridor (or Region) selected, click the “Edit” button, and check the “Allow capital programming?” checkbox, and then click “Update”.

7.2.1 Changes to the Crossings Page

With “Allow Capital Programming?” set to true, the format of the forms on the “Devices” and “Costs” tab on the Crossings page will appear differently.

Also, on the “APS model” and the “HSR model” forms there is a drop-down menu for selecting the year. Because the year of implementation for phases I and II can vary from crossing to crossing, the alternate case for the corridor may be different in each year. The predicted accidents and occurrences on the two forms may vary from year to year.

7.2.1.1 Crossing Page – Devices Tab

The following figure shows the form on the Crossings Page when the “Devices” tab of the toolbar is selected.

Figure 1 – Crossing Page with the Devices Tab Selected in Edit Mode



Data for the crossing MP:145.28 ID:641847B		Update	Cancel
	Item	Value	
Edit all	Year of Phase I Investment	2008	
Edit all	Year of Phase II Investment	2009	
Edit all	Base Case Device	Gates	
Edit all	Base Case Supplementary Safety Measure	None	
Edit all	Phase I Device	Gates	
Edit all	Phase I Supplementary Safety Measure	None	
Edit all	Phase II Device	Gates	
Edit all	Phase II Supplementary Safety Measure	None	

Edit to modify the data for the selected crossing.
NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import!"
NOTE: Supplementary safety measure can only be selected for gated crossings.

This form with the Devices tab of the toolbar selected, allows you to enter data on the device type and the supplementary safety measure type for a specific crossing in each of three instances: Base Case, Alternate Case (with Phase I investment) and Alternate Case (with Phase II investment).

For each crossing there are drop-down lists for selecting a base case device, as well as Phase I improvements and Phase II improvements. For the base case and each phase, there is a drop down list for a supplementary safety measure.

For each crossing, in each Phase there is a drop-down list designating the year of implementation (i.e., the year before the first year of operation with the improvement).

7.2.1.2 Crossing Page – Cost Tab

This form with the Costs tab of the toolbar selected allows you to enter cost data for the costs associated with the base case and each phase of improvement.

For the principal device and supplementary safety device, there are text boxes for base case and phases I and II annual operating and maintenance costs, base case and phases I and II annual other lifecycle cost, and phases I and II capital cost.

There is also a text box for roadway improvement capital costs for each of the two phases of investment.

Figure 2 - Cost Tab Screenshot

Select data to view / edit: [General](#) [Devices](#) [Highway](#) [Rail](#) [Cost](#) [APS model](#) [HSR model](#)

Data for the crossing MP:145.28 ID:641847B Update Cancel

	Item	Value
Edit all	Year of Phase I Investment (modify in Devices view)	2008
Edit all	Year of Phase II Investment (modify in Devices view)	2009
Edit all	Principal device - Base Case Ann. Oper. & Maint. Cost (000 \$)	<input type="text" value="2.5"/>
Edit all	Principal device - Base Case Ann. Other Lifecycle. Cost (000 \$)	<input type="text" value="0"/>
Edit all	Principal device - Phase I Ann. Oper. & Maint. Cost (000 \$)	<input type="text" value="2.5"/>
Edit all	Principal device - Phase I Ann. Lifecycle. Cost (000 \$)	<input type="text" value="0"/>
Edit all	Principal device - Phase I Capital Cost (000 \$)	<input type="text" value="0"/>
Edit all	Principal device - Ph. II Alt. Case Ann. Oper. & Maint. Cost (000 \$)	<input type="text" value="2.5"/>
Edit all	Principal device - Ph. II Alt. Case Ann. Lifecycle. Cost (000 \$)	<input type="text" value="0"/>
Edit all	Principal device - Ph. II Alt. Case Capital Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Base Case Ann. Oper. & Maint Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Base Case Ann. Other Lifecycle. Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Phase I Ann. Oper. & Maint. Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Phase I Ann. Other Lifecycle Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Phase I Capital Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Phase II Ann. Oper. & Maint. Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Phase II Ann. Lifecycle. Cost (000 \$)	<input type="text" value="0"/>
Edit all	SSM - Phase II Ann. Capital Cost (000 \$)	<input type="text" value="0"/>
Edit all	Roadway Improvement Phase I Capital Cost (000 \$)	<input type="text" value="0"/>
Edit all	Roadway Improvement Phase II Capital Cost (000 \$)	<input type="text" value="0"/>

Edit to modify the data for the selected crossing.
 NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import"
 NOTE: SSM stands for "supplementary safety measure".

7.2.2 Creating a Capital Plan for Case Study 2

Improvements to the corridor will be executed throughout the 2010-2019 period, and will mainly consist of closures, grade separations, and standard device upgrades. In Volume 1 of this workshop, the 30 riskiest crossings of the corridor were identified, and each of these will receive device improvements. Furthermore, 8 crossings were identified as needing to be closed, and 2 crossings will undergo a grade separation. The subsequent sections will outline the methods used to find closure and grade separation candidates.

The table below summarizes the capital plan, including the approximate base cost of the improvements for each year:

Table 1 - Capital Program for the Champaign Corridor

Year	Device Improvements to Corridor	Supplementary Safety Measures for Corridor Devices	Initial Cost (in thousands)
2010	3 Closures	Barrier curbs for 5 gates	\$135
2011	3 Closures, 1 Gate	Barrier curbs for 3 gates	\$335
2012	2 Closures, 1 Gate	Barrier curbs for 3 gates	\$315
2013	1 Gate	Barrier curbs for 3 gates	\$275
2014	1 Grade Separation		\$7000
2015	1 Gate	Barrier curbs for 4 gates	\$290
2016	1 Gate	Barrier curbs for 4 gates	\$290
2017	1 Gate	Barrier curbs for 4 gates	\$290
2018	1 Gate	Barrier curbs for 4 gates	\$290
2019	1 Grade Separation		\$7000

7.2.3 Entering Data for the Case Study

After opening your browser to GradeDec.Net you should find yourself on the “**Settings**” page. Make sure that the IL Workshop dataset is the selected dataset. Click on the “Create New Corridor” link that is on the right side of the page next to the corridor selection drop-down menu. After clicking, the browser will show a new page “Create New Corridor”. Select the option “Create a new corridor by copying an existing corridor in the dataset” and select the “Champaign, IL” corridor from the dropdown list. Then, enter a new name for the corridor in the “Name of the new corridor” text box and click submit. You should be redirected back to the “**Settings**” Page and verify that the "Champaign, IL" corridor is selected.

Click on the ‘Results’ tab in the center of the “**Settings**” page, and click “Create New Results Set”. The browser will show a new page “Create New Results Set”. Enter a name in the text box and click “Submit” to create a new results set for the Capital Program.

7.2.3.1 Select Candidates for Closures

Candidates for closures are high-risk, low-volume crossings. Closures can adversely impact neighborhoods and businesses, especially if alternative routings are long and circuitous. Agencies considering closures should gauge the local impacts to determine the suitability of closure. In our case, we will not close a given crossing unless there exist alternate crossings within 2 miles.

To find the low-volume crossings, we use the AADT metric (Annual Average Daily Traffic). We consider a very low-volume crossing to have an AADT less than or equal to 25. To find the distance between crossings, we use the milepost attribute.

Using the navigation menu, go to the Crossings page. In the "Select data to view/edit" row, click on the "Highway" tab. When the page refreshes, find the "AADT" item in the table for crossing data. Click on the "Edit all" link to the left of the "AADT" item to see the AADT for each crossing in the corridor.

Figure 3 - Highway Tab Screenshot

Select data to view / edit: [General](#) [Devices](#) [HIGHWAY](#) [Rail](#) [Cost](#) [APS model](#) [HSR model](#)

Data for the crossing MP:127.09 ID:289067H Edit		
	Item	Value
Edit all	Number of Lanes	4
Edit all	AADT	11700
Edit all	Percent of trucks	4
Edit all	of this, trailers	0
Edit all	Percent of Buses	0
Edit all	T-O-D distribution of auto traffic	Uniform
Edit all	T-O-D distribution of truck segment	Uniform
Edit all	T-O-D distribution of bus traffic	Uniform
Edit all	Distance from closest intersection	0.1
Edit all	Traffic Management Measures?	False

Edit to modify the data for the selected crossing.
 Check "Traffic Management Measures" to enable different values in alternate case.
 NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import"

In the new window, the crossings are displayed in pages 1 through 9. For each page, note the "Crossing ID", "Milepost" and "AADT" of the grade crossings with an "AADT" value of less then or equal to 25. Three of these crossings cannot be closed for lack of available alternative roads. For example, crossing 289107D cannot be closed, or else crossing 289106W would have to travel more than 2 miles in the direction of increasing milepost to reach another crossing (289108K). The two other crossings that cannot be closed for similar reasons are crossings 289110L and 289285D. The following table summarizes which crossings we wish to close:

Table 2 - Closure Candidates

Crossing ID	Milepost	AADT
295280U	214.6	19
289099N	139.33	25
289112A	147.44	25
295286K	220.9	25
295295J	227.3	25
295300D	232.88	25
295011C	264.2	25
295018A	268.26	25

The following table describes the device data to set for each phase of each grade crossing above.

Table 3 - Setting Device Data for Closures

ID	Milepost	Phase I Improvement	Phase I Supplementary Safety Measure	Year to Implement Phase I	Phase II Improvement	Phase II Supplementary Safety Measure	Year to Implement Phase II
289099N	139.33	Closure	None	2010	Closure	None	2011
289112A	147.44	Closure	None	2010	Closure	None	2011
295280U	214.6	Closure	None	2010	Closure	None	2011
295286K	220.9	Closure	None	2011	Closure	None	2012
295295J	227.3	Closure	None	2011	Closure	None	2012
295300D	232.88	Closure	None	2011	Closure	None	2012
295011C	264.2	Closure	None	2012	Closure	None	2013
295018A	268.26	Closure	None	2012	Closure	None	2013

From the navigation menu, click on **Crossings** in order to browse to the **Crossings** Page. Click on the 'Devices' Tab at the center of the **Crossings** page. Select crossing "289099N" from the Crossings List and click "Go" and the device data for the selected crossing will be displayed on the bottom half of the screen. Click on the 'Edit' button in the top right corner of the table. Enter phase I and phase II devices and improvement data to match the data in the first row of the table above. Click "Update" in the upper-right corner of the page when finished. The crossing data should match what appears in the figure below:

Figure 4 – Grade Crossing Closure Example

Data for the crossing MP:139.33 ID:289099N Edit		
	Item	Value
Edit all	Year of Phase I Investment	2010
Edit all	Year of Phase II Investment	2011
Edit all	Base Case Device	Passive
Edit all	Base Case Supplementary Safety Measure	None
Edit all	Phase I Device	Closure
Edit all	Phase I Supplementary Safety Measure	None
Edit all	Phase II Device	Closure
Edit all	Phase II Supplementary Safety Measure	None

Edit to modify the data for the selected crossing.
 NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import"
 NOTE: Supplementary safety measure can only be selected for gated crossings.

Repeat this process for the 7 remaining crossings.

7.2.3.2 Select Candidates for Grade Separation

The natural candidates to consider for grade separation are those crossings that are high risk and high volume. Grade separation practically eliminates accident risk and congestion, however, usually at a high cost. Separation may be extremely costly in urban settings where solutions potentially infringe upon developed and valued real estate.

Since grade separations are expensive, we will choose only the highest-volume crossing in the corridor to receive this upgrade. We will use the AADT metric (Annual Average Daily Traffic) to identify the crossing.

Using the navigation menu, go to the **Crossings** page. In the "Select data to view/edit" row, click on the "Highway" tab. When the page refreshes, find the "AADT" item in the table for crossing data. Click on the "Edit all" link to the left of the "AADT" item to see the AADT for each crossing in the corridor. Browse through each crossing using the page links 1-9 at the bottom of the page, and find the crossing with the highest AADT value (in the "AADT" column). We find that on page 8, crossing 299006U has the highest AADT value (21000) of all the crossings in the corridor (see screenshot below). The crossing with the second highest AADT (20900) is 299005M, and with the third highest AADT (17000) is crossing 299009P. Since all three of these crossings are within 1 mile of each other, among these we will choose the two crossings with the greatest difference in milepost. Our final candidates are **299005M** and **299009P**.

Figure 5 – Crossing with highest AADT

Data for all crossings in corridor				
No.	Crossing ID	Milepost	Description	AADT
141	295056J	288.64	IC - E FRANKLIN ST	1000
142	295057R	289.61	IC - GAS PLANT RD	900
143	295060Y	291.15	IC - GREEN MARKET RD	1150
144	295063U	293.38	IC - UNION AVE	1100
145	295064B	294.69	IC - LACY RD	175
146	295065H	295.45	IC - MAIN ST	950
147	295066P	295.54	IC - W BOARD ST	1850
148	295067W	296.28	IC - COAL RD	500
149	295068D	296.83	IC - HALLIDAYBORO ROAD	250
150	295069K	297.87	IC -	29
151	295079R	298.66	IC - TRUAX TRAER RD	1450
152	295081S	300.73	IC - JONES RD	300
153	295082Y	301.84	IC - HURST RD	4750
154	295083F	302.16	IC - LOGAN ST	1550
155	299002S	305.82	IC - DILLINGER RD	1400
156	299003Y	307.96	IC - E OAK ST	1900
157	299004F	308.03	IC - E JACKSON ST	2400
158	299005M	308.1	IC - MAIN ST	20900
159	299006U	308.23	IC - WALNUT ST	21000
160	299007B	308.49	IC - E COLLEGE ST	2100

Data for all crossings in corridor				
No.	Crossing ID	Milepost	Description	AADT
161	299009P	308.8	IC - E GRAND AVE	17000
162	299012X	311.99	IC - BOSKYDELL RD	2000
163	299013E	316.22	IC - MAKANDA ROAD	600

The following table presents the capital program for these two crossings:

Table 4 - Setting Device Data for Grade Separations

ID	Milepost	Phase I Improvement	Phase I Supplementary Safety Measure	Year to Implement Phase I	Phase II Improvement	Phase II Supplementary Safety Measure	Year to Implement Phase II
299005M	308.1	Gates	Barrier curbs	2010	Grade Separation	None	2014
299009P	308.8	Gates	Barrier curbs	2010	Grade Separation	None	2019

Update the device data for each of the crossings above using the same process as the one described below table 2. As an example, the data for the first row (crossing "299005M") should match what appears in the figure below:

Figure 6 – Grade Separation

Data for the crossing MP:308.1 ID:299005M Edit		
	Item	Value
Edit all	Year of Phase I Investment	2010
Edit all	Year of Phase II Investment	2014
Edit all	Base Case Device	Gates
Edit all	Base Case Supplementary Safety Measure	None
Edit all	Phase I Device	Gates
Edit all	Phase I Supplementary Safety Measure	Barrier curbs
Edit all	Phase II Device	Grade Separation
Edit all	Phase II Supplementary Safety Measure	None

Edit to modify the data for the selected crossing.
 NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import"
 NOTE: Supplementary safety measure can only be selected for gated crossings.

7.2.3.3 Other Improvements

The remaining improvements will concentrate on the thirty risky crossings identified in volume 1.

Seven out of these thirty crossings are non-gated in the base case, and therefore will receive gates as their Phase I device, and barrier curbs as their Phase I supplementary safety device. Barrier curbs are an inexpensive safety measure, which justifies applying them to crossings at the same time as applying gates (i.e. both upgrades occurring in Phase 1). The remaining crossings are gated in the base case; therefore they will only receive barrier curbs in Phase I.

To find which crossings are gated or non-gated in the base case, click on the "Devices" tab in the **Crossings** page, and click on the 'Edit all' link corresponding to the 'Base Case Device' item. In the new window, base case devices can be found for each crossing.

The following table summarizes the device improvements for each of the thirty crossings:

Table 5 - Upgrading the Thirty Riskiest Crossings

ID	Milepost	Phase I Improvement	Phase I Supplementary Safety Measure	Year to Implement Phase I	Phase II Improvement	Phase II Supplementary Safety Measure	Year to Implement Phase II
295322D	246.63	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
289157G	184.25	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
289158N	184.35	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
289134A	166.35	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
295083F	302.16	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
289180B	197.95	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012
295004S	260.2	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012
295323K	247.18	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012
295067W	296.28	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
295044P	279.8	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
289121Y	157.15	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
289185K	198.7	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
295291G	223.2	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
289114N	149.45	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
289125B	158.15	Gates	Barrier curbs	2015	Gates	Barrier curbs	2016
289167M	188.8	Gates	Barrier curbs	2015	Gates	Barrier curbs	2016
295279A	214.45	Gates	Barrier curbs	2015	Gates	Barrier curbs	2016
295288Y	222.85	Gates	Barrier curbs	2015	Gates	Barrier curbs	2016
295284W	219.4	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
289123M	157.9	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
295082Y	301.84	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
289095L	136.92	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
289093X	135.26	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
289136N	168.49	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
295293V	225.2	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
289131E	163.75	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
295320P	244.58	Gates	Barrier curbs	2018	Gates	Barrier curbs	2019
289133T	165.3	Gates	Barrier curbs	2018	Gates	Barrier curbs	2019
289094E	136.67	Gates	Barrier curbs	2018	Gates	Barrier curbs	2019
295016L	266.53	Gates	Barrier curbs	2018	Gates	Barrier curbs	2019

Update the device data for each of the crossings above using the same process as the one described below table 2. As an example, the data for the first row (crossing "295322D") should match what appears in the figure below:

Figure 7 – Improving Crossing 295322D

Data for the crossing MP:246.63 ID:295322D Edit		
	Item	Value
Edit all	Year of Phase I Investment	2010
Edit all	Year of Phase II Investment	2011
Edit all	Base Case Device	Passive
Edit all	Base Case Supplementary Safety Measure	None
Edit all	Phase I Device	Gates
Edit all	Phase I Supplementary Safety Measure	Barrier curbs
Edit all	Phase II Device	Gates
Edit all	Phase II Supplementary Safety Measure	Barrier curbs

Edit to modify the data for the selected crossing.
 NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import"
 NOTE: Supplementary safety measure can only be selected for gated crossings.

