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TRAINING COURSE AND WORKBOOK FOR GRADE CROSSING IMPROVEMENTS EVALUATION USING GRADEDEC.NET

VOLUME 2

TABLE OF CONTENTS

MODULE 8 INVESTMENT ANALYSIS 1

8.1 Introduction 1

8.2 General Framework 1

8.3 Measures of Economic Worth and Efficiency 2

8.4 Comparing Alternatives 3

8.5 Timing Assumptions 4

8.6 Social Costs 4

8.7 Current, Constant and Present Value Dollars 5

8.8 The Discount Rate 5

8.9 Costs and Benefits 7

8.10 Costs 7

8.10.1 Capital 7
8.10.2 Operating and Maintenance Costs 7
8.10.3 Lifecycle Costs 7

8.11 Benefits 8

8.11.1 Safety (Accident Reduction) 8
8.11.2 Other Benefits 8
8.11.2.1 Time Savings 9
8.11.2.2 Vehicle Operating Costs 9
8.11.2.3 Emissions Reductions and Environmental Benefits 9
8.11.2.4 Network Delay 9

8.12 Case Study Benefit-Cost Analysis 10

8.12.1.1 Setting Up Your Data 10
8.12.1.2 Create new scenario 10
8.12.1.3 Modify the scenario data with forecast values and assumptions for your analysis 10
8.12.1.4 Verify or modify parameters and other data values 11

8.12.1.5 Set the simulation parameters and run the simulation 11
8.12.1.6 Defining the scenario 11
8.12.1.7 Populating the scenario with data 11
8.12.1.8 View results table and charts, print report 12

8.13 Benefit-Cost Summary for the Case Study 12

MODULE 9 NON-SAFETY BENEFITS 15

9.1 Introduction 15

9.2 Overview 15

9.3 Queuing Model in GradeDec.NET 17

9.4 Time Savings 18

9.5 Vehicle Operating Cost Savings 18

9.6 Reduction in Emissions 19

9.7 Network Delay 19

MODULE 10 RISK ANALYSIS 29

10.1 Introduction 29
10.1.1 What is Risk Analysis? 29
10.1.2 Why Use Risk Analysis in GradeDec.NET 30

10.2 Selecting a Distribution and Populating with Data 30

10.3 Running a Risk Analysis 31

10.4 Reading the Results 31

10.5 Comparing Alternatives with Risk Analysis 32

10.6 Using the Tornado Chart to Refine Inputs 32

10.7 Result Tables and Charts for the Case Study 33

10.8 Case Study Risk Analysis Results 34

MODULE 11 CAPITAL PROGRAMMING 37

11.1 Introduction 37
11.1.1 What is Capital Programming 37

11.2 Creating a Capital Program 37
11.2.1 Changes to the Crossings Page 37
11.2.1.1 Crossing Page – Devices Tab 37
11.2.1.2 Crossing Page – Cost Tab 38
11.2.2 Entering Data for the Case Study 39

BIBLIOGRAPHY AND SOURCES 47

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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.

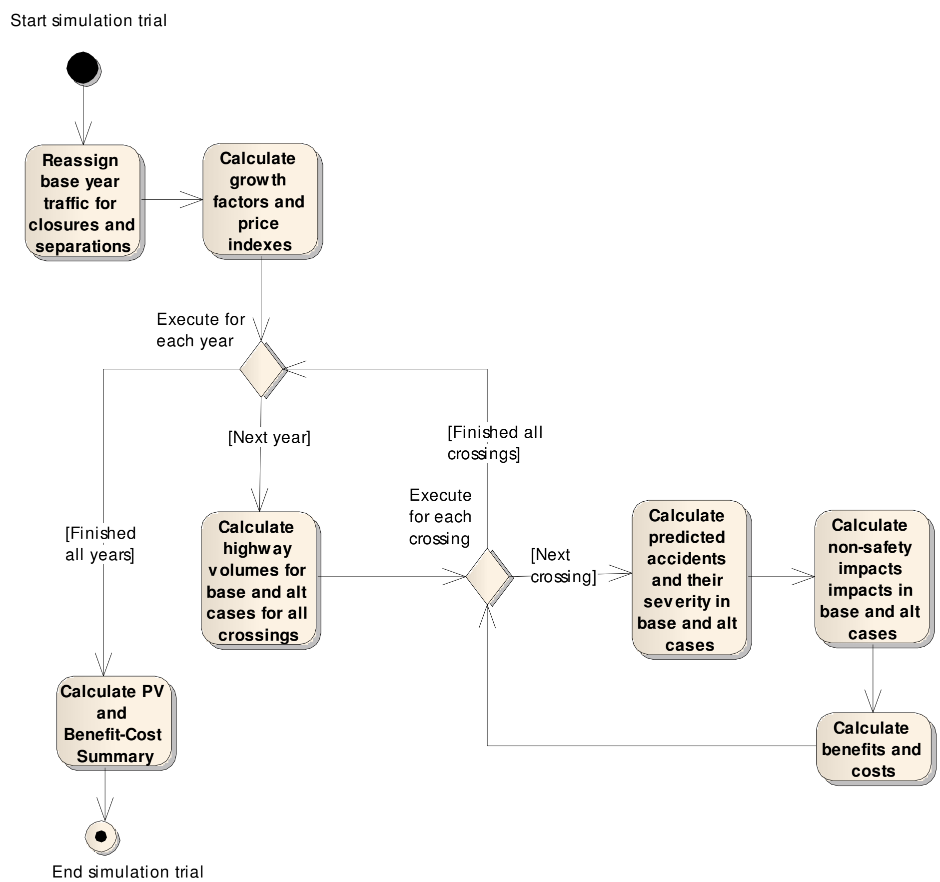
The evaluation (benefit-cost or investment analysis) compares the effects of improvements to the grade crossings (the alternate case) with the effects of the crossings in the base case. "Effects" are quantities that may have a positive value to consumers (like induced trips) and are benefits. Effects 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



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 1 Summary Measures and their Meanings

Measure	Threshold Value - "Passes" the Benefit-Cost Test	Meaning
NPV Net Present Value	NPV>0	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.
BCR Benefit-Cost Ratio	BCR>1	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.
ROR Rate of Return	ROR>discount rate	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

*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).

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 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.

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 – 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:

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 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.

8.9 Costs and Benefits

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

COSTS

- Capital
- Operating and Maintentance
- Other Lifecycle Costs

BENEFITS

- Reduced accidents
- Reduced highway travel delay
- Reduced user borne vehicle operating costs
- Reduced emissions
- Reduced network delay
- Benefits and costs of discouraged or induced travel

Figure 2 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).

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 (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.

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

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

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

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.

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.

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 injury accidents Predicted property damage only Accidents	Predicted fatalities by mode Predicted injuries by mode 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.

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 under two conditions:

Grade separation or closure, or,

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

8.11.2.2 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.

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 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.

8.11.2.4 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.

8.12 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.

8.12.1.1 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.

8.12.1.1.1 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 "Meridian Speedway" 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.

8.12.1.2 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: 2010, last year near term: 2014, end year: 2034) at their default values, or modify them if you wish. These vales 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., Meridian Speedway) 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.

8.12.1.3 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.

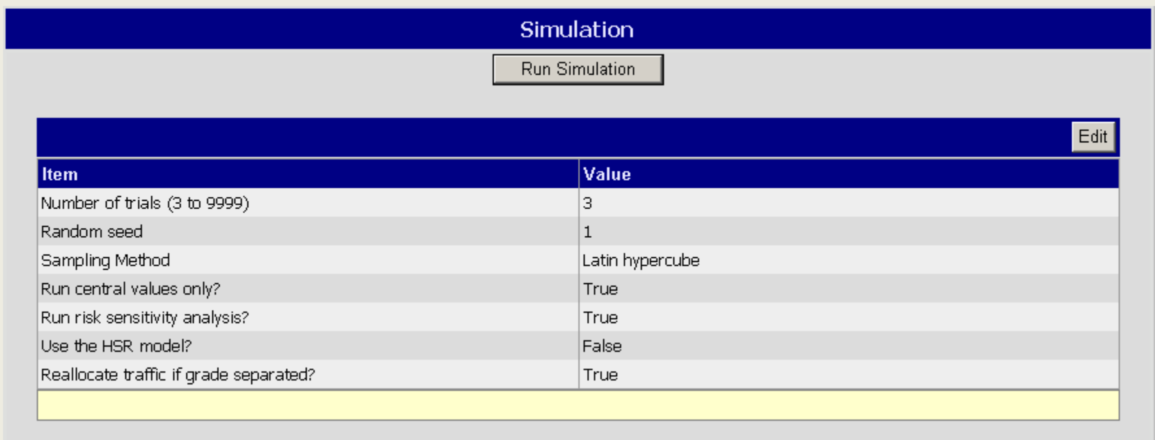
8.12.1.4 Verify or modify parameters and other data values

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.

