
GradeDec.NET

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Training Course and Workbook

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**FEDERAL RAILROAD ADMINISTRATION
 TRAINING COURSE AND WORKBOOK FOR GRADE CROSSING
 IMPROVEMENTS EVALUATION USING GRADEDEC.NET
 VOLUME 2**

TABLE OF CONTENTS

MODULE 7 INVESTMENT ANALYSIS 1

7.1 Introduction..... 1

7.2 General Framework..... 1

7.3 Measures of Economic Worth and Efficiency 2

7.4 Comparing Alternatives 3

7.5 Timing Assumptions 4

7.6 Social Costs 4

7.7 Current, Constant and Present Value Dollars 5

7.8 The Discount Rate..... 5

7.9 Costs and Benefits..... 7

7.10 Costs 7

 7.10.1 Capital 7

 7.10.2 Operating and Maintenance Costs 7

 7.10.3 Lifecycle Costs..... 7

7.11 Benefits..... 8

 7.11.1 Safety (Accident Reduction)..... 8

 7.11.2 Other Benefits 8

 7.11.2.1 Time Savings 9

 7.11.2.2 Vehicle Operating Costs 9

 7.11.2.3 Emissions Reductions and Environmental Benefits 9

 7.11.2.4 Network Delay 9

 7.11.2.5 Benefits/Disbenefits of Induced/Discouraged Demand..... 10

7.12 Case Study Benefit-Cost Analysis 11

 7.12.1.1 Setting Up Your Data..... 12

 7.12.1.2 Create new scenario 12

 7.12.1.3 Modify the scenario data with forecast values and assumptions for
 your analysis 12

7.12.1.4	Verify or modify parameters and other data values	12
7.12.1.5	Set the simulation parameters and run the simulation	13
7.12.1.6	Defining the scenario	13
7.12.1.7	Populating the scenario with data	13
7.12.1.8	View results table and charts, print report	13
7.13	Benefit-Cost Summary for the Case Study.....	13
MODULE 8 NON-SAFETY BENEFITS		15
8.1	Introduction.....	15
8.2	Overview	15
8.3	Queuing Model in GradeDec.NET	17
8.4	Time Savings.....	18
8.5	Vehicle Operating Cost Savings	18
8.6	Reduction in Emissions.....	19
8.7	Network Delay.....	19
MODULE 9 RISK ANALYSIS		29
9.1	Introduction.....	29
9.1.1	What is Risk Analysis?	29
9.1.2	Why Use Risk Analysis in GradeDec.NET	30
9.2	Selecting a Distribution and Populating with Data	30
9.3	Running a Risk Analysis	31
9.4	Reading the Results.....	31
9.5	Comparing Alternatives with Risk Analysis	32
9.6	Using the Tornado Chart to Refine Inputs.....	32
9.7	Result Tables and Charts for the Case Study	32
9.8	Case Study Risk Analysis Results.....	33
MODULE 10 CAPITAL PROGRAMMING.....		35
10.1	Introduction.....	35

10.1.1	What is Capital Programming.....	35
10.2	Creating a Capital Program	35
10.2.1	Changes to the Crossings Page	35
10.2.1.1	Crossing Page – Devices Tab	35
10.2.1.2	Crossing Page – Cost Tab.....	36
10.2.2	Entering Data for the Case Study.....	37
MODULE 11	AGGRAVATING RISK FACTORS.....	43
11.1	Introduction.....	43
11.1.1	What are “aggravating risk factors”?	43
11.2	Adding Aggravating Risk Factors to Crossings.....	43
11.3	Applying Aggravating Risk Factors to the Case Study	45
11.3.1	Copy Previous Greenville Data and Create New Result Set	45
11.4	Predicted Accidents with Aggravating Risk Factors and Their Mitigation..	46
BIBLIOGRAPHY AND SOURCES.....		49

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MODULE 7 INVESTMENT ANALYSIS

7.1 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.

7.2 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” are quantities that may have a positive value to consumers (like induced trips) and 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.

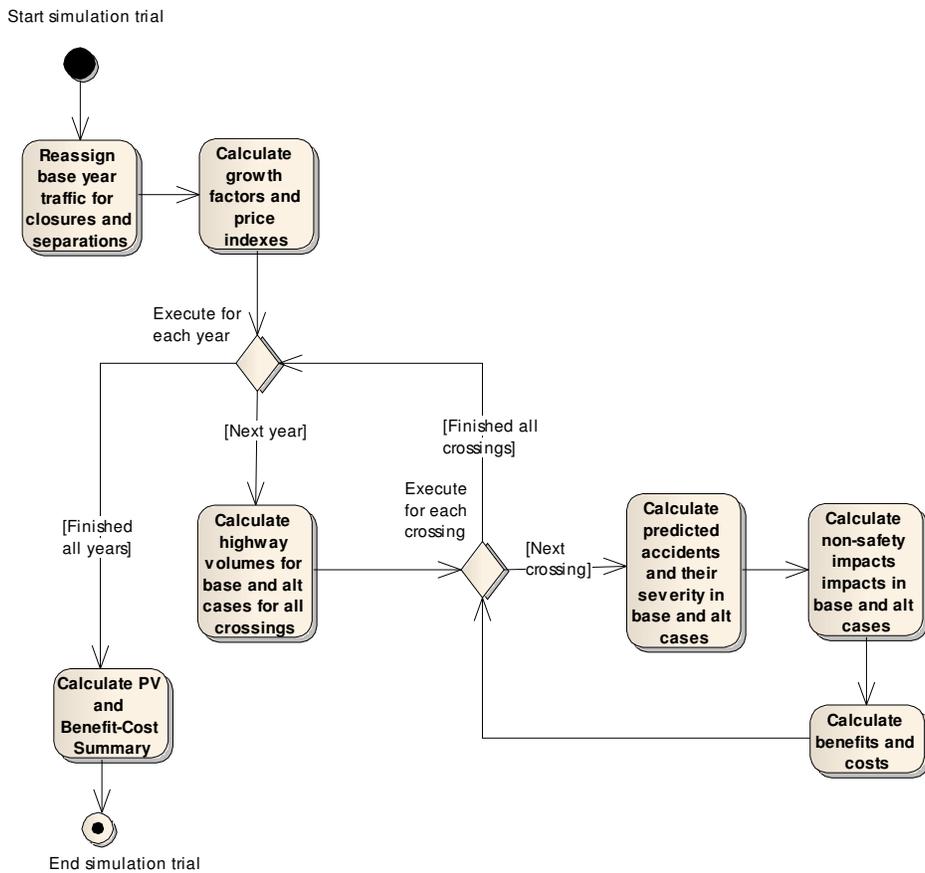
In order to aggregate the benefits across categories and compare them with the costs of capital investment and changes in operating costs, the benefit quantities are monetized (converted to money values) by multiplying them by “social costs”, which are unit prices (see discussion below). In order to 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 1 Investment Analysis Logic Flow in GradeDec.NET



7.3 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 1 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 capturable flow of funds).

7.4 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 and grade crossing. This allows the analyst to target specific problems and refine alternative strategies to quickly and efficiently meet stated investment objectives.

The principal evaluation criteria of GradeDec.NET address overall economic worth. A crossing improvement program's evaluation should be supplemented with qualitative material that informs with regard to overall environmental implication, 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 benefits category and grade crossing. This is useful for honing in on specific problems and refining your alternative so that it best meet objectives while avoiding inefficiencies.