7.2.3.4 Setting Devices for Non-upgraded Crossings

In the past three sections, we scheduled upgrades between 2010 and 2019 for 40 grade crossings. For the remaining 123 crossings in the corridor, we must explicitly state in GradeDec.NET that no upgrades are planned for the period above.

To do this, we must ensure that for each non-upgraded crossing, the Phase II device is the same as the Base Case and Phase I device. In the **Crossings** page, click on the "Devices" tab, then click on the 'Edit all' link corresponding to the 'Phase II Device' item. In the new window, the non-upgraded crossings are those with 'Phase II device' set as 'Not selected'. To save time during this workshop, the base case device for each of these crossings was collected and is displayed in the table below:

Table 6 - Non-upgraded Crossings

Crossing ID	Phase II Device	Page
289084Y	Gates	1
289086M	Gates	1
289089H	Gates	1
289097A	Gates	1
289098G	Gates	1
289100F	Passive	1
289101M	Gates	1
289102U	Gates	1
289103B	Gates	1
289104H	Gates	1
289106W	Passive	1
289107D	Passive	1
289108K	Gates	1
289110L	Passive	1
289113G	Gates	1
289116C	Gates	2
289118R	Gates	2
289119X	Passive	2

Crossing ID	Phase II Device	Page
289120S	Passive	2
289122F	Gates	2
289124U	Gates	2
289126H	Passive	2
289127P	Gates	2
289128W	Passive	2
289129D	Passive	2
289130X	Gates	2
289132L	Passive	2
289135G	Gates	2
289144F	Gates	3
289145M	Gates	3
289148H	Gates	3
289151R	Gates	3
289152X	Gates	3
289154L	Gates	3
289160P	Gates	3
289161W	Gates	3
289162D	Gates	3
289163K	Gates	3
289166F	Gates	3
289168U	Gates	3
289170V	Gates	3
289171C	Gates	3
289172J	Passive	3
289174X	Gates	3
289175E	Gates	4
289177T	Gates	4
289178A	Gates	4
290998U	Gates	4
289184D	Gates	4
289186S	Gates	4
289189M	Gates	4
289190G	Gates	4
295261P	Gates	4
295263D	Gates	4
295264K	Passive	4
295267F	Gates	4
295272C	Gates	4
295273J	Gates	4

Crossing ID	Phase II Device	Page
295276E	Gates	4
295282H	Gates	4
295283P	Gates	5
295285D	Passive	5
295287S	Gates	5
295292N	Passive	5
295294C	Gates	5
295296R	Gates	5
295297X	Gates	5
295298E	Passive	5
295299L	Gates	5
295301K	Gates	5
295302S	Passive	5
295306U	Passive	5
295309P	Gates	5
295310J	Gates	6
295311R	Gates	6
295313E	Gates	6
295314L	Passive	6
295317G	Gates	6
295318N	Gates	6
295321W	Gates	6
295324S	Passive	6
295326F	Gates	6
294985G	Gates	6
294986N	Passive	6
294987V	Gates	6
294991K	Gates	6
294993Y	Gates	6
309277F	Gates	6
294995M	Gates	6
295001W	Gates	6
295002D	Gates	7
295009B	Gates	7
295010V	Gates	7
295014X	Gates	7
295015E	Gates	7
295021H	Gates	7
295027Y	Gates	7
295040M	Gates	7

Crossing ID	Phase II Device	Page
295043H	Gates	7
295046D	Gates	7
295050T	Gates	7
295051A	Gates	7
295052G	Gates	7
295053N	Gates	7
295054V	Gates	7
295056J	Gates	8
295057R	Gates	8
295060Y	Gates	8
295063U	Gates	8
295064B	Passive	8
295065H	Gates	8
295066P	Gates	8
295068D	Gates	8
295069K	Passive	8
295079R	Gates	8
295081S	Gates	8
299002S	Gates	8
299003Y	Gates	8
299004F	Gates	8
299006U	Gates	8
299007B	Gates	8
299012X	Gates	9
299013E	Gates	9

Use the 'Edit' button at the top right corner of the page to set the non-upgraded crossings' Phase II device according to the values in the table above. Use links 1 through 9 below the table to navigate across pages.

7.2.3.5 Setting Default Costs

The final step is to change the default cost of devices used by the crossings. Currently, the 'Flashing Lights with Gates' and 'Grade Separation' devices are vastly underpriced, which can seriously undermine our analysis. The cost of 'Flashing Lights with Gates' should be changed from 106.1 to 230 thousand, and the cost of a grade separation should be increased from 1500 to 7000 thousand.

From the navigation menu, click on **Parameters** in order to browse to the Parameters page. Click on the 'Other data' tab right below the 'Model Parameters, Traffic Distributions, and Other Data' title. From the drop down box, select 'Crossing device costs' and click 'Go'. When the page refreshes, a table will present the various device types and their associated capital cost, operations and maintenance cost, and other

lifecycle costs. Find the third device type, 'Flashing Lights with Gates', and click on the 'Edit' link on the same row. The three categories of cost associated with the device type should now be editable. In the 'Capital Costs' column, change the value from 106.1 to 230. Click the 'Update' link on the same row when finished.

Repeat this step for the 'Separation' device, changing its 'Capital Costs' value from 1500 to 7000. The following figure presents the parameters after the changes have been made:

Figure 8 – Default Crossing Device Costs

Model Parameters, Traffic Distributions and Other Data				
Model parameters	OTHER DATA	Crossing device costs	Go	Restore Defaults
Default Costs for Grade Crossing Devices (thousands of constant dollars)				
Device Type	Capital Costs	Oper. & Maint.	Other Lifecycle	
Passive	1.6 1.6	0.2 0.2	0 0	Edit
Flashing Lights	74.8 74.8	1.8 1.8	0 0	Edit
Flashing Lights with Gates	230 106.1	2.5 2.5	0 0	Edit
Closure	20 20	0 0	0 0	Edit
Separation	7000 1500	0.5 0.5	0 0	Edit
New Technology 1	280 280	5 5	0 0	Edit
New Technology 2	280 280	5 5	0 0	Edit
New Technology 3	280 280	5 5	0 0	Edit

*Values in red are Federal Railroad Administration default values that indicate national averages.

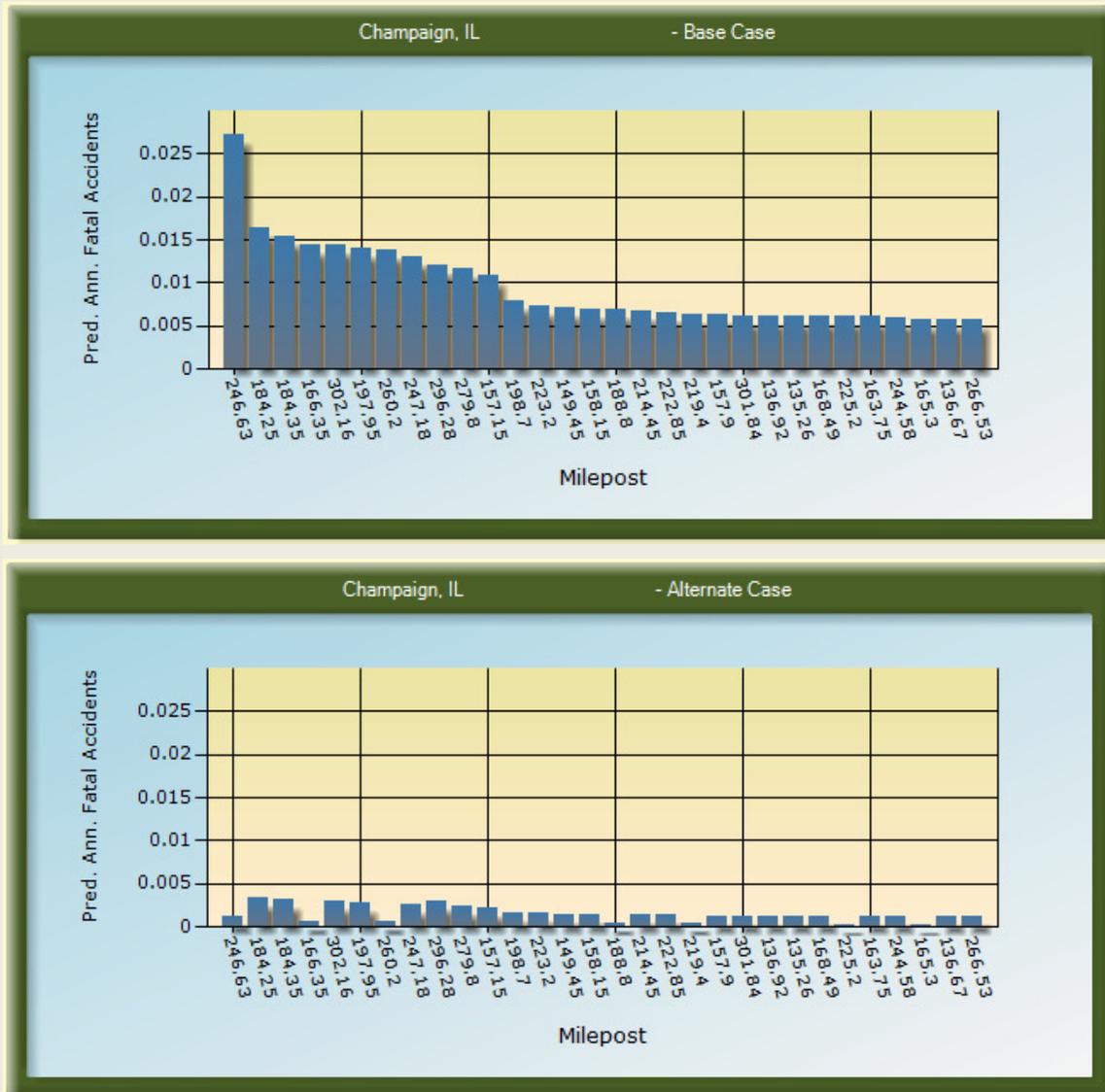
From the navigation menu, click on **Crossings** in order to browse to the **Crossings** page. Place the cursor over **Crossings** from the navigation menu, and click 'Set default costs (all crossings)' from the submenu. This will apply the new default costs to all crossings in the corridor.

7.2.4 Viewing results

Now that the crossings in the corridor have been set up to reflect our capital program, we can see how our upgrades impact the corridor's safety.

In the **Crossings** page, click on the 'APS model' tab, then select the year '2020' for the alternate case and click 'Go'. Refresh the data inside the table by clicking on the 'Recalculate' link, then click on 'Show Chart'. In the new window, select 'Bars - order by risk' in the first drop down, then click 'Go' to see the base case chart (figure 11). To see the alternate case for 2020, select 'Alternate case - base scale' in the second drop down, then click 'Go' (figure 12).

Figure 9 and 10– Predicted accidents for 2011 and 2020



The table below shows the crossing status for each year of operation and the capital cost improvement at each crossing. Note that the year of implementation and the expenditure occur in the year prior to the first year of operation.

Table 7 Annual Capital Program for Crossing 299005M

Year	Main Device	Capital Cost (thous. \$)	Supp Safety Device	Capital Cost (thous. \$)	Total Capital Cost (thous. \$)
2009	Gates	0	None	0	0
2010	Gates	0	None	15	15
2011	Gates	0	Barrier Curbs	0	0
2012	Gates	0	Barrier Curbs	0	0
2013	Gates	0	Barrier Curbs	0	0
2014	Gates	7000	Barrier Curbs	0	7000
2015	Gates	0	Barrier Curbs	0	0

2016	Gates	0	Barrier Curbs	0	0
2017	Separation	0	None	0	0
2018	Separation	0	None	0	0
2019	Separation	0	None	0	0

On the **Crossings** page, click on **Crossings** on the navigation menu and make the selection to generate the Capital Plan Report for the corridor. You can save and/or print this report.

The Capital Plan Report allows you to view the costs of the entire corridor as well as the costs of each individual crossing on a year-by-year basis. The Capital Plan Report is found under the “Crossings” tab on the “Crossings” page (it can only be viewed when “Allow Capital Programming?” on the Settings Page is set to True).

Figure 11 – Capital Plan Report

Milepost: 308.10		ID: 299005M		Description: IC - MAIN ST																					
Active Devices at Crossing		Year		Base	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Base Case: Gates				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Supp. Safety Device: None				<input type="checkbox"/>																					
Phase I: Gates				<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Supp. Safety Device: Barrier curbs				<input type="checkbox"/>																					
Phase II: Grade Separation				<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>					
Supp. Safety Device: None				<input type="checkbox"/>																					
Cost of Improvement (thous. base year dollars)																									
Device				0.0	0.0	0.0	7000.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Supp. Safety Device				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crossing Total				0.0	0.0	0.0	7000.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Above is an example of the Capital Plan Report for one individual crossing (above is 299005M). The chart shows the year in which each phase of the project takes place, including the cost of the improvements below it. Year 1 is the start year, which is set in the Scenario page, and the Base year is one year before the start year. In this case, our base year is 2009, since our start year was set as 2010.

MODULE 8 INVESTMENT ANALYSIS

8.1 Introduction

This section covers the investment analysis framework of GradeDec.NET. It examines the scope of benefits and costs, the timing assumptions, measures of project worth, the model logic for investment analysis and decision support for choosing a preferred alternative. A discussion of the benefits and their calculations are presented in sections 6, 7 and 9.

8.2 General Framework

There may be several factors that motivate the identification and evaluation of improvements at grade crossings. For instance:

A jurisdiction may seek to develop new passenger service on an existing freight or passenger line, and thus needs to address the new accident risk that arises at crossings.

Highway traffic growth, a recent spate of accidents or a local initiative to improve safety in a corridor or region may spawn a search for solutions.

In some areas residents have demanded “quiet zones” where trains approaching crossings cannot sound whistles or horns. In such cases, a jurisdiction needs to implement supplementary safety measures to achieve at least the prescribed level of safety set forth in Federal regulations.

Whatever the motivation, the jurisdiction has a clear vision of the future that includes specified levels of highway and rail traffic. This vision (which may include new rail service, or perhaps, involves only the status quo plus projected growth) represents the base case of the analysis. The base case is the default case against which alternative improvement programs are to be compared. The base case could be a pure “no build” case or it could include a minimal set of crossing improvements that might be implemented as a default improvement program.

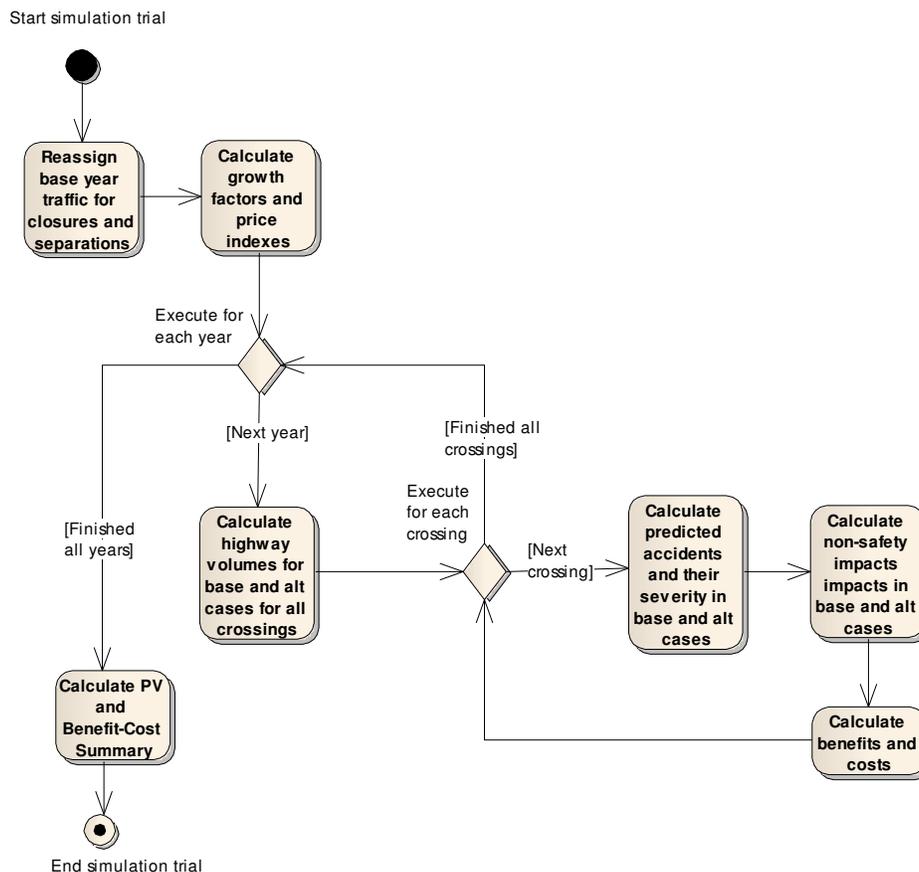
The evaluation (benefit-cost or investment analysis) compares the effects of improvements to the grade crossings (the alternate case) with the effects of the crossings in the base case. “Effects” that may have a positive value to consumers are benefits. Effects of grade crossings are typically negative and are properly called “disbenefits” (e.g., predicted accidents, vehicle delay, emissions). The highway benefit-cost literature often calls these disbenefits “user costs”. The benefits from improvements are, for the most part, a reduction in the disbenefits incurred at grade crossings.