8.12.1.5 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**. One possible set of parameters are shown below:

Figure 3 Simulation Parameters



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.

8.12.1.6 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.

8.12.1.7 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.

8.12.1.8 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.

8.13 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 $10,512,320 and the benefit-cost ratio was 2.504. Moreover, the risk analysis results show that the improvement will almost certainly result in positive net benefits.

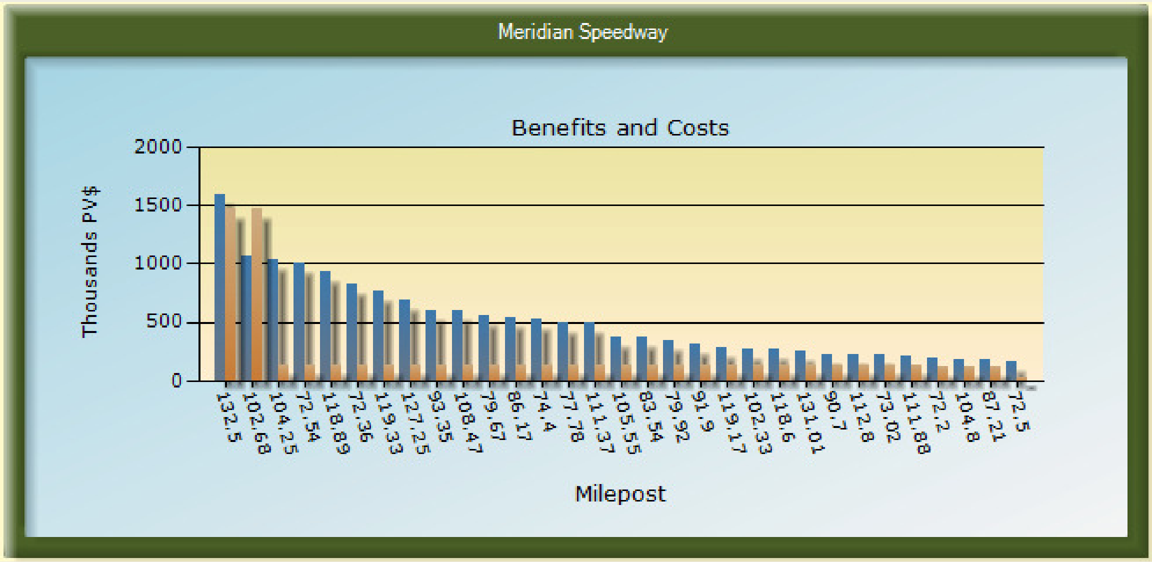
Figure 4 Benefit-Cost Summary for Case Study

Results: Meridian Speedway

Selected results data group: Benefits and Benefit-Cost Summary Go Show summary chart

	Variable	Mean Value	Standard Deviation
View	Safety benefits, thous $ PV	16618.410	NaN
View	Travel time savings, thous $ PV	317.172	NaN
View	Environmental benefits, thous $ PV	1.665	NaN
View	Veh operating cost benefit, thous $ PV	22.519	NaN
View	Network benefits, thous $ PV	1.029	NaN
View	Total benefits, thous $ PV	17503.390	NaN
View	of this, benefits from induced trips, thous $ PV	11.924	NaN
View	of this, disbenefits from induced trips, thous $ PV	-0.076	NaN
View	of this, investment salvage value, thous $ PV	530.748	NaN
View	Total costs, thous $ PV	6991.068	NaN
View	Net benefits, thous $ PV	10512.320	NaN
View	Benefit-cost ratio	2.504	NaN
View	Rate of return (constant dollars), %	18.868	NaN
View	Local benefits (not included in summary), thous $ PV	875.169	NaN

Figure 5 Summary Chart of Benefits and Costs



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

MODULE 9 NON-SAFETY BENEFITS

9.1 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

9.2 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.

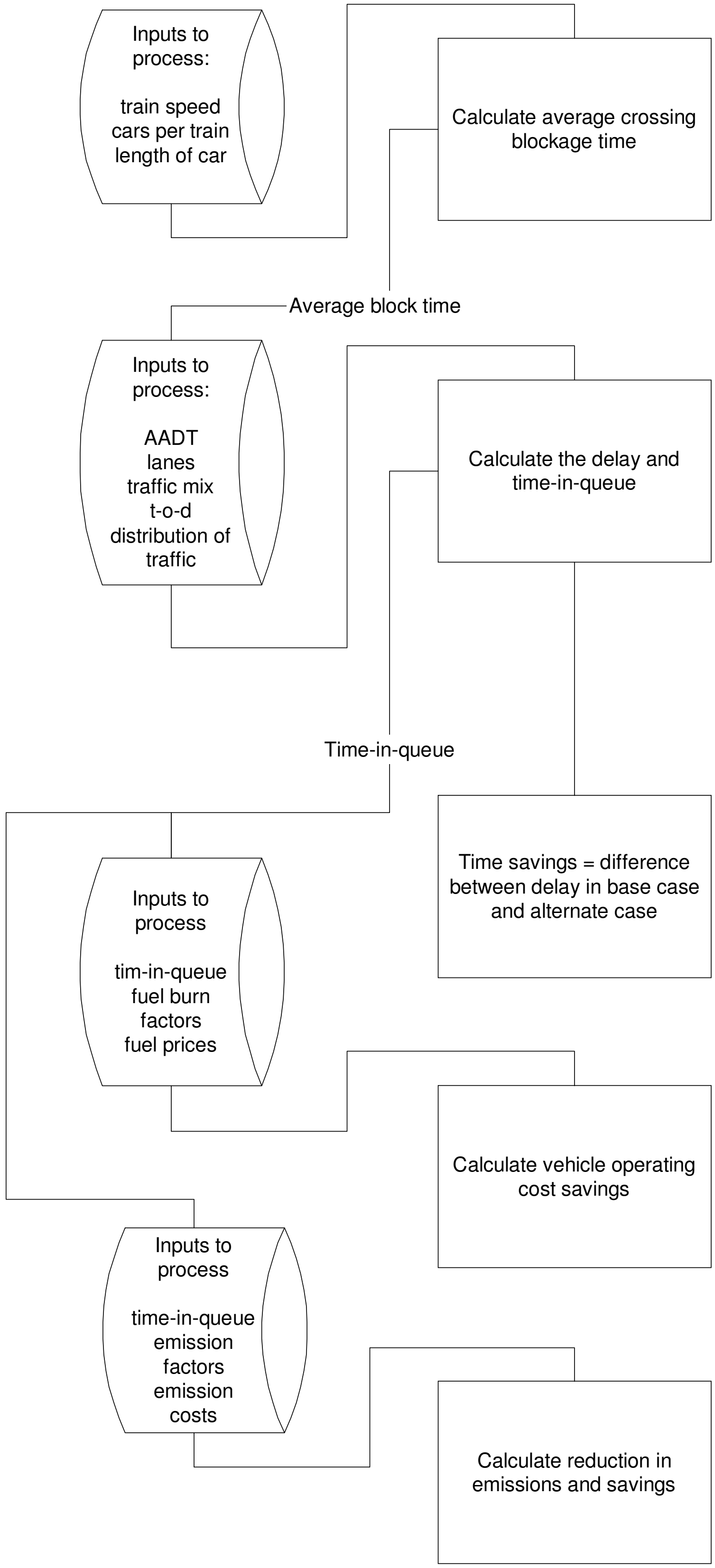
The highway operating characteristics (lanes, AADT, traffic mix) determine the queuing at the crossings, the delay and the time-in-queue.