7.5 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.

7.6 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.

7.7 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 – 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*.

7.8 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 2 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.

7.9 Costs and Benefits

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

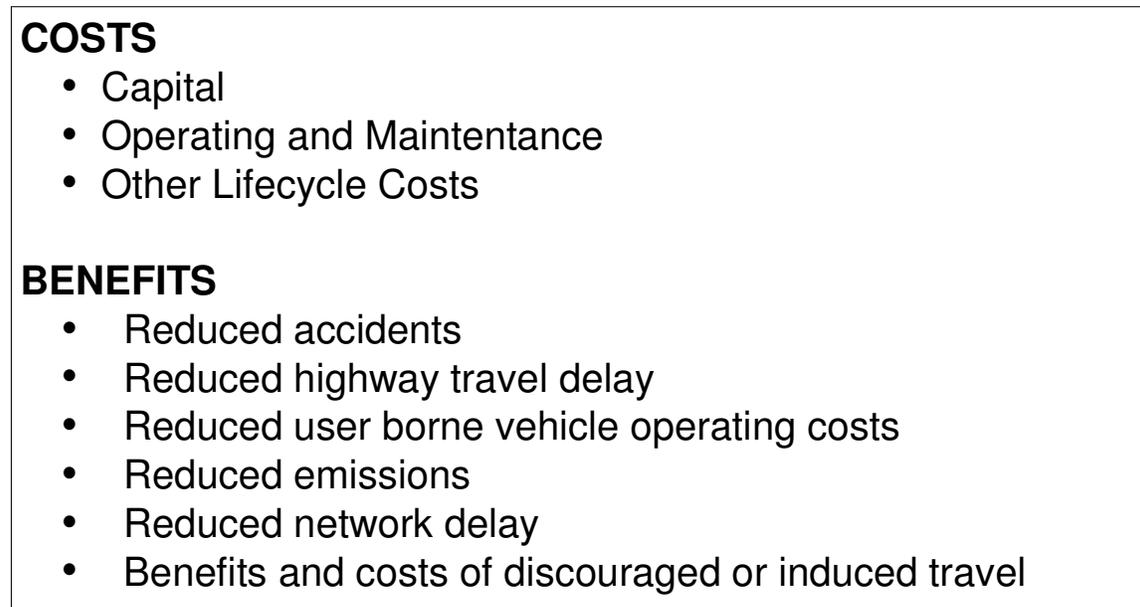


Figure 2 Benefits and Costs in GradeDec.NET

7.10 Costs

7.10.1 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).

7.10.2 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.

7.10.3 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 (i.e., 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.

7.11 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.

Earmarked 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.

7.11.1 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 3 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.

7.11.2 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.

7.11.2.1 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 under two conditions:

Grade separation or closure, or,

Changes in AADT at a crossing due to reassignment given changes at adjacent crossings.

7.11.2.2 Vehicle Operating Costs

Vehicle operating costs benefit accrue when queuing is reduced. The crossing vehicle operating costs are the consumption of fuel and oil by vehicles when queued at a crossing.

7.11.2.3 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 does involve such construction, then conduct the appropriate environmental assessments as 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.

7.11.2.4 Network Delay

Network delay from grade crossings are the impacts of queues at crossings backing into adjacent intersections and thus causing additional delays beyond those of the queued vehicles at the crossing.

7.11.2.5 Benefits/Disbenefits of Induced/Discouraged Demand

By making improvements at crossings a jurisdiction effectively reduces the generalized cost of highway travel - a typical trip over the improved crossing will have lower accident risk and, in some cases, travel time and other delay-related benefits will be realized. While the impact on the total trip cost may be small or negligible, benefit-cost analysis instructs us to account for the benefits from trips that are induced by the reduction in total cost. The traveler's trip-making decision considers only his or her internal cost. However, an induced trip generates external costs (in the form of emissions and added congestion and these costs should be accounted for as well).

The sum of the benefits to existing users and those accruing to new users is called the consumer surplus.

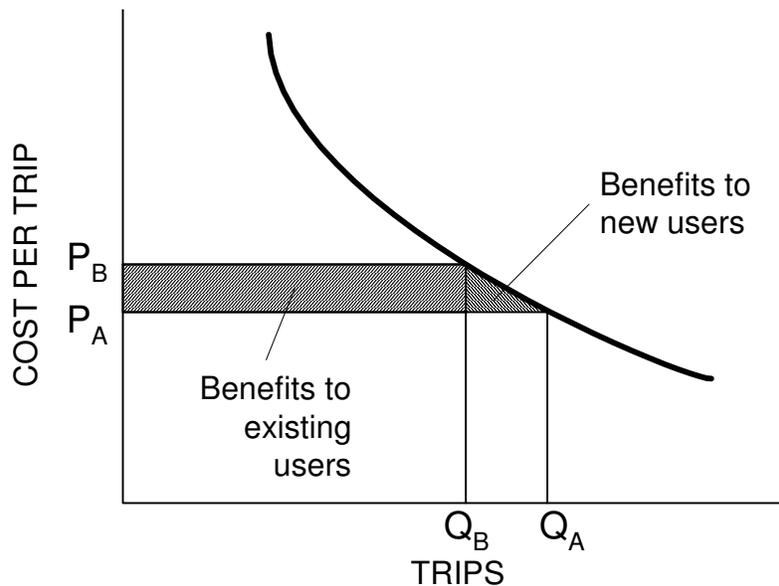


Figure 3 Consumer Surplus and Benefits to New and Existing Users

GradeDec.NET uses two additional parameters to evaluate the benefits of induced demand and the disbenefits from external costs. Values for these parameters are found in the "Highway" section of the scenario data and need to be specified along with the other data in the scenario.

The first value relates travel demand, the quantity of trips, with the generalized cost per trip. The generalized cost per trip is the average cost to the highway user including out-of-pocket costs (fuel, maintenance, etc.) and other user costs (travel time, accident risk). The ratio of the percent change in trips given a percent change in generalized cost is called the demand elasticity with respect to generalized cost. Since demand increases when its cost to the consumer decreases, this elasticity will have a negative value. Studies show this value to be in the range of -.1 to -.05.

The second value that is used to estimate the benefits of induced demand is the percent of user borne trip cost (accident risk and delay) due to the crossing. The following example shows how to estimate this value for a specific corridor.

Suppose, for instance, the average trip using the crossing is 5 miles and we know that per mile vehicle operating cost (without the crossing) is \$0.10¹ per mile, travel time cost is \$0.22 per mile and accident risk cost is \$0.04. Suppose also that the average trip faces a 10% probability of a 2-minute delay at the crossing and a 1 in 10 million chance of a collision. The calculation of the percent of user borne trip cost is shown in the table below.

In most cases, the benefits of induced demand comprise a very small share of the total benefits.

Note that induced demand in GradeDec.NET only affects the automobile segment of highway traffic.