In order to aggregate the benefits across categories and compare them with the costs of capital investment and changes in operating costs, the benefit quantities are monetized (converted to money values) by multiplying them by “social costs”, which are unit prices (see discussion below). In order to compare the benefits and costs that occur in different years, the money values are discounted which brings them to their present value equivalent. The principal measures of economic worth and efficiency, which are benefit-cost decision criteria, are derived from the monetized streams of benefits and costs and are discussed in the next section.

GradeDec.NET implements the investment analysis framework in the following manner. First, the model re-assigns highway traffic as a result of closures or grade separation in the alternate case. In each year, the model determines the projected growth of rail and highway traffic and evaluates the benefits and costs at each crossing and the results are summarized for each crossing and year, and for the entire forecast period as well. Note that GradeDec.NET conducts risk analysis using a technique called Monte Carlo simulation (see the section on risk analysis) so the above procedure is repeated for each trial of a simulation.

The following diagram illustrates the logic flow of a GradeDec.NET analysis.

Figure 12 Investment Analysis Logic Flow in GradeDec.NET



8.3 Measures of Economic Worth and Efficiency

The measures of economic worth are presented in the following table. The summary results of GradeDec.NET include the present value of each benefits category for the corridor or region, and each of the measures of economic worth.

Table 8 Summary Measures and their Meanings

Measure	Threshold Value - "Passes" the Benefit-Cost Test	Meaning
<p>NPV Net Present Value</p>	<p>NPV>0</p>	<p>The Net Present Value* takes the net flows from an investment (benefits less costs including the cost of the investment) and discounts them to equivalent present day value. Maximizing NPV is society's best solution if capital resources are unconstrained.</p>
<p>BCR Benefit-Cost Ratio</p>	<p>BCR>1</p>	<p>The Benefit-Cost Ratio is the present value of benefits divided by the cost. The BCR is an indicator of how much benefit is gained per dollar of cost.</p>
<p>ROR Rate of Return</p>	<p>ROR>discount rate</p>	<p>The ROR is the breakeven discount rate (i.e., for given cost and benefit streams, NPV=0 when the discount rate equals ROR). ROR is an indicator of investment performance and enables comparisons with returns on financial instruments</p>

*See the discussion below about discount rate and present value.

These measures are similar and at the threshold levels they are equivalent. However, each of the three measures can yield a different ranking of alternatives. The ranking by NPV is best for determining the absolute economic worth. However, when capital resources are constrained the BCR ranking tells you which alternative gives the most yield per dollar of cost expended. The ROR ranking allows ready comparison with alternative financial investments (however, note that the social benefits, while possessing economic value, may not be associated with an identifiable or realized flow of funds).

8.4 Comparing Alternatives

The purpose of evaluation is to aid decision-makers and other interested parties in 1) determining whether the costs of improvements are justified by the anticipated benefits, 2) understanding key differences among alternatives 3) demonstrating the extent to which crossing improvements meet objectives.

GradeDec.NET provides its users with a full set of economic benefits for each highway rail grade crossing under analysis. Users have the option to supplement their quantitative analysis with qualitative information on the environmental implications, equity of improvements (especially impacts of closures), legal and administrative feasibility, and community acceptance.

The results and reporting capabilities of GradeDec.NET enable the user to view the investment results for each benefits category at each grade crossing. This allows the analyst to target specific problems and refine alternative strategies to quickly and efficiently meet stated investment objectives.

GradeDec.NET can provide users with an estimate of a project's overall economic worth. Crossing improvement programs should be supplemented with qualitative material that address the overall environmental implications, equity of improvements (especially impacts of closures), financial feasibility, legal and administrative feasibility, and community acceptance.

The results and reporting capabilities of GradeDec.NET enable the user to view the outcomes with a full drill down by each benefit and cost category for each grade crossing. The user can hone in on specific problems to refine alternatives. This is useful for gaining public support and negotiating with the railroads.. For large scale projects, especially those involving grade crossing closures and separations, this may be a long-term iterative process.

8.5 Timing Assumptions

In GradeDec.NET you specify the time horizon of the analysis in the scenario definition, entering the start year, the end year and the last year of the near term. By assumptions, capital investments are made at the end of the year preceding the start year (or, if your analysis includes capital programming, in the year prior to the improvement's first year of operation). The effects at the crossings in the base and alternate cases are evaluated from the start year forward, when the benefits of the improvements begin to accrue.

Thus capital investment outlays are made in the year preceding the start year and in each year there are incremental (alternate less base) costs of operating and maintaining the crossings. In each year from start to end there are benefit streams that equal base case accident and user costs less those costs in the alternate case.

8.6 Social Costs

In calculating benefit components, GradeDec.NET recognizes that these are a direct function of travel forecasts on the highway and rail modes, which tend to grow over time.

For each year of the analysis GradeDec.NET evaluates the effects at each crossing in each benefit category. These effects are converted to money values using the appropriate social cost as a price. What are social costs? They are the equivalent money value of benefits to the consumer and society. If markets were perfectly competitive, then social costs would equal market prices (for goods that are traded in the economy). However, markets exhibit imperfect competition due to government interventions (taxes and subsidies), monopoly power, unemployed labor and other factors, which all serve to create significant variances between social costs and market prices.

Other costs - like the value of a statistical life, travel time, or the cost of emissions - have no directly observable market price tag. These are estimated through techniques that impute social cost through survey methods or from indirect, but observable data.

Social costs effectively apply weights to the different benefits. In general, it is best to defer to “accepted” values that are in use by Federal, State or local agencies, or, that have been employed in major studies. There may indeed exist local conditions or preferences that justify deviating from accepted values. However, the analyst should feel confident that there is ample justification for pursuing alternate social cost values.

8.7 Current, Constant and Present Value Dollars

One should be aware of three different dollar measures, these are:

Current Dollars – current dollars refer to dollar amounts at their face value at the time expended. Current dollar amounts are not adjusted for inflation. For instance, an item that costs \$100 today may cost \$110 five years from now because of price inflation. \$110 is the current dollar cost of the item five years from now.

Constant Dollars – constant dollars are dollar amounts that are inflation adjusted so that they reflect prices prevailing in a particular year (in GradeDec.Net the base year is the basis for constant dollars). The item that costs \$100 this year costs \$100 in constant dollars in any future year. Constant dollars equal current dollars net of the effects of price inflation.

Present Value Dollars –The current worth of a future sum of money or stream of cash flows given a specified rate of return. Future cash flows are discounted at the discount rate, and the higher the discount rate, the lower the present value of the future cash flows. Determining the appropriate discount rate is the key to properly valuing future cash flows, whether they be earnings or obligations. Present value dollars are explained in the next section on the discount rate.

GradeDec.NET reports all benefit-cost metrics in constant dollars. However, because fuel and oil prices can fluctuate dramatically over the analysis period, GradeDec.NET uses the projected change in fuel and oil prices *relative to* the projected change in general prices to calculate fuel and oil cost savings in constant dollars.

For example, given the following two price indexes:

	2020
General Price Index (2010 = 100)	120
Fuel and Oil Price Index (2010=100)	150

(That is, general prices rise by 20 percent in the period between 2010 and 2020 while fuel prices increase by 50 percent in the same period.)

If there are fuel savings of 100 gallons in 2020 and the price per gallon in 2010 is \$2.50, then the 2020 fuel savings in 2010 constant dollars are:

$$\text{Fuel savings} = 100 * \$2.50 * (150/120) = \$312.50$$

With the exception of fuel and oil, GradeDec.NET assumes that the relative prices of goods and services remain constant over the period of analysis. Additional explanation of prices and their calculation in GradeDec.NET is given in the *Reference Manual*.

8.8 The Discount Rate

Costs and benefits that accrue in different time periods are comparable through discounting. Discounting reflects society's preference for realizing benefits sooner rather than later. A discount rate also represents the opportunity cost of capital – presumably, if capital were not invested in grade crossing improvements it could be put to use in alternative investments that would, on average, yield a return equal to or exceeding the discount rate. The discount rate should not be confused with price changes due to inflation.

The discount rate represents society's choice of the appropriate rate of return on its investments and reflects current views on the cost and availability of capital. The choice of discount rate is a policy decision.

The Office of Management and Budget (OMB) specifies a discount rate for use in evaluating federal investments. A proposed rate is based on consideration of capital availability, market conditions, general social preferences for consumption in the present versus consumption in the future. In the 1970s and 1980s OMB recommended a 10 percent discount rate. In the 1990s, a 7 percent constant dollar rate was recommended by OMB. Some economists recommend that the discount rate for long-term infrastructure investment be set as low as 4 percent.

Why is this important? Because many investments will pass a benefit-cost test at a low discount rate, but will fail at a higher rate.

The example below shows a benefits stream in constant dollars, its present value equivalent (at 5 percent discount rate) and the present value for the analysis period (which is the sum of the present value of the benefit in each period).

Table 9 Example of Discounting and Present Value

SAFETY BENEFITS FOR CORRIDOR

	Constant Dollars	Present Value
2009	450.00	428.57
2010	459.00	416.33
2011	468.18	404.43
2012	477.54	392.88
2013	487.09	381.65
2014	496.84	370.75
2015	506.77	360.15
2016	516.91	349.86
2017	527.25	339.87
2018	537.79	330.16
2019	548.55	320.72
2020	559.52	311.56
2021	570.71	302.66
2022	582.12	294.01

PV for Analysis Period

=====>

5003.60

Note that the values in the above table are net of the effects of inflation. The annual increase in benefits is due largely to the increase in traffic and exposure at the grade crossings.

8.9 Costs and Benefits

The figure below shows the benefits and costs that GradeDec.NET evaluates. The following sections describe these.

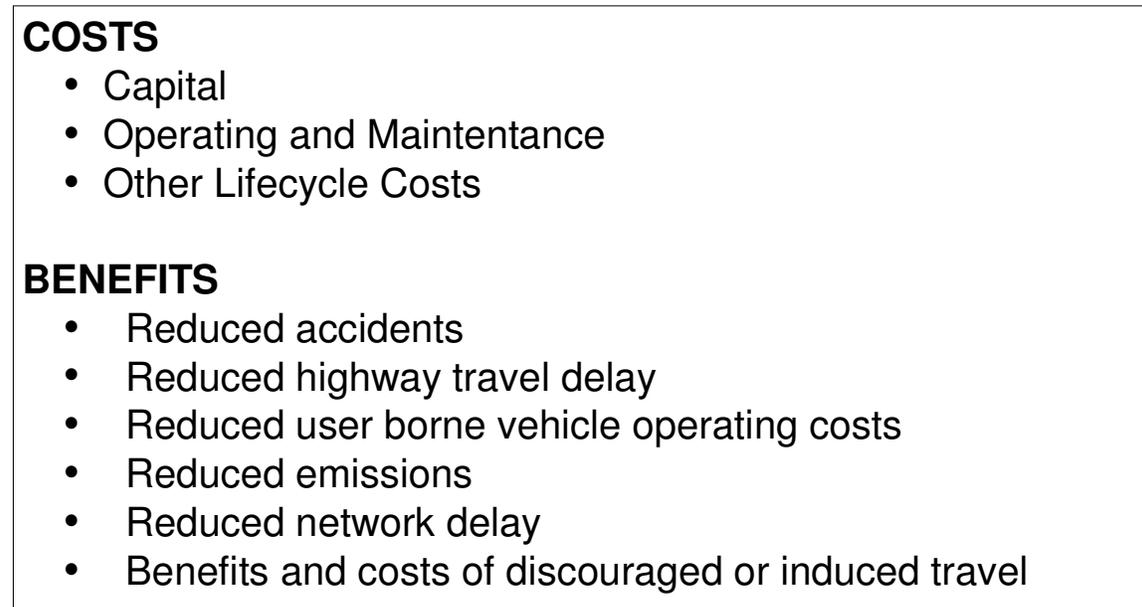


Figure 13 Benefits and Costs in GradeDec.NET

8.10 Costs

8.10.1 Capital

Capital costs are the outlays for grade crossing improvements. The capital costs include the expenses for construction, mechanical devices and any associated expenditures on wiring and communications. The GradeDec.NET model assumes that capital expenditures on grade crossing improvements are made in the year that precedes the first year of the analysis.

If your analysis includes capital programming then investments in one or two phases can be specified for any year for each crossing – *the investments will be operational in the year following the year of investment and from that year benefits will begin to accrue.*

8.10.2 Operating and Maintenance Costs

Operating and maintenance costs are the equivalent fixed annual expenditures in constant dollars required for the sound upkeep and operations of the grade crossing traffic control devices, signage and barriers.

8.10.3 Lifecycle Costs

These costs represent periodic refurbishment of equipments that are not expended annually. The maintenance schedule for the crossing devices may call for certain replacements every three or five years. The lifecycle cost represents the annualized value of the lifecycle cost. Suppose that every third year a crossing device requires a \$1,000 refurbishment. A payment of \$317.21 in each of three years, with a five percent discount rate is equivalent to a payment of \$1000 every third year.

$$\$317.21 \cdot [1 + (1 + .05) + (1 + .05)^2] = \$1000$$

Or, the annual equivalent of \$1000 every third year is equal to:

$$\$317.21 = \left[\frac{\$1000}{1 + (1 + .05) + (1 + .05)^2} \right]$$

Since \$1000 is the anticipated expenditure every three years, \$317.21 is the equivalent annual lifecycle cost expenditure in each year of the analysis.

8.11 Benefits

Benefits in GradeDec.NET can be broadly divided into safety and non-safety benefits. Safety is singled out for the following reasons:

- The relatively high incidence of roadway accidents at crossings.
- Safety concerns at crossings are paramount when considering new rail service.
- Federal funding for grade crossing improvements address the safety concerns almost exclusively.

Safety effects tend to dominate grade crossing evaluations due to the high relative social cost of accidents: For social cost values currently in use, the cost of a fatal accident is equivalent to hundreds of thousands of vehicle-hours of delay.

8.11.1 Safety (Accident Reduction)

Safety benefits are realized when more effective devices or measures are installed at crossings.

The quantity metrics for the safety metric differ with each of the two safety models in GradeDec.NET, per the following table:

DOT Accident Prediction and Severity Model	High Speed Rail Safety Model
Predicted fatal accidents	Predicted fatalities by mode
Predicted injury accidents	Predicted injuries by mode
Predicted property damage only Accidents	Predicted property damage

Table 10 Quantity Metrics for Safety by Model

One advantage of the High Speed Rail Model is the evaluation of injuries and fatalities by the rail and highway modes. Jurisdictions considering high speed rail are often more sensitive to safety on the public carrier mode.

8.11.2 Other Benefits

Other benefits evaluated by grade crossings include several that derive from changes in queuing at grade crossings. The final benefits category – benefits from induced trips – derives from the change in the generalized cost of travel along routes with the grade crossing.

8.11.2.1 Time Savings

Time savings are measured from reduced vehicle delay. Vehicle delay is counted from the time a vehicle slows to enter a queue at a crossing until the time that the vehicle has left the queue and has returned to its “free flow” speed.

In GradeDec.NET changes in vehicle delay occur when queue lengths change. This can happen as a result of the following two conditions:

- Grade separation or closure
- Changes in AADT at a crossing due to reassignment given changes at adjacent crossings.

8.11.2.2 Vehicle Operating Costs

Vehicle operating costs benefits accrue when highway vehicle idling is reduced or eliminated. The crossing vehicle operating costs are the consumption of fuel and oil by vehicles when queued at a crossing.

8.11.2.3 Emissions Reductions and Environmental Benefits

The environmental effects of infrastructure investment are far-reaching and span a number of impact categories. These include:

- Air quality
- Noise
- Other, including water quality, community impacts, wetlands, floodplains, parkland, threatened and endangered species, historical and archaeological sites, hazardous waste sites, secondary and cumulative impacts.