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 4 Overview of Process for Calculating Non-Safety Benefits



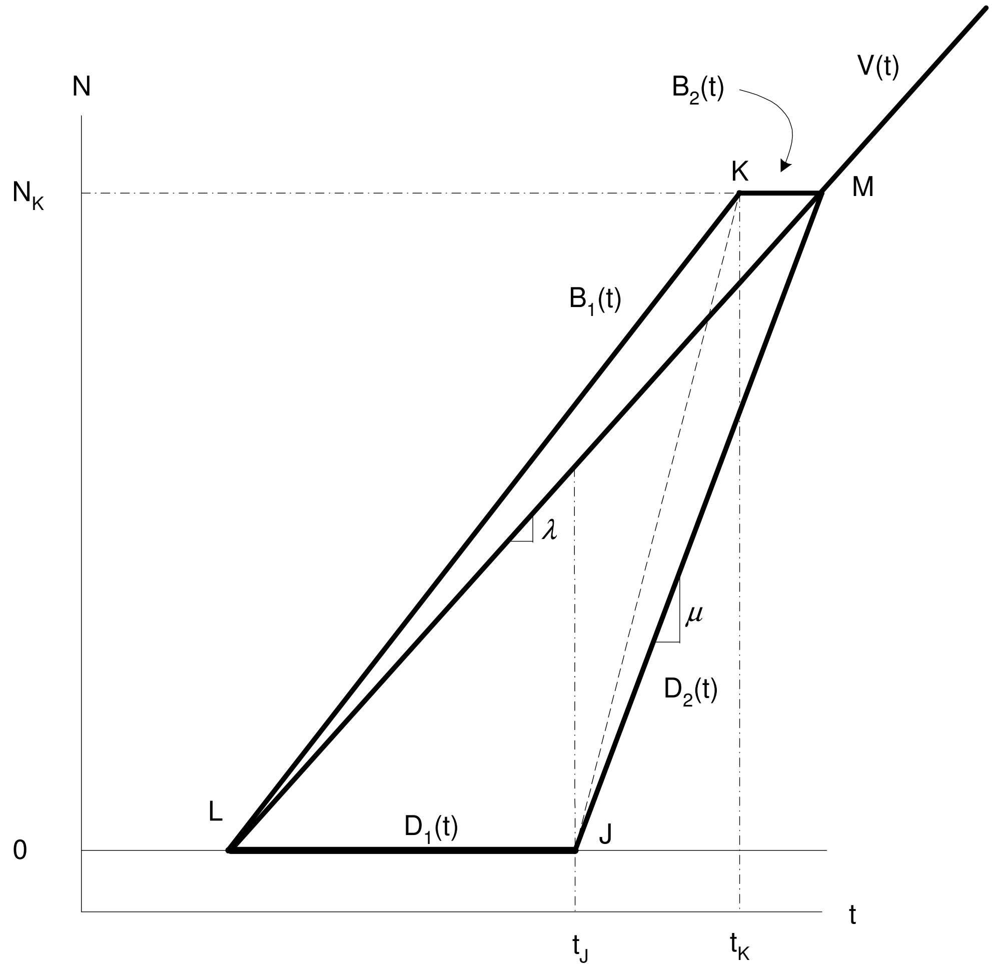
9.3 Queuing Model in GradeDec.NET

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 Manual[1] 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 work[2] 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. Daganza, Transportation Research Record 1572. pp. 140-147.

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



9.4 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.

9.5 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.

9.6 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.

9.7 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.

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 = $\frac{350\ feet}{55\ mph} * \frac{1\ mile}{5280\ feet} * \frac{60\ minutes}{1\ hour} + \frac{36}{60} =$ .6723 minutes Freight train block time = $\frac{4420\ feet}{30\ mph} * \frac{1\ mile}{5280\ feet} * \frac{60\ minutes}{1\ hour} + \frac{36}{60} =$ 2.255 minutes Switch train block time = $\frac{210\ feet}{20\ mph} * \frac{1\ mile}{5280\ feet} * \frac{60\ minutes}{1\ hour} + \frac{36}{60} =$ .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 $= \dfrac{2774.5\ vehicles}{2\ lanes * 3600 \dfrac{\sec}{hour} * 6 \dfrac{hours}{period}} =$ .06422 veh/sec/ lane

STEPS	SOURCE OR EQUATION
B7. Calculate the number of affected vehicles (entering queue) per lane per closure	**Number of affected vehicles = Arrival rate*dispersal rate* average block time/(dispersal rate-arrival rate)** Affected vehicles = $\frac{0.06423 * 0.5 * 68.282}{0.5 - 0.06423}$ =5.032
B8. Calculate delay per lane per closure	**Delay= Affected vehicles* (block time + (1/dispersal rate – 1/arrival rate))*(affected vehicles+1)/2** Delay = $5.032 * \left(68.282 + \left(\left(\frac{1}{0.5} \right) - \left(\frac{1}{0.06423} \right) \right) * \frac{(5.032 + 1)}{2} \right)$ =137.64 vehicle-seconds
B9. Calculate total delay per closure and convert to veh-hours	**Total Delay = Delay per lane*lanes*unit conversion factor** Total Delay =137.64*2*(1 hour / 3600 sec) =0.0765 veh-hours
B10. Allocate delay per closure to highway traffic segments	**Delay by traffic segment = Delay * vehicles in segment / total vehicles** Auto Delay= $0.0765 * \frac{1767}{2774.5}$ = 0.0487 veh-hours Truck Delay= $0.0765 * \frac{852.5}{2774.5}$ = 0.0235 veh-hours Bus Delay = $0.0765 * \frac{155}{2774.5}$ = 0.00427 veh-hours
B11. Multiple by number of closures in period	**Delay = delay per closure * closures** Auto Delay = 0.0487*2.8= 0.1364 veh-hours Truck Delay=0.0235*2.8 = 0.0658 veh-hours Bus Delay=0.000427*2.8 = 0.0120 veh-hours
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.	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
C2 Calculate the time rate of growth of the back of the queue during closure	$\frac{d\,(\textbf{\textit{Back of queue}})}{\textbf{\textit{dt}}} = \frac{\textbf{\textit{arrival rate * freeflow speed * traffic density}}}{\textbf{\textit{freeflow speed * traffic density}} - \textbf{\textit{arrival rate}}}$ $= \frac{0.0642 * 45 * (5280/3600) * 0.05}{45 * (5280/3600) * 0.05 - 0.0642}$ = 0.0655 feet / second
C3 Calculate the time-in-queue per lane	***Time-in-queue=*** $\textbf{\textit{affected vehicles}} * \left(\textbf{\textit{block time}} + \left(\Delta * \frac{(\textbf{\textit{affected vehicles}} + 1)}{2}\right)\right)$ $\textbf{\textit{where }} \Delta = \left(\frac{1}{\textbf{\textit{disperal rate}}} - \frac{1}{d\,(\textbf{\textit{back of queue}})/\textbf{\textit{dt}}}\right)$ =5.0317*(68.282+((1/.5-1/.0642)*(5.0317+1)/2) =142.24 veh-sec
C4. Calculate total time-in-queue per closure and convert to vehicle-hours	**Time-in-Queue = Time-in-Queue per lane*lanes*unit conversion factor** Total Time-in-queue =142.24*2*(1 hour / 3600 sec) =0.07902 veh-hours

STEPS	SOURCE OR EQUATION
C5. Allocate time-in-queue per closure to highway traffic segments	**Time-in-queue by traffic segment per closure = Time-in-queue * vehicles in segment / total vehicles** Auto Time-in-queue = $0.07902 * \frac{1767}{2774.5}$ = 0.05033 veh-hrs Truck Time-in-queue= $0.07902 * \frac{852.5}{2774.5}$ =0.02428 veh-hrs Bus Time-in-queue= $0.07902 * \frac{155}{2774.5}$ =0.00442 veh-hrs
C6. Multiple by number of closures in period to yield total time in queue in period by traffic segment	**Time-in-queue = Time-in-queue per closure * closures** Auto Delay = 0.05033*2.8= 0.14092 veh-hours Truck Delay=0.02428*2.8 = 0.06799 veh-hours Bus Delay=0.004415*2.8 = 0.012361 veh-hours
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	Base Case Auto 0.91 veh-hrs Truck 0.26 veh-hrs Bus 0.02 veh-hrs Alt Case Auto 0 veh-hrs Truck 0 veh-hrs Bus 0 veh-hrs Base on calculations in D for all 4 periods in the day.
D2. Determine average vehicle occupancy	Auto 1.15 Bus 10
D3. Determine passenger value of time and truck vehicle hour	Passenger 10.40 $/hr/occ Truck 18.06 $/hr/veh
D4. Calculate the daily time savings by traffic segment	**Base case delay – Alt case delay** Auto 0.91 veh-hrs Truck 0.26 veh-hrs Bus 0.02 veh-hrs
D5. Calculate the daily benefit	**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)
D6. Calculate annual benefits	**Annual benefit= Sum of daily benefit by mode * annualization factor** $5192.69=(10.87+4.75+2.92)*280