Table 4 Sample Calculation of the Average Percent of Trip Cost at Crossing for a Highway User

Vehicle operating cost per mile (dollars)	0.10
Travel time cost per mile	0.22
Accident risk cost per mile	0.04
Number of miles of average trip	10
Trip cost without crossing (dollars)	3.62
Probability of delay	5%
Duration of delay (minutes)	2
Value of time (dollars / hour)	10.00
Vehicle operating cost of delay (dollars / hour)	1.20
Crossing delay cost (dollars)	0.037
Probability of accident at crossing	0.00001%
Cost of accident - average severity (dollars)	200000
Crossing accident risk cost	0.020
Total crossing cost of trip	0.057
Total cost of trip	3.680
Percent of trip cost at crossing	1.6%

7.12 Case Study Benefit-Cost Analysis

The data in the previous section are all entered from the Corridor Crossings Page. With this data alone, the user can conduct safety impact analyses from within this form. The user can view a ranking of the crossings for the base case and the alternate case, generate reports and evaluate the corridor-wide safety impacts.

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.

¹ This value is representative for many conditions. It includes fuel, oil, tire wear and maintenance, accident risk and use depreciation. It does not include insurance, time depreciation or other fixed costs of car ownership.

7.12.1.1 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.

7.12.1.1.1 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 “CSX Greenville, 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.

7.12.1.2 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. You can leave the year settings (Start year: 2009, last year near term: 2013, end year: 2033) at their default values, or modify them if you wish. 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., Lincoln 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.

7.12.1.3 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.

7.12.1.4 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.

7.12.1.5 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**. 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.

7.12.1.6 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.

7.12.1.7 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.

7.12.1.8 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.

7.13 Benefit-Cost Summary for the Case Study

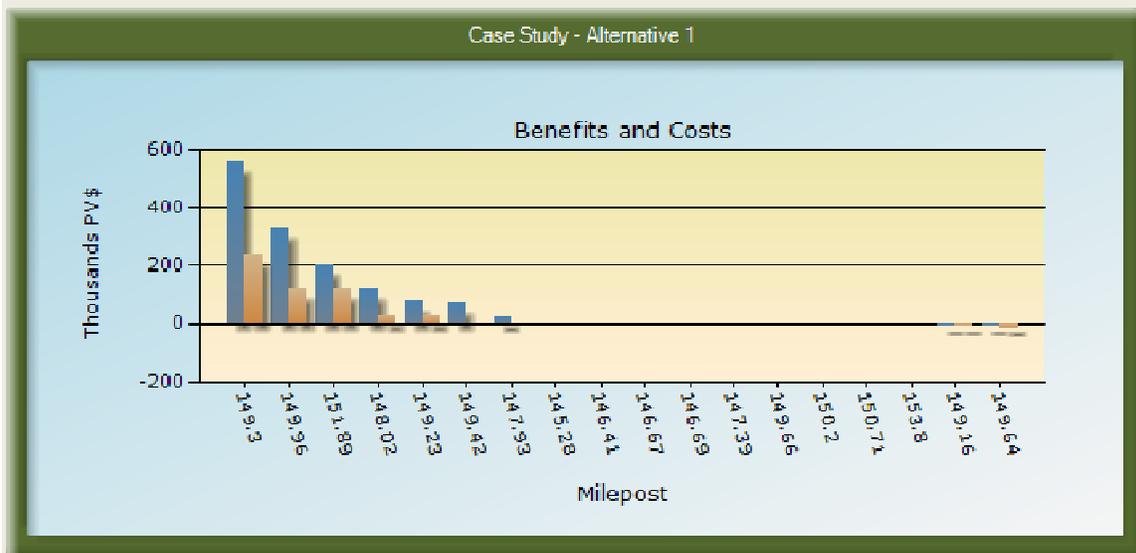
The following table shows the benefit cost summary. The summary shows that most of the benefits are from safety. There is a net disbenefit for time savings and user costs due to the re-routing of traffic from closed crossings. The benefit-cost summary chart shows that all of the improved crossings had benefits that strongly exceeded the costs. The net benefit from the improvements was \$896 thousand and the benefit-cost ratio was 2.757.

Moreover, the risk analysis results show that the improvement will almost certainly result in positive net benefits.

Figure 4 Benefit-Cost Summary for Case Study

Results: Case Study - Alternative 1			
Selected results data group: Benefits and Benefit-Cost Summary			
Variable	Mean Value	Standard Deviation	
Safety benefits, thous \$ PV	1383.619	211.436	View
Travel time savings, thous \$ PV	-19.462	3.54934	View
Environmental benefits, thous \$ PV	-0.093	0.027856	View
Veh operating cost benefit, thous \$ PV	-1.267	0.198227	View
Network benefits, thous \$ PV	-0.062	0.046195	View
Total benefits, thous \$ PV	1405.673	211.455	View
of this, benefits from induced trips, thous \$ PV	0.429	0.088308	View
of this, disbenefits from induced trips, thous \$ PV	-0.370	0.085585	View
of this, investment salvage value, thous \$ PV	42.879	0	View
Total costs, thous \$ PV	509.813	0	View
Net benefits, thous \$ PV	895.860	211.455	View
Benefit-cost ratio	2.757	0.41477	View
Rate of return (constant dollars), %	19.965	3.65638	View
Local benefits (not included in summary), thous \$ PV	70.316	24.637	View

Figure 5 Summary Chart of Benefits and Costs



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

MODULE 8 NON-SAFETY BENEFITS

8.1 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

8.2 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.

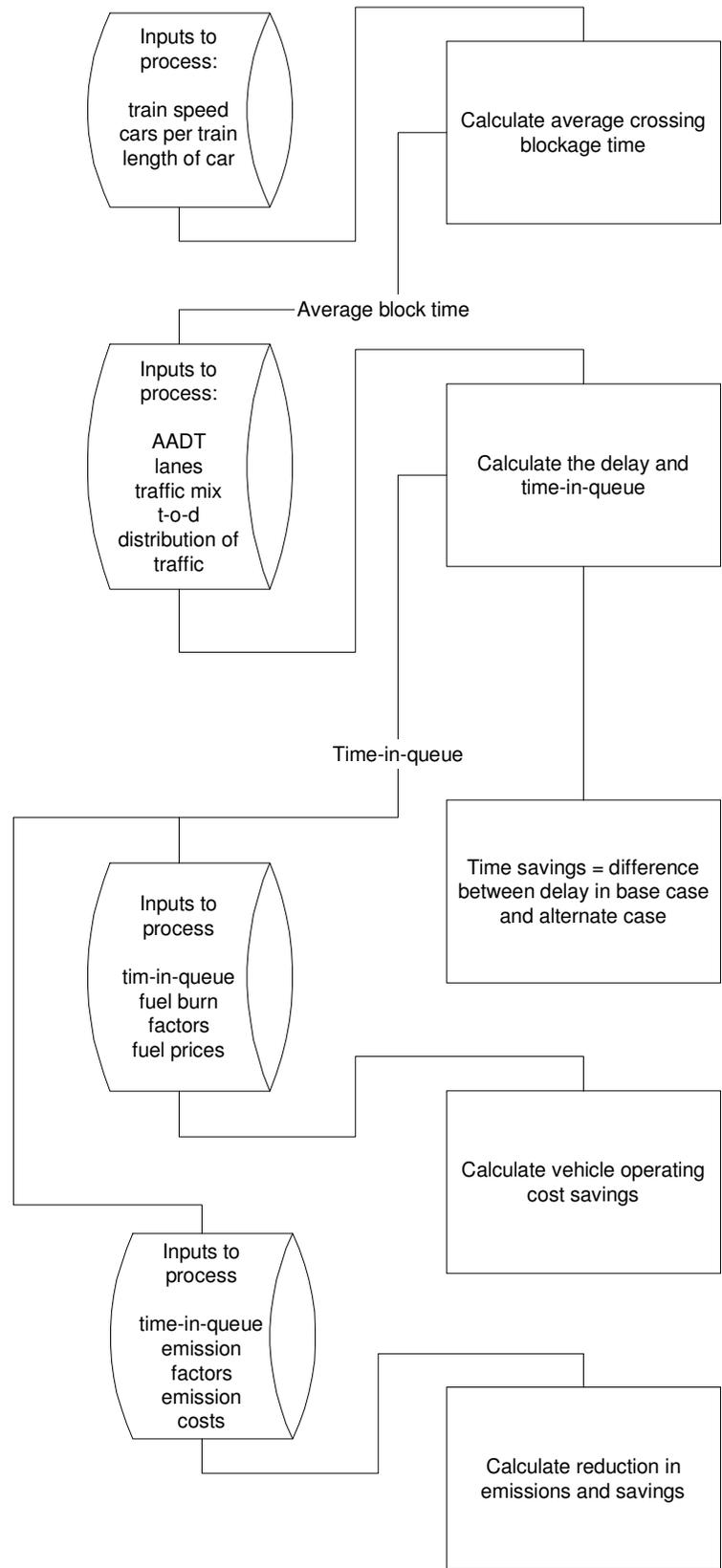
The highway operating characteristics (lanes, AADT, traffic mix) determine the queuing at the crossings, the delay and the time-in-queue.