Clearly, major construction for a grade separation could result in some of the other impacts cited above. If your improvement program involves such construction, then environmental assessments are required.

GradeDec.NET explicitly evaluates reduced emissions as a benefit. While GradeDec.NET does not evaluate the impacts of noise, it does evaluate whether mitigation programs for “quiet zones” reduces accident risk to compliant levels in accordance with the proposed rule.

GradeDec.NET reports the reduced levels of pollutants (CO, HC and NOx) in each of three years (start, last year near term, and end). For high traffic roads, the reduction in emissions from crossing improvements may contribute towards meeting compliance threshold levels of these Clean Air Act criteria pollutants.

The social costs for the criteria pollutants are based on EPA estimates.

8.11.2.4 Network Delay

Network delay refers to the additional delay caused when the queued vehicles at grade crossings back into adjacent intersections to cause additional vehicle delay.

8.1 Benefit-Cost Analysis (Case Study 1, regional model)

In order to conduct an investment analysis of proposed improvements, the user needs to define a scenario, or specify an existing scenario, and populate the scenario with data.

8.1.1.1 Setting Up Your Data

The following sections describe how to set up the additional data structures and data required for the benefit-cost analysis of the case study.

8.1.1.1.1 Create new results set

On the main navigation menu, click on the link **Settings** to return to the **Settings** page. On the **Settings** page, click on the radio button on the next to “Selected results set” and then click the lower of the two “New” links. This will launch the **New Results** page. On this page, enter the name of the new results set “IL Regional, Base” and then click the “Create” button. Your browser will create the results set and shift back to the **Settings** page. Now from the drop down list select the newly created results set.

8.1.1.2 Create new scenario

Now click on the radio button next to “Selected scenario” and then click the lower of the two “New” links. This will launch the **New Scenario** page. Select “Copy an existing scenario” and select from the drop down list the sample “Base scenario” scenario. Change the year settings to:

- Start year: 2010
- Last year near term: 2014
- End year: 2034

These values determine the first and last years of the analysis time horizon, and, the periods in which the respective near-term and far-term growth rates are applied. Enter a name for the scenario (e.g., Illinois Regional base) and click on “Create”. Your browser will create the scenario and shift back to the **Settings** page. Now from the drop down list select the newly created scenario.

8.1.1.3 Modify the scenario data with forecast values and assumptions for your analysis

Click on the **Scenario** link of the main navigation menu. Your browser will transfer to the **Scenario** page. This page will display the scenario that you selected. This scenario is pre-populated with the sample values copied from the “Base scenario”. Modify these values to suit your analysis.

The scenario data variables are organized by topic areas: rail operations, highway, social costs and prices. You select a topic area by using the drop down list on the upper left. You select a variable within a topic area by browsing to it using the up and down

pointing finger icons, or by clicking on a “Select” link in the table in the lower part of the page.

The data for the scenario variables are either a fixed value, or two or three values that define a probability distribution. You select the type of probability distribution (skewed bell, normal, uniform or triangle) from the drop down list at the upper left of the page. You enter values in the designated text boxes and buttons on the toolbar allow you to commit (“save”) your modifications, undo them or refresh the chart and the tables on the page.

8.1.1.4 Verify or modify parameters and other data values

Browse to the **Parameters** page by clicking on the link on the main navigation menu. On this page select from the toolbar at the top “Model Parameters”. Select from the drop down list a table of values to view. If for your analysis you have local information that is better suited than the standard values supplied with GradeDec.NET, then edit the model values here (see the *Model Reference*) for documentation of the equations in the GradeDec.NET model.

8.1.1.5 Set the simulation parameters and run the simulation

Browse to the **Simulation** page by clicking on the link on the main navigation menu. On this page set the parameters for running a risk analysis of the benefit-cost of the program of improvements defined in **Crossings**, with the probability distributions described in **Scenario**. One possible set of parameters are shown below:

Figure 14 Simulation Parameters

Simulation	
<input type="button" value="Run Simulation"/>	
<input type="button" value="Edit"/>	
Item	Value
Number of trials (3 to 9999)	3
Random seed	1
Sampling Method	Latin hypercube
Run central values only?	True
Run risk sensitivity analysis?	True
Use the HSR model?	False
Reallocate traffic if grade separated?	True

You can run your simulation with the default values, or modify them and take advantage of the options on this page. When ready, click on the green traffic light icon to run the simulation. When completed, your browser will shift to the **Results** page.

8.1.1.6 Defining the scenario

From the Settings Form, the user either selects a scenario or creates a new scenario by selecting the “Create new scenario” option from the menu. To define a scenario the only requirements are to enter values for: scenario name, start year of the analysis, last year of

near term, and last year. The user can select to pre-populate the scenario with data from an existing scenario, or, all scenario data can be initialized with default values.

8.1.1.7 Populating the scenario with data

The scenario contains variables and data that are divided into five groups: Rail operations, highway operations, social costs and prices. For each variable, the user can specify either a fixed value or one of several probability distributions. The probability distributions require either 2 or 3 values that describe a range from which values are sampled during a simulation (see the section on risk analysis). When entering data for a new scenario it is often helpful to export the data to a spreadsheet using the export option from the toolbar in the Scenario Form, and then modify the data in a spreadsheet and import it back to GradeDec.NET.

The sections on Investment Analysis, Safety and Non-Safety Benefits discuss how the scenario data are used to arrive at the calculation of benefits.

8.1.1.8 View results table and charts, print report

On the **Results Page** view your analysis results on the tables and charts that this page makes available. These are shown in the Risk Analysis Module.

8.2 Benefit-Cost Summary

The following table shows the benefit cost summary. The summary shows that most of the benefits are from safety. There is a net disbenefit for time savings and user costs due to the re-routing of traffic from closed crossings. The benefit-cost summary chart shows that all of the improved crossings had benefits that strongly exceeded the costs. The net benefit from the improvements was \$-6,319,570 and the benefit-cost ratio was 0.819.

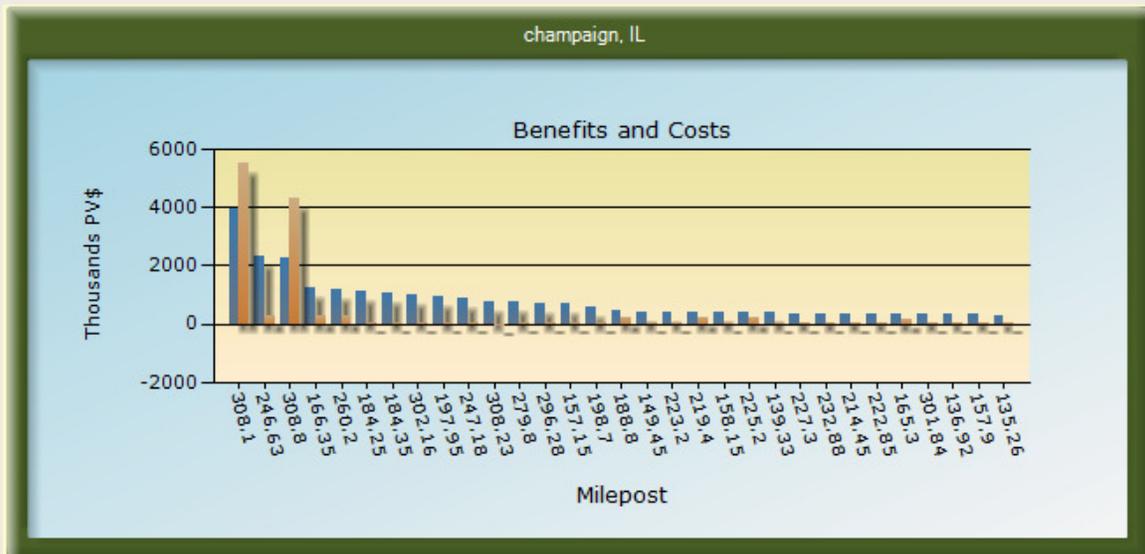
Figure 15 Benefit-Cost Summary for Case Study 1

Results: ICC region results			
Selected results data group: Benefits and Benefit-Cost Summary <input type="button" value="Go"/> Show summary chart			
	Variable	Mean Value	Standard Deviation
View	Safety benefits, thous \$ PV	25745.530	NaN
View	Travel time savings, thous \$ PV	42.398	NaN
View	Environmental benefits, thous \$ PV	0.275	NaN
View	Veh operating cost benefit, thous \$ PV	4.599	NaN
View	Total benefits, thous \$ PV	28661.320	NaN
View	of this, benefits from induced trips, thous \$ PV	25.925	NaN
View	of this, disbenefit from induced trips, thous \$ PV	-0.029	NaN
View	of this, investment salvage value, thous \$ PV	2842.618	NaN
View	Total costs, thous \$ PV	34980.890	NaN
View	Net benefits, thous \$ PV	-6319.570	NaN
View	Benefit-cost ratio	0.819	NaN
View	Rate of return (constant dollars), %	1.914	NaN
View	Local benefits (not included in summary), thous \$ PV	1433.066	NaN

Figure 17 Benefit-Cost Summary for Case Study 2

Results: champaign, IL			
Selected results data group: <input type="text" value="Benefits and Benefit-Cost Summary"/> <input type="button" value="Go"/> Show summary chart			
	Variable	Mean Value	Standard Deviation
View	Safety benefits, thous \$ PV	21088.770	NaN
View	Travel time savings, thous \$ PV	6010.459	NaN
View	Environmental benefits, thous \$ PV	27.880	NaN
View	Veh operating cost benefit, thous \$ PV	380.426	NaN
View	Network benefits, thous \$ PV	53.981	NaN
View	Total benefits, thous \$ PV	29604.010	NaN
View	of this, benefits from induced trips, thous \$ PV	10.881	NaN
View	of this, disbenefits from induced trips, thous \$ PV	-2.228	NaN
View	of this, investment salvage value, thous \$ PV	2033.843	NaN
View	Total costs, thous \$ PV	8865.340	NaN
View	Net benefits, thous \$ PV	20738.670	NaN
View	Benefit-cost ratio	3.339	NaN
View	Rate of return (constant dollars), %	99.999	NaN
View	Local benefits (not included in summary), thous \$ PV	1480.200	NaN

Figure 18 Summary Chart of Benefits and Costs



Risk analysis results for the case study corridor are included in the Risk Analysis Module.

ANALYSIS WORKSHEETS

NON-SAFETY BENEFITS (Module 8)

A. Average Crossing Block Time

STEPS	SOURCE OR EQUATION
A1. Determine average number of daily rail operations in corridor by type (passenger, freight, switch) and average speed at the crossing.	Example: Trains per day by type 6 passenger, 4 freight, 4 switch Average train speed at crossing (mph) 55 passenger, 30 freight, 20 switch
A2. Determine the average car length and the number of cars by train type	Example: Number of cars per train 6 passenger, 72 freight, 4 switch Length of car (ft.) 50 passenger, 60 freight, 40 switch
A3. Calculate the train length by type	Train Length = number of cars * car length + length of locomotive Passenger=6*50+50=350 feet Freight = 60*72+50=4370 feet Switch = 40*4+50=210 feet
A4. Calculate the block time by train type Note: The factor 36/60 accounts for a gate closure lead time of 36 seconds.	Block time minutes = train length / train speed * units conversion factors+(36/60) Passenger train block time = $\frac{350 \text{ feet}}{55 \text{ mph}} * \frac{1 \text{ mile}}{5280 \text{ feet}} * \frac{60 \text{ minutes}}{1 \text{ hour}} + \frac{36}{60} = .6723 \text{ minutes}$ Freight train block time = $\frac{4420 \text{ feet}}{30 \text{ mph}} * \frac{1 \text{ mile}}{5280 \text{ feet}} * \frac{60 \text{ minutes}}{1 \text{ hour}} + \frac{36}{60} = 2.255 \text{ minutes}$ Switch train block time = $\frac{210 \text{ feet}}{20 \text{ mph}} * \frac{1 \text{ mile}}{5280 \text{ feet}} * \frac{60 \text{ minutes}}{1 \text{ hour}} + \frac{36}{60} = .7193 \text{ minutes}$
A5. Calculate the average block time	Average block time = Sum (number of trains*train block time) / (Total number of trains) Average block time = $(0.6723*6+2.255*4+0.7193*4)/(6+4+4)= 1.138 \text{ minutes}$

ANALYSIS WORKSHEETS
NON-SAFETY BENEFITS (Module 8)
B. Calculate Highway Vehicle Delay Due to Crossing Closure

STEPS	SOURCE OR EQUATION
B1. Determine: Average annual daily traffic (AADT) at crossing; composition of highway traffic by traffic segment (auto, truck, bus); time-of-day percent of highway traffic by segment in period; number of highway lanes at crossing	Example: AADT 15500 Percent auto 76% Percent truck 22% Percent bus 2% For Period Late AM (6-12) Daily auto traffic in period 15% Daily truck traffic in period 25% Daily bus traffic in period 50% Number of highway lanes 2
B2. Determine total number of daily trains; percent daily trains in period; average block time	Total number of daily trains =14 (see A1 above) Example: For Period Late AM (6-12) Daily trains in period 20% Average block time = 1.138 *60 = 68.282 seconds (see A5 above)
B3. Calculate the number of trains in period	Trains in period = daily number of trains * % of daily trains in period Trains in period = 14*0.2=2.8
B4. Determine highway speed of freeflow, traffic density at speed 0, vehicle dispersal rate per lane when closure ends	Example: Freeflow highway speed 45 mph Traffic density at speed 0 0.05 veh/ft Vehicle dispersal rate 0.5 veh/sec
B5. Calculate total vehicles in period	Vehicles=AADT*percent type in traffic*percent of daily traffic in period Auto = 15500*0.76*0.15 = 1767 Truck= 15500*0.22*0.25 = 852.5 Bus = 15500*0.02*0.5 = 155 Total Vehicles = Auto+Truck+Bus = 2774.5
B6. Calculate vehicle arrival rate per lane at crossing in period	Arrival rate =Total Vehicles / (lanes * seconds in period) Arrival rate = $\frac{2774.5 \text{ vehicles}}{2 \text{ lanes} * 3600 \frac{\text{sec}}{\text{hour}} * 6 \frac{\text{hours}}{\text{period}}} =$.06422 veh/sec/ lane

STEPS	SOURCE OR EQUATION
B7. Calculate the number of affected vehicles (entering queue) per lane per closure	<p>Number of affected vehicles = Arrival rate*dispersal rate* average block time/(dispersal rate-arrival rate)</p> $\text{Affected vehicles} = \frac{0.06423 * 0.5 * 68.282}{0.5 - 0.06423} = 5.032$
B8. Calculate delay per lane per closure	<p>Delay= Affected vehicles* (block time + (1/dispersal rate – 1/arrival rate))*(affected vehicles+1)/2</p> <p>Delay =</p> $5.032 * \left(68.282 + \left(\left(\frac{1}{0.5} \right) - \left(\frac{1}{0.06423} \right) \right) * \frac{(5.032 + 1)}{2} \right)$ <p>=137.64 vehicle-seconds</p>
B9. Calculate total delay per closure and convert to veh-hours	<p>Total Delay = Delay per lane*lanes*unit conversion factor</p> <p>Total Delay =137.64*2*(1 hour / 3600 sec) =0.0765 veh-hours</p>
B10. Allocate delay per closure to highway traffic segments	<p>Delay by traffic segment = Delay * vehicles in segment / total vehicles</p> <p>Auto Delay=0.0765 * $\frac{1767}{2774.5}$ = 0.0487 veh-hours</p> <p>Truck Delay=0.0765 * $\frac{852.5}{2774.5}$ = 0.0235 veh-hours</p> <p>Bus Delay =0.0765 * $\frac{155}{2774.5}$ = 0.00427 veh-hours</p>
B11. Multiple by number of closures in period	<p>Delay = delay per closure * closures</p> <p>Auto Delay = 0.0487*2.8= 0.1364 veh-hours Truck Delay=0.0235*2.8 = 0.0658 veh-hours Bus Delay=0.00427*2.8 = 0.0120 veh-hours</p>
B12. Calculate in each period and sum for daily delay by traffic segment	Repeat above procedure for other periods of day and sum

**ANALYSIS WORKSHEETS
NON-SAFETY BENEFITS (Module 8)
C. Calculate Highway Vehicle Time-in-Queue Due to Crossing
Closure**