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	Base Case Auto 0.94 veh-hrs Truck 0.27 veh-hrs Bus 0.02 veh-hrs Alt Case Auto 0 veh-hrs Truck 0 veh-hrs Bus 0 veh-hrs Base on calculations in D for all 4 periods in the day.
E2. Determine idle burn rates	Fuel / Oil Auto .00969 .00063 Truck .01841 .00134 Bus .02067 .00119
E3. Determine fuel and oil costs	Gasoline 1.59 $/gal Diesel 1.43 $/gal Oil 3.76 $/qt
E4. Calculate quantities of fuel and oil saved by traffic segment	**Fuel saved=veh-hrs time-in-queue reduction* 60 * fuel burn rate** **Oil saved = veh-hrs time-in-queue reduction * 60 * oil burn rate** <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 <u>Oil</u> Auto=0.94*60 * .00063 = .00059 qt Truck = 0.27*60*.00134=.00036 qt Bus = 0.02 * 60 *.00119 = .00003 qt
E5. Calculate value of fuel and oil saved	**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

ANALYSIS WORKSHEETS
NON-SAFETY BENEFITS (Module 8)
F. Calculate Emissions Reduction Benefit

9.7.1.1.1.1.1 STEPS	SOURCE OR EQUATION
F1. Determine total daily time-in-queue by highway traffic segment in base and alternate cases	Base Case Auto 0.94 veh-hrs Truck 0.27 veh-hrs Bus 0.02 veh-hrs Alt Case Auto 0 veh-hrs Truck 0 veh-hrs Bus 0 veh-hrs Base on calculations in D for all 4 periods in the day.
F2. Determine emission burn rates	The following are emission rates of idling vehicles, grams per minute **HC / CO / NOx** Auto 0.302985 / 4.85986 / 0.091555 Truck 0.2559 / 3.1446 / 0.2754 Bus 0.6655 / 11.85 / 0.183
F3. Determine emission costs	HC 2040 $/ton CO 50 $/ton NOx 2765 $/ton
F4. Calculate quantity of emissions saved	**Emission Saved = Reduction in Time-in-queue * emissions rate * 60** <u>HC</u> Auto = 0.94*0.302985*60=17.08 grams Truck= 0.27*0.2559*60=4.18 grams Bus=0.02*0.6655*60=0.99 grams <u>CO</u> Auto = 0.94*4.85986*60=273.94 grams Truck= 0.27*3.1446*60=51.31 grams Bus=0.02*11.85*60=17.58 grams <u>NOx</u> Auto = 0.94*.091555*60=5.16 grams Truck= 0.27*0.2754*60=4.49 grams Bus=0.02*0.183*60=0.27 grams
F5. Calculate average daily benefit from emissions reduction	**Benefit from Emissions Reduction = Sum(Emissions_Saved)*Cost*1 ton/ 907185 grams** HC = (17.08+4.18+0.99)*2040/907185=$0.05001 CO = (273.94+51.31+17.58)*50/907185=$0.01889 NOx = (5.16+4.49+0.27)*2765/907185=$0.03025 Total = $0.05001+$0.01889+$0.03025=$0.09916
F6. Annual benefit	$0.09916*280=$27.76

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MODULE 10 RISK ANALYSIS

10.1 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.

10.1.1 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.

10.1.2 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.

10.2 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.

10.3 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).

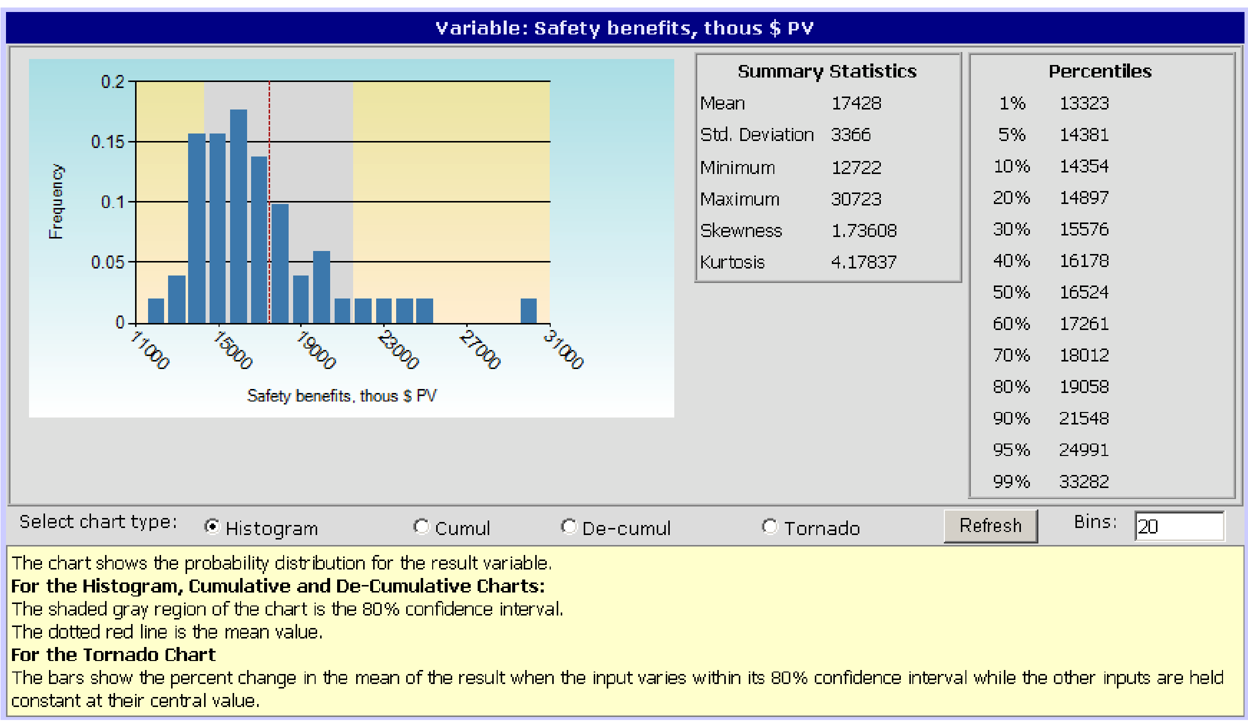
Invoke the simulation form.

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.

10.4 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 $17,428,000. The gray region on the chart show the 80% confidence interval, that is, they mark the 10 percent lower and upper limits (the 10^{th} and 90^{th} percentiles) of the range of the variable. The results tell us that:

- There is 80 percent confidence that the result will lie between $14,354,000 and $21,548,000.
- There is a 90 percent probability that the result will exceed $14,354,100.
- There is a 10 percent probability that the result will exceed $21,548,000.

10.5 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).

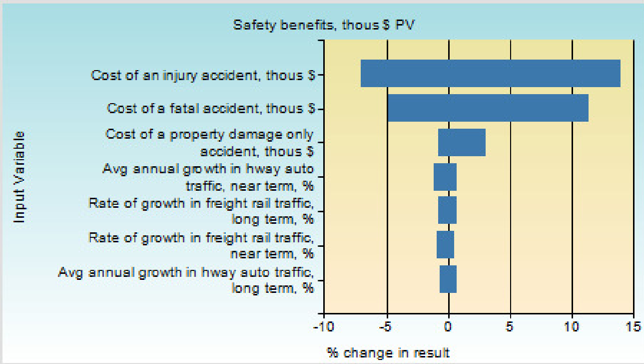
10.6 Using the Tornado Chart to Refine Inputs

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 10^{th} and 90^{th} 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

Variable: Safety benefits, thous $ PV



Summary Statistics	
Mean	17428
Std. Deviation	3366
Minimum	12722
Maximum	30723
Skewness	1.73608
Kurtosis	4.17837

Percentiles	
1%	13323
5%	14381
10%	14354
20%	14897
30%	15576
40%	16178
50%	16524
60%	17261
70%	18012
80%	19058
90%	21548
95%	24991
99%	33282

Select chart type: ○ Histogram ○ Cumul ○ De-cumul ⦿ Tornado [Refresh]

The chart shows the probability distribution for the result variable.
For the Histogram, Cumulative and De-Cumulative Charts:
The shaded gray region of the chart is the 80% confidence interval.
The dotted red line is the mean value.
For the Tornado Chart
The bars show the percent change in the mean of the result when the input varies within its 80% confidence interval while the other inputs are held constant at their central value.