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 5 Overview of Process for Calculating Non-Safety Benefits



8.3 Queuing Model in GradeDec.NET

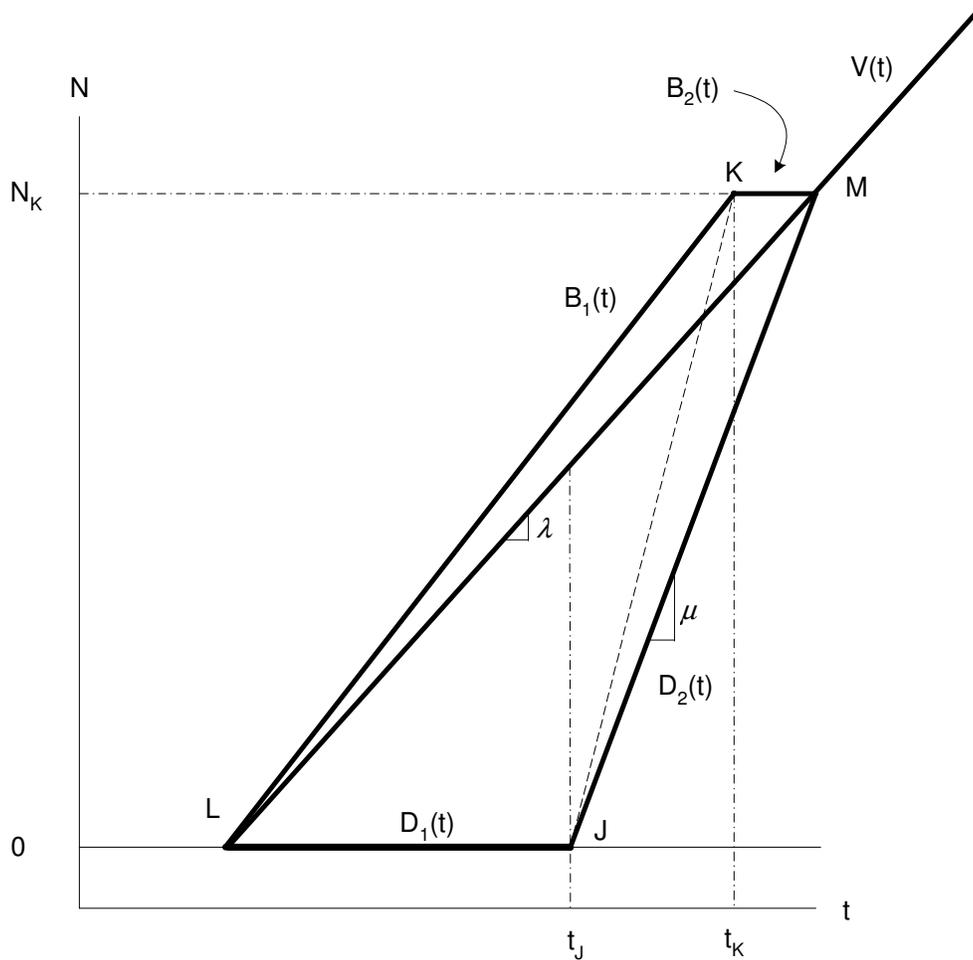
Accurate estimates of the non-safety benefits due to grade crossing investments depend upon properly quantifying the time highway vehicles spend queued behind closed gates. Most often, the conventional time-space model developed in the 1985 Highway Capacity Manual² is used to estimate highway vehicle 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 work³ 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.

² *Highway Capacity Manual 2000*, Transportation Research Board, Washington, DC, 2000.

³ *Using Input-Output Diagram to Determine Spatial and Temporal Extents of Queue Upstream of a Bottleneck*, Tim Lawson, David J. Lovell, and Carlos F. Daganza, Transportation Research Record 1572, pp. 140-147.

Figure 6 Model for calculating delay and time-in-queue



8.4 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.

8.5 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.

8.6 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.

8.7 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.

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 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 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 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 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																								
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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	$\frac{d(\textit{Back of queue})}{dt} = \frac{\textit{arrival rate} * \textit{freeflow speed} * \textit{traffic density}}{\textit{freeflow speed} * \textit{traffic density} - \textit{arrival rate}}$ $= \frac{0.0642 * 45 * (5280 / 3600) * 0.05}{45 * (5280 / 3600) * 0.05 - 0.0642}$ $= 0.0655 \text{ feet / second}$																								
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																							
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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>																								