STEPS	SOURCE OR EQUATION																								
C1: Determine: Freeflow speed; traffic density at speed 0; average block time; arrival rate; dispersal rate; number of affected vehicles; highway vehicles in period by traffic segment; trains in period; number of lanes.	<table> <tr> <td>Freeflow speed (see B4)</td> <td>45 mph</td> </tr> <tr> <td>Traffic density at speed 0 (see B4)</td> <td>0.05 veh/ft</td> </tr> <tr> <td>Average block time (see B2)</td> <td>68.282 sec</td> </tr> <tr> <td>Arrival rate (see B6)</td> <td>0.0642 veh/sec/lane</td> </tr> <tr> <td>Dispersal rate (see B4)</td> <td>0.5 veh/sec</td> </tr> <tr> <td>Affected vehicles (see B7)</td> <td>5.032 vehicles</td> </tr> <tr> <td>Highway vehicles in period (see B5) of this,</td> <td>2774.5</td> </tr> <tr> <td> Auto</td> <td>1767</td> </tr> <tr> <td> Truck</td> <td>852.5</td> </tr> <tr> <td> Bus</td> <td>155</td> </tr> <tr> <td>Trains in period (see B3)</td> <td>2.8</td> </tr> <tr> <td>Number of lanes (see B1)</td> <td>2</td> </tr> </table>	Freeflow speed (see B4)	45 mph	Traffic density at speed 0 (see B4)	0.05 veh/ft	Average block time (see B2)	68.282 sec	Arrival rate (see B6)	0.0642 veh/sec/lane	Dispersal rate (see B4)	0.5 veh/sec	Affected vehicles (see B7)	5.032 vehicles	Highway vehicles in period (see B5) of this,	2774.5	Auto	1767	Truck	852.5	Bus	155	Trains in period (see B3)	2.8	Number of lanes (see B1)	2
Freeflow speed (see B4)	45 mph																								
Traffic density at speed 0 (see B4)	0.05 veh/ft																								
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Highway vehicles in period (see B5) of this,	2774.5																								
Auto	1767																								
Truck	852.5																								
Bus	155																								
Trains in period (see B3)	2.8																								
Number of lanes (see B1)	2																								
C2 Calculate the time rate of growth of the back of the queue during closure	$d(\textit{Back of queue}) = \frac{\textit{arrival rate} * \textit{freeflow speed} * \textit{traffic density}}{\textit{freeflow speed} * \textit{traffic density} - \textit{arrival rate}}$ $= \frac{0.0642 * 45 * (5280 / 3600) * 0.05}{45 * (5280 / 3600) * 0.05 - 0.0642}$ $= 0.0655 \text{ feet / second}$																								
C3 Calculate the time-in-queue per lane	$\textit{Time-in-queue} = \textit{affected vehicles} * (\textit{block time} + \left(\Delta * \frac{(\textit{affected vehicles} + 1)}{2} \right))$ $\textit{where } \Delta = \left(\frac{1}{\textit{dispersal rate}} - \frac{1}{d(\textit{back of queue})/dt} \right)$ $= 5.0317 * (68.282 + ((1/.5 - 1/.0642) * (5.0317 + 1) / 2))$ $= 142.24 \text{ veh-sec}$																								
C4. Calculate total time-in-queue per closure and convert to vehicle-hours	<p>Time-in-Queue = Time-in-Queue per lane*lanes*unit conversion factor</p> $\text{Total Time-in-queue} = 142.24 * 2 * (1 \text{ hour} / 3600 \text{ sec})$ $= 0.07902 \text{ veh-hours}$																								

STEPS	SOURCE OR EQUATION
C5. Allocate time-in-queue per closure to highway traffic segments	<p>Time-in-queue by traffic segment per closure = Time-in-queue * vehicles in segment / total vehicles</p> <p>Auto Time-in-queue = $0.07902 * \frac{1767}{2774.5} = 0.05033$ veh-hrs</p> <p>Truck Time-in-queue = $0.07902 * \frac{852.5}{2774.5} = 0.02428$ veh-hrs</p> <p>Bus Time-in-queue = $0.07902 * \frac{155}{2774.5} = 0.00442$ veh-hrs</p>
C6. Multiple by number of closures in period to yield total time in queue in period by traffic segment	<p>Time-in-queue = Time-in-queue per closure * closures</p> <p>Auto Delay = $0.05033 * 2.8 = 0.14092$ veh-hours</p> <p>Truck Delay = $0.02428 * 2.8 = 0.06799$ veh-hours</p> <p>Bus Delay = $0.004415 * 2.8 = 0.012361$ veh-hours</p>
C7. Calculate in each period and sum for time-in-queue by traffic segment	Repeat above procedure for other periods of day and sum

**ANALYSIS WORKSHEETS
NON-SAFETY BENEFITS (Module 8)
D. Calculate Time Savings Benefit**

STEPS	SOURCE OR EQUATION																								
D1. Determine total daily delay by highway traffic segment in base and alternate cases	<table> <tr> <td>Base Case</td> <td></td> <td>Base on calculations in D</td> </tr> <tr> <td>Auto</td> <td>0.91 veh-hrs</td> <td>for all 4 periods in the</td> </tr> <tr> <td>Truck</td> <td>0.26 veh-hrs</td> <td>day.</td> </tr> <tr> <td>Bus</td> <td>0.02 veh-hrs</td> <td></td> </tr> <tr> <td>Alt Case</td> <td></td> <td></td> </tr> <tr> <td>Auto</td> <td>0 veh-hrs</td> <td></td> </tr> <tr> <td>Truck</td> <td>0 veh-hrs</td> <td></td> </tr> <tr> <td>Bus</td> <td>0 veh-hrs</td> <td></td> </tr> </table>	Base Case		Base on calculations in D	Auto	0.91 veh-hrs	for all 4 periods in the	Truck	0.26 veh-hrs	day.	Bus	0.02 veh-hrs		Alt Case			Auto	0 veh-hrs		Truck	0 veh-hrs		Bus	0 veh-hrs	
Base Case		Base on calculations in D																							
Auto	0.91 veh-hrs	for all 4 periods in the																							
Truck	0.26 veh-hrs	day.																							
Bus	0.02 veh-hrs																								
Alt Case																									
Auto	0 veh-hrs																								
Truck	0 veh-hrs																								
Bus	0 veh-hrs																								
D2. Determine average vehicle occupancy	<table> <tr> <td>Auto</td> <td>1.15</td> </tr> <tr> <td>Bus</td> <td>10</td> </tr> </table>	Auto	1.15	Bus	10																				
Auto	1.15																								
Bus	10																								
D3. Determine passenger value of time and truck vehicle hour	<table> <tr> <td>Passenger</td> <td>10.40 \$/hr/occ</td> </tr> <tr> <td>Truck</td> <td>18.06 \$/hr/veh</td> </tr> </table>	Passenger	10.40 \$/hr/occ	Truck	18.06 \$/hr/veh																				
Passenger	10.40 \$/hr/occ																								
Truck	18.06 \$/hr/veh																								
D4. Calculate the daily time savings by traffic segment	<p>Base case delay – Alt case delay</p> <table> <tr> <td>Auto</td> <td>0.91 veh-hrs</td> </tr> <tr> <td>Truck</td> <td>0.26 veh-hrs</td> </tr> <tr> <td>Bus</td> <td>0.02 veh-hrs</td> </tr> </table>	Auto	0.91 veh-hrs	Truck	0.26 veh-hrs	Bus	0.02 veh-hrs																		
Auto	0.91 veh-hrs																								
Truck	0.26 veh-hrs																								
Bus	0.02 veh-hrs																								
D5. Calculate the daily benefit	<p>Auto = Delay Savings*Average Occupancy * Pass Value of time Truck = Delay Savings*Truck Value of Time Bus=Delay Savings*(Average Occupancy*Pass Value of Time + Truck Value of Time) \$10.87 = 0.91*1.15*10.40 \$4.75 = 0.26*18.06 \$2.92=.02*(10*10.40+18.06)</p>																								
D6. Calculate annual benefits	<p>Annual benefit= Sum of daily benefit by mode * annualization factor \$5192.69=(10.87+4.75+2.92)*280</p>																								

MODULE 9 RISK ANALYSIS

9.1 Introduction

GradeDec.NET conducts an analysis of benefits and costs over the time horizon of the project. Over the course of this time horizon there are considerable uncertainties and, consequently, the outcome of the analysis is itself highly uncertain. Since GradeDec.NET is supporting resource allocation and other decisions, we need a means of getting a handle on the uncertainty in order to reach truly informed decisions.

There are three principal pages and several charts in GradeDec.NET that accommodate risk analysis. These are:

The Scenario page – in this page the analyst enters input probability distribution ranges. Using this page, the analyst can visualize the input distributions using the automated charting capability.

The Simulation page – in this page the analyst sets the risk analysis simulation parameters and runs the analysis. Here the analyst can choose to run central values only and whether or not to conduct a risk sensitivity analysis (see discussion below under the section on Using the Tornado Chart).

The Results page – in this page the user can navigate among and view the risk analysis results. From this page the user can also invoke special results chart and the tornado chart for each results variable.

9.1.1 What is Risk Analysis?

Risk analysis is a means of quantifying the uncertainty inherent in an analysis. One of the principal sources of uncertainty in an analysis is forecasting the future (i.e., growth in highway and rail traffic). Since, to one degree or another, forecasts will always be wrong, there is limited value in a point estimate forecast. Two possible solutions to the point estimate dilemma are: 1) high-low-middle forecasts and 2) sensitivity analysis. Both of these approaches have serious shortcomings as follows:

- **High-low forecasts** are developed through arbitrarily tweaking the middle result upwards and downwards, or by tweaking several key model variables. Results are not associated with likelihood of occurrence and may encourage decision-makers to mistakenly believe each outcome is equally probably.
- Sensitivity analysis allows one variable to vary over a range while all other variables are held fixed. The classic “what if” analysis misrepresents real life as variables don’t move one at a time while everything else remains fixed. Hence, sensitivity analysis results are of limited use.

Risk analysis offers an alternative approach to high-low forecasts and sensitivity analysis in dealing with project uncertainty. The risk and uncertainty of a result is best reflected as a probability distribution. Instead of a forecast result that says “the answer is 10” as with a point estimate, a probability distribution enables descriptive statements like “the expected value of the result is 10 and there is an 80% probability that the value will lie between 8 and 13”.

The risk analysis method for arriving at the probability distributions of results is given by the following steps:

Define your analytic model that is used for deriving point estimates (also called a deterministic model).

Find probability distributions for each of the model's input variables (a section below describes this process). In GradeDec.Net, the input values that are allowed to vary are all defined within the Scenario.

Randomly sample from the input distributions and solve the model. Repeat this process hundreds or thousands of times (this repeated process of sampling and solving is called Monte Carlo simulation).

The multiple results for a given result variable describe a probability distribution.

9.1.2 Why Use Risk Analysis in GradeDec.NET

In GradeDec.Net, risk analysis refers to the risk that expected project benefits will not materialize over time. This could happen if, for example, highway traffic forecasts did not materialize. GradeDec.Net allows its users to provide a range of highway and rail traffic grow rates to account for the uncertainty associated with traffic forecasts over the analysis period..

Because GradeDec.Net can use a range of values for key input values, the resulting risk analysis provides richer information to decision makers. One example of its usefulness is in analyzing risk-yield tradeoffs (see section below).

Another use of risk analysis is to find an outcome level that has a probability of achievement. Rather than committing to an expected value, decision makers can commit to more certain outcomes.

Finally, the analysis can reveal the risks and weaknesses that really affect the project and can use the information to iteratively refine the alternatives and thus mitigate risks.

9.2 Selecting a Distribution and Populating with Data

Follow the steps below to populate an input variable in the Scenario Data Form:

Select a central value – the central value is your “best guess” value that you would use in a point estimate analysis.

Select a distribution based upon the best available data

Choose a range that accommodates that the full range of possible values and their probabilities.

The following describes the available distributions in GradeDec.NET and how they might be used in your analysis.

Skewed bell – this distribution, which is a normal distribution when no skew is present, is a good choice for a wide range of variables. You need either data or good judgments that indicate the 10% upper and lower limits.

Normal - suited for variables that are symmetric and may be normally distributed. Only requires two input values: mean and standard deviation.

Triangle – the triangle distribution is well-suited for ranges that have firm maximum and minimum values and a most likely value.

Uniform – use the uniform distribution when there is equal probability that the actual will lie anywhere in a designated range.

It's good practice to document you selections on forms like the one in the figure below.

We will perform a risk analysis for each case study.

9.3 Risk Analysis: Case Study 1 (regional model)

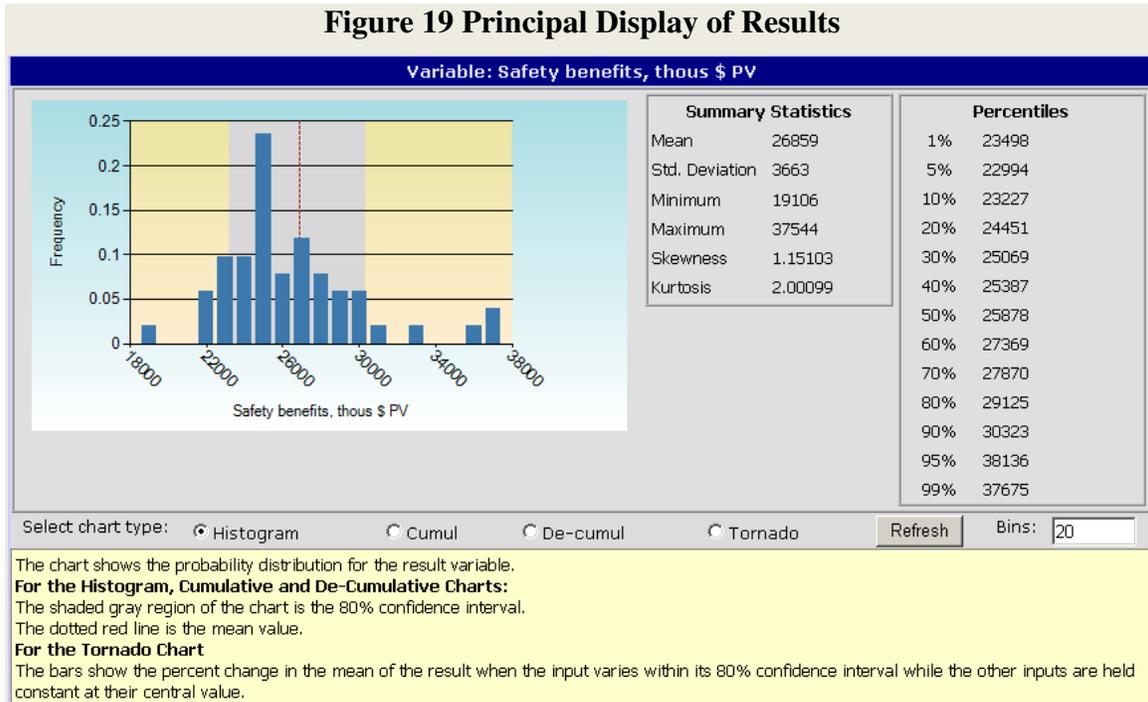
9.3.1 Running a Risk Analysis

Follow these steps to run a risk analysis:

1. Enter and verify the data in your region definition (Settings Form), crossings (Region Crossings Form), scenario definition (Settings Form) and scenario. Make sure that the following years are set for the scenario in the Settings Form:
 - a. Start year: 2010
 - b. Last year near term: 2014
 - c. End year: 2034
2. Be sure that the region, scenario and results file for your analysis are selected (e.g., they show in the “Current Selections” frame).
3. Invoke the simulation form.
4. Enter the number of trials (51 trials should be adequate for a first cut, use 500 trials for a final analysis). Set your sampling method to "Latin hypercube". Select whether or not to conduct a risk sensitivity analysis (this feature enables the tornado charts, however, it can be time-consuming). Make sure that 'Run Central Values Only?' is set to false before starting the simulation.
5. Click on the “Run Simulation” button.

9.3.2 Reading the Results

Figure 19 Principal Display of Results



The above shows the Results page when the results variable “Safety benefits, thous \$ PV” is selected. The summary statistics show that the mean or expected value of the result is \$26,859,000. The gray region on the chart show the 80% confidence interval, that is, they mark the 10 percent lower and upper limits (the 10th and 90th percentiles) of the range of the variable. The results tell us that:

- There is 80 percent confidence that the result will lie between \$23,227,000 and \$30,323,000.
- There is a 90 percent probability that the result will exceed \$23,227,000.
- There is a 10 percent probability that the result will exceed \$30,323,000.

9.3.3 Comparing Alternatives with Risk Analysis

Risk matters. If the anticipated NPV of two alternatives are roughly equal, yet one has much larger downside risk, then the less risk alternative is preferred. The risk analysis of alternatives will typically offer trade-offs between the risk and yield associated with alternatives. In the figure below we chart the mean NPV (yield) against the standard deviation of NPV (risk).