10.7 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

Simulation

[Run Simulation]

[Edit]

Item	Value
Number of trials (3 to 9999)	500
Random seed	1
Sampling Method	Latin hypercube
Run central values only?	False
Run risk sensitivity analysis?	True
Use the HSR model?	False
Reallocate traffic if grade separated?	True

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.

10.8 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

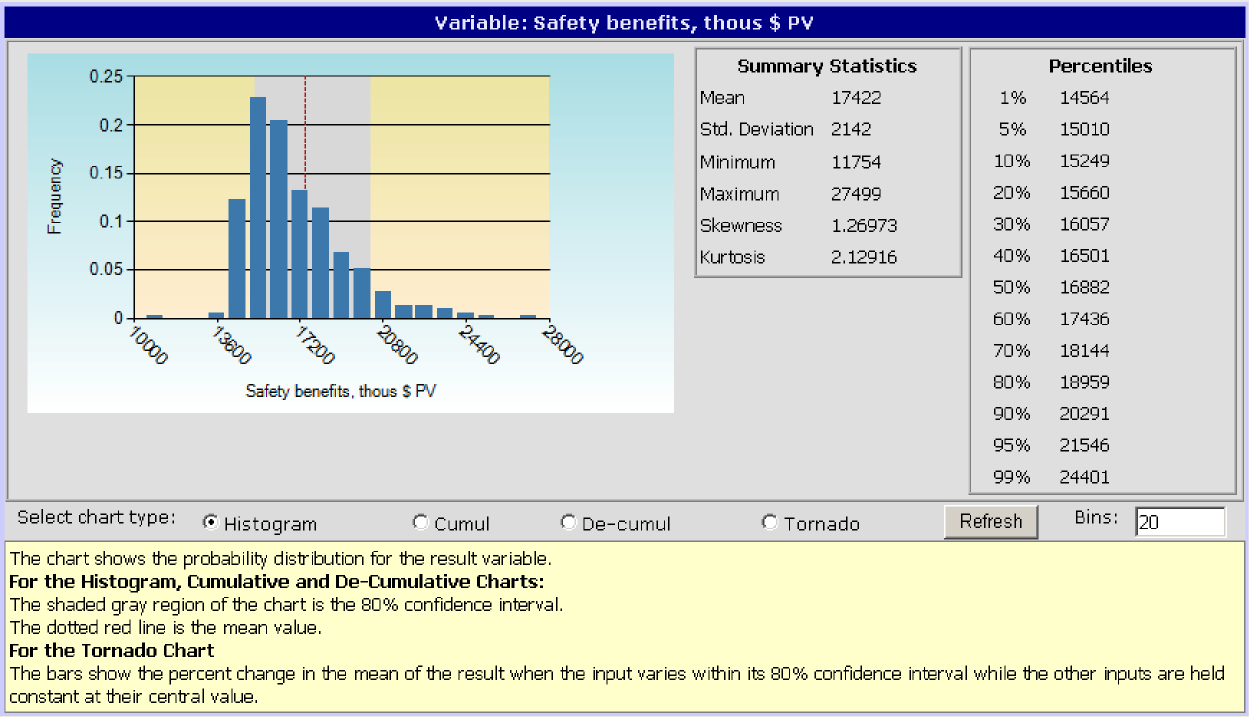
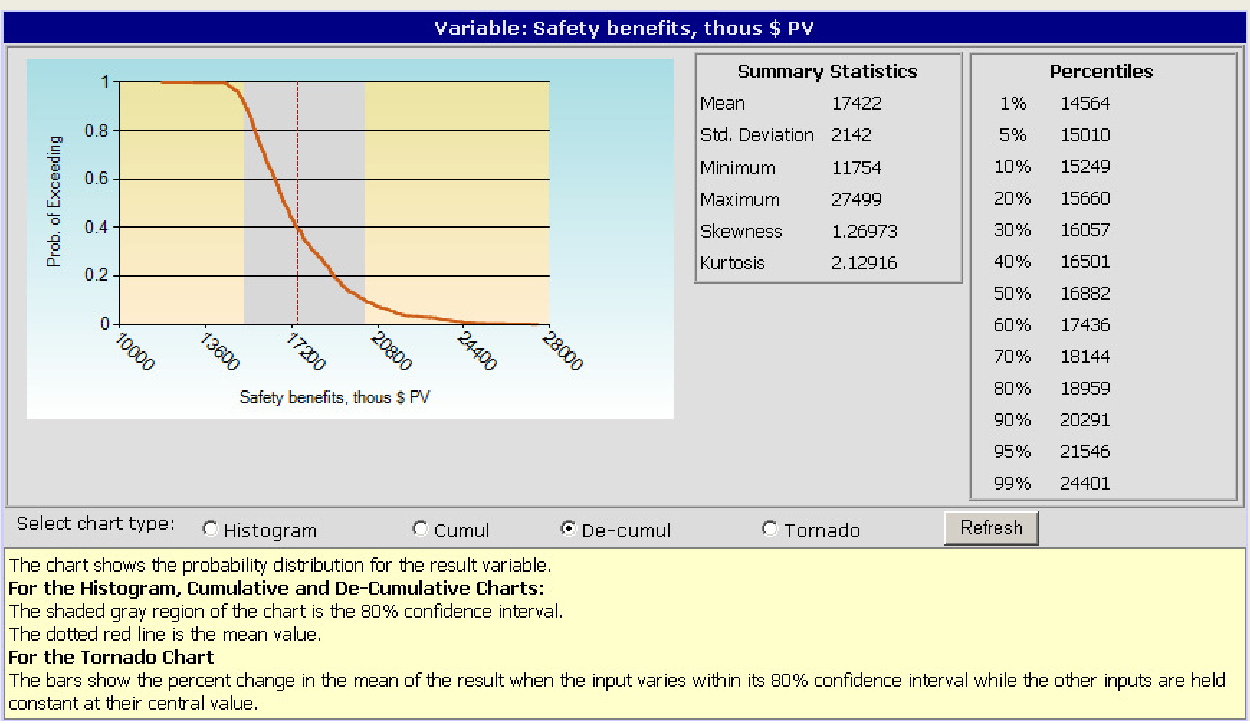


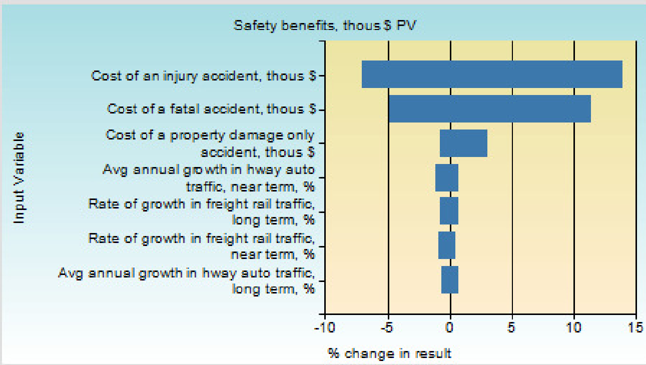
Figure 11 De-Cumulative Probability Chart of Safety Benefits



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 Tornado Chart of Safety Benefits

Variable: Safety benefits, thous $ PV



Summary Statistics	
Mean	17422
Std. Deviation	2142
Minimum	11754
Maximum	27499
Skewness	1.26973
Kurtosis	2.12916

Percentiles	
1%	14564
5%	15010
10%	15249
20%	15660
30%	16057
40%	16501
50%	16882
60%	17436
70%	18144
80%	18959
90%	20291
95%	21546
99%	24401

Select chart type: ○ Histogram ○ Cumul ○ De-cumul ◉ Tornado [Refresh]

The chart shows the probability distribution for the result variable.
For the Histogram, Cumulative and De-Cumulative Charts:
The shaded gray region of the chart is the 80% confidence interval.
The dotted red line is the mean value.
For the Tornado Chart
The bars show the percent change in the mean of the result when the input varies within its 80% confidence interval while the other inputs are held constant at their central value.

MODULE 11 CAPITAL PROGRAMMING

11.1 Introduction

11.1.1 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.

11.2 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".