**ANALYSIS WORKSHEETS
NON-SAFETY BENEFITS (Module 8)
E. Calculate VOC Savings**

STEPS	SOURCE OR EQUATION																								
E1. Determine total daily time-in-queue 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>0.94 veh-hrs</td> <td>for all 4 periods in the</td> </tr> <tr> <td>Truck</td> <td>0.27 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	0.94 veh-hrs	for all 4 periods in the	Truck	0.27 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	0.94 veh-hrs	for all 4 periods in the																							
Truck	0.27 veh-hrs	day.																							
Bus	0.02 veh-hrs																								
Alt Case																									
Auto	0 veh-hrs																								
Truck	0 veh-hrs																								
Bus	0 veh-hrs																								
E2. Determine idle burn rates	<table> <tr> <td></td> <td>Fuel</td> <td>Oil</td> </tr> <tr> <td>Auto</td> <td>.00969</td> <td>.00063</td> </tr> <tr> <td>Truck</td> <td>.01841</td> <td>.00134</td> </tr> <tr> <td>Bus</td> <td>.02067</td> <td>.00119</td> </tr> </table>		Fuel	Oil	Auto	.00969	.00063	Truck	.01841	.00134	Bus	.02067	.00119												
	Fuel	Oil																							
Auto	.00969	.00063																							
Truck	.01841	.00134																							
Bus	.02067	.00119																							
E3. Determine fuel and oil costs	<table> <tr> <td>Gasoline</td> <td>1.59</td> <td>\$/gal</td> </tr> <tr> <td>Diesel</td> <td>1.43</td> <td>\$/gal</td> </tr> <tr> <td>Oil</td> <td>3.76</td> <td>\$/qt</td> </tr> </table>	Gasoline	1.59	\$/gal	Diesel	1.43	\$/gal	Oil	3.76	\$/qt															
Gasoline	1.59	\$/gal																							
Diesel	1.43	\$/gal																							
Oil	3.76	\$/qt																							
E4. Calculate quantities of fuel and oil saved by traffic segment	<p>Fuel saved=veh-hrs time-in-queue reduction* 60 * fuel burn rate Oil saved = veh-hrs time-in-queue reduction * 60 * oil burn rate</p> <p><u>Fuel</u> Auto = 0.94 * 60 * .00969 = 0.55 gal Truck = 0.27 * 60 * .01841 = 0.30 gal Bus = 0.02 * 60 * .02067 = 0.03 gal</p> <p><u>Oil</u> Auto=0.94*60 * .00063 = .00059 qt Truck = 0.27*60*.00134=.00036 qt Bus = 0.02 * 60 *.00119 = .00003 qt</p>																								
E5. Calculate value of fuel and oil saved	<p>Value of Fuel Saved =Sum(Fuel)*Price Value of Oil Saved =Sum(Oil)*Price Value of fuel saved=(0.55+0.03)*1.59+0.3*1.43=\$1.3468 Value of oil saved=(.00059+.00036+.00003)*3.76=\$0.0037 Total daily vehicle operating cost savings = \$1.35 Total annual VOC savings = \$1.35*280=\$378.13</p>																								

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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.

High-low forecasts are developed through arbitrarily tweaking the middle result upwards and downwards, or by tweaking several key model variables. While some analyst has offered a judgment that the outcome will “likely” fall in the range between high and low, no real information about the probability of outcomes is offered. The proliferation of alternative outcomes without quantifying what each outcome actually represents may in fact confuse instead of clarify. An equally unfortunate possibility is that the high-low-middle approach falsely lulls decision-makers into believing that the true risks of the forecast have been accounted for.

With sensitivity analysis one input variable is allowed to vary over a range while all other variables are held fixed. This is your classic “what if” analysis, however, in real life variables don’t move one at a time while everything else remains fixed. In this regard the information afforded by a sensitivity analysis is very limited.

Risk analysis offers an alternative approach to dealing with 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).

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

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.

9.3 Running a Risk Analysis

Follow these steps to run a risk analysis:

Enter and verify the data in your corridor definition (Settings Form), crossings (Corridor Crossings Form), scenario definition (Settings Form) and scenario.

Be sure that the corridor, scenario and results file for your analysis are selected (e.g., they show in the “Current Selections” frame).

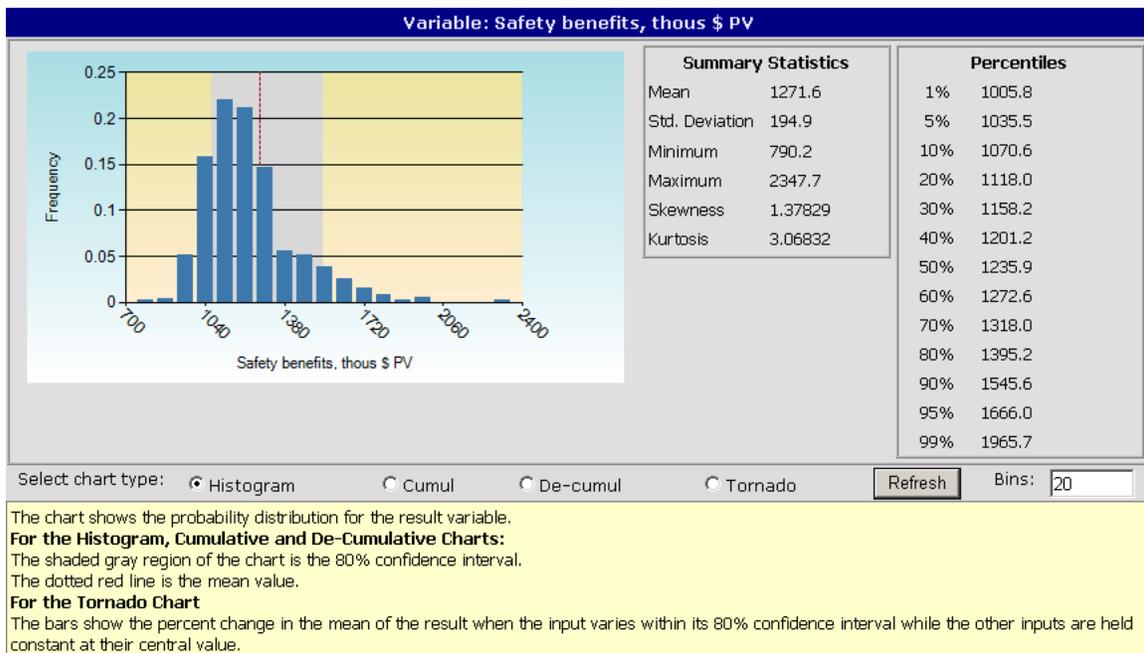
Invoke the simulation form.

Enter the number of trials (51 trials should be adequate for a first cut, use 500 trials for a final analysis). Select whether or not to conduct a risk sensitivity analysis (this feature enables the tornado charts, however, it can be time-consuming).

Click on the “Run Simulation” button.

9.4 Reading the Results

Figure 7 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 \$228,950. 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 \$1,517,100 and \$1,680,600.
- There is a 90 percent probability that the result will exceed \$1,680,600.
- There is a 10 percent probability that the result will exceed \$1,165,100.

9.5 Comparing Alternatives with Risk Analysis

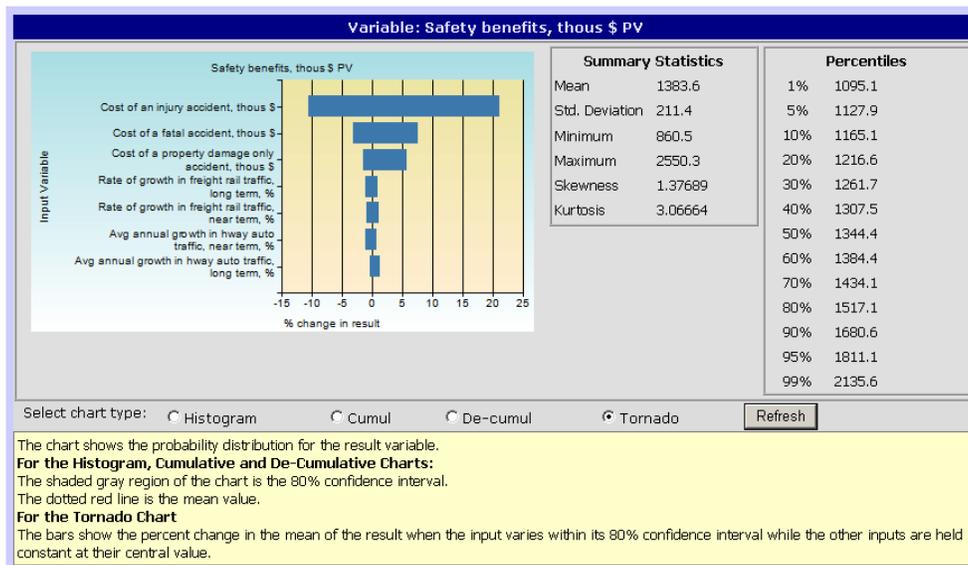
Risk matters. If the anticipated NPV of two alternatives are roughly equal, yet one has much larger downside risk, then the less risk alternative is preferred. The risk analysis of alternatives will typically offer trade-offs between the risk and yield associated with alternatives. In the figure below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

9.6 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.