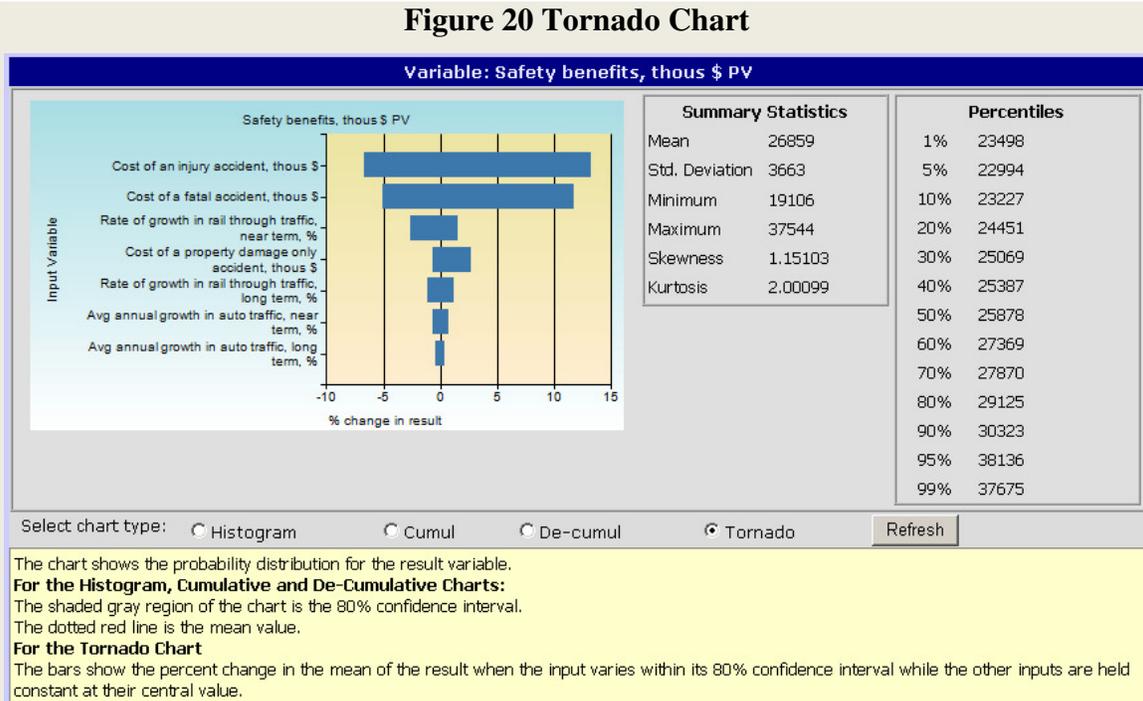
9.3.4 Using the Tornado Chart to Refine Inputs

If when running your simulation you checked the box to run a risk sensitivity analysis, then you can view tornado charts like the one below. The tornado chart shows how the result varies when all the inputs are held at their mean values except for one input

variable, which is allowed to vary between its 10th and 90th percentile. The inputs are ranked in the order of their impact on the variance of the result.

The tornado chart is useful in identifying the factors that are the largest contributors to risk. With this information the analyst can focus efforts on refining input ranges so as to reduce the variance of results and not waste time on factors whose variance has little or no impact on the outcomes.

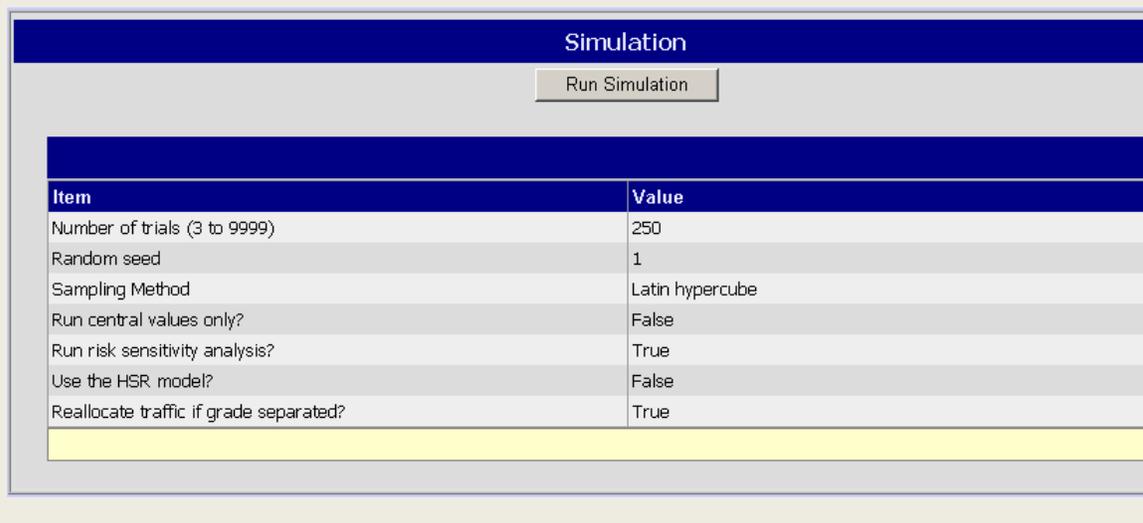
Figure 20 Tornado Chart



9.3.5 Result Tables and Charts

The simulation for the case study was run with the following parameters:

Figure 21 Simulation Page with Parameters Set for Case Study Simulation



As indicated, the simulation was run with 250 trials. The Accident Prediction and Severity Model was used (that is, the HSR model was not used). A risk sensitivity analysis was run.

9.3.6 Risk Analysis Results

The following charts show the risk analysis results for the safety benefits. The upward skew of the histogram indicates that there is more possible upside benefit than downside risk.

Figure 22 Histogram of Safety Benefits for Case Study

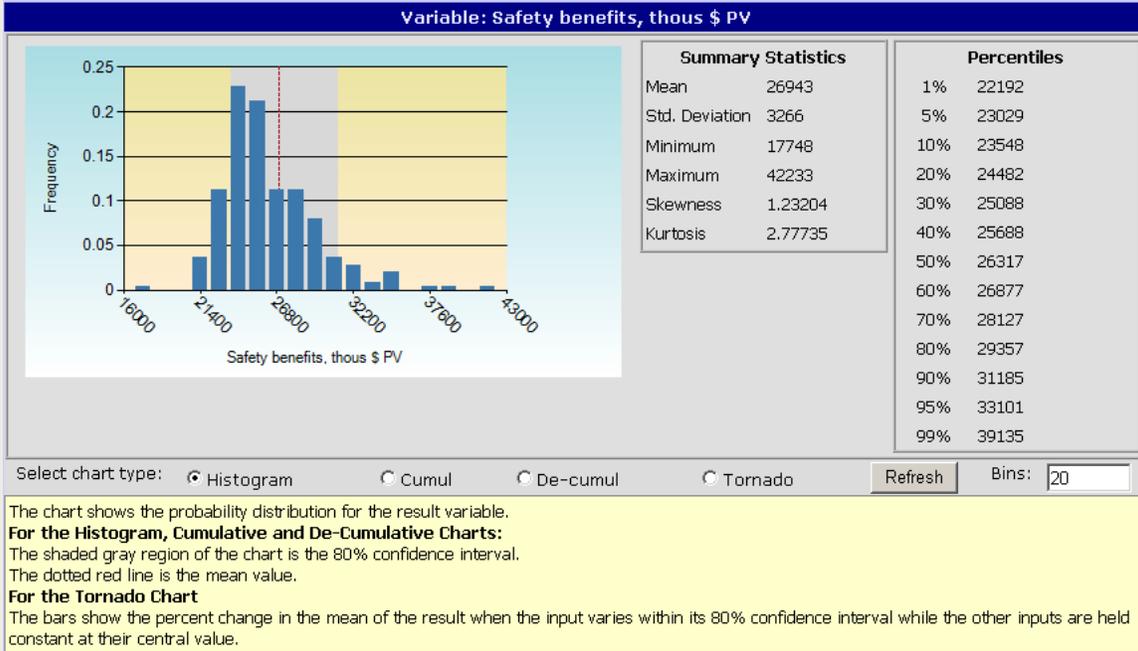
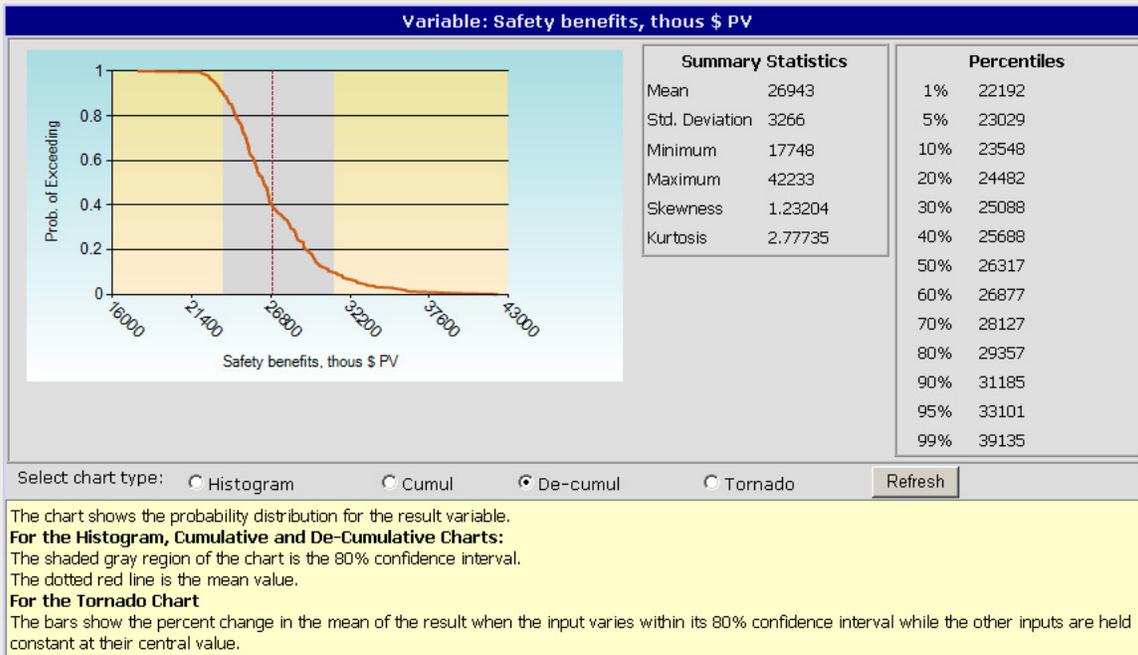
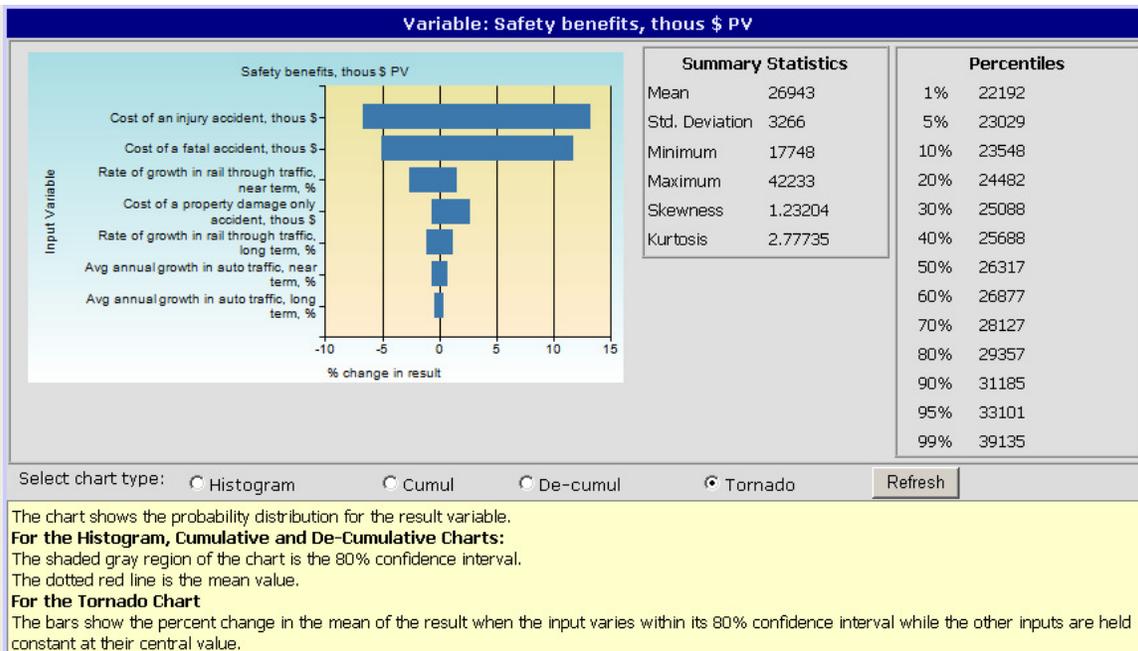


Figure 23 De-Cumulative Probability Chart of Safety Benefits



The tornado chart shows that most of the variability in the safety benefit is due to the variability in the social costs. The variability in the traffic growth forecasts also contribute to the variability of the outcome.

Figure 24 Tornado Chart of Safety Benefits



9.4 Risk Analysis: Case Study 2 (corridor model)

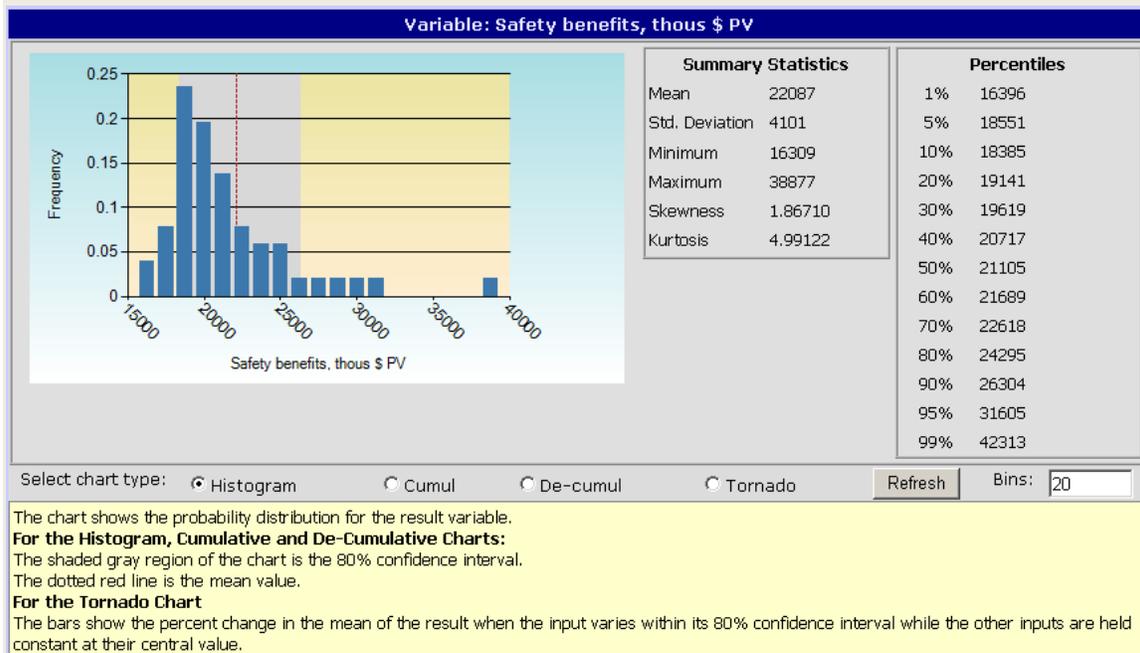
9.4.1 Running a Risk Analysis

Follow these steps to run a risk analysis:

1. Enter and verify the data in your corridor definition (Settings Form), crossings (Corridor Crossings Form), scenario definition (Settings Form) and scenario.
2. Be sure that the corridor, scenario and results file for your analysis are selected (e.g., they show in the “Current Selections” frame).
3. Invoke the simulation form.
4. Enter the number of trials (51 trials should be adequate for a first cut, use 500 trials for a final analysis). Set your sampling method to "Latin hypercube". Select whether or not to conduct a risk sensitivity analysis (this feature enables the tornado charts, however, it can be time-consuming). Make sure that 'Run Central Values Only?' is set to false before starting the simulation.
5. Click on the “Run Simulation” button.

9.4.2 Reading the Results

Figure 25 Principal Display of Results



The above shows the Results page when the results variable “Safety benefits, thous \$ PV” is selected. The summary statistics show that the mean or expected value of the result is \$22,087,000. The gray region on the chart shows the 80% confidence interval, that is, they mark the 10 percent lower and upper limits (the 10th and 90th percentiles) of the range of the variable. The results tell us that:

- There is 80 percent confidence that the result will lie between \$18,385,000 and \$26,304,000.
- There is a 90 percent probability that the result will exceed \$18,385,000.
- There is a 10 percent probability that the result will exceed \$26,304,000.