11.2.1 Changes to the Crossings Page

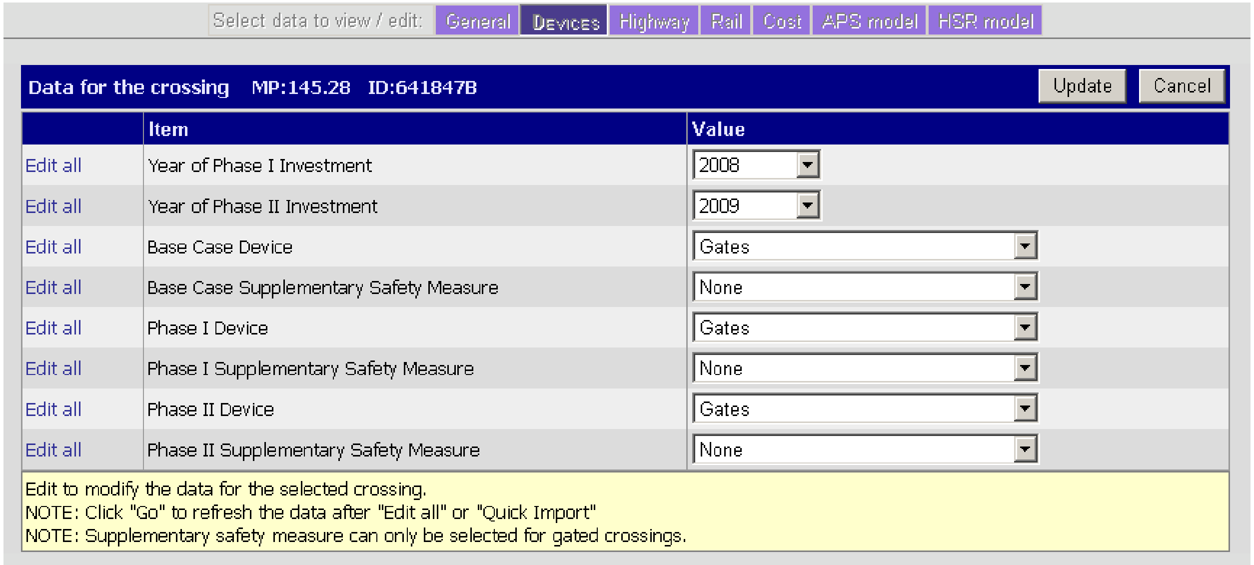
With "Allow Capital Programming?" set to true, the format of the forms on the "Devices" and "Costs" tab on the Crossings page will appear differently.

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.

11.2.1.1 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



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).

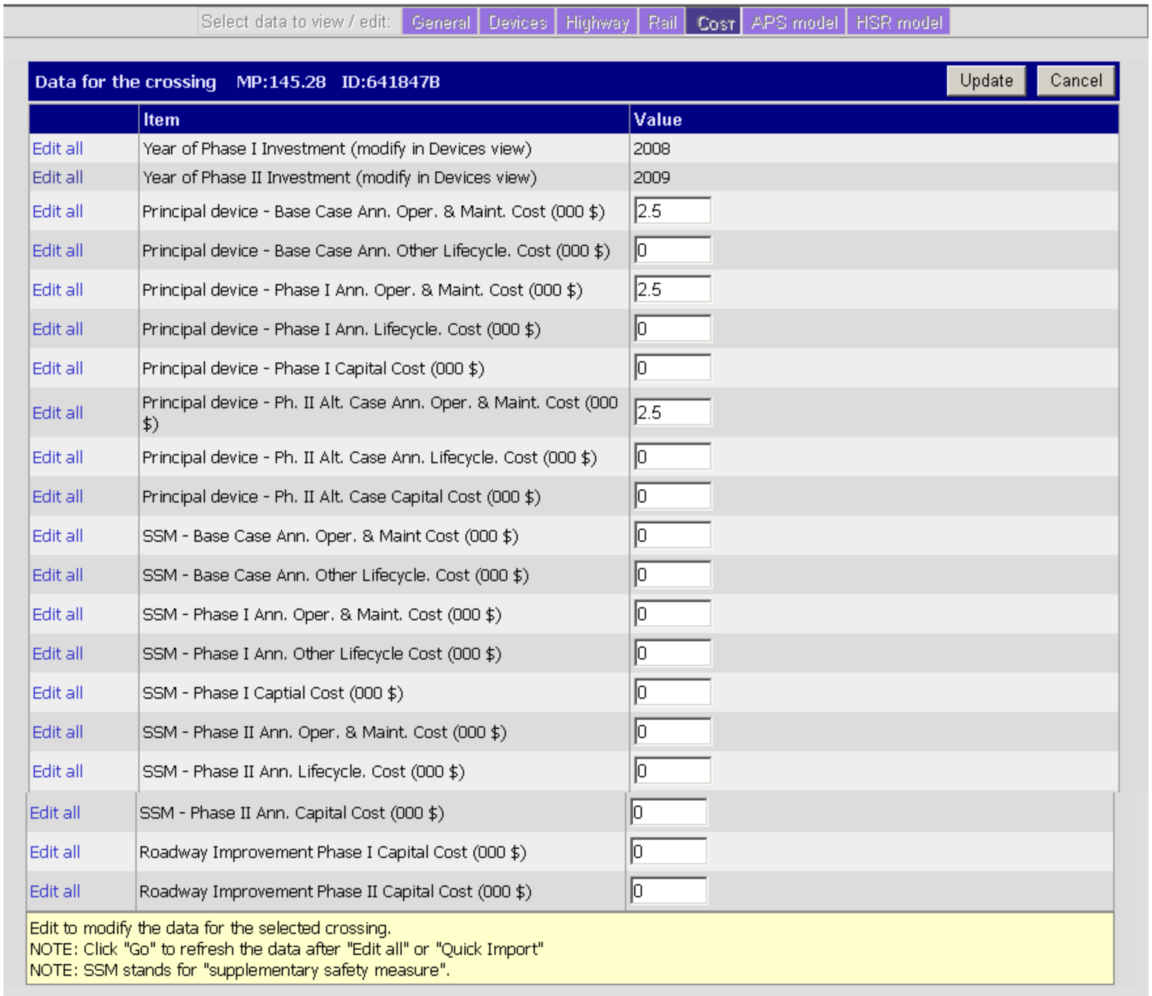
11.2.1.2 Crossing Page – Cost Tab

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 $)	2.5
Edit all	Principal device - Base Case Ann. Other Lifecycle. Cost (000 $)	0
Edit all	Principal device - Phase I Ann. Oper. & Maint. Cost (000 $)	2.5
Edit all	Principal device - Phase I Ann. Lifecycle. Cost (000 $)	0
Edit all	Principal device - Phase I Capital Cost (000 $)	0
Edit all	Principal device - Ph. II Alt. Case Ann. Oper. & Maint. Cost (000 $)	2.5
Edit all	Principal device - Ph. II Alt. Case Ann. Lifecycle. Cost (000 $)	0
Edit all	Principal device - Ph. II Alt. Case Capital Cost (000 $)	0
Edit all	SSM - Base Case Ann. Oper. & Maint Cost (000 $)	0
Edit all	SSM - Base Case Ann. Other Lifecycle. Cost (000 $)	0
Edit all	SSM - Phase I Ann. Oper. & Maint. Cost (000 $)	0
Edit all	SSM - Phase I Ann. Other Lifecycle Cost (000 $)	0
Edit all	SSM - Phase I Captial Cost (000 $)	0
Edit all	SSM - Phase II Ann. Oper. & Maint. Cost (000 $)	0
Edit all	SSM - Phase II Ann. Lifecycle. Cost (000 $)	0
Edit all	SSM - Phase II Ann. Capital Cost (000 $)	0
Edit all	Roadway Improvement Phase I Capital Cost (000 $)	0
Edit all	Roadway Improvement Phase II Capital Cost (000 $)	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".

11.2.2 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 LA 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 "Meridian Speedway" 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 "Meridian speedway" 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.

In Volume 1 of this workshop, various improvements to the corridor were suggested in the form of alternate devices and/or alternate supplementary safety measures. With capital programming, a user can implement these improvements over any number of years, thus spreading the total improvement cost. The improvements from Volume 1 are revisited in the table below, and they are spread out more or less evenly to control yearly costs.