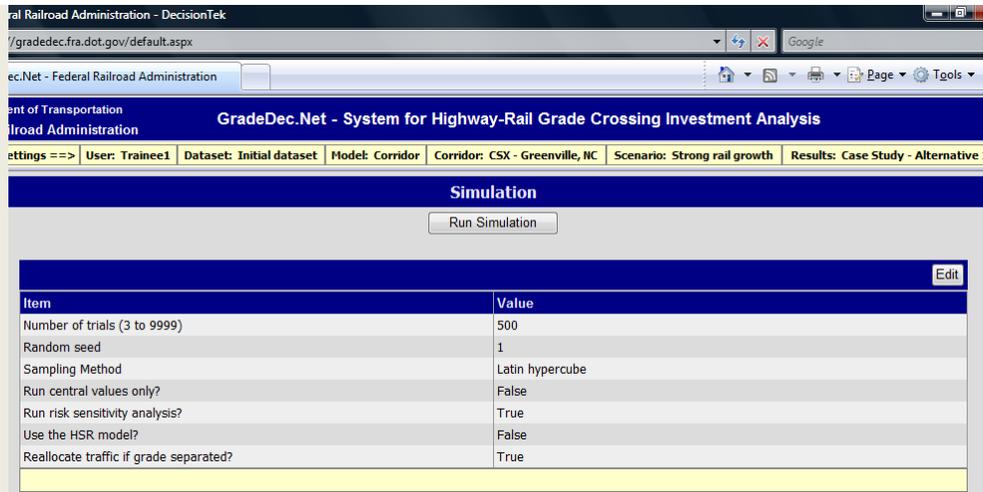
Figure 8 Tornado Chart



9.7 Result Tables and Charts for the Case Study

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

Figure 9 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.

9.8 Case Study 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 10 Histogram of Safety Benefits for Case Study

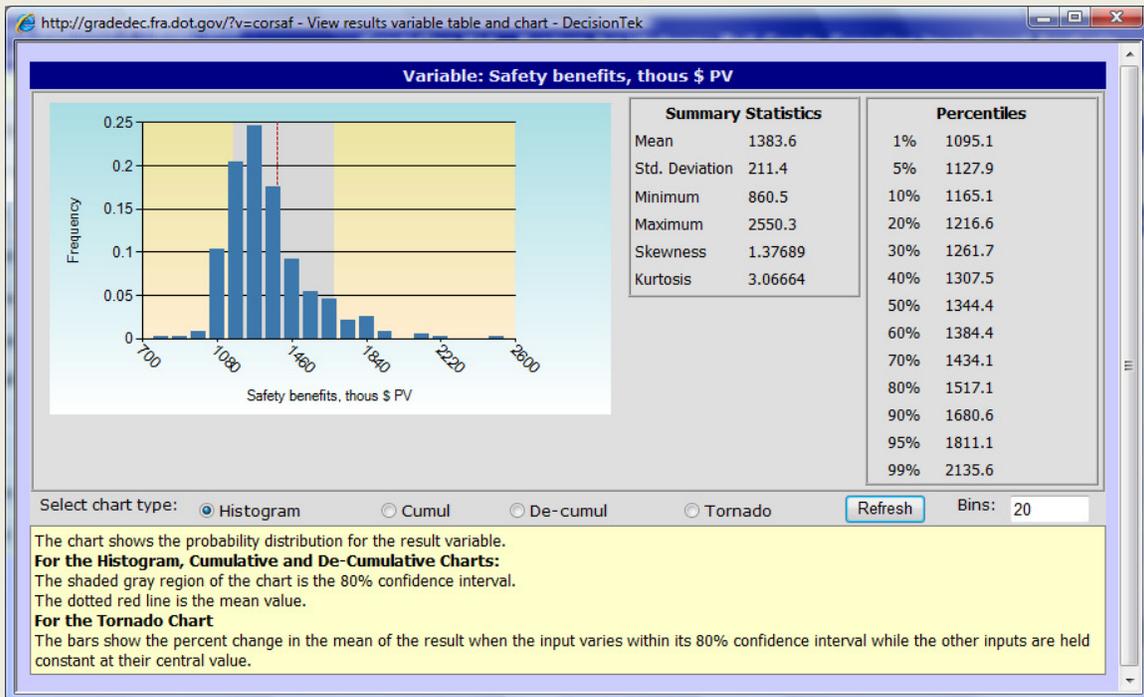
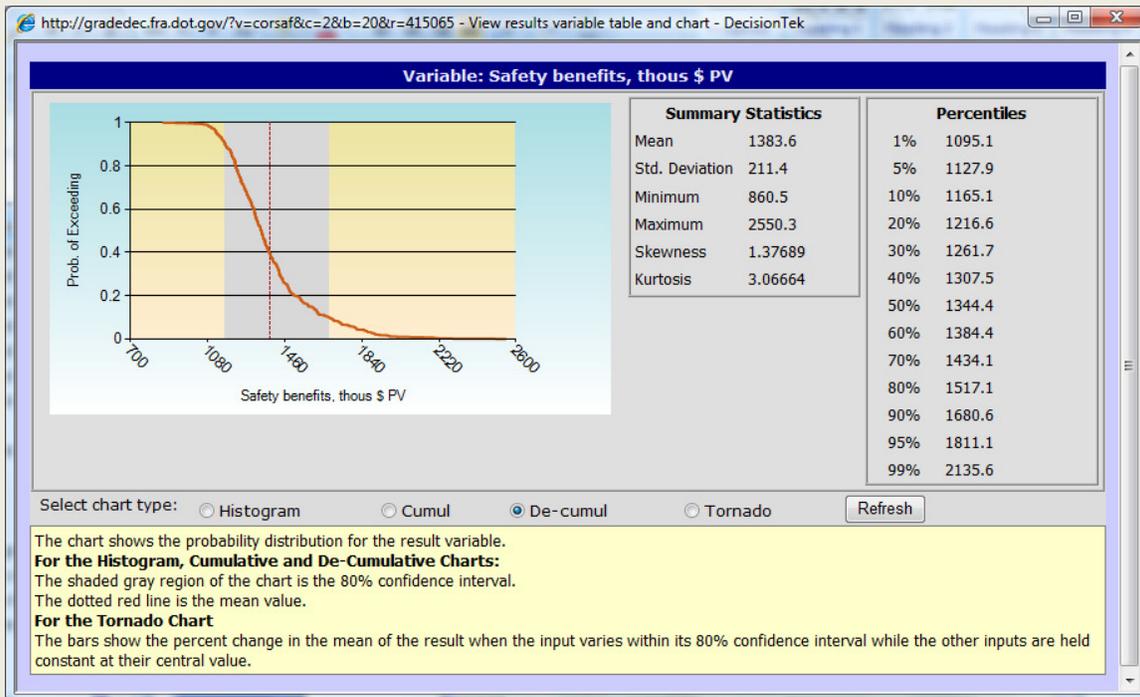
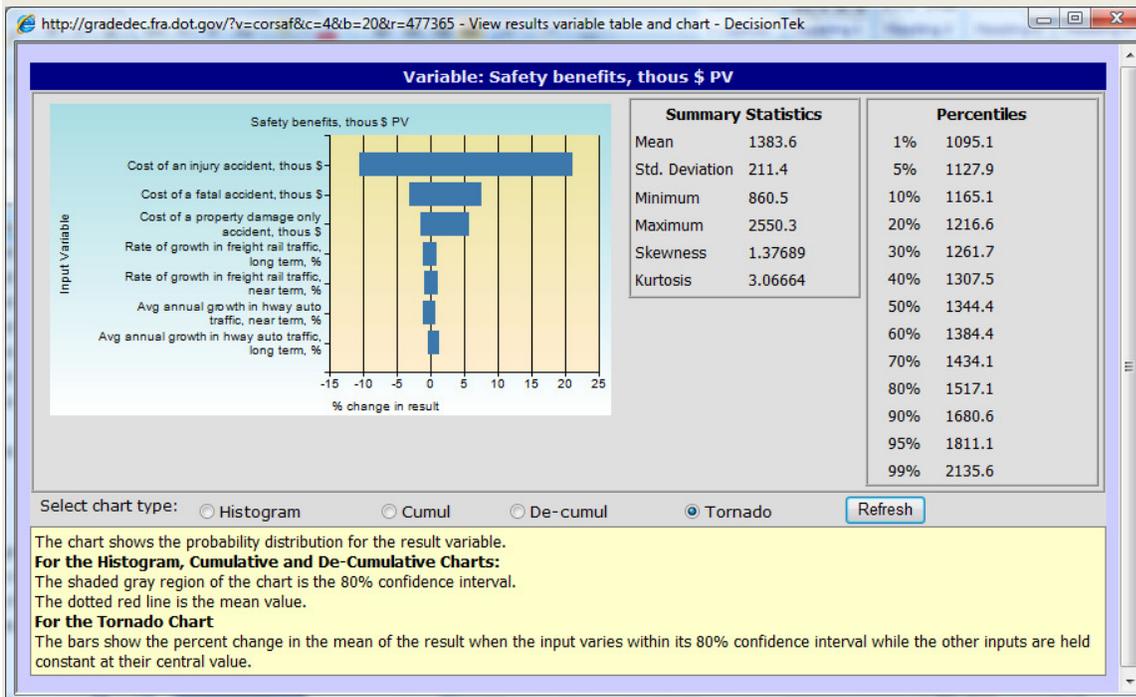