9.4.3 Comparing Alternatives with Risk Analysis

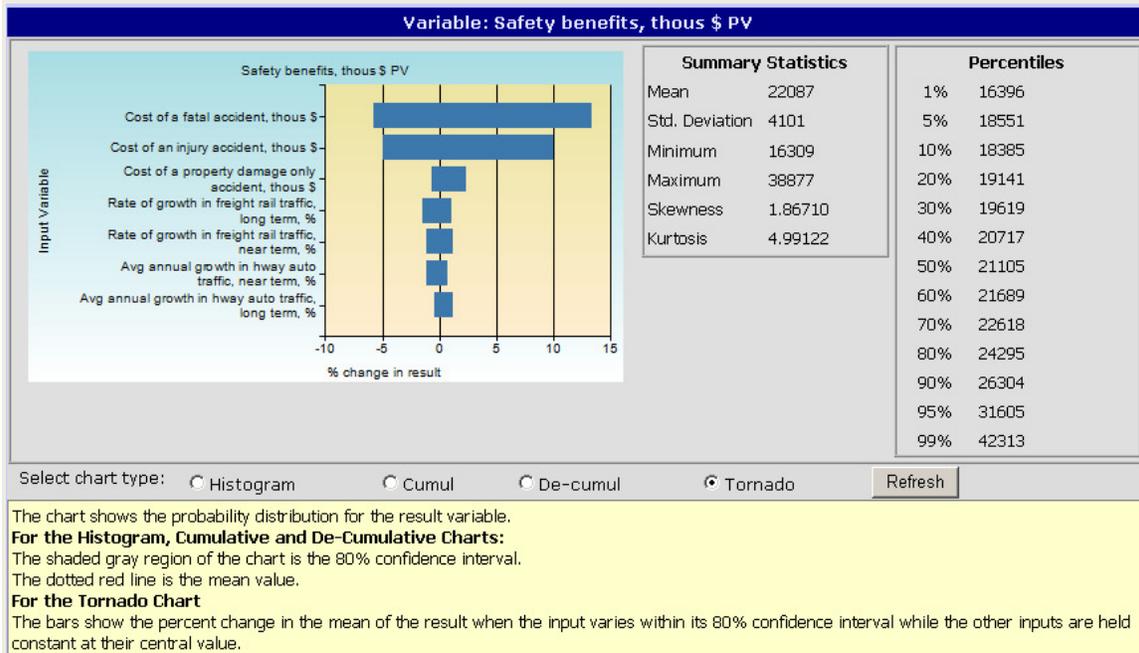
Risk matters. If the anticipated NPV of two alternatives are roughly equal, yet one has much larger downside risk, then the less risk alternative is preferred. The risk analysis of alternatives will typically offer trade-offs between the risk and yield associated with alternatives. In the figure below we chart the mean NPV (yield) against the standard deviation of NPV (risk).

9.4.4 Using the Tornado Chart to Refine Inputs

If when running your simulation you checked the box to run a risk sensitivity analysis, then you can view tornado charts like the one below. The tornado chart shows how the result varies when all the inputs are held at their mean values except for one input variable, which is allowed to vary between its 10th and 90th percentile. The inputs are ranked in the order of their impact on the variance of the result.

The tornado chart is useful in identifying the factors that are the largest contributors to risk. With this information the analyst can focus efforts on refining input ranges so as to reduce the variance of results and not waste time on factors whose variance has little or no impact on the outcomes.

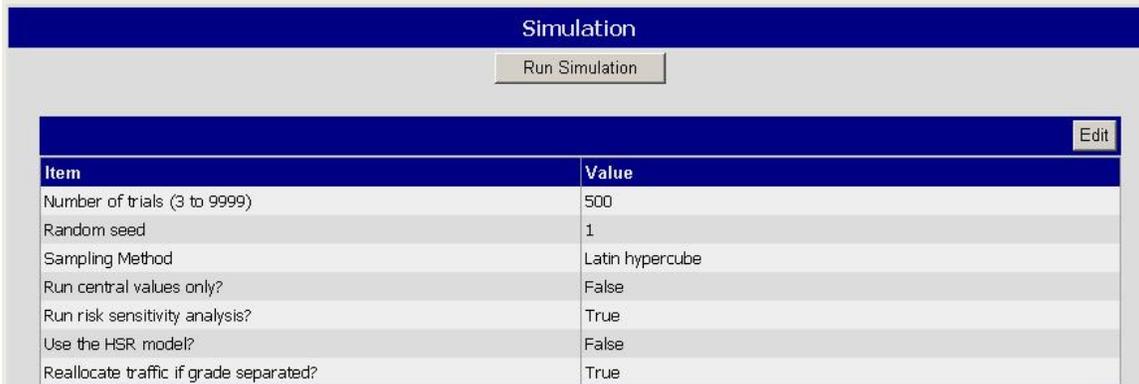
Figure 26 Tornado Chart



9.4.5 Result Tables and Charts

The simulation for the case study was run with the following parameters:

Figure 27 Simulation Page with Parameters Set for Case Study Simulation



As indicated, the simulation was run with 500 trials. The Accident Prediction and Severity Model was used (that is, the HSR model was not used). A risk sensitivity analysis was run. As the alternative did not include grade separations, the “Re-allocate traffic if grade separated?” parameter had no impact.

9.4.6 Risk Analysis Results

The following charts show the risk analysis results for the safety benefits. The upward skew of the histogram indicates that there is more possible upside benefit than downside risk.

Figure 28 Histogram of Safety Benefits for Case Study

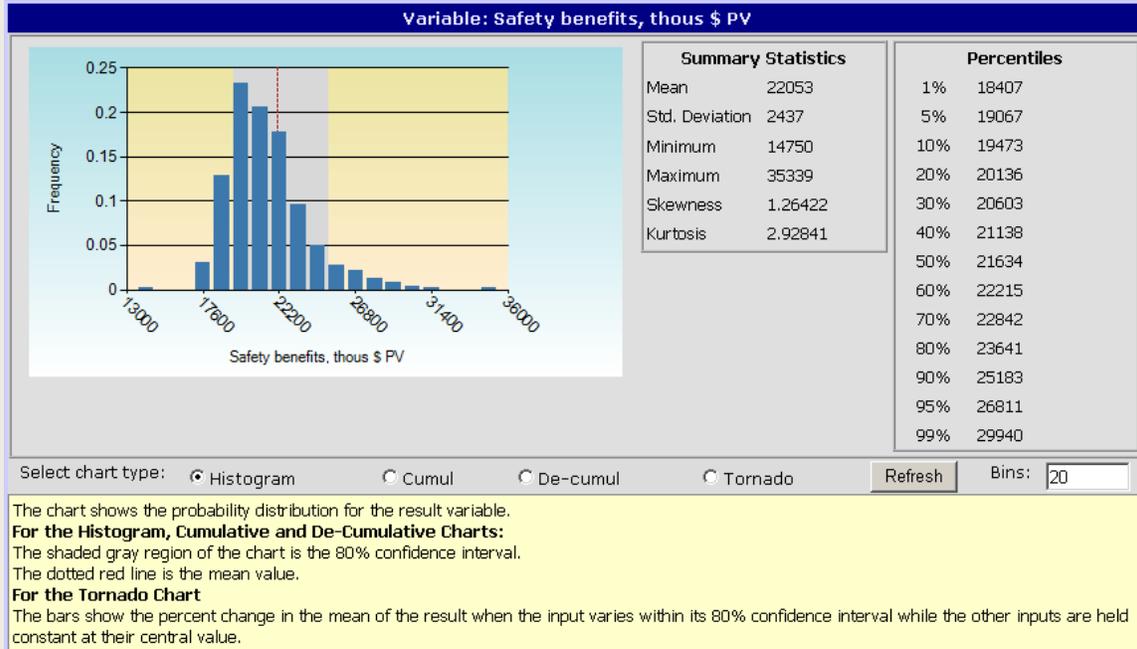
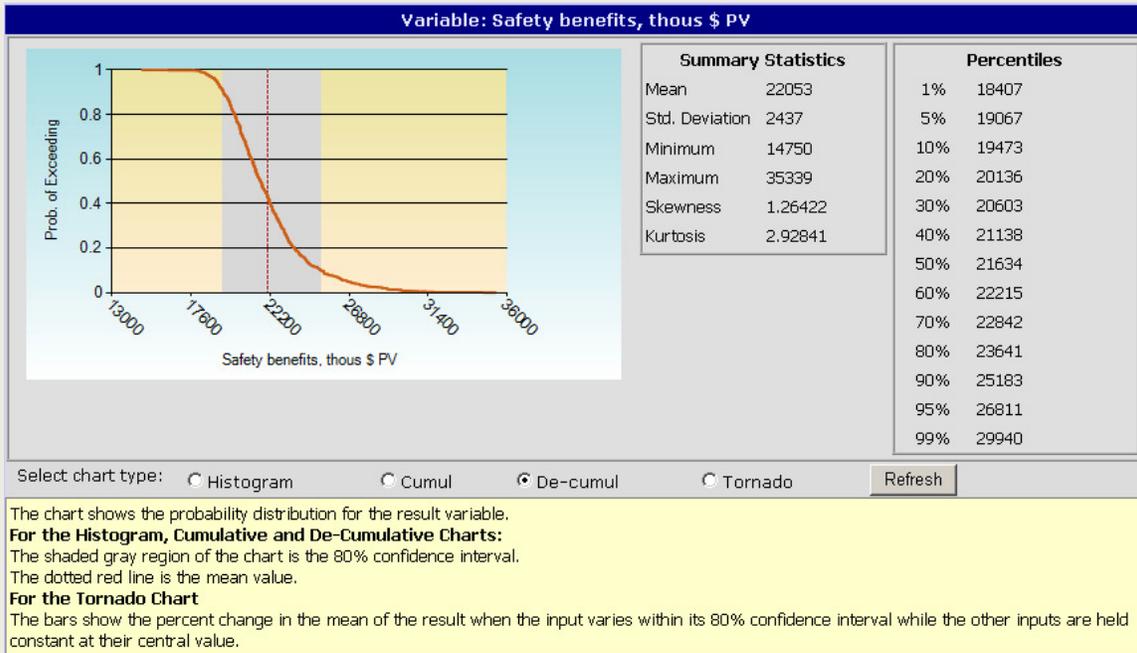
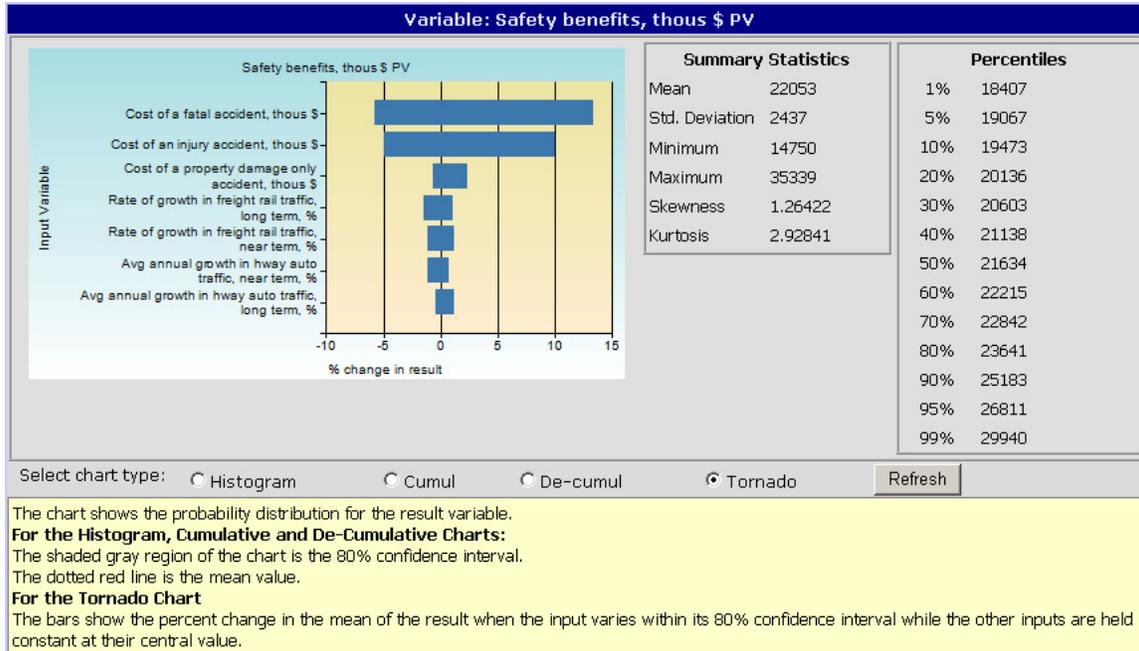


Figure 29 De-Cumulative Probability Chart of Safety Benefits



The tornado chart shows that most of the variability in the safety benefit is due to the variability in the social costs. The variability in the traffic growth forecasts also contribute to the variability of the outcome.

Figure 30 Tornado Chart of Safety Benefits



MODULE 10 NON-SAFETY BENEFITS

10.1 Introduction

In this section we examine the non-safety benefits from grade crossing improvements. GradeDec.NET evaluates the benefits due to reduced queuing at crossings. Reduced (or increased) queuing and motor vehicle delay can occur in a corridor if there is at least one closed or grade separated grade crossing.

In the case of closure, GradeDec.NET assigns the traffic from the closed crossing to adjacent crossings.

For an improvement of grade separation, if adjacent crossings are sufficiently close to the grade separated crossing, some traffic will divert towards the grade separated crossing. Thus, in addition to the reduced delay of the base case traffic at the grade separated crossings, the drawing of traffic away from queues at other crossings will further reduce queuing in the corridor.

Queuing of highway vehicles, and the changes in queuing that result from crossing improvements, results in the following benefits (disbenefits) for reduced (increased) queuing:

Travel time savings

Vehicle operating cost savings

Emissions reductions

Network delay savings

10.2 Overview

This overview provides a brief description of the calculation of the non-safety benefits:

The railroad operating characteristics (train speed, train length, average car length) in the corridor determine the crossing closure time.

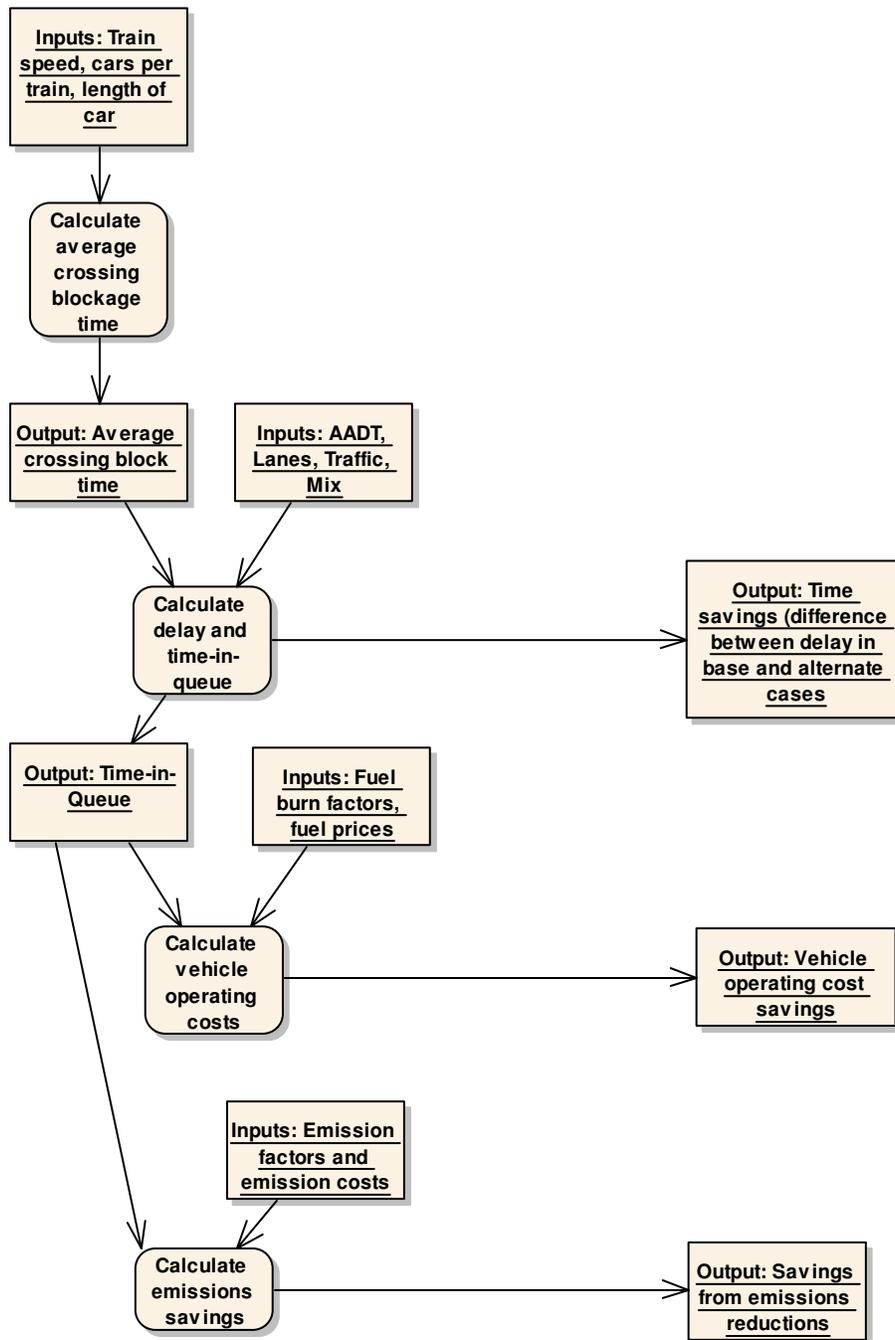
The highway operating characteristics (lanes, AADT, traffic mix) determine the queuing at the crossings, the delay and the time-in-queue.

The delay and the vehicle mix enable the calculation of the changes in delay and travel times.

The time-in-queue enables the calculation of the vehicle operating costs and the emissions from idling while queuing at the crossings.