Table 6 – Capital Program for the Meridian Speedway

Year	Device Improvements to Corridor	Supplementary Safety Measures for Corridor Devices	Initial Cost (in thousands)
2010	7 Closures	Barrier curbs for 26 gates	$660
2011	4 Gates	Barrier curbs for 4 gates	$1000
2012	4 Gates	Barrier curbs for 4 gates	$1000
2013	4 Gates	Barrier curbs for 4 gates	$1000
2014	4 Gates	Barrier curbs for 4 gates	$1000
2015	1 Grade Separation		$7000
2016	5 Gates	Barrier curbs for 5 gates	$1250
2017	5 Gates	Barrier curbs for 5 gates	$1250
2018	2 Gates	Barrier curbs for 2 gates	$1060
2019	1 Grade Separation		$7000

Each crossing has the possibility to receive a Phase I and Phase II device improvement. The following table demonstrates how improvements occur in each of these phases, using the 2010 closures as an example.

Table 7 – Grade Crossing Closures

ID	Milepost	Phase I Improvement	Phase I Supplementary Safety Measure	Year to Implement Phase I	Phase II Improvement	Year to Implement Phase II	Phase II Supplementary Safety Measure
302522H	79.67	Closure	None	2010	Closure	2011	None
302560S	108.65	Closure	None	2010	Closure	2011	None
302558R	107.88	Closure	None	2010	Closure	2011	None
302585M	122.5	Closure	None	2010	Closure	2011	None
302537X	93.35	Closure	None	2010	Closure	2011	None
302598N	131.01	Closure	None	2010	Closure	2011	None
302530A	87.21	Closure	None	2010	Closure	2011	None

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 "302522H" 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 8 – Crossings Page with Devices Tab Selected in Edit Mode

Data for the crossing MP:79.67 ID:302522H 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	None selected
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.

Continue this process for the 6 remaining crossings.

In 2010, we also require that 26 gated crossings each have barrier curbs. This number was not chosen arbitrarily; in order to add barrier curbs to a crossing it must already be gated, and only 26 crossings are gated in the base case. In order to eventually add barrier curbs to all non-closed, non-grade-separated crossings, we will need to upgrade each of those crossings to gates first.

The following table lists the 26 gated crossings, and the devices and supplementary safety measures to input for each phase. Two of these crossings will be grade separated during the second phase of their investment.

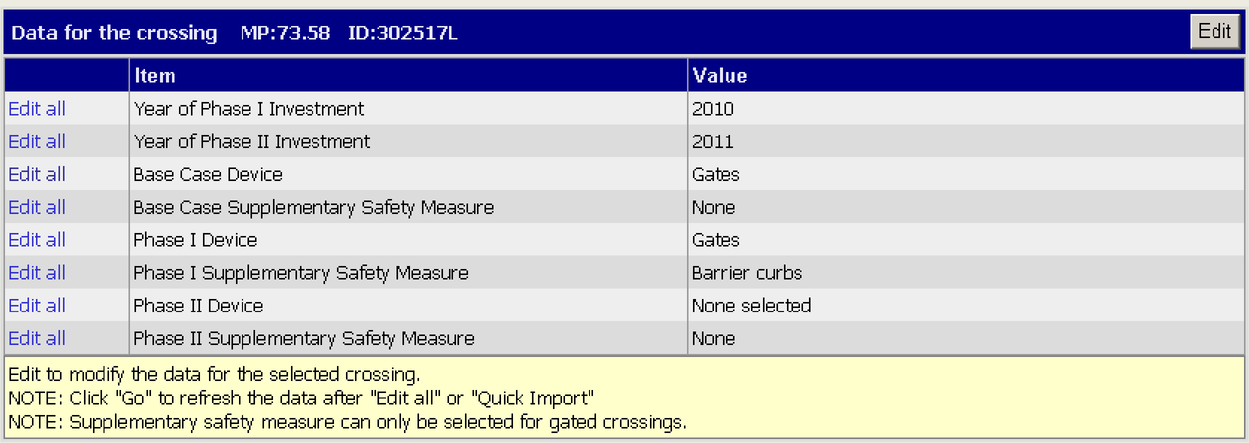
Table 8 – Barrier curbs in 2010

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
302517L	73.58	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302519A	74.4	Gates	Barrier curbs	2010	Grade Separation	None	2015
302520U	76.83	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302521B	77.78	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302527S	84.24	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302528Y	86.17	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302529F	86.53	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302540F	95.41	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302541M	96.99	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302543B	100.89	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302544H	101.86	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302548K	102.62	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302549S	102.68	Gates	Barrier curbs	2010	Grade Separation	None	2019
302550L	102.8	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011

302557J	107.05	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302561Y	109.62	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302562F	110.4	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302563M	111.37	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302564U	111.46	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302576N	118.52	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302580D	119.27	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302582S	119.41	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302583Y	119.5	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302584F	120.17	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302589P	126.39	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011
302591R	127.25	Gates	Barrier curbs	2010	Gates	Barrier curbs	2011

Update the device data for each of the crossings above using the same process as the one described below table 7. As an example, the data for the first row (crossing "302517L") should match what appears in the figure below:

Figure 9 – Example of Barrier Curb in 2010



The remaining crossings in the corridor are non-gated in the base case. Each of these should eventually become gated, and barrier curbs should be added as a supplementary safety measure. The table below lists the remaining crossings, and their devices and supplementary safety measures to input for each phase:

Table 9 – New Gated Crossings and Barrier curbs

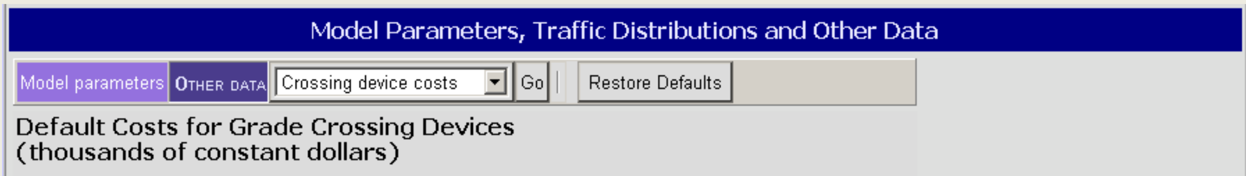
ID	Milepost	Phase I Improvement	Phase I Supplementary Safety Measure	Year to Implement Phase I	Phase II Improvement	Phase II Supplementary Safety Measure	Year to Implement Phase II
302511V	72.2	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012
302513J	72.36	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012
295859R	72.5	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012

302514R	72.54	Gates	Barrier curbs	2011	Gates	Barrier curbs	2012
302516E	73.02	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
302523P	79.92	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
302526K	83.54	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
302531G	88.42	Gates	Barrier curbs	2012	Gates	Barrier curbs	2013
302532N	89.21	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
302535J	90.7	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
302536R	91.9	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
302538E	94.15	Gates	Barrier curbs	2013	Gates	Barrier curbs	2014
302546W	102.33	Gates	Barrier curbs	2014	Gates	Barrier curbs	2015
302553G	104.25	Gates	Barrier curbs	2014	Gates	Barrier curbs	2015
302554N	104.8	Gates	Barrier curbs	2014	Gates	Barrier curbs	2015
302556C	105.55	Gates	Barrier curbs	2014	Gates	Barrier curbs	2015
302559X	108.47	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
302565B	111.88	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
302566H	112.8	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
302571E	115.37	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
302577V	118.6	Gates	Barrier curbs	2016	Gates	Barrier curbs	2017
302578C	118.89	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
302579J	119.17	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
302581K	119.33	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
302590J	127.16	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
302592X	127.29	Gates	Barrier curbs	2017	Gates	Barrier curbs	2018
302599V	131.09	Gates	Barrier curbs	2018	Gates	Barrier curbs	2019
302603H	132.5	Gates	Barrier curbs	2018	Gates	Barrier curbs	2019

The final step is to change the default cost of devices used by the crossings. 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 10 – Default Crossing Device Costs