Figure 11 De-Cumulative Probability Chart of Safety Benefits



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 12 Toranodo Chart of Safety Benefits



10.1 Introduction

10.1.1 What is Capital Programming

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.

10.2 Creating a Capital Program

The first step in creating a capital program for a corridor 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”.

10.2.1 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.

10.2.1.1 Crossing Page – Devices Tab

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

Figure 4 – Crossing Page with the Devices Tab Selected in Edit Mode

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	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 are 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).

10.2.1.2 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 improvements.

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 7 - 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".

10.2.2 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 NC 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 “CSX - Greenville, NC” 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 “CSX - Greenville, NC” 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.

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 a crossing 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 to edit the device data for the crossing to (see the figure below).

Figure 10 – Crossings Page with Devices Tab Selected in Edit Mode

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	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.

For each crossing, enter phase I and phase II devices and improvement data to match the data in table below. For each crossing, after data is entered, click on the "Update" button to save and register changes. Note that when the improvement is the same for Phases I and II, this indicates that there is no Phase II improvement.

Table 6 Alternatives for Crossings in Corridor (Phased)

ID	Milepost	Phase I Improvement	Year to Implement Phase I	Phase II Improvement	Year to Implement Phase II
641847B	145.28	Gates	2008	Gates	2009
641850J	146.41	Gates	2008	Gates	2009
641851R	146.67	Gates	2008	Gates	2009
641853E	146.69	Passive	2008	Passive	2009
641857G	147.39	Gates	2008	Gates	2009
641860P	147.93	Gates	2008	Gates	2009
641553R	148.02	Closure	2008	Closure	2009
641557T	149.16	Gates	2008	Gates	2009
641558A	149.23	Gates	2008	Gates	2009
641609H	149.3	Gates + Barrier Curbs	2008	Gates + Barrier Curbs	2009
641610C	149.42	Closure	2008	Closure	2009
641855T	149.64	Lights	2008	Lights	2009
641854L	149.66	Lights	2008	Lights	2009

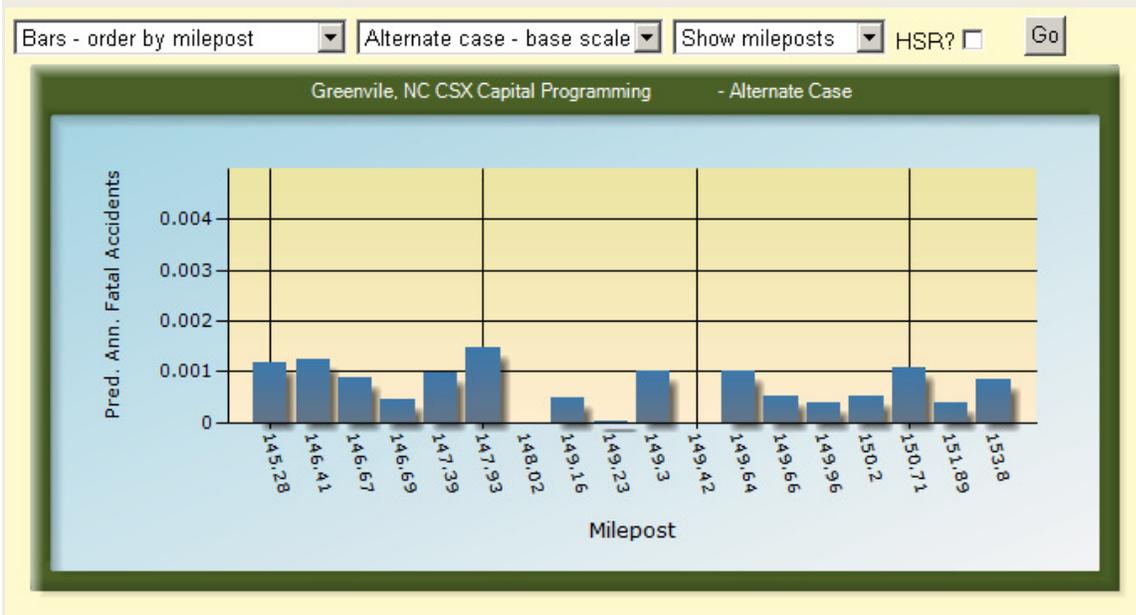
641614E	149.96	Gates + Barrier Curbs	2008	Gates + Barrier Curbs	2009
641615L	150.2	Gates	2008	Gates	2009
642719W	150.71	Gates	2008	Gates	2009
641618G	151.89	Gates	2008	Grade Separation	2012
641620H	153.8	Gates	2008	Gates	2009