Network delay (highway network impacts not including the queued vehicles at the crossing) is imputed by the relationship of queue length to the distance from the nearest intersection to the crossing.

Table 11 Overview of Process for Calculating Non-Safety Benefits



10.3 Queuing Model in GradeDec.NET

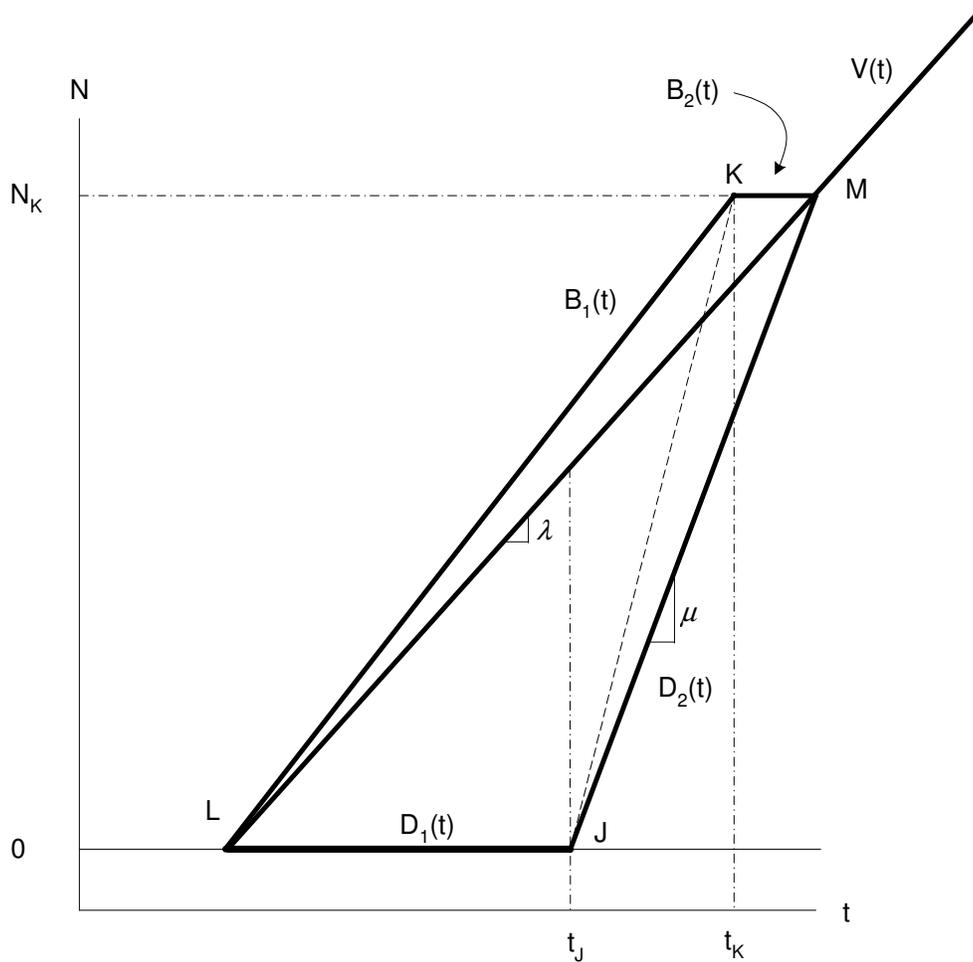
Accurate estimates of the non-safety benefits due to grade crossing investments depend upon properly quantifying the time highway vehicles spend queued behind closed gates. Most often, the conventional time-space model developed in the 1985 Highway Capacity Manual¹ is used to estimate highway vehicle delay associated with grade crossings. This approach can be time consuming and does not lend itself to easily identifying distinct values for “delay” and “time in queue”. Delay, or the difference in travel time caused by blocked grade crossings, is the appropriate measure for estimating all time-related benefits. However, when estimating benefits associated with reduced energy consumption and emissions, the appropriate measure to use is the time spent in queue.

Recent work² has remapped the conventional time-space queuing model into a graphical construct plotting the cumulative vehicles in queue against time. With some relatively unrestrictive simplifying assumptions, time-in-queue is derived as a multiple of delay. Both highway delay and time in queue are readily calculated using easy-to-obtain data. The analysis framework is shown in Figure 1.

¹ *Highway Capacity Manual 2000*, Transportation Research Board, Washington, DC, 2000.

² *Using Input-Output Diagram to Determine Spatial and Temporal Extents of Queue Upstream of a Bottleneck*, Tim Lawson, David J. Lovell, and Carlos F. Daganzo, Transportation Research Record 1572. pp. 140-147.

Figure 31 Model for calculating delay and time-in-queue



10.4 Time Savings

Time savings in GradeDec.NET are the time value of the travelers on the highway mode time the social cost. For each of the traffic segments:

Auto – time savings (base less alternate) equals vehicle-hours of delay times vehicle occupancy times the social cost (value of time).

Truck – time savings (base less alternate) equals vehicle hours times the truck value of time.

Bus – time savings (base less alternate) vehicle-hours of delay times average bus occupancy time the value of time plus the driver’s value of time.

10.5 Vehicle Operating Cost Savings

Vehicle operating cost savings are calculated for each vehicle type (auto, truck and bus). GradeDec.NET includes burn factors for fuel and oil for each vehicle type. The model calculates the quantities of fuel and oil that are consumed by each traffic segment and multiplies by the appropriate cost.

Because there may be significant fluctuations between the general increases in the price level and those of petroleum-based products, GradeDec.NET allows user input for general price increases and oil price increases.

10.6 Reduction in Emissions

The calculations for emissions reductions are similar to those of vehicle operating cost saving. The emissions model is based upon models developed by the Environmental Protection Agency and is based upon the three principal criteria pollutants from the Clean Air Act Amendment – carbon monoxide, nitrous oxides and hydrocarbons.

10.7 Network Delay

The network delay calculation assumes that when queuing at crossings backs into the nearest intersection, some disruption of traffic flow occurs. For crossings that are in close proximity to highway intersections, these network delays can be significant.

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MODULE 11 AGGRAVATING RISK FACTORS

11.1 Introduction

11.1.1 What are “aggravating risk factors”?

GradeDec.NET calculates grade crossing predicted accidents using the US DOT Accident Prediction and Severity (APS) model (and, alternately, the HSR Model). Five-year accident history is the main predictor of future accidents in the accident prediction model, but 94% of the public at-grade crossings have had no accidents in the past five years. The accident severity model is limited to data housed within the National Grade Crossing Inventory Database, which does not include site specific information like proximity to hazardous material storage facilities. As a result, states have had a very difficult time ranking safety among crossings with like attributes according to the APS models. To remedy this situation, the FRA has conducted research to identify “aggravating risk factors” that can be easily observed at individual grade crossings and that increase the probability and severity of an accident.

11.2 Adding Aggravating Risk Factors to Crossings

From the navigation menu, click on “Crossings” to browse to the Crossings Page. Click on the ‘APS model’ tab, click “Edit” and set the “Include aggravating risk factors?” option to “True” by checking the checkbox. When set to True, the format of the Crossings page will include the “Aggravating Risk” tab and options:

Figure 32 Crossings Page - Aggravating Risk Factors - Base Case

Select data to view / edit:		GENERAL	Devices	Highway	Rail	Cost	APS model	HSR model	
Data for the crossing MP:132.18 ID:289086M									
Select data to view / edit:		BASE CASE	Alternate Case						Edit
1. Sight Distance Factors									
Quadrant sight distances	All quads clear								
Stop line sight									
Is sight distance from either stop line > 1896 feet? (Given maximum timetable speed 79 mph)	Yes								
2. Alignment and Grades									
Crossing skew in degrees (between roadway and track centerlines)	60 - 90								
Does any approach to the crossing equal or exceed the following grades?	All approaches < 3%								
Is signage in use at the crossing?	Yes								
Public access	Public access is allowed								
Total Aggravating Risk Occurrence Score: 52									
3. Derailment Factors									
Track curvature	Track tangent								
Railroad grade	Less than or equal to 1.5%								
Special Trackwork	No adjacent special trackwork								
4. Obstructions for Collision									
Obstructions within 10 feet of centerline	All quads clear								
Obstructions within 85 feet of centerline	All quads clear								
5. Contributing Factors									
School bus	Non-bus route								
Proximity to water	Not adjacent to water								
Parallel roadway	No adjacent parallel roadway								
6. Fire/Hazmat/Spill/Explosion Factor									
Heavy Trucks	Low percentage trucks								
Industrial Area	Non-industrial area access								
Hazmat storage	No adjacent hazmat storage								
Flammable material storage	No adjacent flammable material								
Total Aggravating Risk Severity Score: 60									

The aggravating risk factors form allows you to enter data for factors for a specific corridor’s base case and alternate case. The factors are divided into those that impact accident occurrence and those that impact accident severity, and these can be set for both the base and alternate cases.

The factors for occurrence are: 1) Sight Distance, and 2) Alignment and Grades.

The factors for severity are: 1) Derailment, 2) Obstructions for Collisions, 3) Contributing factors, and 4) Fire/Hazmat/Spill and Explosion.

If you click edit, you will have access to dropdown menus for each of the above sections.

For the base and alternate case, this tab also displays the Total Aggravating Risk Occurrence score and the Total Aggravating Risk Severity score.

Depending upon the values set for these factors, there will be a score between 0 and 60 for occurrence and a score between 0 and 60 for severity. For an occurrence score of 0, the total predicted accidents will be 1.3 times as great as without considering aggravating factors. For a

score of 60 the total predicted accidents will be 0.7 times as without considering aggravating factors.

For a severity score of 0, the total share of casualty (fatal and injury) accidents will be 1.3 times as great as without considering aggravating factors. For a score of 60 the share of casualty accidents will be 0.7 times as without considering aggravating factors.

11.3 Applying Aggravating Risk Factors to Case Study 2

11.3.1 Copy Previous Corridor Data and Create New Result Set

After opening your browser to GradeDec.Net you should find yourself on the “**Settings**” page. Make sure that the IL Workshop dataset is the selected dataset. Click on the “Create New Corridor” link that is on the right side of the page next to the corridor selection drop-down menu. After clicking, the browser will show a new page “Create New Corridor”. Select the option “Create a new corridor by copying an existing corridor in the dataset” and select the “Champaign, IL” corridor from the dropdown list. Then, enter a new name for the corridor in the “Name of the new corridor” text box and click “Submit”. You should be redirected back to the “**Settings**” Page and verify that your new corridor is selected.

Click on the ‘Results’ tab in the center of the “**Settings**” page, and click “Create New Results Set”. The browser will show a new page “Create New Results Set”. Enter a name in the text box and click “Submit” to create a new result set for the Aggravating Risk Factors.

Browse to the Crossings Page using the Navigation Bar. Select crossing 17 (ID 289108K, MP 145.43). Let’s change its alternate case device to Gates with no Supplementary Safety Measure (i.e., no change from the base case). The only changes for the crossing should be those due to mitigating aggravating risk factors.

Click on the ‘Aggravating Risk’ tab of the toolbar and select the base case (Click on the ‘Base’ tab of the toolbar at the center of the page) and then click on the “Edit” button to edit the data.

Make the following changes:

- Change “Quadrant Sight Distance” value to ‘Four Quadrants Restricted’
- Change "Is sight distance from either stop line > 2160 feet? (Given maximum timetable speed 90 mph)" value to 'No'
- Change "Does any approach to the crossing equal or exceed the following grades?" value to '10% or greater or humped'
- Change "Is signage in use at the crossing?" value to 'No'
- Change "Railroad Grade" value to 'Greater than 1.5%'
- Change "Obstructions within 10 feet of centerline" value to 'Four quads obstructed'
- Change "Obstructions within 85 feet of centerline" value to 'Four quads obstructed'
- Change "School bus" value to 'Potential bus route'
- Change "Parallel roadway" value to 'Adjacent parallel roadway'
- Change "Heavy trucks" value to 'High percentage trucks'

- Change "Industrial area" value to 'Industrial area access'
- Change "Hazmat storage" value to 'Adjacent hazmat storage'
- Change "Flammable material storage" value to 'Adjacent flammable material'

Click 'Update' when finished. The occurrence score should change to '10' and the severity score should now be '11' (See Figure 31).

Now select the alternate case by clicking on the "Alternate" tab on the toolbar. The occurrence score should already be '52' and the severity score should be '60' (See Figure 32). Make no changes to the Alternate Case.

Figure 33 Aggravating Risk Tab Screenshots - Base Case

Select data to view / edit:		BASE CASE	Alternate Case	Edit
1. Sight Distance Factors				
	Quadrant sight distances		Four quads restricted	
	Stop line sight			
	Is sight distance from either stop line > 2160 feet? (Given maximum timetable speed 90 mph)		No	
2. Alignment and Grades				
	Crossing skew in degrees (between roadway and track centerlines)		60 - 90	
	Does any approach to the crossing equal or exceed the following grades?		10% or greater or humped	
	Is signage in use at the crossing?		No	
	Public access		Public access is allowed	
Total Aggravating Risk Occurrence Score: 10				
3. Derailment Factors				
	Track curvature		Track tangent	
	Railroad grade		Greater than 1.5%	
	Special Trackwork		No adjacent special trackwork	
4. Obstructions for Collision				
	Obstructions within 10 feet of centerline		Four quads obstructed	
	Obstructions within 85 feet of centerline		Four quads obstructed	
5. Contributing Factors				
	School bus		Potential bus route	
	Proximity to water		Not adjacent to water	
	Parallel roadway		Adjacent parallel roadway	
6. Fire/Hazmat/Spill/Explosion Factor				
	Heavy Trucks		High percentage trucks	
	Industrial Area		Industrial area access	
	Hazmat storage		Adjacent hazmat storage	
	Flammable material storage		Adjacent flammable material	
Total Aggravating Risk Severity Score: 11				

Figure 34 Aggravating Risk Tab Screenshots - Alternate Case

Data for the crossing MP:145.43 ID:289108K	
<div style="display: flex; justify-content: space-between; align-items: center;"> Select data to view / edit: <div style="display: flex; gap: 5px;"> Base Case ALTERNATE CASE </div> Edit </div>	
1. Sight Distance Factors	
Quadrant sight distances	All quads clear
Stop line sight	
Is sight distance from either stop line > 2160 feet? (Given maximum timetable speed 90 mph)	Yes
2. Alignment and Grades	
Crossing skew in degrees (between roadway and track centerlines)	60 - 90
Does any approach to the crossing equal or exceed the following grades?	All approaches < 3%
Is signage in use at the crossing?	Yes
Public access	Public access is allowed
Total Aggravating Risk Occurrence Score: 52	
3. Derailment Factors	
Track curvature	Track tangent
Railroad grade	Less than or equal to 1.5%
Special Trackwork	No adjacent special trackwork
4. Obstructions for Collision	
Obstructions within 10 feet of centerline	All quads clear
Obstructions within 85 feet of centerline	All quads clear
5. Contributing Factors	
School bus	Non-bus route
Proximity to water	Not adjacent to water
Parallel roadway	No adjacent parallel roadway
6. Fire/Hazmat/Spill/Explosion Factor	
Heavy Trucks	Low percentage trucks
Industrial Area	Non-industrial area access
Hazmat storage	No adjacent hazmat storage
Flammable material storage	No adjacent flammable material
Total Aggravating Risk Severity Score: 60	

11.4 Predicted Accidents with Aggravating Risk Factors and Their Mitigation

The predicted accidents without the aggravating risk mitigation (base case) and the predicted accidents with mitigation (alternate case) are shown in the following figure:

Figure 35 Effects of Mitigating Aggravating Risk Factors

Crossings in the Corridor

Select a crossing to view or edit:

17. MP:145.43 ID:289108K IC - HA1/MILLA GROVE R

18. MP:146.45 ID:289110L IC -

19. MP:147.44 ID:289112A IC - 1250N

20. MP:148.45 ID:289113G IC - 1150N

21. MP:149.45 ID:289114N IC - N LINE ST

22. MP:152.6 ID:289116C IC - 750N

23. MP:154.11 ID:289118R IC - 600N

24. MP:155.11 ID:289119X IC - 500N

25. MP:156.15 ID:289120S IC - 400N

26. MP:157.15 ID:289121Y IC - WELL HOUSE RD

Go

↑

↓

Enter "Delete Crossings" mode

Select data to view / edit: General Devices Highway Rail Cost APS MODEL Aggravating risk HSR model

Data for the crossing MP:145.43 ID:289108K Edit

	Item	Value
Edit all	Number of accidents in previous five years at the crossing	0
Edit all	Include aggravating risk factors?	True

Edit to modify the data for the selected crossing.
NOTE: Click "Go" to refresh the data after "Edit all" or "Quick Import"

[Recalculate](#) [Show Chart](#)

This Crossing			Corridor Summary	
	Base	Alt	Base	Alt
Fatal	0.006414	0.002453	0.755111	0.485850
Injury	0.007274	0.002781	1.139498	0.771437
PDO	0.016503	0.006310	2.644685	1.812909
Total	0.030190	0.011543	4.539294	3.070197

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