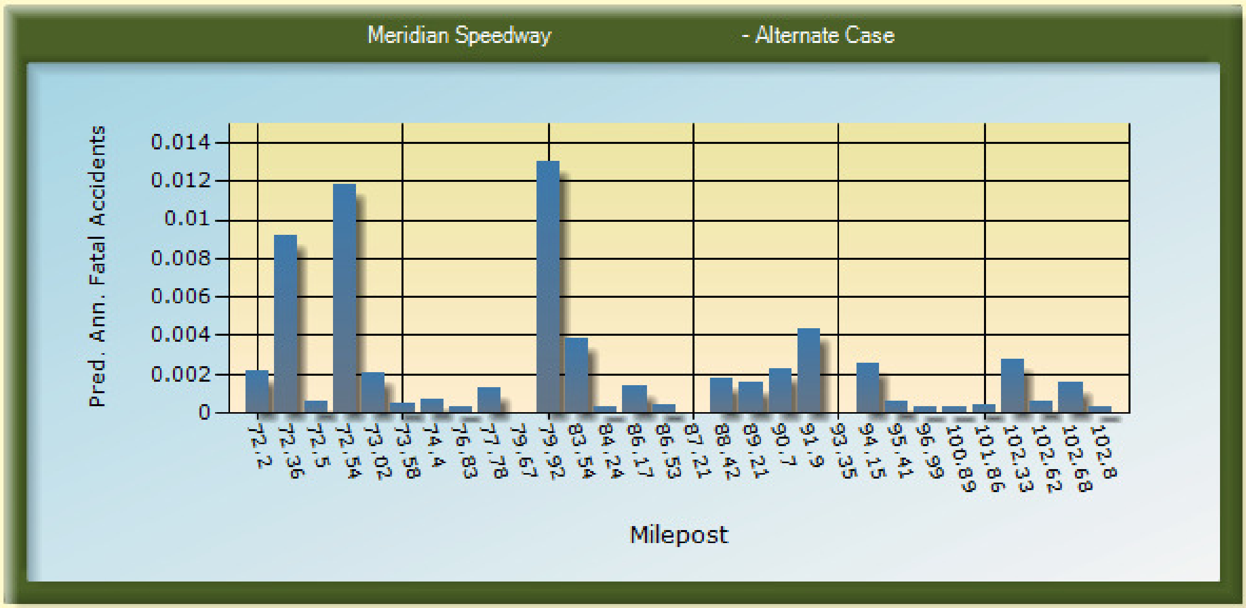
Device Type	Capital Costs	Oper. & Maint.	Other Lifecycle	
Passive	1.6 1.6	0.2 0.2	0 0	Edit
Flashing Lights	74.8 74.8	1.8 1.8	0 0	Edit
Flashing Lights with Gates	230 106.1	2.5 2.5	0 0	Edit
Closure	20 20	0 0	0 0	Edit
Separation	7000 1500	0.5 0.5	0 0	Edit
New Technology 1	280 280	5 5	0 0	Edit
New Technology 2	280 280	5 5	0 0	Edit
New Technology 3	280 280	5 5	0 0	Edit

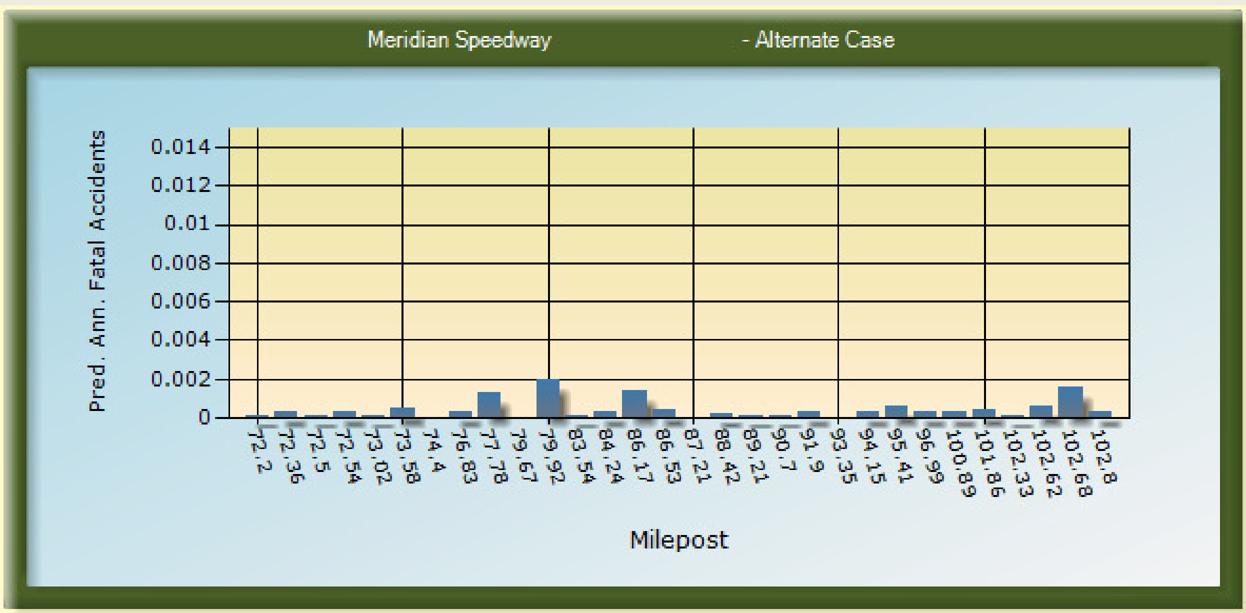
*Values in red are Federal Railroad Administration default values that indicate national averages.

From the navigation menu, click on **Crossings** in order to browse to the Crossings Page. Lay 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.

View the predicted accidents chart before and after the implementation is in effect for crossing 302519A, milepost 74.40. Shown below are the predicted accident charts of 2010 and 2016 (On the Crossings Page, click on the APS model tab. Select the year 2010 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 2016).

Figure 11 and 12 - Predicted Accidents for 2010 and 2016





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 5 Annual Capital Program for Crossing 302530A

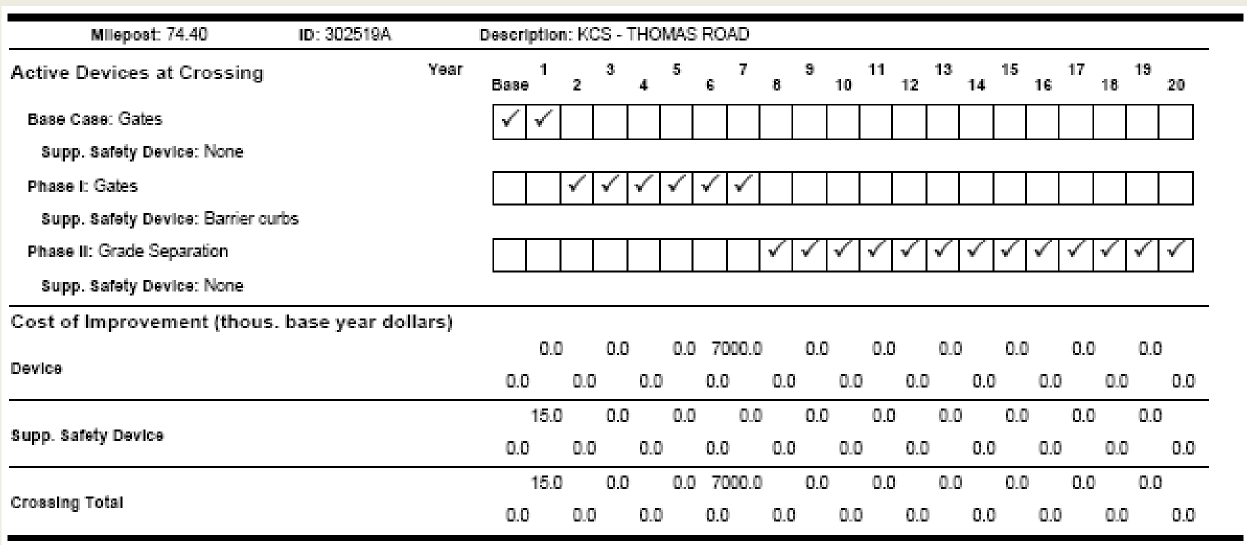
Year	Main Device	Capital Cost (thous. $)	Supp Safety Device	Capital Cost (thous. $)	Total Capital Cost (thous. $)
2009	Gates	0	None	0	0
2010	Gates	0	None	15	15
2011	Gates	0	Barrier Curbs	0	0
2012	Gates	0	Barrier Curbs	0	0

2013	Gates	0	Barrier Curbs	0	0
2014	Gates	0	Barrier Curbs	0	0
2015	Gates	0	Barrier Curbs	0	0
2016	Gates	7000	Barrier Curbs	0	7000
2017	Separation	0	None	0	0
2018	Separation	0	None	0	0
2019	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



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. 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.

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