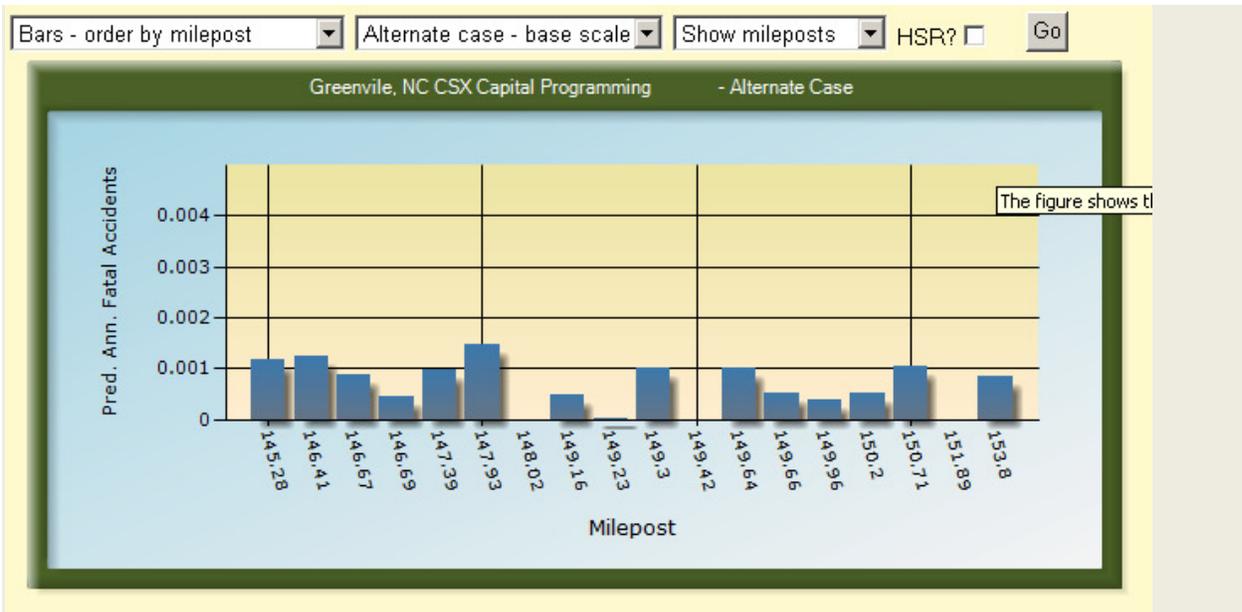
In the above plan, all of the Phase I improvements will be implemented in 2008 (first year of operations with the improvement will be 2009). Only the crossing at milepost 151.89 will have a Phase II improvement, and it is set for implementation in 2012.

After entering the devices data, from the 'Crossings' submenu, select "Set default costs for all crossings".

View the predicted accidents chart before and after the implementation is in effect for crossing 641618G, milepost 151.89. Shown below are the predicted accident charts of 2009 and 2013 (On the Crossings Page, click on the APS model tab. Select the year 2009 for the alternate case and then click the "Go" button. Click "Recalculate" and then click on the Show Chart link. Repeat steps for the year 2013).

Figure 11 and 12 - Predicted Accidents for 2009 and 2013





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 641618G

Year	Main Device	Capital Cost (thous. \$)	Supp Safety Device	Capital Cost (thous. \$)	Total Capital Cost (thous. \$)
2008	Gates	0	Mountable Curbs	15	15
2009	Gates	0	Mountable Curbs	0	0
2010	Gates	0	Mountable Curbs	0	0
2011	Gates	0	Mountable Curbs	0	0
2012	Separation	5000	None	0	5000
2013	Separation	0	None	0	0
2014	Separation	0	None	0	0
2015	Separation	0	None	0	0
2016	Separation	0	None	0	0
2017	Separation	0	None	0	0
2018	Separation	0	None	0	0

From the Crossings page Actions menu you can print a report of the capital program for the corridor.

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 14 - Capital Plan Report

Milepost: 151.89	ID: 641618G	Description: Greenville, NC CSX Capital Programming
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		P
Supp. Safety Device: None		
Phase I: Gates		P P P P
Supp. Safety Device: Mountable curbs		
Phase II: Grade Separation		P P P P P P P P P P P P P P P P
Supp. Safety Device: None		
Cost of Improvement (thous. base year dollars)		
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 1500.0 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
		15.0 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 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
		15.0 0.0 1500.0 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 641818G). The chart shows the year in which each phase of the project takes place, including the cost of the improvements below it.

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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 13 Crossings Page - Aggravating Risk Factors - Base Case

Select data to view / edit:		General	Devices	Highway	Rail	Cost	APS model	AGGRAVATING RISK	HSR model
Data for the crossing MP:151.89 ID:641618G									
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 > 840 feet? (Given maximum timetable speed 35 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: 37									
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		Four quads obstructed							
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: 48									

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 the Case Study

11.3.1 Copy Previous Greenville 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 NC 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 “CSX - Greenville, NC” 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 “CSX - Greenville, NC” 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 641618G, MP 151.89). 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.

Change the “Quadrant Sight Distance” and “Obstruction within 85 feet of centerline” drop-down menus to ‘Four Quadrants Restricted’ so that the data matches the data in Figure 13. Click ‘Update’. The occurrence score should change to ‘37’ and the severity score should now be ‘48’ (See Figure 13).

Now select the alternate case by clicking on the “Alternate” tab on the toolbar and then click on the “Edit” button to edit the data. Change the “Quadrant Sight Distance” and “Obstruction within 85 feet of centerline” drop-down menus to ‘All Quads Clear’ so that the data matches Figure 14 on the next page. Click Update. The occurrence score should be ‘52’ and the severity score ‘60’ (See Figure 14).

Figure 14 Aggravating Risk Tab Screenshots - Alternate Case

Select data to view / edit: **General** **Devices** **Highway** **Rail** **Cost** **APS model** **AGGRAVATING RISK** **HSR model**

Data for the crossing MP:151.89 ID:641618G

Select data to view / edit: **Base Case** **ALTERNATE CASE**

1. Sight Distance Factors
 Quadrant sight distances **All quads clear**
 Stop line sight
 Is sight distance from either stop line > 840 feet?
 (Given maximum timetable speed 35 mph) **Yes**

2. Alignment and Grades
 Crossing skew in degrees **60 - 90**
 (between roadway and track centerlines)
 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 15 Effects of Mitigating Aggravating Risk Factors

tings ==> User: Trainee1 Dataset: Initial dataset Model: Corridor Corridor: CSX - Greenville, NC w/ Aggravated Risk Scenario: Strong rail growth Results: Placeholder - Corridor Model

Crossings in the Corridor

Select a crossing to view or edit: Enter "Delete Crossings" mod

- 9. MP:149.23 ID:641558A CSX - 4TH ST
- 10. MP:149.3 ID:641609H CSX - 5TH
- 11. MP:149.42 ID:641610C CSX - ALLEY
- 12. MP:149.64 ID:641855T CSX - DICKINSON STREET
- 13. MP:149.66 ID:641854L CSX - TENTH STREET
- 14. MP:149.96 ID:641614E CSX - 14TH STREET
- 15. MP:150.2 ID:641615L CSX - HOWELL ST.
- 16. MP:150.71 ID:642719W CSX - ARLINGTON BLVD
- 17. MP:151.89 ID:641618G CSX - GREENVILLE BLVD
- 18. MP:153.8 ID:641620H CSX -

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

Data for the crossing MP:151.89 ID:641618G

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	0.001195	0.000855	0.020178	0.013097
Injury	0.005483	0.003926	0.105445	0.068380
PDO	0.013336	0.009548	0.279589	0.179291
Total	0.020014	0.014329	0.405211	0.260768

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